Portrait of Louis-Nicolas Robert, the inventor of the first continuous paper-making machine. (From a water-colour made by his sister; in the collection of M. René Putois.)

The Paper-making Machine

ITS INVENTION, EVOLUTION AND DEVELOPMENT

R. H. CLAPPERTON

Author of
Paper-making by Hand
and
Modern Paper-making

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MANY and varied accounts have been written regarding the invention and early evolution of the paper-making machine. Most of these differ, often in important points, although they have a good deal in common. Some of them contain very inaccurate statements and show the writers to have no real knowledge of the facts, which can be obtained from those records which abound in the Patent Office, Public Record Office, and other places. For some years the author has been collecting material for a book on the evolution of the paper-making machine, recently having two consecutive strokes of good fortune, the first being when he met the late D. M. Henshaw, of Messrs. W. C. Holmes and Company, in Huddersfield, who was also connected with the firm of Bryan Donkin and Company Limited, Chesterfield. Henshaw produced no less than nine of Bryan Donkin's private diaries, in most of which there is a wealth of information connected with the early days of Donkin's work on the Fourdrinier paper-making machine. Day-to-day entries in the diaries, all dated, and obviously quite authentic, are in Donkin's own handwriting. Both Henshaw and Mr. Chambers, of Bryan Donkin and Company Limited, further assisted by allowing the author to see a large number of drawings which are in the possession of the Bryan Donkin firm at Chesterfield, and have been kept since the early days of Donkin's engineering works at Fort Place, Bermondsey. Photographs were made of these on Henshaw's instructions and many of them are reproduced in this book to show the evolution of the paper-making machine. The author is also indebted to him for the portrait of Donkin, in the form of a bust, reproduced on p. 306, which is now in the possession of the Bryan Donkin Company in Chesterfield.

A short biography of Bryan Donkin, F.R.S., appears in a book by Harry J. Donkin, which shows that he had many other engineering and mechanical achievements to his credit besides the Fourdrinier machine.

The other stroke of good fortune came when the late Cecil H. Sanguinetti, of the British Paper Company Limited, Frogmore, allowed the author to see the papers of his brother, V. Sanguinetti, which he had been collecting for many years with the object of writing a book on similar lines to the present volume, but chiefly connected with the early machines at Frogmore and Two Waters Mills. He presented the author with all the relevant documents: pictures; reports; patent specifications; and everything connected with the project which his brother had in mind. Sanguinetti's research work had been extremely thorough for he took nothing for granted and corroborated all his findings with cross references in the archives of the Patent Office and the Public Record Office. He also obtained information from every conceivable source, including Paris and Grenoble. In France itself, many were able to supply him with information about Louis Robert and the Didot brothers.

Among Sanguinetti's papers was a report written by John Gamble about his connection with the Louis Robert machine, and of his bringing it to England and introducing it to the Fourdriniers, as well as an account of the subsequent work done by Gamble in collaboration with Donkin and others on the machine. It is a most unfortunate thing that Sanguinetti did not live to publish his work on this subject, and the author is very fortunate in being able to present some of this now to those interested, in the hope that they will find it of absorbing interest.

Mr. G. F. Chambers has been most helpful in looking out many of the drawings made by Donkin and his staff in the early days, and he also loaned a ledger containing the quotations for, and the ultimate detailed costs of, many paper-making machines and complete paper-mill plant supplied both in England and in many other countries in Europe. These authentic figures give a good idea of the cost of paper-making equipment a hundred years ago and more.

Much help has been received from the Science Museum and the Patent Office Library, who allowed the author to see plans, pictures, and very old patents. The author has also been fortunate owing to the help of Mr. Town, of Leeds, in being able to consult a paper-mill directory of 1853, from which much useful information has been obtained about the mills operating at that time. He is also indebted to Mr. Don, of *The Paper Maker*, for being allowed to see a paper-mill directory of 1866. A paper-trade directory of the world, of 1884, has also been used as a source. From these, much information can be obtained about the width and types of paper-making machines which were being used during the middle of the nineteenth century.

Mention must also be made of the book *La Feuille Blanche*, to which Madame Rigaud contributed an extremely interesting and authentic article from which useful information and pictures have been obtained of the early machine of Louis Robert. Valuable information about the early Bryan Donkin machines installed in Sweden has been made available by the proprietors of the Klippans Paper Mill, and also through the kindness of Doctor Steenberg, and Mr. Olle Anderson, of the Swedish Forest Products Research Laboratory. Mr. Serlachius has kindly supplied information about, and the author has seen, the Bryan Donkin machine supplied to Tervakoski in 1851, which is still running and making paper. He has also given the author photographs, showing the name "Bryan Donkin, London" on the drying-cylinders.

The late John Paramor, of the Watford Engineering Works, contributed information about the original engineering works belonging to Tidcombe, at Watford, who also built paper-making machines in the early days, and was a contemporary of Donkin. Messrs. Bertrams Limited have supplied information about their early machines of a hundred years ago, together with ledgers containing particulars of machines supplied to Mr. Edward Lloyd and other people in the middle of the last century.

Much interesting information has been obtained about the firm of Messrs. J. and E. Hall Limited, the successors to John Hall, of Dartford, from Mr. Hesketh's book, in which he wrote about the history and activities of this well-known firm. A. W. Baines, of J. and E. Hall Limited, has also loaned the author photographs which are reproduced in the book.

Alfred Haigh, of Brittains Limited, Cheddleton, has supplied information about the Ivy House Paper Mills, which were operated by the two sons of Henry Fourdrinier, and has loaned a book containing an excellent account of Louis Robert's invention, including a biography of the inventor. The author has received extremely interesting information of the early days of paper-making on the paper-making machine from the late Walter C. Warrell, the grandson of Marchant Warrell, the first machineman to run a Fourdrinier paper-making machine at Two Waters Mill almost a hundred and fifty years ago. A reproduction of the printed portrait of Marchant Warrell is included among the illustrations.

Guy Ibbotson has given information about his family's connection with the paper-trade, which dates back to the earliest days of the Fourdrinier machine, as the Ibbotson family were among the first to obtain a licence from the Fourdriniers to operate a paper-making machine, on the 1st July, 1807.

The British and Colonial Printer and Stationer, 13th September, 1888, contains an account given here of the origin of the St. Neots Paper Mill, where the fourth Fourdrinier machine was installed, and also its connection with the Towgoods, who eventually became very famous paper-makers.

Further useful facts about John Hall and Bryan Donkin are taken from the history of Bryan Donkin and Company, by Harry J. Donkin. There is authentic information available in *The Paper Trade Review*, volume X, 7th December, 1888, in which there is an account of an interview with Bryan Donkin, junior, the son of Bryan Donkin, F.R.S.

I am glad to acknowledge the help given by the following friends in various ways: Sydney Eccles for old directories and in other ways; John Cooper Marsden for pictures; Edward Chadderton for Bryan Donkin's diaries; Frank Oldham and D. Janet Glover for much help with typing; and to George Tatlock for reading the proofs. W. E. Church and W. O'Dea, of the Science Museum, also gave much valuable help with the patents and pictures. I am indebted also to E. F. J. Dean, of *The World's Paper Trade Review*, for help and encouragement, to H. Voorn, of Haarlem, and also to G. D. Clapperton for pictures, to Y. Seki of Mitsubishi Heavy Industries of Tokyo, Japan, for information and pictures in Appendix 6, and to Eden C. Cook of Smith, Winchester and Company for the account of his company.

Finally I have to acknowledge with many thanks the permission of the controller of Her Majesty's Stationery Office, through the Patent Office and the Science Museum, for the use of Patents and Crown Copyright photographs throughout this book.

I would point out that many illustrations in the book have been much reduced in size from the original drawings accompanying the patents, and consequently some letters and numbers on the drawings are extremely small.

INTRODUCTION

WHILE the main part of this book is concerned almost entirely with the evolution of the Fourdrinier paper-making machine, mention has also been made of the machine invented by John Dickinson (now called a vat or mould machine), which worked on different principles. This machine followed shortly after the re-designed Fourdrinier machine of 1807, when John Dickinson and Bryan Donkin were friends and were doing various work for each other. In fact, at one time John Dickinson ceased to develop his mould machine, and installed a Fourdrinier-type machine which he purchased from Donkin. There was, at the beginning, a certain amount of jealousy between the two about the rival merits of the two types of machine, but subsequently they composed their differences since the mould machine, and many other things invented by John Dickinson, had a good deal to do with the main development of the Fourdrinier machine.

While the continuous-wire machine for making wove paper, as patented by the Fourdriniers, was being developed, other machines were being developed at the same time, with a view to making laid papers, as the dandy-roll had not at that time come into use. Many different people spent large sums of money on trying to mechanize the hand-mould in various ways. These developments continued for nearly twenty years, but eventually the chain-mould machine was given up altogether in favour of the continuous-wire machine which was able, after the invention of the laid dandy, to produce better laid papers than could usually be made by hand at that time.

On 25th July, 1805, Joseph Bramah of London, the famous engineer, took out a patent covering several "improvements in the art of making paper". All of these referred to the mechanization of various processes which had until then been carried out by hand.

One of these improvements was to make paper in endless sheets by means of a broad wheel like a water-wheel. This wheel was covered with wire cloth, and had raised edges to prevent the lateral discharge of the stuff, which was fed onto the wheel from a cistern above, but allowing the water to leave the stuff through the wire. Opposite the feeding point on the wheel was placed a roller, covered with felt, called "the couching roller, because it takes the paper from the mould, as they reciprocally turn. There are likewise two other rollers, also covered with felt or woollen cloth, which are placed in firmer contact with each other, and between which the sheet is conducted from the couching roller."

While there is no doubt that Bramah had some knowledge of paper-making and of some of the technical terms used, nevertheless he did not commit any of his ideas to paper, in the form of drawings, which one might have expected of such an eminent engineer. It does not seem that his patents influenced either Bryan Donkin or John Dickinson in their contemporaneous work, although Dickinson may possibly have been influenced in favour of the cylinder mould machine as opposed to the endless wire machine being developed by Donkin.

One of the most interesting things which has come to light during the research work into the evolution of the paper-making machine and the various subsidiary parts of it, is the surprising number of inventions which were made and incorporated into the machine and then discontinued, only to be re-invented a hundred years or more afterwards, and hailed as very important developments for the Fourdrinier machines of today. Many of these re-inventions have become very firmly established parts of the modern paper-making machine. In fact, it would be true to say that without some of them the modern paper-making machine could not operate at the speeds which are common nowadays.

Notable among these are the inward-flow revolving strainer, invented by John Dickinson and re-introduced a hundred years afterwards by Reinicke and Jasper, Banning and Seybold, James Bertram and Son Limited, and others. Another important piece of equipment, invented even earlier, was the suction couch-roll, patented by George Dickinson, and of almost the same design as the Millspaugh couch-roll of the present day. There was also the slotted strainer-plate, invented by Thomas Ibotson; and single-tier drying, using drying-cylinders with dry felts for a Fourdrinier paper-making machine, which was the invention of Thomas Crompton (his first patent). This method of single-tier drying has only recently started to come back again on Fourdrinier machines in all parts of the world.

On the first paper-making machine, Donkin introduced the expanding pulley for obtaining differences in speed of the draws and differences in speed of the shake. This type of speed variation control was practically non-existent on many paper-making machines up to thirty or forty years ago, when speed variation for the draws on the wet-end and presses of the paper-making machine, and even on the drying cylinders, was obtained by the crude method of sticking pieces of belting to the pulley with resin size, in order to increase its diameter.

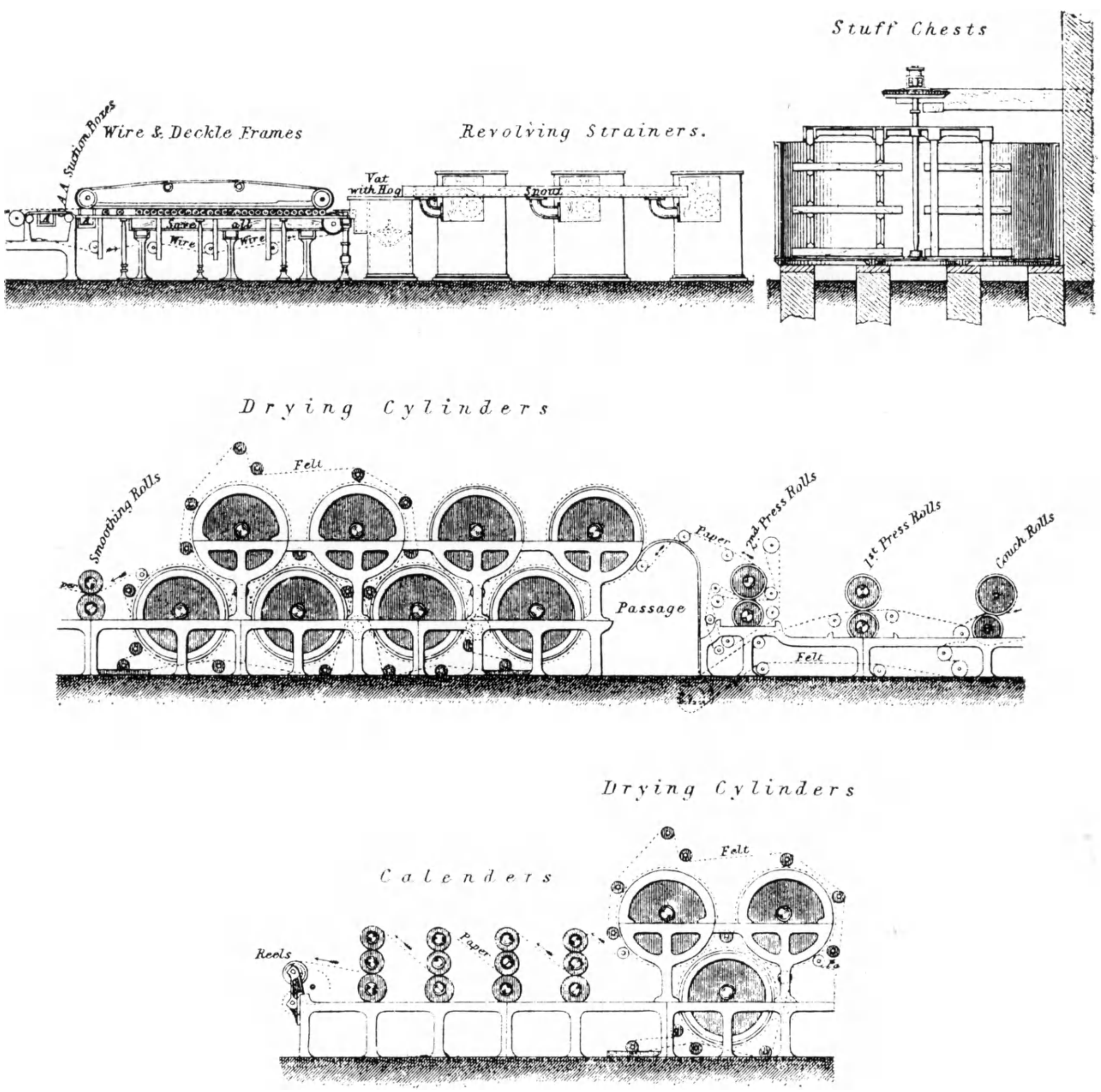
The importance of back-water or white-water which drains through the wire was recognized on the first Fourdrinier machine that was built. Arrangements were made to scoop this water up from the trays under the wire, and take it back to the beaters and chests. Yet in very recent times many paper-making machines were in operation in parts of England and the Continent on which no attempt was made to save the back-water at all. It was simply allowed to run down the river, and fresh water was used for emptying beaters and for diluting the paper-stock at the mixing box.

Very interesting accounts of the value put upon the Fourdrinier machine and its ability to make paper in continuous lengths were given by many witnesses who gave evidence before a Select Committee of the House of Commons enquiring into the Fourdrinier patent in May, 1837. This Committee was enquiring into the possibility of compensating the Fourdriniers from public funds. Many men, whose names are now famous in the printing and publishing world, gave evidence to the effect that the value of the machine to the country was immense. Among the witnesses who came forward were the Hansards who as private individuals in those days printed the proceedings of Parliament. Many of the potters of Staffordshire, in particular, were most enthusiastic in their praises of the thin papers which could be made on the Fourdrinier machine for transferring the design onto the pottery which they made, by means of transfer papers; pottery being then, as now, a very important export from this country. The vast increase in reading matter, made possible by the rotary printing press, which followed closely upon the production of paper in reels, was stressed by many of the witnesses. The production of paper in reels enabled books to be produced at infinitely less cost, and made possible the cheap production of news-sheets and newspapers, which was extremely important in the dissemination of news throughout the whole country.

This introduction must end on a sad note, as it has to be mentioned that, of the early pioneers who invented, developed, and financed the machine through the difficult years of its evolution, Louis Robert, Henry Fourdrinier, Didot St. Leger and Gamble, all died in comparative poverty. Robert died at 66 while managing a small school at Vernouillet, on the 28th August, 1828, leaving a wife and six children. Didot, who had returned to France, died in 1829 near the same village; and Henry Fourdrinier died on the 9th September, 1854, at the age of 88, at the old Rectory, Mavesyn Ridware, near Rugeley. John Gamble was still living in 1857, and there does not appear to be any authentic date of his death. These four men, who were so intimately connected with, and who gave so much of their lives and fortunes to, the development of the Fourdrinier machine, lived to see many successful paper-mills in which hundreds of paper-making machines were operating, from which they themselves were able to get nothing at all. The Bryan Donkin Company alone had built 197 paper-making machines before Henry Fourdrinier died, and by that time many other engineering firms were also building this type of machine. The Fourdrinier firm, of which Henry Fourdrinier was the head, lost at least £60,000 in the first ten years of the development of the machine, and became bankrupt in the process. Leger Didot lost his paper-mill and his business; Gamble lost his paper-mill at St. Neots to Matthew Towgood; and Robert was left completely out of it by everybody, and eventually got nothing but a statue and memorial many years after he died.

It has been thought advisable not to interrupt the story of the evolution of the machine by including particulars of the men who were chiefly concerned with its early development, but rather to refer to all these in biographical form in the latter half of the book.

As some readers may not be conversant with the terms used to describe the various parts of a paper-making machine, it has been thought desirable to print a picture of a machine on which some of the important parts most frequently mentioned are shown. This appears below.



1

The First Paper-making Machine

THE paper-making machine of today is something that we take for granted. Little is known of its origin or of the tremendous amount of work and ingenuity which was put into the making of a machine which would produce paper in a continuous web, as compared with the single sheets which had always been made by hand.

Paper was invented in the year A.D. 105 in China, and from that time up to the end of the eighteenth century all paper throughout the world was made one sheet at a time on a mould by a vatman. He dipped his mould into the vat of stuff and drew out the fibres mixed with water which drained away through the meshes of the mould and left him with a wet sheet of pulp. This product was afterwards couched off onto a piece of cloth or felt before having the water squeezed out of it and was then finally dried by being hung in the open air.

The man who first put into practice the idea of making paper mechanically in long lengths, and who produced a machine on which to do it, was a Frenchman named Nicolas Louis Robert,* who worked in the office of a paper-mill owned by Leger Didot† at Essonnes in France. Louis Robert was born in Paris in 1761. He began work as a lawyer's clerk, and later became a proof-reader in a printing office after having served for some years in the French Army.

During the Revolution, after his return from service in North America, he was employed by Leger Didot in the counting-house of the Essonnes Paper Mill. His previous occupations hardly seemed to prepare him for the task of inventing a paper-making machine, but this idea captured his imagination and he began to give a great deal of attention to the problems involved. His intelligence, and the encouragement of his employer from time to time, eventually enabled him to create a machine destined to revolutionize the art and practice of paper-making. After much experimental work, which occupied several years, and many improvements indicated through practical use, his machine made paper.

It is certain, however, that this crude machine had a short life and was never able to make paper continuously on a commercial scale. There was no continuous paper-making machine working commercially in France until many years after Louis Robert's invention, in fact not till 1816, when a machine was installed at the mill of Messrs. Berte and Grevenich, at Saint-Roch, Commune de Sorel Moussel, Eure-et-Loir. This machine, made by Calla, proved to be a failure, and it was not until 1822 that a Fourdrinier machine, built by Bryan Donkin and installed in a French mill, became the first commercially successful paper-making machine. Great credit is undoubtedly due to Robert, for not only did he solve the problem of working a long and broad flexible endless mould by mechanical means, using an endless running wire, but he also foresaw that paper in long lengths would find special uses. Initially, it occurred to him that it would be more useful if wallpaper could

* Biography, pp. 279–83
† Biography, pp. 285–6

be made in rolls, instead of in panels. In his time this appeared to be the only purpose to which a long strip of paper could be put. In Paris at that time there was a very great demand for wallpapers of every description for decorating the rooms of the larger houses. It is due almost entirely to this demand that paper on rolls was ready in time for rotary printing, a need which stimulated the inventive genius of Louis Robert.

A French authority has this to say about Robert's machine: "As to the manufacture of paper mechanically, the first idea was formed in 1798. Robert, working at a paper-mill at Essonnes, inventor, helped by Leger Didot, proprietor of the factory, made one machine which did not work."

Although Robert's original idea was not brought to fruition in France, possibly chiefly on account of the disturbed political situation at the time, he was granted a patent by the French Government for fifteen years.

Shortly after Robert had started to work as an accountant in the offices of the paper-mill at Essonnes, he was promoted to a post which involved his being a kind of clerk inspector of the workers. This was probably due to the experience he had gained as a soldier, because there was a great deal of trouble with workers in French factories at this time. It was the trouble experienced in managing about three hundred men in a mill making paper by hand which determined Robert to try to produce some means by which paper could be made mechanically and by only a few men, so as to be independent of the large numbers required in a hand-made paper mill. A French account states that he was vividly struck by the grave difficulties presented in directing three hundred workers, who were influenced and made truculent by the Revolution.

At Didot's mill at Essonnes they manufactured the paper used in the making of the *assignats*, or paper money used by the Government, and lack of discipline of the workers had often caused serious troubles. Robert told his employer, Leger Didot, of his idea and was authorized by him to make use of material and workmen in the factory to carry out his project of designing and erecting a machine that would make paper by mechanical means. The first model made was by no means perfect and did not come up to Robert's own expectations, although the results obtained were satisfactory enough to encourage him in the hope that he would eventually succeed. For some years after his initial attempt, Robert did nothing further towards perfecting the work until Didot took him to task about this, and encouraged him to continue and make a success of it by offering to help him and to enter into an agreement with him about financing it. Robert, thus encouraged, turned again to the work and, after many experiments which occupied him about three years, succeeded in constructing a model of the machine which realized his hopes and made paper continuously, but of very narrow width.

Robert and Didot tried out the machine secretly together, and this was so satisfactory that Didot gave him the necessary authority to make a large machine on the lines of the model which had been so successful.

It is fortunate that there is an account in English by Didot's brother-in-law, John Gamble. At the time of the invention of this paper-making machine by Robert, Gamble, an Englishman, was employed by the British Government in the office of Captain James Coates, of the Royal Navy, in Paris, who was a councillor for the exchange of prisoners of war in France. The following account is given by John Gamble:

> Louis Robert, a native of France, is the person to whom we are indebted for the paper-making machine. I had frequent opportunities of seeing him at work on his first model, in 1796, 1797 and 1798, at the Paper Manufactory at Essonnes, eight leagues from Paris, Département de Seine-et-Oise (which at that period belonged to Monsieur Leger Didot, my brother-in-law), where Louis Robert was employed as book-keeper. His first model was no larger than a bird organ, and the slips of paper he made with it were not wider than a piece of common tape, but of various lengths. Robert possessed a natural mechanical genius, and

> was never so happy as when employed in inventing or improving some piece of machinery, but unfortunately, the only time he could devote to his favourite pursuit was in the evening, after the counting-house business was over, and many a time I have heard him blamed and reproached by his employer, Leger Didot, for wasting so much time on an invention that would never be brought to perfection. However, Robert persevered, and in about two years produced a model which performed so satisfactorily that M. Didot was, at last, induced to afford him the means of making a machine upon a larger scale, which was called the working-model. Orders were given to the carpenters, smiths, millwrights and other workmen employed at the manufactory to take directions from, and execute any work, that Robert might require for his paper-making machine. In a few months from that time a machine was completed capable of making paper of the width of Colombier (24 in.), and of various lengths, being the kind of paper usually employed for paper hangings of which the consumption in France was immense. Owing to the great difficulty, at that time, of sizing and pressing sheets of paper of great length with the presses usually employed in paper-mills, the length was generally limited to twelve yards, but a fresh difficulty arose in the process of drying it; it was suspended on lines in the drying loft, but from its weight when in the wet state it contracted so much in the middle, during the drying, that it was rendered unfit for the use of the paper stainers; the next attempt was by laying these long sheets horizontally on the lines; and by adjusting several of the frames or trebles on a level line, the inconvenience of the partial shrinking of the paper when suspended in a vertical direction was remedied. Many of these long sheets were sold to the paper stainers of Paris. After a series of experiments and improvements, Louis Robert applied to the French Government for a patent, or brevet d'invention.

Robert, however, was unable to raise the £30 necessary to obtain a French patent, so he wrote to the French Government and pointed this out, asking if they would be willing to grant him a patent without payment of any money. His letter is as follows:

> 9th September, 1798
>
> To the Minister of the Interior,
> Citizen Minister,
>
> After many years, during which I have been employed in one of the principal paper factories of the Republic, I have given thought to simplifying the methods of manufacture of paper and making it infinitely less expensive, and above all in making a paper of extraordinary length without the help of a single workman and by purely mechanical means. I have at last succeeded by hard work, experience and expense, in manufacturing a machine which fulfils perfectly the purpose I proposed. With the greatest economy in time and labour it makes an exceptional paper twelve to fifteen metres long if one wishes. Here, in a few words, are the advantages which I obtain by my machine constructed at the factory of citizen Didot at Essonnes. I say of a truth and this is the place to say it, that I have received from citizen Didot the greatest help in the making of this machine; his works, his workers and his purse have been at my disposal with such generosity and such confidence such as one does not find except in a true lover of the arts, but I do not wish, neither have I the right, to make further uses of these resources at this moment, when I ask of you, citizen Minister, for the patent which would safeguard my rights and give them to me myself. My finances do not permit me to pay at once the tax on this patent, which I desire to have for fifteen years, nor to pay the expenses of a model. It is for this reason that I beg of you, citizen Minister, to appoint commissioners to examine my machine, constructed in full size, on the spot, and as a result of their report made to you, to grant me a gratuitous patent in consideration of the immense utility of my discovery.
>
> (signed) Louis Robert.

On the 5th October, 1798, the Minister replied pointing out that it was impossible to do what Robert requested, in view of the laws governing patents, but that if the machine produced the results claimed, he would have pleasure in suggesting to the Government that they make him an award such as is accorded to inventors of useful works. He added that he was authorizing the members of the *Conservatoire des Arts et Métiers* to send a draughtsman to be attached to the establishment at Essonnes: "The Draughtsman is instructed to make a drawing of your machine, and I ask you, citizen, to give him all particulars necessary to fulfil the mission with which he is instructed." The letter was signed: *Salut en Fraternité, François de Neufchateau.*

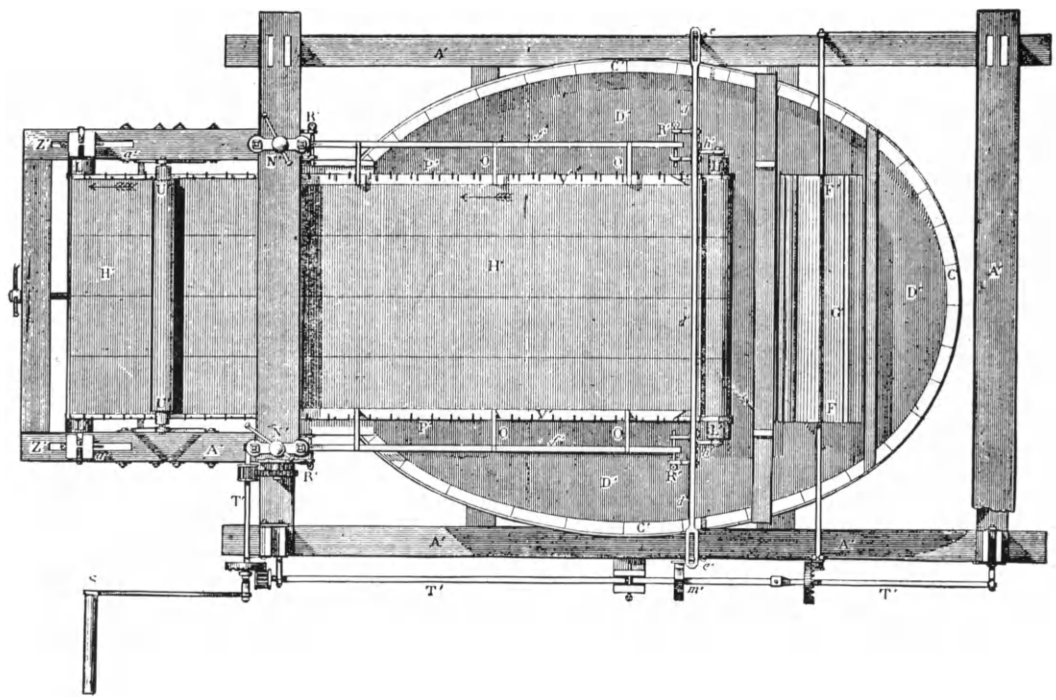
The Government's interest in the new invention was quickly shown in a most efficient way, for on the 4th December, 1798, Robert received a letter from the Ministry as follows:

> Citizen,
>
> In conformity with your request, I have submitted the drawings of the machine which you have invented, and by means of which one can make paper of extraordinary length, to men of science. It appears from their report that this machine is useful and merits the attention of the Government. Under these conditions, citizen, I think that your work entitles you to a national award. I have, therefore, decided that you shall be awarded the sum of 3000 francs in the way of encouragement. The Accountant-General of my Ministry will immediately remit to you the warrant necessary to this effect. You will recognize, citizen, in this favour the interest that I take in the progress of art, and I desire that this encouragement will give you the scope to employ yourself in all those things necessary to develop the industry.
>
> Fraternal greetings,
>
> François de Neufchateau.

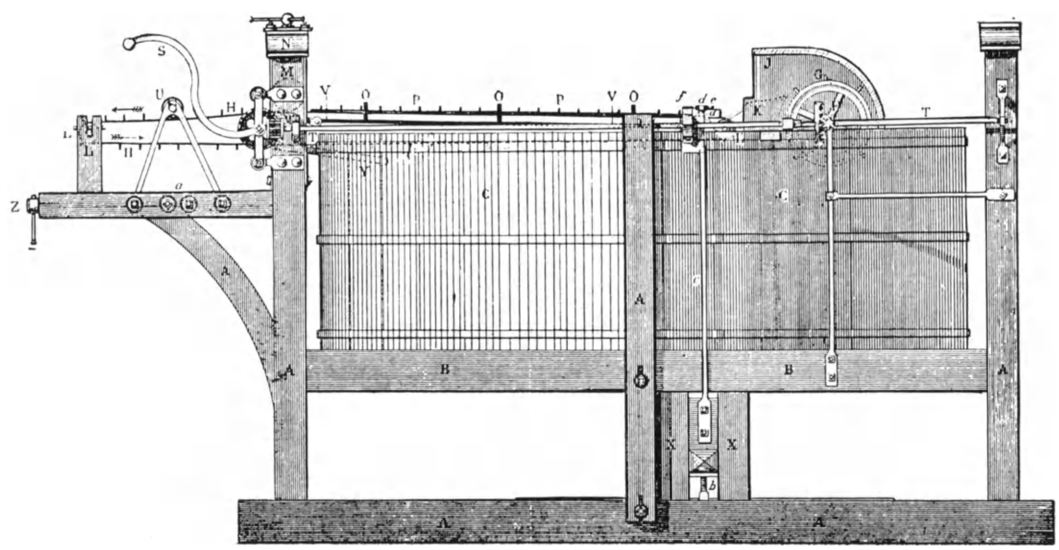
Placed in a position by this government award to surmount the purely financial obstacles which prevented him from obtaining his patent, Robert immediately completed the necessary legal formalities and obtained, on the 18th January, 1799, the patent he asked for.

The following is a description of the patent of the first paper-making machine invented by Robert (after the original designs presented in the patent of 18th January, 1799):

> The machine, which was under 10 ft in length, was put in action by a workman turning a handle (S), and by means of suitable shafts (T) motion was imparted to other parts of the machine.
>
> The whole machine rested upon a stout wooden framework (A) supporting a large oval chest containing the mixture of water and pulp discharged into it from the beaters used for breaking down the rags and reducing them to pulp. At the end of this chest rotated an enclosed cylinder or drum (F) fitted with eight copper bars (G) projecting from the surface of the drum. This was controlled by means of suitable gearing fixed on the shafts (T). As the drum revolved, the copper knives in turn scooped up part of the pulp and discharged it onto an inclined board (K), from which it flowed to the endless machine wire. The cover (J) served to prevent the mixture of pulp and water being thrown out from the chest into the air.
>
> The machine wire (H), carrying the pulp, was a long wire cloth, made after the fashion of a laid dandy or mould cover, with the ends carefully sewn together, forming an endless wire which rotated in a horizontal position and was kept in motion by the rollers (L). The wire passed between felt-covered rollers, which served to press out the excess of water. The machine wire, on passing the roller, reversed its direction back to the first roller at the front of the machine. By its continuous movement the machine wire carried the pulp thrown upon it by the drum, between the rollers (N), much of the water escaping through the meshes of the wire cloth, a further quantity being pressed out and returned to the



No. 1. Plan of Robert's paper-making machine as patented in France in 1799.



No. 2. Section of Robert's paper-making machine as patented in France in 1799.

stuff-chest by means of the doctor (Y). After this pressure, the pulp reached a certain degree of coherence and solidity sufficient to enable the workman to detach it from the wire and cause it to gather round the roll (U). This roll pressed lightly upon the wire and rested in open adjustable bearing sockets, so as to carry the gradual increase in the diameter of the roll of paper since the wet paper was continuously rolled up. When the roll became full it was possible to replace it with another without stopping the machine. The only attention to be given at this stage was to make the rollers quite damp before putting them into position. It was only this moisture which made it possible to take hold of the sheet of paper and to detatch it automatically from the machine wire.

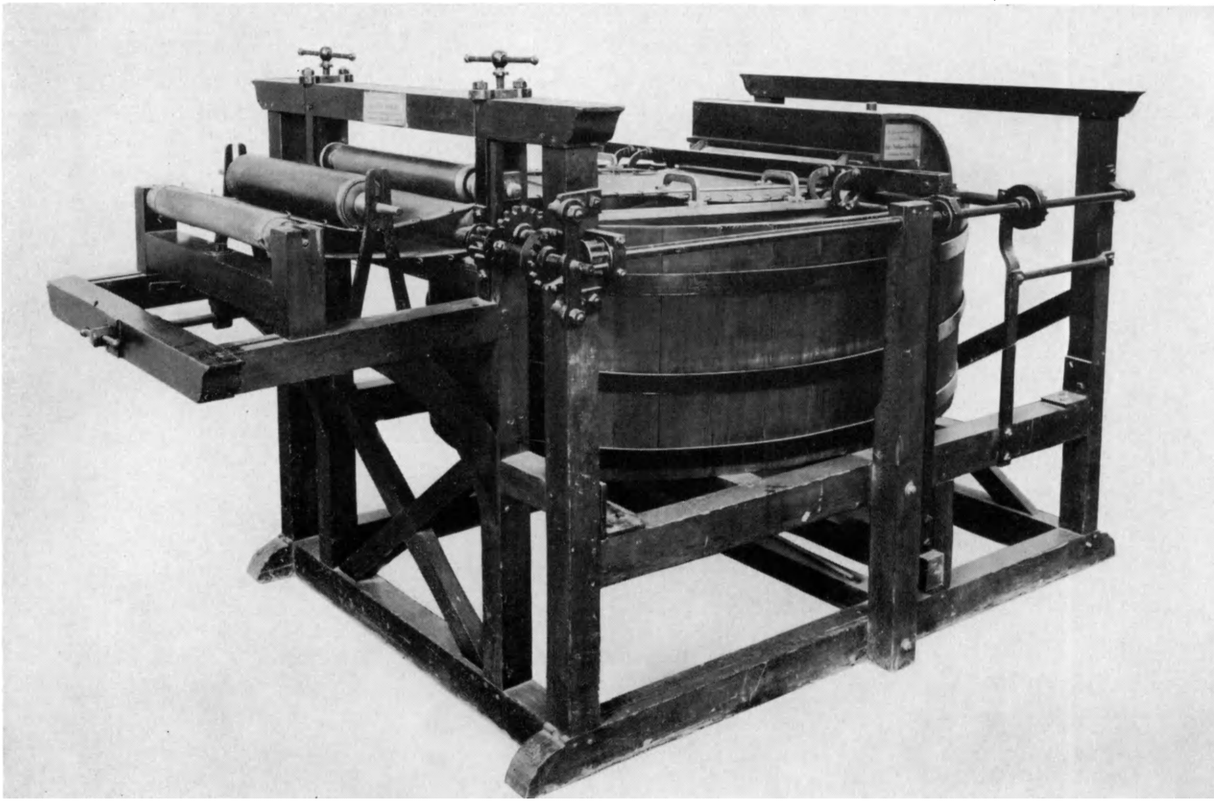
To prevent the pulp thrown upon the machine wire by means of the blades of the drum (F) escaping at the sides, some bars of copper (V) rested at each side of the wire. These bars (the deckles) retained the pulp from running off the wire until it reached the press rollers. They were fixed to the rod (f) for regulation of the width of the sheet. Just as it was necessary to keep the wire evenly stretched in width, it was equally important to keep it stretched in the direction of its length. This was accomplished by the stretching rolls (L) carrying the wire. The rollers at the head of the machine were fixed, but those at the end of the machine could be adjusted by the screw (Z). In this way the wire was stretched as desired. Although the wire had to be level across the width, the contrary took place along the direction of length, the wire being on the slope upwards from the head of the machine towards the winding-up rolls. This slope was required in order to facilitate the escape of the water in proportion as the pulp advanced along the wire, where ultimately it was passed through the squeezing rolls.

Arrangements were fitted to regulate the thickness of the sheet by means of bars (G) which passed a known quantity of pulp and water onto the wire, and if the stuff-chest drum threw too much stuff, the excess flowed back into the chest by varying the slope of the wire, and so the thickness was altered accordingly. In spite of the slope, the distance between the press rolls (M) and the winding-up roll (L) would have been insufficient for the removal of the surplus water, had it not been for a shake motion imparted to the wire, which further caused the fibres to cross one another and combine together before being pressed by the rollers. This shaking motion was produced by the cross-bar (d) placed across the chest at the head of the machine, with its ends working on guide-pins (e), and connected to the vertical bar (c), having its end fastened to a block sliding between the chest support (x). The block could be adjusted by the screw spring (b). The transverse bar (d) was connected to the side bars (f), operating the flat bars on either side of the machine wire. An intermittent motion was imparted to the mechanism by the toothed wheel (m) fixed to the main shaft (t) of the machine. By raising or lowering the bar (d) with the help of the screw (b), the slope of the wire could be altered.

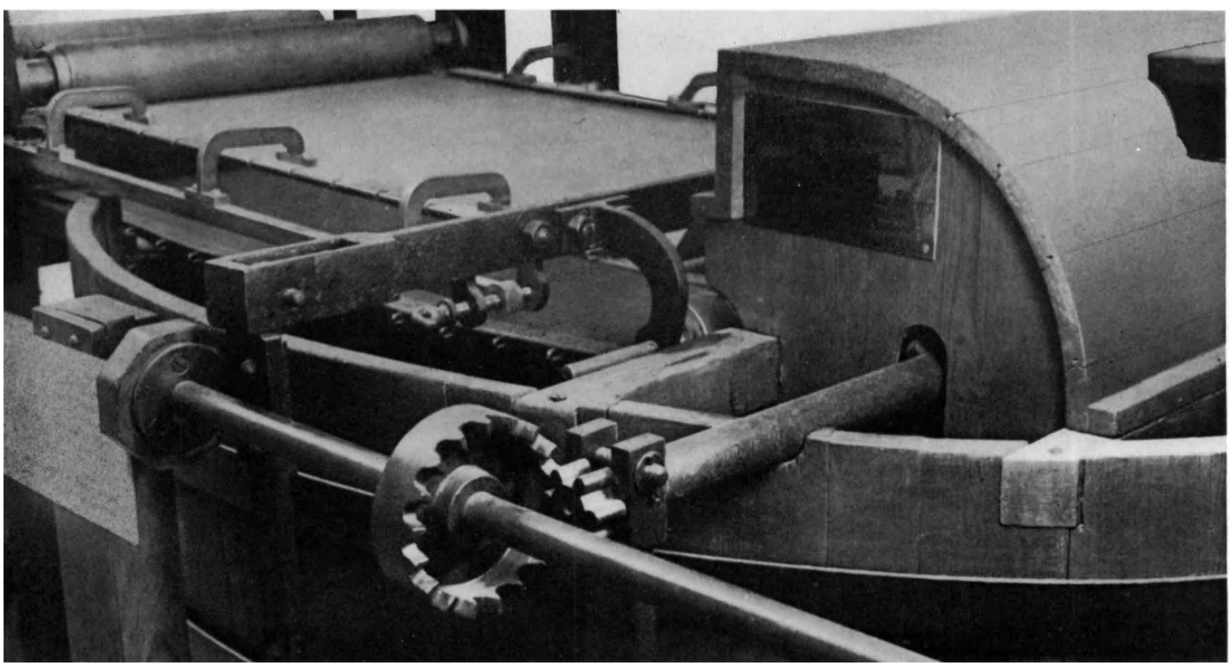
Robert was, at the time of his patent being granted, 37 years old; and he saw all obstacles levelled and had hopes of a brilliant future. Leger Didot appreciated the immense value of Robert's invention and never doubted that the monopoly of it would be reserved for him. In effect, Robert had too many obligations to refuse to treat with him for the concession of the machine. From another point of view also, Robert's capital would not allow him to exploit his invention alone, either by erecting a paper-mill or attempting to find the necessary capital, or alternatively to finance workshops for making the machine.

When Robert obtained his patent Didot had offered to buy it from him with all its rights for the sum of 60,000 fr., 6,000 fr. of which were to be paid in cash, and the balance in instalments, Robert to receive the interest on the balance until it should be wiped out. Robert accepted Didot's proposition, which clearly showed that Didot had every confidence in the future of the invention, in spite of its faults and the practical difficulties encountered on the first machine. The negotiations, however, broke down because of certain demands made by Robert on the subject of guarantees as to the payment of the balance. The sum of 6,000 fr. was actually paid on the signing of the agreement, but the balance was never paid to Robert.

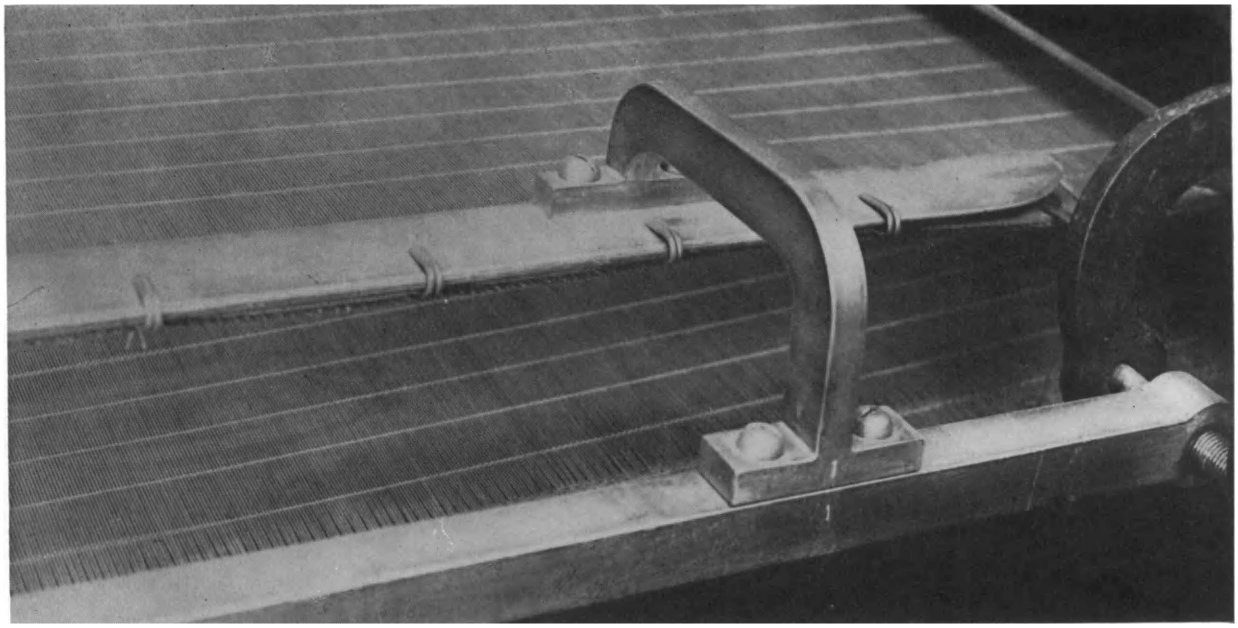
One of the conditions which Robert desired to add was that he himself should be personally associated with the manufacture of the paper, but Didot would not consent to this. Didot lodged an appeal against these conditions and during the interval before the case came to trial Robert took his machine away to Darnetal, near Rouen, and attempted to start a paper factory there. His resources were very limited, however, only consisting of the first instalment which Didot had paid him, and soon he saw that he would have to close his works. The upshot of the quarrel was a lawsuit



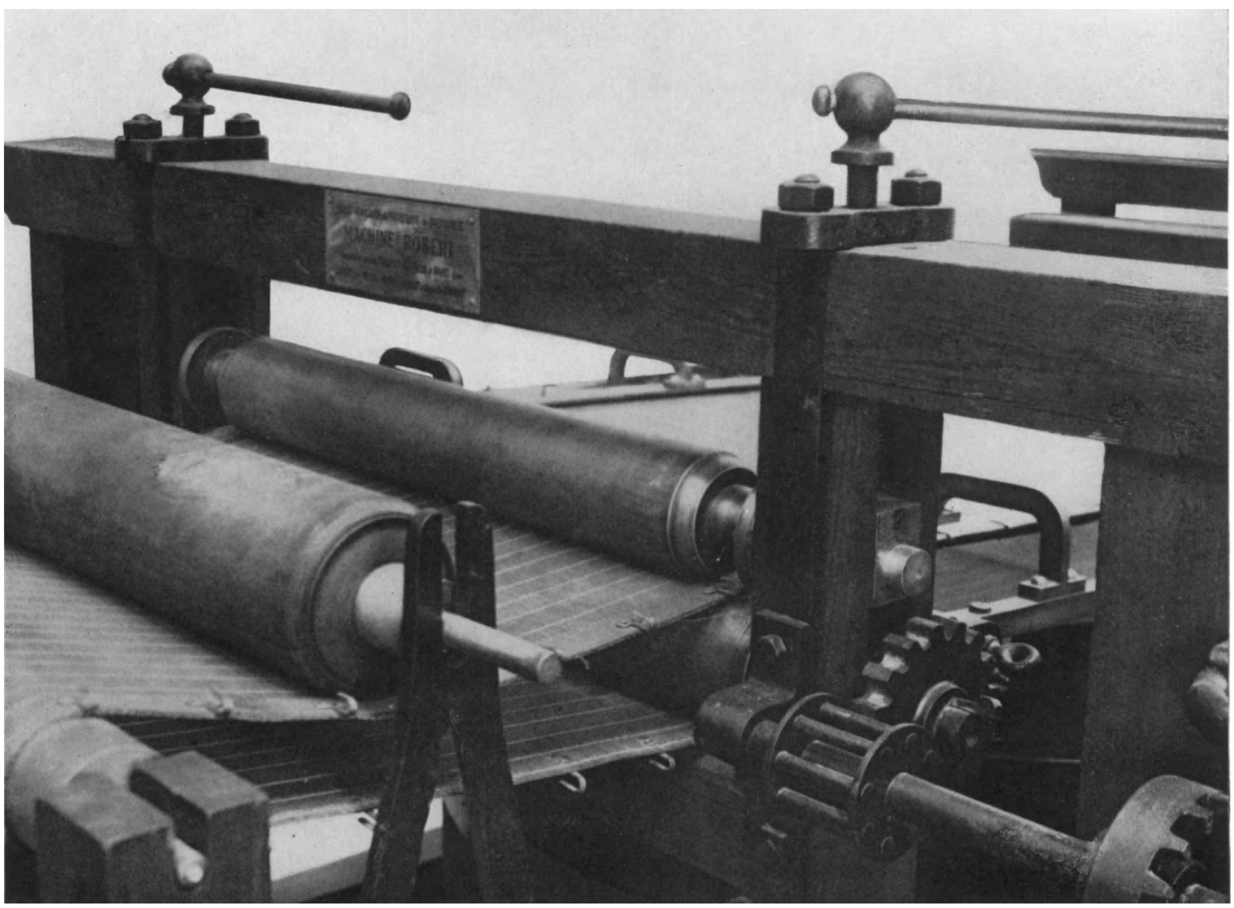
No. 3. Model of Robert's paper-making machine at the École de Papeterie, Grenoble. This picture shows the gearing for turning the machine, also the arrangement for shaking the wire. The pressing rollers, reel-up roll and wire return roll are also shown.



No. 4. View of the model showing drive for the lifting cylinder—under the cover—and the hexagonal wheel for operating the shake mechanism.



No. 5. The wire cloth of the model machine and the arms for keeping the wire taut.



No. 6. View showing the pressing rollers above and below the wire and the reel-up roll.

started by Didot, who alleged that he had the right to be considered as co-proprietor of the machine on account of the advice and help he had given to Robert during its construction, the expenses which it had occasioned him, and all the tools he had placed at the disposal of the inventor. However, after useless attempts at conciliation, the court gave a judgement stating that since the name of Robert only appeared on the patent, and since Didot had not, at the time of the gift to Robert made by the Minister of the Interior, claimed any personal participation in the invention, the original belonged to Robert only. The court, in consequence, ordered that the machine should be restored to Robert on the condition that he should reimburse Leger Didot with the expenses he had been put to in connection with it.

Robert was forced to go back and live in Paris, because Didot lodged an appeal against the judgement which gave Robert the machine. Robert's wife was ill and his future outlook now seemed to be very dark. He was in such low water that he wrote to Fleurigeon, who had loaned him money on previous occasions, and told him that all he wanted for his paper-making machine, his patent, and the privilege of exploiting it, was 25 gold louis, in order that he might move to some other place and start life again.

Fortunately for both parties, a reconciliation was made between Robert and Didot, and they came to an agreement at last as to the price for the sale of the patent. The deed of sale was drawn up on the 28th March, 1800, by Monsieur Silly, a lawyer in Paris. By this act, which had a considerable influence on the destinies of Robert, he sold to Didot the rights associated with his invention of the 18th January, 1799. He also undertook in respect of his concession to deliver to Didot a new machine as well as a full-size model of a new apparatus for pressing and stretching the paper, which had recently been invented by Robert, and detailed instructions for certain special processes employed by Robert for sizing paper. The sale price of the patent and equipment was fixed at 27,400 fr., of which 2,400 fr. were paid on account, and the remainder was to be payable from the commencement of manufacture of paper at Essonnes. Robert also agreed that for three months he would direct the operations connected with manufacturing and sizing of paper which was then being produced at Essonnes. Robert, in fact, was never paid the balance of the money, namely 25,000 fr. (about £1,200), and he again took legal proceedings against Didot for the recovery of the money, or the patent. On 23rd June, 1801, Robert recovered his patent by a decision of the court.

Gamble states that Didot had a contract with the Republic for the supply of paper for the *assignats*, or paper money which was being printed by the new Government of the Revolution, and had this to say about it:

> ... this paper was frequently sent in a damp state, in covered carts, drawn by post horses, to the printing office in Paris, was immediately printed and signed by the proper authorities during the night, and as soon as the paper was sufficiently dry, it was issued in the morning to the public. I remember that numerous laughs and jokes took place when Didot returned from Paris with a small bundle of *assignats* under his arm, which was all that he had received in payment for the many cart-loads of paper with which he had supplied the Government; the only difference was that when they came back with Didot they had been printed and signed by some of the revolutionary demagogues then at the head of the Government. The fate of the *assignats* is well known. I recollect being in Paris during the time they were ordered to be burnt, and I saw their fragments flying over the heads of thousands of persons who had been utterly ruined by their introduction.

2

The First British Paper-making Machine Patent

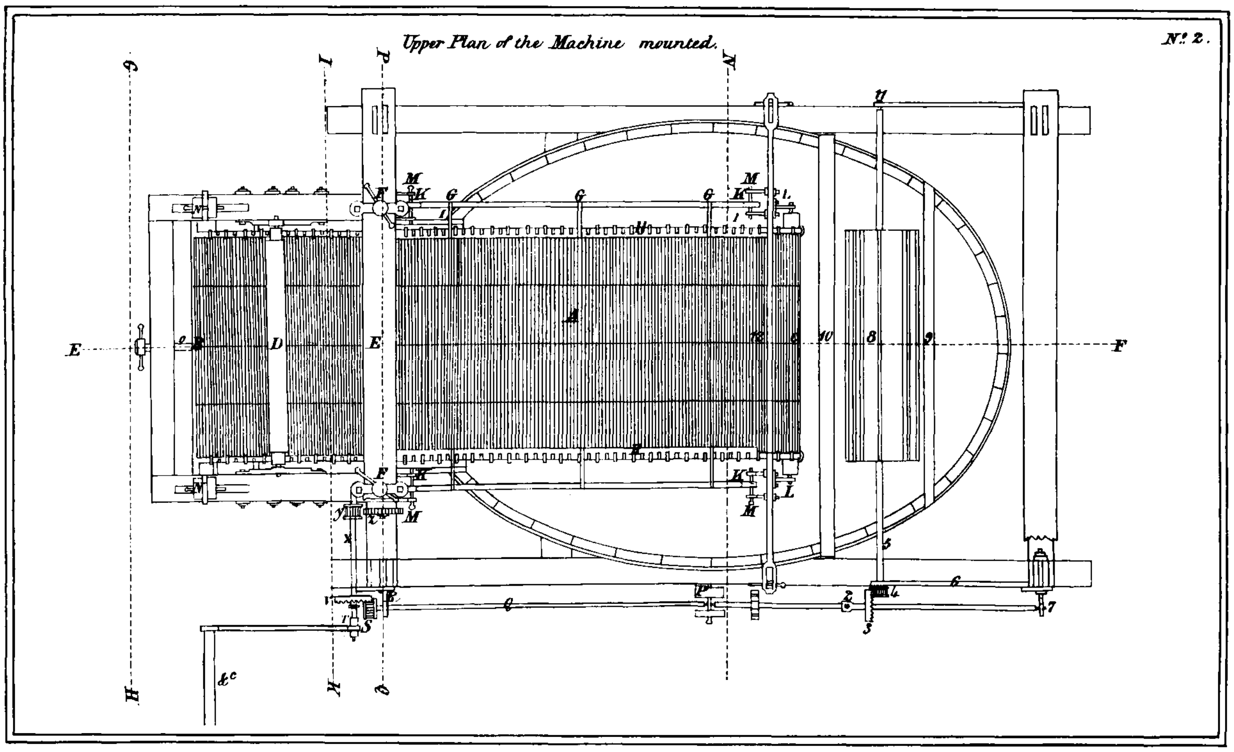
DIDOT was very anxious to get a patent taken out in England in 1801 before Robert recovered his patent from him. Things were very difficult in France at that time owing to the political situation and it is certain that Leger Didot wanted to get out and come to England. This was not possible at the time so he proposed that Gamble should take the patent and samples of paper to England. At this time 8000 tons of paper a year were being made by hand in England. The following summarized account was taken from Gamble's report:

Leger Didot had suggested to Gamble that he should go over to England and take out the patent there for the paper-making machine. Gamble's remuneration was intended to come out of the profits that might be obtained by the sale of the machine in England. Gamble consulted his superior officer, Captain Coates, and, receiving his sanction and advice, he agreed with Didot that he would undertake the mission and leave Paris in a fortnight. Being an Englishman, and in the employ of the British Government, Gamble had no difficulty in obtaining a passport. Gamble says that in the month of March, 1801, he left Paris to proceed to London, and Captain Coates gave him a letter of introduction to T. Mantell, Esq., at that time the mayor of Dover. On arriving at Dover, Gamble lost no time in waiting upon the mayor, who, as he says, with true British hospitality, invited him to dine, to meet a few of his friends from London, amongst whom was Mr. Millikin, a gentleman residing in Norfolk Street, London. In the course of conversation during dinner Gamble told Millikin that he was on his way to London to take out patents for a machine for making paper, upon which Millikin said that on his return to London he would be very happy to introduce Gamble to one of the most respectable wholesale stationers' houses in London, that of Messrs. Bloxham and Fourdrinier. Gamble said he would be very pleased indeed to avail himself of the introduction.

When Millikin returned to London, Gamble accompanied him to Sherbourne Lane, where he was introduced to the Fourdriniers. Millikin told them that Gamble was taking out patents for a machine for making paper on an entirely new principle. At the same time Gamble showed them nine or ten rolls of paper, of considerable length, which had been made by Louis Robert's paper-making machine at Essonnes, and Messrs. Fourdrinier were very pleased and astonished at the rolls of paper. Prior to leaving, Gamble said that the Fourdriniers had expressed themselves to be very happy to purchase a share in the patent, and requested that they might have the first offer.

In 1801 the first English patent was granted to John Gamble. It was entitled "Machinery for Making Paper," and numbered 2487. Gamble's specification was simply a translation of Louis Robert's original patent specification. Metres had been converted to feet, and the whole of the specification consisted of an explanation of the drawings which Gamble brought with him from

France when he came over at the request of Leger Didot. In the actual drawings deposited, inches are shown as *pouces*, and feet as *pieds*. There are nine drawings in all, the principal ones being an elevation of the machine on the right side, and a cut of this showing the interior of the vat, with the hog, etc., a plan of the press-part of the machine, a cut of the interior of the vat, and lateral elevation of the press-part.



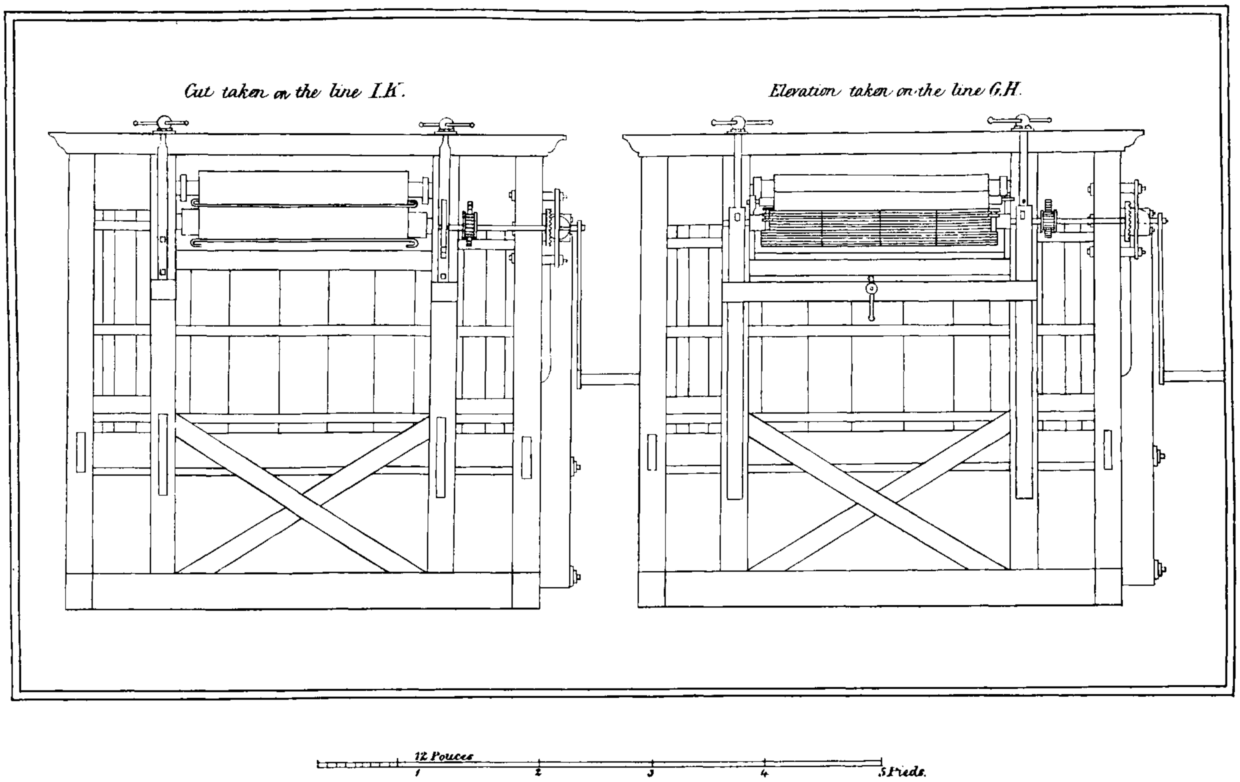
No. 7. Plan of Robert's paper-making machine from the English patent of John Gamble, 1801. This drawing shows the oval vat, lifting roll (8), wire cloth (A), press rolls (E), reel-up roll (D), also the turning handle.

Soon after the patent was obtained, an agreement was entered into by Gamble with the Fourdriniers for the purchase by them of one-third of the patent rights. This was the first transaction by which Messrs. Fourdrinier became connected with, and interested in, the paper-making machine. It was a commercial speculation on their part which unfortunately did not prove a profitable one, either to themselves or to any of the persons originally connected with it.

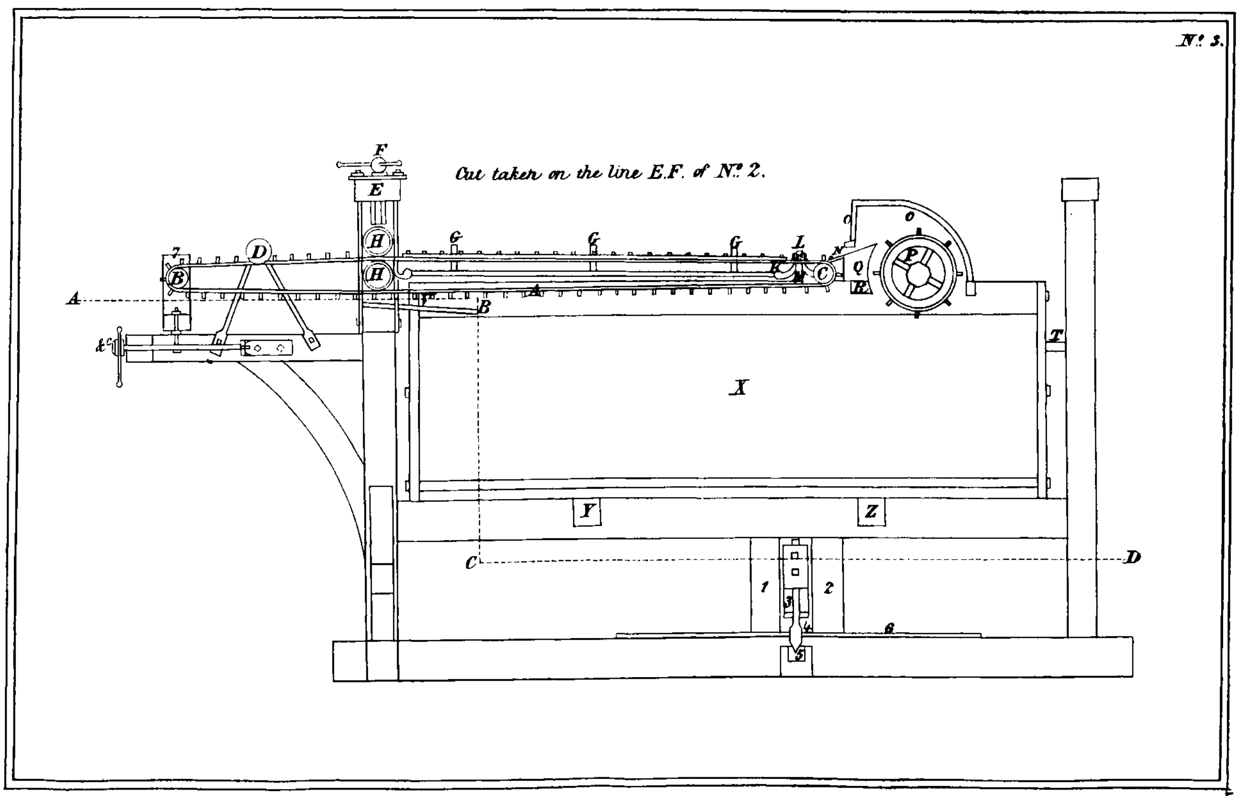
In the latter part of the year 1801, Gamble says that he returned to France for the purpose of having detailed drawings made of the machine. These drawings, Gamble says, were those he delivered with his specification for his first patent in 1801, and they were deposited in the Enrolment Office in Chancery Lane, London. During the short time that Gamble was thus engaged in Paris he made arrangements with Didot and Robert to have the original working model, which was then at Essonnes, sent over to England, as it would materially assist in the construction of other machines. After much trouble and expense the machine arrived in London.

The short peace, which took place in 1802 and was called the Treaty of Amiens, afforded Didot the opportunity of coming over to England, where he was introduced to Messrs. Bloxham and Fourdrinier by Gamble.

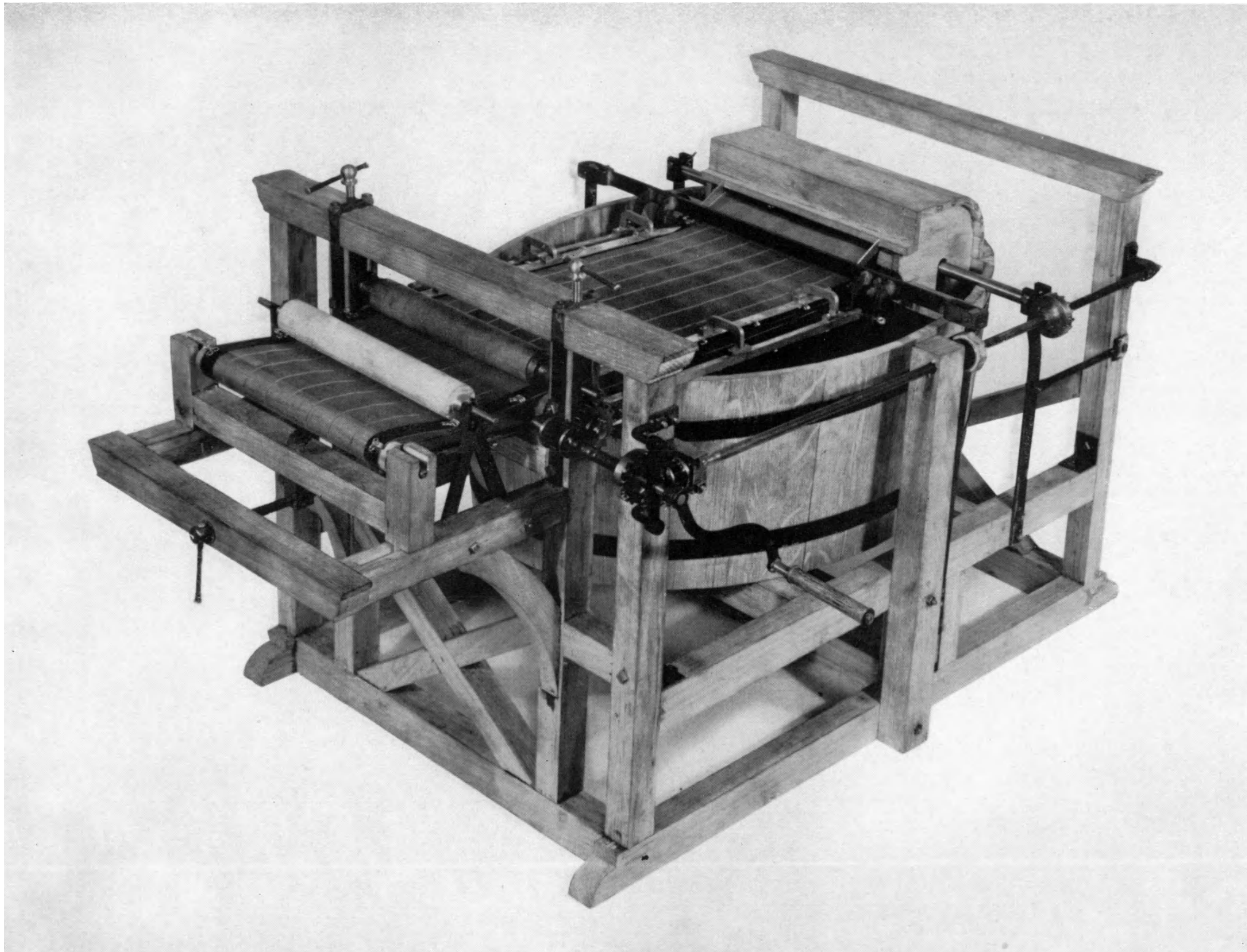
After the machine had been received in England, it was thought desirable to commence a series of experiments for improving it, and thus the working model was sent to the factory of John Hall, at Dartford, who was at that time the millwright of the Fourdrinier firm. As soon as the model was



No. 8. Sections of the machine taken from the reel-up end, showing turning handle, and on right wire passing round the return roll.



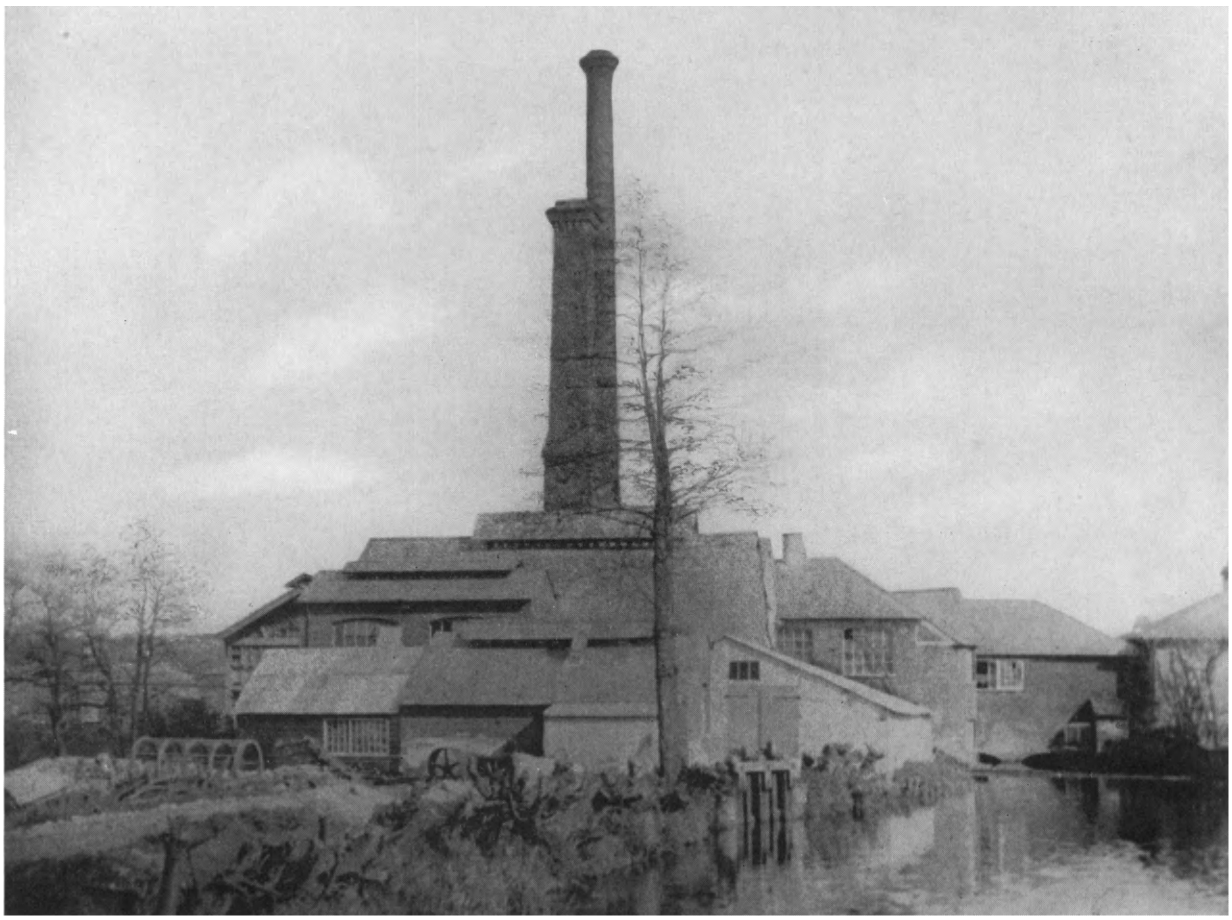
No. 9. Section from front of machine, showing lifting wheel (P), under the cover at right, for raising stuff from vat onto wire at (Q). The endless wire, press rolls, reel-up roll and wire return roll are also shown, also the tray for returning water from the press into the vat at (B).



No. 10. Working model of Robert's paper-making machine at the Science Museum, South Kensington.

erected and fit for work different improvements were attempted, and Didot and Gamble spent the greater part of their time at Dartford in suggesting, making, and superintending the alterations required.

At that period Bryan Donkin was engaged in business in Dartford as a mould-maker, and being an extremely ingenious and clever mechanic, who had previously served his apprenticeship with Hall, the latter asked him to help with the machine. He assisted materially in improving it, and in 1803 the French working model, after nearly three years of diligent and unremitting experiments and improvements, was erected at Frogmore Mill, near Two Waters, in Hertfordshire, which Messrs. Fourdrinier had taken for the purpose.



No. 11. Frogmore Mill, Hemel Hempstead, where the original machine of Robert was erected in 1803, and where the first re-designed machine of the Fourdriniers and Gamble, and built by Bryan Donkin, was erected in 1803.

Gamble left London and moved to Two Waters to superintend and explain to the different manufacturers, who had been invited to inspect the machine, the great advantage it possessed over the old method of paper-making.

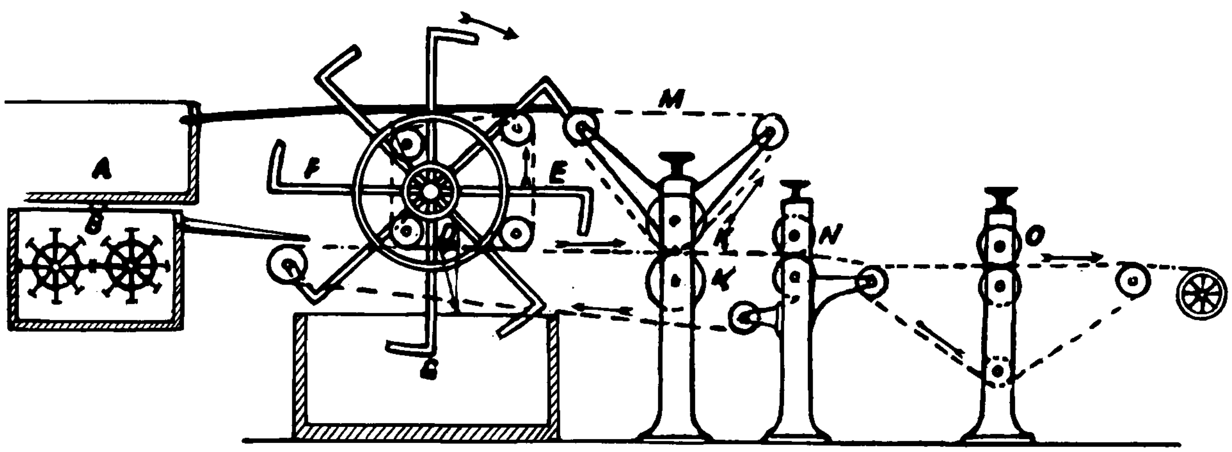
Here it would be as well to give some particulars of the French model which came over to England in Donkin's own words. He made these statements before the House of Lords. "In the beginning of 1802 part of a paper-making machine, said to have been used in France for the purpose of making paper, was sent to John Hall's at Dartford by Messrs. Bloxham and Fourdrinier for the purpose of a model to enable Hall to construct one of a larger dimension but upon the same plan.

Men were accordingly employed to connect these parts of the machine which had been received, and to supply those that were missing, and repair others that were found defective. After spending much time, and incurring a considerable expense, without success; for there was not, in any of the attempts, paper produced of such quality as to be fit for market."

The machine remained at Hall's until June, 1802, during which time no considerable improvements had been made, when Donkin agreed with Messrs. Bloxham and Fourdrinier to conduct the business on their account, as several improvements had been suggested, and many and various experiments were made to ascertain their efficacy. The later series of improvements which were made were sufficient to induce the Fourdriniers to set about making a working model on a larger scale (about April, 1803), as they had by this time decided that with the help of Donkin they had a good chance of producing a paper-making machine which would work continuously. With this end in view they resolved to take premises of their own to be devoted entirely to perfecting the invention. They approached Donkin with the idea that he would consider undertaking the experimental work and the building of the machine. He agreed that he would do this if Hall gave him permission, as Hall had actually been given the job by the Fourdriniers, and Donkin had at one time been apprenticed to Hall. They were, in any case, related by marriage, Bryan Donkin having married John Hall's sister-in-law.

Hall, who does not appear to have been particularly interested in the paper-machine at that time, readily gave his consent for Donkin to take the machine to London, and to work for the Fourdriniers. Accordingly, a site at Fort Place, Bermondsey, was selected and the factory erected, the whole undertaking being carried out on behalf of the Fourdriniers by Donkin, who had had charge of all the work while the machine was still at Hall's at Dartford.

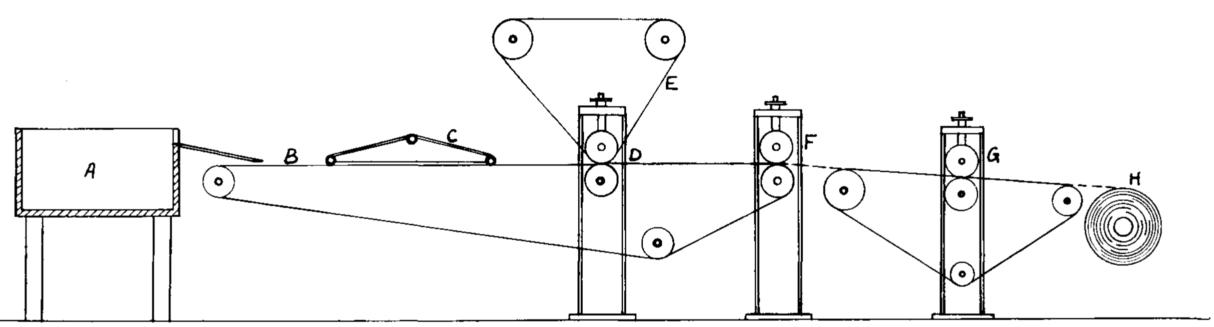
In April, 1803, the factory at Bermondsey was started, and work began on another working model. In March, 1804, this working model was erected at Frogmore Mill, in Hertfordshire, which Messrs. Bloxham and Fourdrinier had taken for its accommodation under very disadvantageous circumstances. The machine was 27 ft long and 4 ft wide. Donkin goes on to say that their first assay with this machine gave them the pleasure of seeing many of their attempted improvements completely successful, but yet very far from being perfect. Some of these improvements were patented by Gamble in his second application on the 5th December, 1803, in which he claimed that there were six improvements: the first one related to the hog, or lifting wheel, in the vat, which was called the "fly". This lifted up the pulp and caused it to run onto the wire. In the original model there was one wheel, rather like a water-wheel, which took the stuff out of the vat and caused it to fall on the wire, but in the improved patent the first wheel lifted the material up and deposited it on a smaller wheel which was revolving above the surface of the pulp, and the small wheel delivered it through the "cap" represented on the drawing. The second improvement related to the method of providing the shake to the machine, and this was done by causing the pin fixed to the upright pivoted bar of the wire frame to be moved in a wavy groove, or cavity, cut in the side of the wheel. This made the shake much more steady and less jerky than the original method patented by Louis Robert, which consisted of eight flat sides on the wheel which was in fact an octagon. The third one related to the deckle. In the original specification the stuff was kept from running off the edge of the wire by strips of snake skin stitched to the edges of the wire, and by fixed pieces of copper, but in this improvement two pieces of wood were fixed with their lower edges nearly in contact with the wire, and between these there was an endless strap of leather which moved round pulleys at the ends of the strips of wood and passed along the wire with the same speed as the wire itself. This, of course, was the first introduction of the deckle strap. The fourth improvement had to do with keeping the wire flat. This was achieved by sewing a number of buttons with very long shanks to the edges of the wire; these passed through slots in copper rulers, or straight-edges, on each side of the machine, and thus kept the wire from forming wrinkles. The ruler-bars were part of the shake frame. The fifth improvement mentioned by Gamble, and claimed in his second specification, was the substitution of a wire or string to cut the paper across when it was of sufficient length, instead of the wooden knife which was in the original Louis Robert patent. The sixth improvement claimed was that when "the circulating piece of considerable dimension",



No. 12. Donkin's development of Robert's machine in 1803, comprising new claims made in Gamble's second patent of 5th December, 1803. The lifting brackets for agitating the stock in the chest and transferring it to the wire are shown, also the back-water tank and lifting wheel for transferring the machine back-water back to the chest. There are two top wires, the first (D) over the centre of the wire, supported round four rollers, the second at the first wire press (K). There is a second wire press or couch (N), from which the web of paper is transferred to an endless felt, which carries it through a press (O).

which meant the wire, was fairly long and wide, he supported it and prevented it from sagging downwards by one or more rollers revolving underneath it, which was the first introduction of what we now know as the tube rolls.

Donkin says that in June, 1804, after spending three months in finding out and remedying some of the chief defects in the machine, they began another machine of a much bigger size, and this was set to work at Two Waters Mill in 1805. He says that although this machine had the advantage of a much better construction and some improvements resulting from experience, much remained to be done, and owing to the frequent interruptions and delays consequent upon and necessary to the introduction of and attempts at improvements, the machine had cost a great deal of money. In fact, the Fourdriniers spent, from June, 1802, to April, 1803, £1337 10*s.* not including the bill



No. 13. Further development of the machine by Donkin in 1804. This machine still retains the second top wire (E) at the first press rolls on the wire. The first top wire is replaced by deckle straps (C). The second wire press or couch is shown at (F), and the wet press, with felt, at (G).

from Hall, of Dartford. Again, this machine at Frogmore cost, from April, 1803, to April, 1804, a further £1555 7*s*., and again, from April, 1804, to June, 1807, another £2395 15*s*.

The £1337 10*s*. was spent on the original model which was brought from France, and which, according to Donkin, was never a success. The other amount of £1555 7*s*. was spent on a new machine which was constructed at Bermondsey, in Donkin's shop, for Frogmore. This machine, which was continually being improved from 1804 to 1807, cost a further £2395 15*s*., but this made it a fairly satisfactory paper-making machine, and by this time it was the subject of the Fourdrinier–Gamble patent of 1807, and it was a commercial success.

Donkin compares the machine which was brought from France with the earlier Donkin machines, and mentions that firstly, in the machine brought from France, the means used for delivering the pulp on the wire was so bad that there was no chance of making paper of a uniform thickness. Secondly, the width of the wire determined the width of the paper, so that the paper-maker, if he wished to make different widths of paper, had to have different widths of wire and different widths of cylinder press rolls, of a corresponding length according to the paper needed. In other words, there was no means of shifting the deckles in or out.

One of the earliest improvements made in England was the alteration in the feeding of the pulp onto the wire, thus ensuring uniformity of substance. The width of the sheet could also be increased or diminished quite easily by movable deckles, so that various widths of paper could be made on the machine with a wire 54 in. in width.

The third improvement claimed by Donkin concerned the fact that the shaking motion was communicated to the wire in Robert's machine in a very irregular way, so that the paper was never properly closed or "shut". Donkin said that this was the most difficult and delicate part of the operation, as the look and the strength of the paper depended upon the proper application of a quick vibratory motion given to the wire while the paper was travelling along it in a liquid state. The vibration caused a variation in the number of minute fibres laid in a horizontal position and they were more regularly distributed over the surface of the wire, forming with each other, as the water left them, a kind of casual intersection. By this intersection, or felting of the fibres, the strength and beauty of the paper was improved as a greater or lesser number of the fibres were laid horizontally or parallel with the sheet of paper when made. Donkin altered the shake so that the means of communicating this to the wire was arranged in such a way that the length and number of shakes per minute could be adjusted with ease to suit the nature of the pulp.

The fourth defect in the machine which was put right by Donkin was the imperfect manner by which the wire was extended laterally, as this had caused damage to the wire which was often torn to pieces. On the improved machine the wire was conducted in the proper direction and stretched laterally, or sideways, by means of friction wheels, which relieved it from a great deal of friction and unnecessary tension, and by which the durability of the wire was much increased.

In Robert's model the edges of the paper were very imperfectly formed and frequently caused it to adhere to the top press-roll and be torn. The edges of the paper were much improved in the Donkin machine by the movable deckle, which now made it possible for the paper to be manufactured with a clean and perfect edge.

On Robert's machine there was no effective way of preventing the pulp from running back over what we should call the breast-roll into the vat. Donkin improved this by stretching a piece of oiled silk across the machine, in the manner of what we now call the apron. He states that this effectively prevented the stuff from running back.

It must be remembered that these paper-making machines were running very slowly, and the paper made was fairly thick, so that as the water and stuff came down the sloping board onto the wire there would obviously be a tendency for water to run back down the breast-roll.

On Robert's machine the wet-end, or wire-part, was more or less combined with the first press in that the pressing-rollers, which at the same time couched the sheet from the wire, had an endless felt running over them and the surface of the paper was inclined to stick to the felt; it was necessary to have the felt changed and washed every half hour according to the quality of the paper. Donkin altered this and instead of the endless felt passing between the first pair of rolls on the upper surface of the paper, an endless sheet of woven wire was introduced, and he states that this proved a very valuable acquisition to the machine, because, prior to its adoption, the greatest speed of the machine was 20 ft/min under the most favourable circumstances. With the top wire the machine frequently ran at 34 ft/min, and the wire never required changing until worn out and lasted about three months. This wire and its arrangement on the machine is shown in the drawings accompanying the specification of the Fourdriniers of 1807. Donkin continues:

> On Robert's machine the paper was removed by hand from the surface of the wire, after passing between the press-rolls, and it was deposited upon a sheet of endless felting, or flannel; and upon that it was made to pass between a second pair of press-rolls to receive a harder pressure. The uncertain manner in which the sheets were divided, and the wet state of the paper, occasioned much of it to be torn and otherwise wasted. In order to get over these difficulties it was necessary that the first machine, with the wire and presses, should be so connected with the second press that the paper might, by the action of the machine itself, pass from the wire to the felt without the assistance of manual labour. To this end it was absolutely necessary that the velocity of the two pairs of rolls should be exactly alike, for should the press-rolls move faster than those of the first—or wet—machine, the paper would be torn; and if slower it would be suffered to return upon the underside of the wire and be spoilt. There not only existed the great difficulty of making two pairs of press-rolls with that degree of mathematical truth required, and determining their relative motion with equal precision, that the paper and felting, being elastic bodies, their velocity became affected by the different degrees of compression given to the press-rolls. It was therefore necessary to introduce some adjustable mode of communicating the motion from the one to the other, which, after many experiments, and at last a very expensive apparatus, namely, an expanding pulley, capable of being regulated by a screw when at work, was made.
>
> On Robert's machine the process was really performed by two distinct and separate machines, and by two operations. The first consisted of the vat, wire and pressing-rollers on the wire. The second, of a felt and rollers, generally called the press. In removing the paper from the first machine to the second it was liable to much injury from its being too wet to bear handling.

In other words the paper had to be handled as it was coming off the wire at the couch, and the trouble in handling this waterleaf can well be imagined. On Donkin's machine the paper was made in very long lengths, and subsequently sub-divided by cutting by hand. Gamble confirms that in 1805 an entirely new machine was erected at Two Waters Mill, capable of making paper 54 in. wide, and containing all the latest improvements made up to that period. This machine was 24 ft 5 in. long and 5 ft wide.

Shortly after this Henry and Sealy Fourdrinier and John Gamble were granted the new patent in their joint names, which embodied all the new improvements made by Donkin and the others in the intervening years. By the time this patent was granted, on the 14th August, 1807, and numbered 3068, tremendous improvements had been made, and the machine was virtually the same in principle, so far as the wet-end and press-part are concerned, as the Fourdrinier machines of today. There are differences, some of the equipment used by the Fourdriniers having been dispensed with, and other things added. Nevertheless, it is easily recognizable as a Fourdrinier wire and press-part by anyone who knows a modern paper-making machine. It is obvious that a great deal of money must have been expended by the Fourdriniers to enable Donkin to make all these improvements from 1803 until 1807, and a tremendous amount of time and thought must have been spent upon it by Gamble and Donkin.

The Two Waters Mill and drying house cost £2726 8*s*. 7*d*. and the Two Waters machine was £4203 17*s*. 10*d*. This was a very great deal of money at the time. In addition, during this period, £3000 was spent at Bermondsey on the engineering works there.

Gamble continued to superintend the new machine at Two Waters, as well as Frogmore Mill, until 1807.

The first patent to embrace the Fourdriniers as well as Gamble was granted in the reign of George III on the 14th August, 1807, and entitled: "An act for Prolonging the Term of certain Letters Patent assigned to Henry Fourdrinier and Sealy Fourdrinier for the Invention of making Paper by means of Machines." It was granted to Henry Fourdrinier and Sealy Fourdrinier, of Sherbourne Lane, London, Paper Manufacturers, and John Gamble, of Saint Neotts, in the county of Huntingdon, Papermaker. The patent was a prolongation of the Gamble patent of 1803 which had been assigned partly to the Fourdriniers by Gamble shortly after his original patent in 1801.

Henry Fourdrinier had in fact been granted a patent himself in 1806 for "making a machine, for manufacturing paper of an indefinite length, laid and wove, with separate moulds". This was the original idea of Didot, who had persuaded Fourdrinier to patent it, because Didot, being an enemy alien at the time, could not do it himself. It was the original of the chain-mould machine, to be mentioned later, the development of which, from 1806 to 1817, at Didot's insistence, was to cost the Fourdriniers very dear; and it was eventually a complete failure.

3

The Paper-making Machine of 1807

THE specification of the patent of 1807 is accompanied by a drawing which shows the elevation and also the plan of the machine with a "key" composed of alphabetical letters and figures. The specification goes on to say that the pulp in the chest was diluted with water to bring it to the required consistency, and then run through apertures in the side of the vat. The pulp was conducted from thence by an inclined plane in a uniform stream upon the surface of the revolving web* which was so placed that its surface would be as nearly level as possible, and its revolving motion was in the direction in which the stream of pulp ran from the vat.

The web was kept extended by a breast- and couch-roll, but in this case the couch-roll did not drive the web, both these rolls being driven by the web itself. Between the breast- and couch-roll there was a series of small rolls to support the web and keep it level so that it did not sag between the rolls.

The width of the sheet of paper on the web was determined by two pieces of wood set edgeways upon the web exactly parallel to each other, and to the line of motion of the web. These pieces were generally made 3 in. in depth, 1 in. thick, and about 4 ft long, extending from that part of the web which was next to the vat in the direction of the line of motion, between and also in contact with the under edges of those pieces as well as the upper surface of the web. Two endless straps of leather, of a width corresponding to the thickness of the pieces of wood, were placed between the pieces of wood and caused to revolve upon pulleys with a velocity equal to that of the revolving web. Similar pieces and straps were also in contact with the under surface of the web, exactly opposite to those on the upper surface, so that the web was pressed between the upper and under strap and pieces of wood and the liquid pulp was thereby prevented from running off towards the side. These pieces and their leather straps were called "dickles".†

Near that part of the web on which the pulp fell from the inclined plane, and between it and the vat, was placed a flap of oiled silk or other flexible material—the apron—one edge of which rested upon the web, the other being fastened to a piece of wood laid across the surface of the web, but not touching it, the length of the wood corresponding to the width between, and supported at each side by the dickle. The flap of oiled silk was to prevent the pulp from running back over the breast-roll towards the vat.

Between the two principal or extreme rollers, the breast-roll and couch-roll, upon which the web revolved and about 2½ ft from the couch-roll, two other rollers were placed, one above the other. The upper part of the web, with the paper forming on it, was passed between these two rollers for the purpose of pressing out the water. These were called the first- or wet-press cylinders.

In order to protect the pulp, which was still in a soft state before passing between these cylinders, from being dislodged or otherwise injured by the upper roller coming immediately in contact with

* In the specification "web" means "wire".

† "Dickle" is the deckle.

it, another revolving web of wire or other material, which may be felting, also endless and of the same width as the one above, but not as long, was fixed above the press. This was called the "upper web", to distinguish it from the wire or "lower web". This upper web passed between the two cylinders, that is the wet-press, so that its under surface fell upon the surface of the pulp and protected it from the action of the cylinder. These wet-press cylinders were provided with screws in order that pressure could be brought to bear on the paper. They were driven by the passage of the two wires with the pulp between them and in consequence all the other rolls which were in contact with the wire. As long as these webs continued to revolve, and the pulp continued to be supplied and ran upon the surface of the under web, the machine would continue to make a sheet of paper of continually increasing length. But as the paper, having passed between the first-press cylinders, had not obtained such a degree of consistency and strength as to allow it to be removed from the machine to be cut into sheets, it was passed through a second pair of pressing rollers called the second- or dry-press, where it received a further degree of pressure and consequent strength.

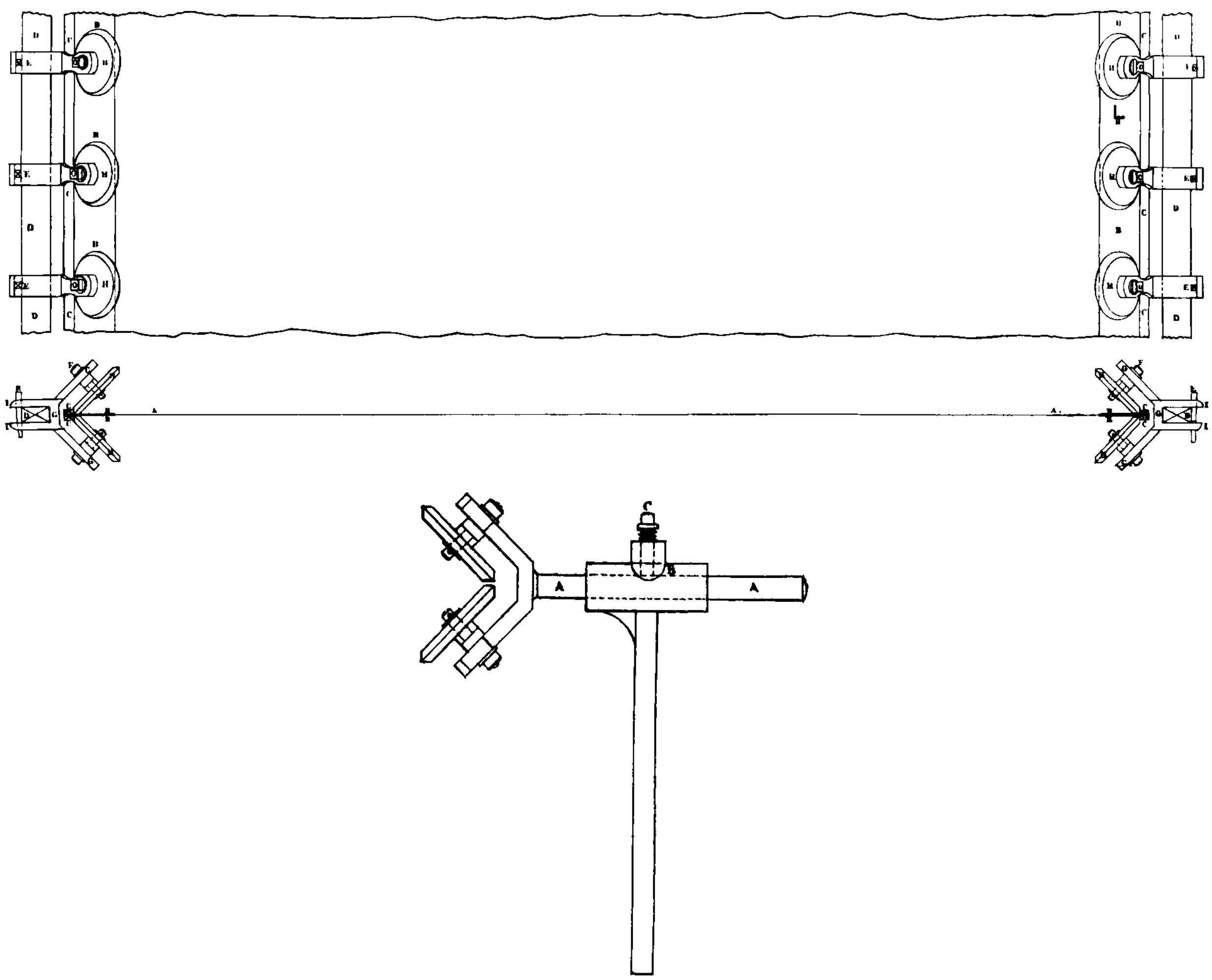
The second- or dry-press consisted of a pair of cylinders intended to apply strong pressure, and in consequence these were made of hard metal, preferably brass which did not rust. They were turned true and smooth, and placed one above the other at a convenient distance from, and exactly parallel with, the first-press cylinders.

Between the second-press cylinders there was a revolving web of felting and this felting revolved upon, and was kept stretched by, two other rollers, one on each side of the cylinders; by driving these cylinders the felting revolved upon the rollers in the same direction, and with the same velocity, as the under web. When the paper had passed the first-press, and arrived at the end- or couch-roll upon which the web revolved, it was removed from the web and deposited upon the wet felt, and thus was made to pass between the second-press cylinders. The paper was then wound upon reels or rollers which were successively removed and others supplied as they became full of paper. The long sheets thus obtained were, by a subsequent process, cut into others of the required dimensions.

The method of working the machine in detail, as patented by the Fourdriniers in 1807, was as follows: First of all there was a chest, and then what was called a "vat". This "vat" was in fact a small chest which was kept full of stuff, and in which there were two hogs, or stirrers, fixed horizontally about the middle of the vat to keep the fibres and water properly mixed. The vat discharged the pulp into another trough, which we should call the breast-box, through a number of holes lined with copper tubing. These holes were covered, when the machine was shut down, by a copper plate in which other holes were cut. The plate could be moved horizontally across the front of the vat, and so cause the holes to be opened to any degree required, according to the speed of the machine and the weight of the paper being made. These holes were fixed about half-way up the vat, so that there was always a good deal of stuff in circulation in the vat itself. It was in effect a multiple slide valve, or stuff gate.

The small wooden or copper box into which the vat discharged also had a hog in it to keep the stuff in motion. The stuff then overflowed along a straight-edge from this small vat down an inclined plate of polished and very flat copper. This copper projection slice terminated in another copper box which had a slot across the full width of the bottom; and out of this, which was really there to check the flow of stuff, the stuff passed onto an oiled silk apron which led it down onto the web or wire. There was one main wire or web on which the stuff travelled. This performed the same function as the ordinary wire on a modern Fourdrinier wet-end, but instead of being driven by the couch-roll it was driven by two press-rolls between which it had to pass, and these press-rolls also caused another web of wire or felt to revolve, in this case on top of the stuff. This was quite a short wire, held in position by stretching-rollers, and was only in contact with the top of the stuff just before it came through the wet-press; it really performed in some ways the function of a large wove dandy working on a modern wet-end.

The main or lower wire, or web, on which the stuff passed along, was made to shake by a horizontal shaking mechanism worked by a crank, in the same way as the modern wet-end shakes. The wire was supported on tube-rolls which, before the wire reached the wet-press, were supported on the lower- or under-dickle. These dickles correspond to our deckles, but instead of having only one on the top of the wire, there was also one underneath it, and they performed two functions. First, they regulated the width of stuff on the wire, and secondly, they had fixed to them a series



No. 15. This drawing shows the rollers (H) for keeping the wire tight across the machine, also details of the clutch and the expanding pulley or rigger. These latter show remarkable engineering skill for such an early machine and were not in general use on many paper-making machines eighty years later.

of small rollers in which the edge of the wire worked. These rollers guided the wire and stopped it from running to the back or front of the machine. The dickles were two pieces of wood, lined with brass, guiding between them a leather strap or dickle-strap, which revolved on rollers between the two wooden dickles, and touching the wire. This operated in the same way as a modern rubber deckle-strap. On to each edge of the wire was sewn a piece of thin canvas, upon which in turn was sewn a piece of much thicker canvas, while the wheels of the dickle-pulleys, revolving one on top of the canvas strap and one underneath it, kept the wire taut across the machine, as well as guiding it. These dickle-pulleys were adjustable and could be brought out towards the frame of the machine to tighten the wire if it tended to run up in the middle.

It would appear from this elaborate arrangement that the wire-cloths available were not so flat, and did not run so straight as the wires we have today, and, of course, there was as yet no guide-roll.

The copper plate bringing the stuff onto the breast-roll end of the web could be adjusted for slope according to the speed of the machine or the quantity of the stuff required to make the substance of paper. The shake motion was so arranged that it could shake from one quarter to one inch laterally, and at a speed of from one hundred to two hundred shakes per minute, the alteration in speed being controlled by varying the amount of water over a water-wheel.

Transference of the sheet of paper from the wire web to the wet-felt was effected by what was called the couch, but the couch-roll in this machine of 1807 was what we should call the first wet-felt roll. This was quite a small roll placed immediately under the wire-return roll and could be made to press against the underneath part of this roll by means of a lever. It worked as follows: when the stuff came along the wire, and had been through the first wet-press, it came to a large roll round which the wire was passed on its return journey to the breast-roll of the machine. In order to take the paper off the wire at this roll, the first wet-felt roll, round which was revolving the continuous wet-felt, was lifted up by means of the lever, and made to press against the paper on the wire and drag it off. As soon as the paper had been carried some distance along the felt, it started to pull itself off the wire by its own momentum; it was then possible to drop the couch or felt-roll from contact with the wire, the machine continued to run, and the paper continued to be peeled off the wire just in the same way as it is on a modern machine. As is well known, on slow machines without suction-presses at the present time the web of paper is dabbed off the wire by hand, or, if there is a suction couch-roll, it is blown off by air on to the felt; when a certain amount has been taken off by the felt, the felt continues to drag the paper from the wire by its momentum.

The wet-felt then carried the paper over a large roll situated immediately before the second- or dry-press, and the felt, after passing over this roll, took a downward course, and then over a small guide-roll through the brass press-rolls. As the paper passed between the brass press-rolls it stuck to the top-roll, from which it was doctored off by a weighted iron doctor. As the paper fell away from the doctor on to the wet-felt again, the wet-felt continued to drag it away from the press-roll, and so carried it on to the reel-up, which was a sparred drum on which the wet paper was wound. There were no drying-cylinders in this early model.

The wet-felt was guided in the same way as we have described for the wire web, namely, by dickles and small rollers which served to stretch it outwards and also to make it run straight. The reason why the wire web with the wet-felt were made to go into the first wet-press or second dry-press respectively at a downward angle was due to the fact that it was much easier to get rid of the water this way, and the water tended not to run back into the paper once it had been squeezed out at the press. Both first wet-press and second dry-press-rolls were placed directly on top of each other, and not set off at any angle, as they were all fitted with screws to apply the pressure required. The staggered couch had not yet been invented.

The width of the endless wire-cloth on this first machine was 54 in. by about 31 ft long. Both the wire web and also the wire on the first wet-press were provided with stretch-rolls, in order that they could be kept tight and so that any natural stretch in the wire could be taken up. The wet- or dry-press felts were also fitted with stretch-rolls.

The machine was invariably driven by a water-wheel in those days, because it was stated in the patent that this provided by far the steadiest method then known of keeping a constant speed. The water-wheel drove through toothed pinions, several sets of spur wheels and shafting, and eventually on to the line-shaft, from which the power was transmitted by the ingoing shaft to the paper-making machine by friction pulleys. Belts were also used to drive the shake apparatus and the backwater lifter, and the press-rolls at the wire and felt dry-press; at these two points there were also clutches provided for starting and stopping them.

The method of transmitting the drive from the water-wheel is shown in the drawing. First of all the water-wheel drove directly a large toothed wheel, this in turn driving two smaller wheels. One of these had on its shaft an expanding rigger, or belt pulley. This was so constructed that its diameter could be varied by causing its periphery to expand or contract, as it was appreciated that very fine adjustments in the draws between the different sections of the machine were necessary to prevent either the paper from breaking, if the draws were too tight, or from running up the couch or presses if the draws were too slack. This very ingenious expanding rigger or pulley is shown in No. 16. This pulley drove a belt which, at its other end, passed round another expanding pulley, and from this an ingoing shaft went to the clutch situated immediately at the end of the journal of the wet-press roll. Fixed to the journal of this wet-press roll, and nearer to the body of the roll than the clutch, was a friction pulley. This friction pulley was flanged at an angle of 45°, so that it might contact a similar flanged pulley, and transmit the drive from the ingoing shaft to the press at right angles along another shaft to two more friction pulleys. The second of these was placed on the end of the dickle shaft, and this was to drive the dickles.

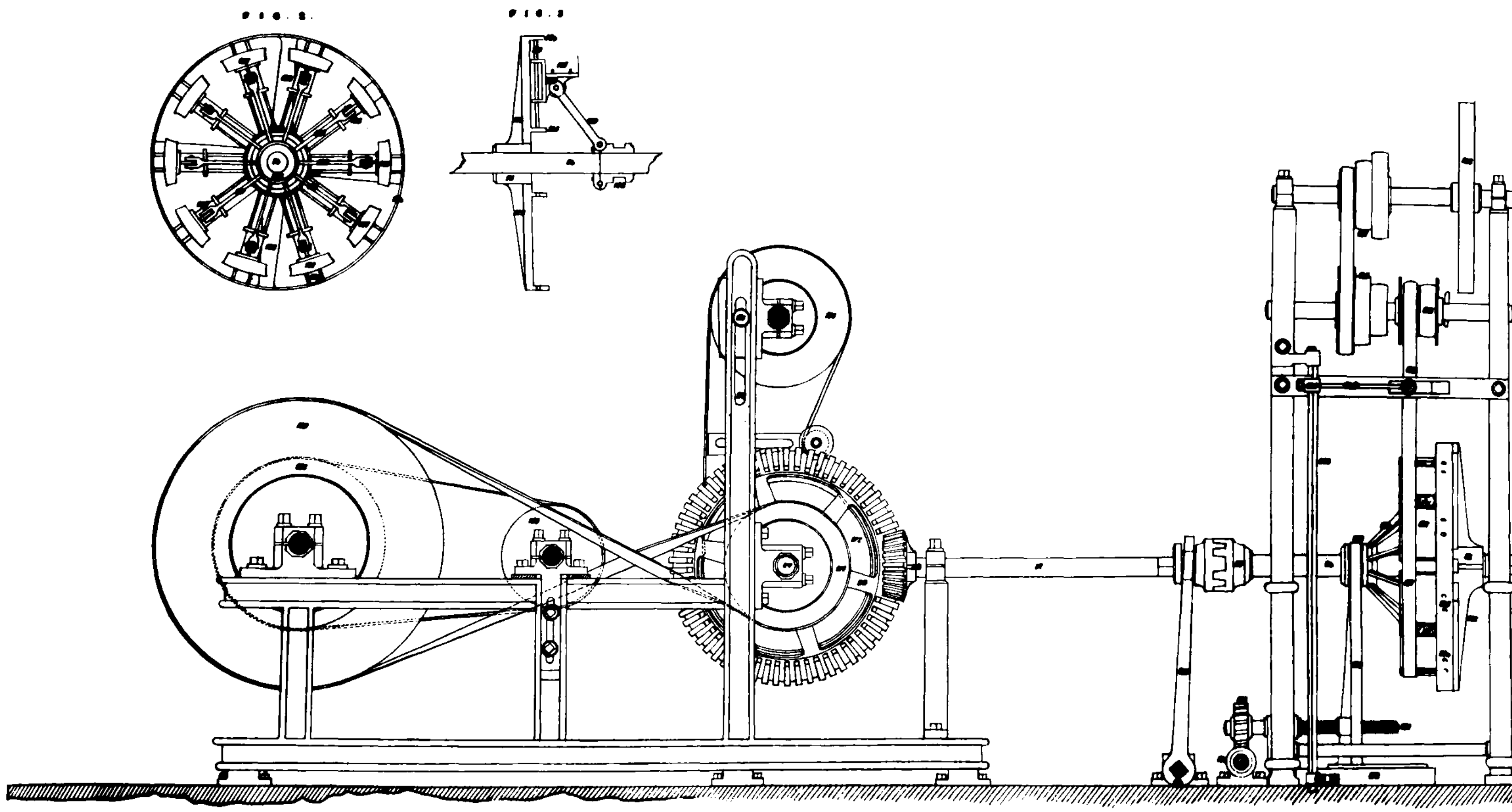
It is interesting to note in connection with these variable-speed pulleys that well over a hundred years after they had been in use by Donkin and the Fourdriniers on their very early machines, there were many comparitively modern machines in Great Britain, as in other parts of the world, with no expanding or cone pulleys provided. Any variations in draw at couch and presses had to be obtained by the very clumsy method of sticking pieces of belting on to the surface of the pulley to increase its diameter, or, conversely, digging off pieces of belting from the pulleys by means of a crowbar, while the machine was in motion, thus obtaining whatever alterations in draw were required in a very haphazard manner.

The author has had plenty of experience of this method of changing speeds of draws. Not only was this clumsy method very unreliable, but it was also extremely dangerous, and led to much trouble from slack belts when this "bulking" or packing was removed.

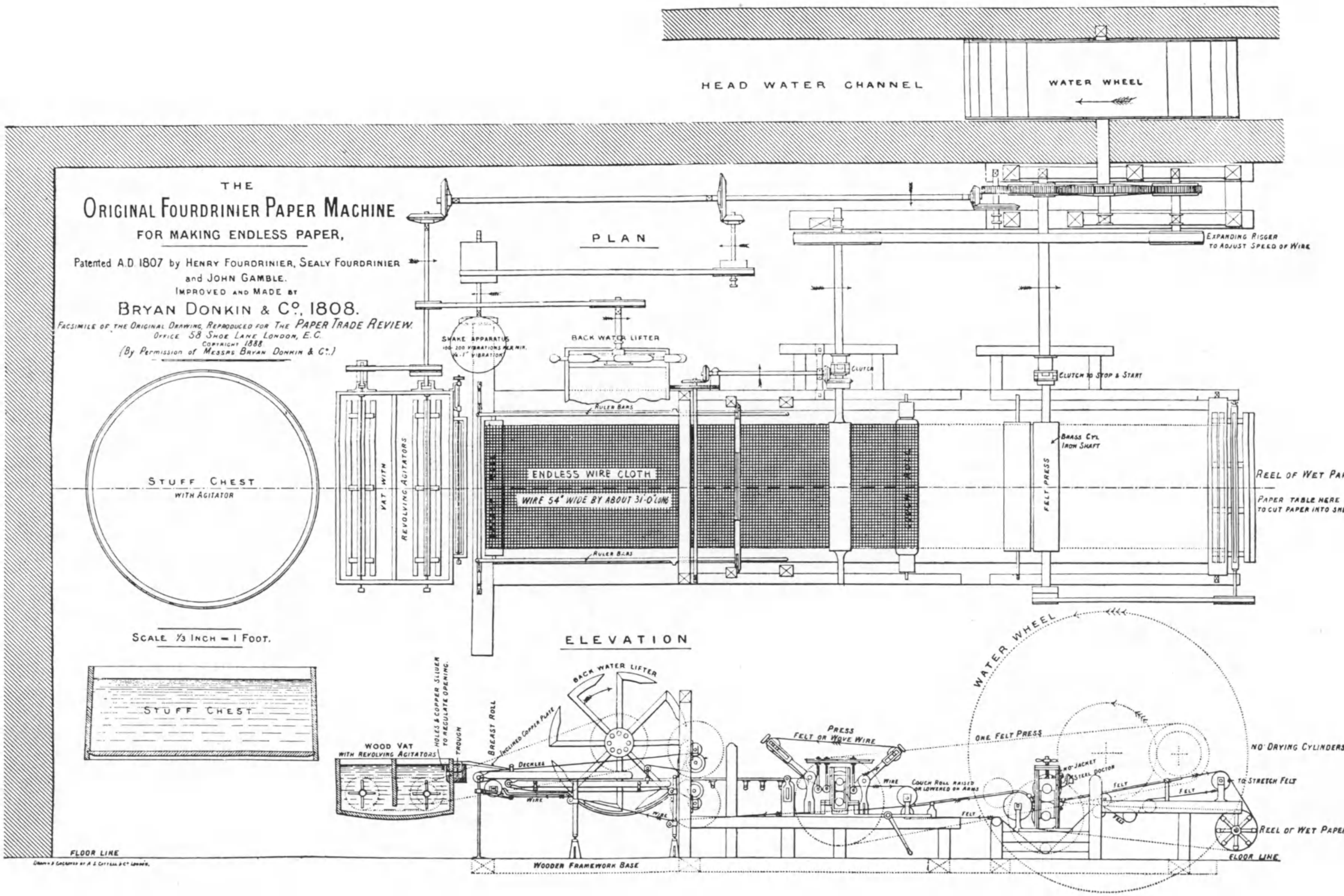
The friction drive operated as follows: At the end of the shaft there was a cast-iron solid pulley with one of its sides perfectly flat, against which the edge of the other wheel was held with such a degree of pressure that the friction between the flange and the edge of the wheel caused the wheel to revolve and drive the shaft. It was possible to obtain a variable speed with these flanged pulleys in the following way: If the pulleys were at the ends of the respective shafts, and at right angles, and one of the pulleys were made so that it could be moved along the shaft, the speed of this pulley could be made variable by causing it to revolve against the extreme outside edge of the other pulley, or altering the gear ratio by putting it nearer to the centre. This method of altering the speed has been used in modern times on motor cars and motor cycles and other machinery.

From the foregoing description of the expanding and contracting pulleys, and the friction pulleys arranged on the ends of shafts, it will be seen that there were two methods of altering the draws, or the speeds, of various parts of the machine. Even nowadays the methods employed on modern machines as a rule provide only one method of altering the draw, and that is either by means of a cone-pulley with a belt, or electrically in the case of a variable-speed drive. On the very earliest machine backwater trays were fitted under the wire, and a backwater tank and lifting wheel were also provided to take the back- or white-water to the stuff-chest, the value of this water having been realized almost as soon as the original machine started up.

It seems strange, but it is a fact, that over a hundred and twenty-five years after Donkin perfected the machine and made use of all the valuable white-water from the trays under the wire, there were many paper-mills in Britain and elsewhere which neglected to recover any of this back-water, and used nothing but fresh water both for letting down the beaters and also for diluting the



No. 16. The expanding pulley, pinion wheels, clutch and stepped pulleys for altering speeds on the Fourdrinier machine of 1807. All this engineering work was introduced and carried out by Bryan Donkin.



No. 17. Plan and elevation of the Fourdrinier paper-making machine of 1807, copied from the original drawing of Bryan Donkin.

stuff at the mixing box. Nor had they any arrangements for recovering the water lost through the wire at the paper-making machine.

In the early machines a back-water wheel with lifting buckets was preferred to the more obvious pump because it did not cause the stuff to form into small rolls and lumps by friction in the plunger pump, these afterwards forming unsightly lumps in the paper. This was before the days of revolving inward-flow or other type strainers, or knotters.

We have already mentioned that the shake motion could be altered in speed by controlling the amount of water passed to another water-wheel, but when there was no such water-wheel available the variation in speed of the shake motion was given by two friction wheels similar to those already described.

When this early paper-making machine was in operation there were no machines available for cutting or slitting the paper, so that it was necessary to cut the paper by hand, and the following method was adopted: A large wooden frame, or table, whose length was determined by the dimensions of the sheet into which the reel of continuous paper was to be cut, and corresponding in width to the widest sheet which the paper-making machine could make, was provided just beyond the end of the paper-making machine. The reel containing the paper was removed from the machine and placed immediately above one end of this table, the pivots of the reel being supported and allowed to turn in two wooden posts fixed to the ends of the table. Two workmen, one on either side of the table, took hold of the corners of the sheet on the roll and drew off a length of it and spread it on the table. Near the end of the table there were two long hardened-steel plates, about 3 in. in width, about $\frac{1}{8}$ in. thick, and longer than the widest paper to be cut. These two steel plates were fixed to two strong iron bars by means of screws or clamps. They were placed in such a position across the table that the upper edges of the steel plates were parallel with and about 1/20 in. from each other and in the same plane with the upper surface of the table upon which the paper was to be spread. The lower edges of the steel plates were extended to a considerable distance from each other, so that a vertical section of the plates, or a section made at right angles with their edges, would form two sides of an equilateral triangle, or their relative positions would somewhat resemble the outer strokes or legs of the letter A. The upper edges of these steel plates were ground so that the basils formed by grinding the edges were in line with each other, and the inside or opposite edges of the two plates were sharp. One or more hardened steel wheels, about 3 in. in diameter, and turned true, having a sharp edge basilled away on both sides, like a cold chisel, were fixed to an axis on which they could revolve; the edges of these wheels were placed between the opposed edges of the hardened steel plates, and the wheels were caused to revolve upon them from one end to the other, the paper having been previously spread upon the table and over the edges of the steel plates. The wheel was then weighted down, and the paper cut by the action of the wheel with its sharp edge against the sharpened edges of the steel plates, as the wheel revolved upon them.

Another pair of steel plates, and more hardened steel wheels, were placed farther along the table, at a place exactly corresponding to the length of the sheet of paper to be cut. By having the steel plates fixed at the correct distance from each other, and with the small revolving cutter wheels fixed on a frame so that all wheels could operate at the same time, in each slot between the steel plates a sheet of paper could be cut with one movement of the wheel across the table.

Two workmen, one stationed at each side of the table, drew the paper from the reel and spread it upon the table. The first end of the paper was taken over, or beyond, the pair of steel plates farthest from the reel, care being taken to see that the edges of the paper were parallel with the edge of the table, or rather at right angles with the edges of the steel plates, so that the angles or corners of the sheets of paper, when cut, would be square. The workmen were guided or directed in the operation by having several conspicuous lines drawn along the table in the correct direction, parallel to which they laid the edges of the sheet. The paper being thus deposited, or spread uniformly upon the table, and over the edges of the steel plates, the man on whose side the carriage with the free cutting wheel stood, pushed it across the table to the man on the opposite side, where it was retained ready for cutting the next sheet. When the paper was pulled off the reel for the second sheet to be cut, the leading edge of the paper was square, so that sufficient paper was pulled off to give two sheets. The leading sheet was pulled the required distance beyond the cutters farthest from the reel, and thus, with one operation of the cutting wheels, two sheets were cut off, and so on until the reel of paper had been cut up.

This method of cutting the paper seems very crude when compared with the extremely ingenious devices which were employed on the paper-making machine itself, and it would appear that Donkin and Gamble had given very little attention to the matter of cutting the paper, at least in these early days. And yet the author has seen, in France, in the middle 1930s, much more crude methods employed in cutting paper than those just described. In fact, the method employed in France was to have a large table at the end of the machine, and to reel the paper on a very big skeleton drum. When sufficient paper was on the drum, the machine was shut down, the paper was cut with a sharp knife, and fell onto the table. It was dragged across the table in a length of about 10–12 ft, and about 60 in. wide. There were slots cut in steel plates which were let into the surface of the table. To cut the paper into sheets a man stood on the top of it and inserted a thin knife such as is used for cutting hay from a rick. The knife was inserted into the slot, and with a sawing motion up-and-down the man walked backwards across the table, cutting the paper as he went. When he had completed a cut across the width of the table he got down and the paper was pulled along the required distance to give the size of sheet needed. He then mounted the table again and proceeded to cut with his hay-knife a further slice of paper. When the paper had been cut crossways into long strips about 20 in. wide by 60 in. long, the paper was turned round until it was at right-angles to its previous position. The man cut the paper again by the same method, and in this way the paper was cut into square chunks or reams about 20 in. x 30 in., or whatever other size was required.

Soon after the 1807 patent an attempt seems to have been made to float a company in London to exploit the new paper-making machine. A prolonged search has not led to the discovery of the names of any of those who were responsible for the idea, but the advertisement of the prospectus which was found in *The Morning Chronicle* (London, Thursday, 19th November, 1807) is given below:

THE INTENDED LONDON PUBLIC SUBSCRIPTION
PAPER MANUFACTURING COMPANY

> In becoming Proprietors to Public Companies, persons of thinking minds will make their election of that which is most worthy their attention; as such, if universality of demand for an article, for which as yet no substitute has been found, then Paper in all its various sorts and qualities is of the first importance, and that its manufacture should be made with the best of materials, and at as reasonable a rate as possible to the venders and consumers, is the avowed intention of this Public Company, for establishing an undertaking, that the public may be benefited by.
>
> The immense quantity of Paper used in this town and city, sent up from distant parts of the country, at considerable expense, is astonishing, independent of what is exported; and what is yet singular, by far the greater part of the finest materials, for making the best Paper, are sent from the metropolis for its manufacture; this is one considerable expence that will be saved by the manufactory being in the vicinity of the metropolis in which manufactory will be introduced, such as a system of improved mechanical machinery, wrought by simplified steam engines, as will in the very article of labour alone, reduce it five and twenty per cent. independent of the time saved in manufacturing.
>
> As the promoters of this plan presume to possess some knowledge of science, they also

declare their best wishes for the spreading abroad and wide diffusion of literature; and as the best vehicle for this purpose is certainly Paper, it can only be done extensively when that article is manufactured reasonably. This has been a stimulus to them for promoting a Public Company, in which view it must meet with the approbation of every lover for the spreading of knowledge whether human or divine.

A Prospectus, and every other information, may be obtained at the Company's Surveyor's Office, 26 'Change-alley, from ten till four.

EXPENDITURE FOR IMPROVEMENTS AND EXPERIMENTS AT FROGMORE AND TWO WATERS FROM JUNE, 1802, TO JUNE, 1807

				£	s.	d.
Improvements and Experiments upon the original model from June, 1802, to April, 1803, exclusive of Mr. Hall's Bill				1327	10	0
Frogmore Machine from April, 1803, to April, 1804				1555	7	0
Frogmore Mill and Machine from April, 1804, to June, 1807				2395	15	0
Two Waters Machine	£4203	17	10			
Value of the Machine, etc.	£1450	0	0			
Expenses on alterations and improvements				2753	17	10
				8032	9	10

All this expenditure led to the perfection of the machine as a commercial success, and the patent specification of 1807, established the Fourdrinier machine more or less as we know it today, and led to many orders being placed by paper-makers all over the British Isles.

The following is a list of the first sixteen commercial paper-making machines, in addition to the experimental models which were made in Bermondsey by Bryan Donkin, for the Fourdriniers, from 1804 to 1809. The length and width of the wires are given in each case. As was to be expected, the first two machines were for Frogmore and Two Waters, the Frogmore machine being made in 1804, as a result of experiments there on the original model of 1803, and the Two Waters machine in 1805. They were numbered 1 and 2 respectively. The fourth machine was supplied in 1807 for St. Neots Mill, and was the machine which was supposed to be given to Gamble as payment for all he had done in bringing over the machine from France and introducing it to the Fourdriniers. The licence for all these sixteen machines was granted to the various people in 1807, the first one being granted to Elizabeth and James Swann, of Eynsham, Oxford, on the 20th May. The next person to have a licence for a machine was Barnabas Sullivan, of Cork, on the 4th November, 1807. J. B. Sullivan had three machines licensed to him in 1807, two for Cork and one for Blarney, near Cork, and must have been a considerable paper-maker, as he had sixteen vats working before he put the machines in. The machines were fairly widely spread over the British Isles in these early days, the first one, after the Fourdriniers' own mills, being supplied to the Swanns of Eynsham; then the three to Southern Ireland for J. B. Sullivan; Lewis Smith, of Aberdeen, and Jno. Phipps, of Dover, had one each. There was also a Martindale, of Cambridge; Bacon Novino, of Norwich; Wrightons and Company, of Warwick; and Ibotson and East, of Colnbrook, as well as John Buttenshaw, whose mill was at West Peckham, Kent.

LENGTH AND WIDTH OF THE FIRST SIXTEEN PAPER-MAKING MACHINES MADE IN BERMONDSEY, 1804–1809

Year			Length ft	Length in.	Width ft	Width in.
1804	No. 1	Frogmore	27	4	4	0
1805	No. 2	Two Waters	24	5	5	0
1807	No. 3	Jno. Phipps, Dover	33	6	5	0
1807	No. 4	St. Neots	33	6	5	0
1807	No. 5	J. B. Sullivan, Dripsey, near Cork (for St. Neots but sent to Cork)	33	6	5	0
1807	No. 6	L. Smith, Peterculter, Aberdeen	33	6	5	0
1807	No. 7	E. Martindale, Cambridge	28	11	5	0
1807	No. 8	James Swann, Eynsham	33	6	5	0
1810	No. 9	J. Sullivan, Cork	32	0	4	0
1810	No. 10	J. B. Sullivan, Blarney	32	0	4	0
1810	No. 11	R. Elliot, Chesham	25	0	4	0
1809	No. 12	Ibotson and East, Colnbrook	33	6	5	0
1809	No. 13	J. Wright (Wright and Pepper)	25	0	5	0
1809	No. 14	St. Neots, 2nd machine	25	0	5	0
1809	No. 15	J. Buttenshaw, West Peckham, Kent	25	0	5	0
1810	No. 16	Bacon Novino, Norwich	25	0	5	0

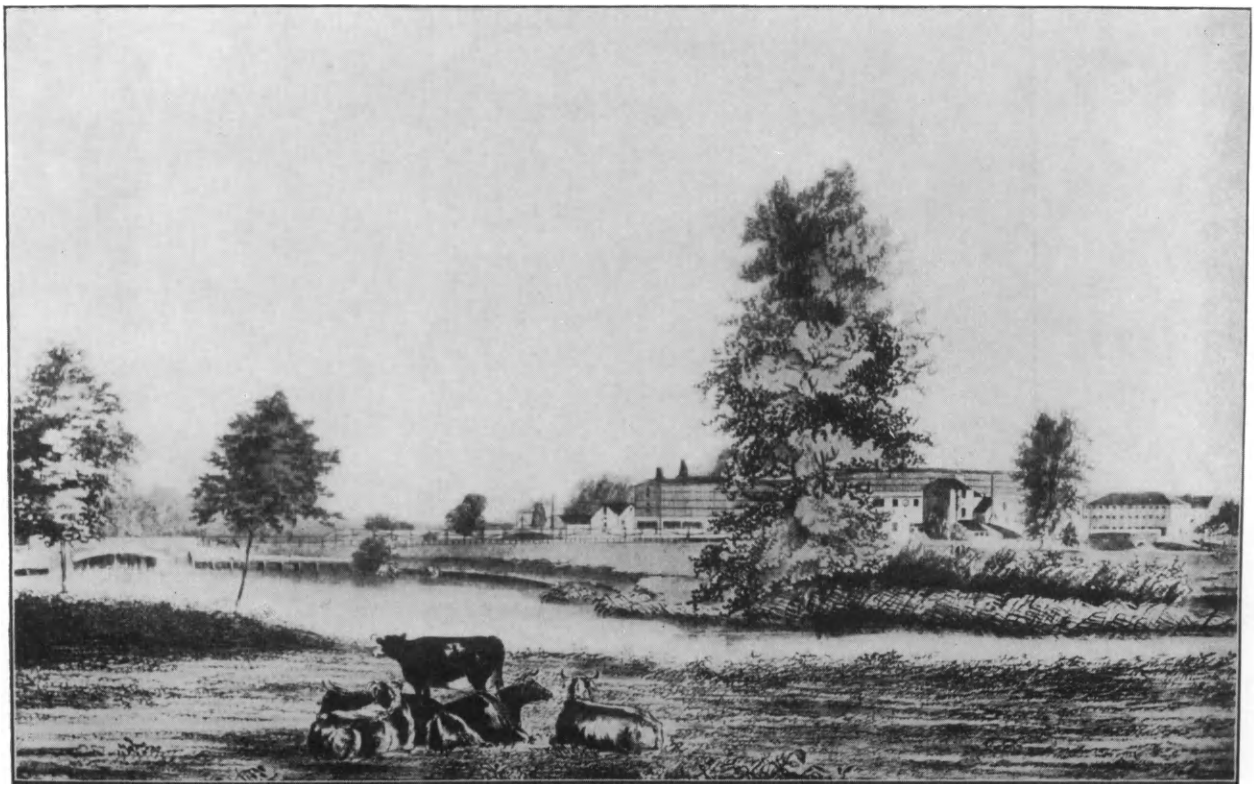
4

The Fourdriniers' Struggle for Development

GAMBLE had apparently been sharing the financial burden with the Fourdriniers during the time of his work on the machines after he had come from France and obtained the original patent in England. He seems to have been a kind of general manager and supervisor for the Fourdriniers. However, on 7th January, 1804, and again on 29th December of the same year, he had assigned his patent to the Fourdriniers by an indenture for certain considerations, presumably because he could not afford to bear the responsibility of further financial sharing of what was proving to be a very costly project. He continued, however, to work for the Fourdriniers at Frogmore and Two Waters until 1807, when he joined with them in the new patent, and they took him into partnership at a new mill they had bought at St. Neots.

In 1807 the Fourdriniers, who had taken over a corn mill at St. Neots, in Huntingdonshire, in 1804 started to equip it with two Fourdrinier machines, and intended to hand these over, together with the mill, to John Gamble as his reward for having brought the machine over and introduced it to them. The business was to be carried on under the name of John Gamble and Company, and the profits were to be divided into three equal parts between the brothers Fourdrinier and Gamble. The business was in fact carried on under this name until 1811. Gamble, who had been living at Two Waters superintending that mill and Frogmore, removed to St. Neots in 1807. The Fourdriniers agreed, by Articles of Partnership, to find all capital and equip the mill with two machines for the use and benefit of Gamble and Company, and without the payment of royalties. The latter, it is to be noted, made each machine worth £5000, although its purchase price was very much less. This sum was actually paid down by Phipps of Dover, and Swann of Eynsham, Oxfordshire, for a machine, with unlimited rights to manufacture paper on it without the usual further royalties. From this act on the part of the Fourdriniers towards Gamble it is obvious that they intended to be honourable and to reimburse Gamble and provide him with a good investment and source of income for his part in introducing the machine, and also for the long years of work he had done at Frogmore and Two Waters with Donkin in helping to perfect the machine, and in his managing of the mills.

By the time, however, that Gamble had moved to St. Neots, the Fourdriniers were in great difficulties financially. They were rather under the influence of Matthew Towgood, and in 1809 they had to make over their share in the mill at St. Neots to him, on account of the large amount of money they owed, so instead of installing the second machine, as originally intended, they sold it to Sullivan of Cork, in order to get some badly needed cash. When the subject of supplying the second machine came up, the Fourdriniers had no longer any interest in St. Neots, and Towgood would not erect a second machine unless Gamble was prepared to put up half the money for it. Towgood knew perfectly well that Gamble had no money to do this, and he promptly dissolved the partnership and got Gamble right out of the mill altogether, owing to some flaw in the Fourdriniers' original agreement. This was the end of Gamble's association with paper-making after ten years



No. 18. Old engraving of St. Neots Mill where the fourth paper-making machine made by Donkin was erected by the Fourdriniers. The mill was managed by John Gamble and subsequently sold by the Fourdriniers to Towgood, who worked it for many years.

of diligent work, and after all the trouble he had taken in bringing the patents and model from Paris, in taking out the patents in England, and helping to get the machine into working order. He had given up his job with the Navy and thrown himself wholeheartedly into paper-making, only to lose everything in the end by what seemed very much like a trick.

TOTAL EXPENDITURE BY THE FOURDRINIERS, 1803–1807

	£	s.	d.
On the original model	1327	10	0
On the working model at Frogmore to April, 1804	1555	7	0
Frogmore Mill and machine from April, 1804, to June, 1807	2395	15	0
Two Waters Mill and Dryinghouse, 1805	2726	8	7
Two Waters Machines, 1805–1807	4203	17	10
St. Neots Mill, 1807	11,276	15	4
St. Neots Machine, 1807	2745	2	7
	2600	0	0
	28,830	16	4
Bermondsey	3000	0	0
	31,830	16	4

The Fourdriniers were beginning to feel the financial strain of the years of work and expense they had put into the perfecting of the machine.

Matthew Towgood was a banker who had advanced money to the Fourdriniers, and they took him into their firm of Bloxham and Fourdrinier as a partner. It was about this time that the Fourdriniers leased their engineering works at Bermondsey to Donkin, who undertook to build the machines on a royalty basis, paying them between £80 and £200, according to the size of the machine. The Fourdriniers were also at the same time to receive a royalty on the paper produced by all users of the machines. They had spent very considerable sums of money by this time in trying to protect their patent and getting it prolonged for a further seven years. By an Act of Parliament, passed on the 14th August, 1807, Gamble's privilege of fourteen years from April, 1801, was prolonged to fifteen years after the date of the Act, an extension of seven years upon the original patent. The Fourdriniers showed good reason, in their spending so much on their experiments, and in the national importance of the object, why the patent should be extended fourteen years from the latter date, and would have obtained justice from Parliament in this respect but for an unworthy artifice of Lord Lauderdale in the House of Lords. He was the person who took the objection, and by introducing a regulation in a standing order of the House of Lords that none but the original inventor should have an extension, even though the Fourdriniers were as good as the inventors of the operative machine, he defeated the honourable intention of his brother peers, whose committee said:

> We will give seven years, and Mr. Fourdrinier may apply again if it should turn out that the seven years that we propose to give to Mr. Fourdrinier should not give sufficient time to afford any chance of his receiving any remuneration for the expense that he had incurred in introducing this invention.

The bill passed in the Commons for fourteen years, but it was limited by this ruse of Lord Lauderdale's to seven, and he put the standing order on the books of the upper house, which prevented Messrs. Fourdrinier from having any benefit from their invention.

About this time it is obvious that the Fourdriniers were getting fairly desperate; they had spent a tremendous amount of money, and had become heavily indebted to Matthew Towgood, to whom they had had to give St. Neots Mill. Towgood had deprived Gamble of any of his rights in it, though it had actually been made over to Gamble by the Fourdriniers. The House of Lords had turned down their application for an extension of the patent, which was being infringed. Paper-makers who had actually bought the machine were refusing, on petty technical grounds, to pay royalties to them; Didot was a continual source of expense, as they had to finance him all the time he was in England, and he was always claiming additional remuneration for improvements which he said he had made, when these had really mostly been made by other people, notably Donkin.

The original firm of Bloxham and Fourdrinier changed to Henry and Sealy Fourdrinier when Bloxham became frightened of the financial position being created by the expenditure on the machines. The firm became Fourdriniers (Henry and Sealy), Towgoods (Matthew Senior and Junior), and Fourdrinier (Charles) in 1809. By the 31st October, 1809, the name was changed to Fourdriniers (Henry and Sealy), Towgood (Matthew Junior), Fourdrinier (Charles), and Hunt (Joseph B.). Towgood's London address was in Sherborne Lane; evidently he took over the Fourdriniers' stationer's business there before moving to Upper Thames Street.

In the early part of the year 1809, Donkin and the Fourdriniers were concerned with quite a number of mills for which they had made, or were making, paper-making machines. About this time alterations and improvements were being made to Two Waters Mill and the Fourdriniers were quite evidently wanting to get more output from it by putting in more beaters, but Donkin was against this, as he did not consider there was enough water power. New vats, dickles, ruler-bars, etc., were sent to Two Waters to be incorporated in the machine. Henry Fourdrinier wanted to buy four beating-engines from a Mr. Curtis for £55 each, including plates, two of which were elbow-plates. At this time there were only four beating engines at Two Waters Mill, and Donkin insisted that there was seldom enough water to work more than the four. He suggested that it was much cheaper to alter the present water-wheel so as to make it go slower, and at the same time to raise the beating engines.

About March, 1809, new methods were being tried out at Two Waters for cutting the paper on flat reels, using a hand-knife to do this, in order to cut the slab of paper off the reel and let it drop on to the table before cutting it into reams. The experiments using the so-called flat reel were apparently not successful, and Pinson, the paper-maker at Two Waters, thought it would be much better to reel the paper on square reels so that the quantity of paper wasted before would be halved. The paper from the square reel boxes was cut off without removing the reel from the paper-making machine. This square reel was a success, and Didot had one made for Frogmore.

The actual alterations to the machine at Two Waters were started on the 14th March, 1809, and, according to Donkin, the alterations and improvements were very much needed, as he says in his diary that much alteration for the worse had taken place during the previous few months, and that it would take a great deal more to put it in a working state.

The machine-man at Two Waters at this time was Marchant Warrell.

One of the things which Didot had done away with was the expanding rigger, or pulley, and Donkin says that he had at last convinced Didot of the absurdity of trying to do without this. Donkin says that he found several parts of the machine in a very objectionable shape, and he was sure they would require alteration. He goes on to say :

> . . . but from the known perverseness and obstinacy of Didot I did not point them out to him. The height between the top of the vat and the edge of the trough over which the pulp has to run upon the inclined plane onto the wire is too small; instead of being 2½ in. it ought to have been 7 or 8 in., which would have allowed a greater variation of the height of the pulp in the vat, without materially affecting the quantity delivered upon the wire, and the consequent thickness of the sheet of paper. The quantities delivered at the different depths through the main orifice will always be to each other as the square root of those depths respectively.

Donkin thought that the braces used to stiffen the ruler-bars (shake-frame) would be found injurious in making the paper, as they would make the wet-end too rigid. He also says that the back-water trough, or apron, under the wire should not be allowed to shake with the wire.

During the spring and early summer of 1809 Donkin and the Fourdriniers worked assiduously on machines they had already made for other people, and supplied new ones. They went to see a Mr. Stafford, and agreed on the situation and dimensions of the stuff-chest for his new machine. At this time it was agreed by Donkin, at the request of Didot, that the wires of the machines to be made in the future should be only 25 ft long instead of the 33 ft 6 in. which they had been until then.

Donkin went to Mr. Buttenshaw's at West Peckham, Kent, to examine the proposed situation for his paper-making machine. He received directions to make the machinery conform to a water-wheel 12 ft in diameter, overshot, and the machine-house to be brought in 8 ft above the bottom of the water-wheel. The machine was erected at Bermondsey, but a short time afterwards Henry Fourdrinier told Donkin to take Buttenshaw's machine to pieces and have it sent to the mill. They had recently supplied a new paper-making machine to Messrs. Ibotson and East, at Colnbrook, and Mr. East had expressed himself perfectly satisfied with its performance. Donkin had also visited Wright's mill at Marlow, and took the necessary measurements preparatory to making a plan for the new mill and machine-house.

No. 20. Marchant Warrell, machine-man at Two Waters Mill. He is thought to have been the first machine-man and was the father of a long line of paper-makers, who still flourish. He is here shown wearing the paper hat which until recently was commonly worn by paper-makers.

It was decided now not to put in another machine at Frogmore Mill, as they only had seven years of their lease to run, and they were either going to repair the present wheel so as to drive the engines now there, or put in a new one. Frogmore Mill was leased by the Fourdriniers from Christopher Thomas Tower, who sold it later as a going concern to the Grand Junction Canal Company, in 1817. This proves that Frogmore was in no sense an experimental mill, but a commercial concern.

Donkin frequently had a great deal of trouble with Didot during this period, and had in many ways a very poor opinion of him. He writes of him in June, 1809, in the following way:

> Didot came to the factory and examined his hydraulic pump (intended for a perpetual motion) which we have now ready for an experiment. He enquired what I now thought of it, if I had not now a better opinion of it. I told him that, being perfectly satisfied of the impossibility of a perpetual motion, I could never change my opinion.

In the middle of July, Donkin and Henry Fourdrinier went to St. Neots to see the new method of cutting paper which Gamble had put into practice. Donkin said: "It is very simple and expeditious, and I think the best of any we have tried." No details are given in Donkin's diary of the actual method employed.

From St. Neots they went to Two Waters to see the start-up of the machine which had been altered, and Donkin says that most of the alterations appeared to answer very well. "The wire appears quite long enough now that it has been reduced to 25 ft in length." He says it made very good edges without the bottom deckles (that is, the deckles underneath the wire, as well as on top). The paper was very well made omitting the silk apron leading from the projection board onto the wire. He says that the flat reels for reeling up the paper did not do very well, as they were too weak, and the small lead-rolls were improperly placed.

Donkin refers again to Didot going to the works at Bermondsey about the perpetual motion pump, and says: ". . . he seems as little acquainted with the principle of the thing as ever, and retains his absurd idea of producing a perpetual motion", notwithstanding the calculation that Donkin had given to him. Didot wanted Donkin to make another large pump, in which the piston in one might be rising while the other one was descending. Donkin again expostulated with him on the absurdity of the scheme, but to no purpose. "Didot said he was mad, and that the experiments he meant to try were for his own information and not mine; as he did not understand the calculation he could only be satisfied by experiment.

"I asked Didot if I might draw upon M. Renard for the amount of Didot's bill at the factory. He said no, but that he intended to pay for the new patent against Messrs. Fourdrinier, and requested I would inform Mr. H. Fourdrinier of his intention."

Didot asked Donkin to arrange an appointment with Henry Fourdrinier so that they could have a discussion together about the differences which had arisen between himself and Donkin. The idea was that Henry Fourdrinier should be the arbitrator. The following is an account, in Donkin's own words, of a meeting which took place on the 2nd August, 1809, between Didot, Henry Fourdrinier, Donkin and Renard, who was Didot's friend. Donkin says:

> He gave me a letter containing his reasons for wishing to see me, mainly, to remove by a proper explanation some unfavourable impressions which he conceived had been made upon my mind by certain insinuations and reports very much to his prejudice and contrary to the truth. And as one means of obtaining a good understanding between us, he wished it to be clearly understood what part of the inventions lately made as tending to improve the paper-making machine, he thought he was entitled to claim as his own, and also to point out what belonged to me. On reading his letter, in which he enumerated the improvements, I perceived he laid claim to several he had no right to, and which were my own invention. The letter having been read in the presence of Messrs. Henry and Sealy Fourdrinier, I was then requested to say if I objected to Didot's claim, and to name such improvements as I conceived he had assumed as his own, and which I thought belonged to me. I told them that as I could see no good end to be answered in discussing this subject, but on the contrary that I suspected it would give occasion for fresh controversies, which would neither promote the interest or satisfaction of either party, I strongly recommended

to pass it over in silence. I was induced the more earnestly to give this advice as I had, in casting my eye over the articles enumerated by Didot as his invention, discovered several which I should be under the disagreeable necessity of claiming as my own. And should it be insisted on by Didot that what he said was true, it would only be opposing my veracity against his, and an inducement to both to expose and detect the disgrace and falsehood of each other. I was, however, though very reluctantly, induced to name two instances, and, as I expected, excited Didot's passion to a very great degree. He at last, however, very dextrously pretended we had misunderstood each other relative to one of them, and after about an hour's quarrelling said he meant a different thing.

Donkin's first mention of Towgood was in July, 1809, when he went and saw Matthew Towgood and Gamble about St. Neots, and it was agreed to alter the water-wheel there, now an overshot one, and make it a breast-wheel, and increase the diameter from 10 ft to 11 ft 10 in., which was as large as it could possibly be without moving the head-frame. Donkin also pointed out that they would have to make a new cellar, or artificial tail-race for the tail-water, as the present one was not big enough for both wheels, and caused the water to back-up about 16 in. on the wheels.

In August, 1809, the Fourdriniers arranged with Donkin that he should instruct Pim, the engineer at Two Waters, to alter the stuff-chest, and have two round ones with a vertical agitator in each instead of one square one, driving them with the pump wheel. This is the first mention of circular vertical stuff-chests with vertical agitators in place of the original rectangular chests with horizontal hog.

In September, 1809, Donkin went to Two Waters, along with L. Aubrey, his mechanic, to see how the machine was working. He found Pim, the engineer, making experiments to improve the method of bringing the pulp onto the wire, it having been found that in using the general deliverer —that is, the wooden projection board—the pulp had to fall a considerable distance, causing it to run upon the wire with too much velocity. They lowered the delivery-board, making it very nearly level, and then Donkin suggested they should put back the silk apron to the lower edge of the delivery-board, to the thin strip of wood fastened onto the silk over which the stuff would have to flow, and by that means check the velocity with which it would otherwise run upon the wire. They tried this, and there was some improvement, and Donkin said he thought it would answer very well.

In September Donkin was the arbitrator between the Fourdriniers and Martindale, of Cambridge, who had purchased one of the Fourdrinier machines, concerning the amount of money Martindale was to pay for it. The Fourdriniers had on many occasions great difficulty in getting payment for the machines which they had sold to various paper-makers, and had had to enter into many lawsuits to establish their rights to the charges they had made. They were also trying to make some arrangements regarding their assets, to gain further capital for their business, and in September Sealy Fourdrinier asked Donkin if he could find someone to join him in buying the engineering business in Bermondsey, saying that they would enter into an agreement with Donkin to take all their paper-making machines from him at a certain price which would be agreed upon. The following day the Fourdriniers asked Donkin and John Hall to give a joint opinion on the spot, of the value of Two Waters Mill. Hall and Donkin went to Two Waters and examined the mill, but would not put a value on it until they had seen the lease.

Donkin mentions that while they were there they went to Frogmore Mill and found the Frogmore machine making tissue paper, and with new iron rollers in the second press. He said that they answered extremely well, did not strain the paper, and were not inclined to be indented by hard substances passing between them, as happened with the brass and copper rolls previously used.

Hall, Donkin, and Henry Fourdrinier examined the lease of Two Waters, to assist them in making the valuation. Donkin and Hall then went to Dartford and finally agreed upon the value of Two Waters Mill at £14,000.

At this time Donkin discussed with Henry Fourdrinier his proposed alterations to the breast-roll to shorten the wire still further. Donkin told him that he wished to attempt this improvement, and had no objection to disclosing his plan on the understanding that Didot should have no authority to interfere, and that Donkin should receive remuneration in some way proportionate to the resulting advantages. Donkin says that his wish was that the Fourdriniers should derive the full benefit as they would have done had they themselves made the improvement. He thought Didot had used him very badly in attempting to deprive him of the credit to which he was entitled for several of his former improvements. He ought not, and should not, so far as Donkin could prevent it, derive any benefit from this proposed new improvement. The Fourdriniers said they had no objection to making an arrangement by which Donkin should derive some advantage from the success of the experiment, but they did not see that it was feasible to prevent Didot from receiving his share to which he was entitled according to their agreement with him. Henry Fourdrinier, who told him that he would be at liberty to keep it a secret until some terms or mode of remuneration should be agreed upon between them, agreed that Donkin should make a model of his proposed improvement at Bermondsey, to which the Fourdriniers would contribute £100.

Obviously Didot must have been entitled to some remuneration, for it was at his instance that Gamble had brought the machine over to England and ultimately sold the patent to the Fourdriniers, but he must have been a source of enormous expense to the Fourdriniers over a long number of years, as they had to finance him in England, and pay to some extent for his extravagant and stupid ideas to be tried out. There were other people who had some sympathy with him who were also prepared to finance him, among these was M. Renard.

About this time, Donkin paid several visits to Bacon, of Norwich, who had a mill at Taverham. The object of Donkin's visit was to decide where the paper-making machine which Bacon had bought from the Fourdriniers should be erected. There was long discussion about the height of the machine-house, as there was only a 4 ft fall at the water-wheel. While Donkin was at Norwich, Bacon informed him that he had invented a machine for printing, and wished him to assist him in perfecting it. For the help that Donkin might give him, Bacon said he had no objection to Donkin's participating in the eventual profits. Donkin saw Bacon's model of his machine, and said that he was of the opinion that when perfected it would facilitate very greatly the operation of printing. He agreed to Bacon's proposal, and promised to make another model immediately upon his return to Bermondsey.

It was at this time that Donkin heard about John Dickinson's paper-making machine. This was the machine which worked with a mould in a vat, in place of the Fourdrinier-type wet-end of the machines which Donkin made. Elliot, who had a Fourdrinier machine at Chesham, told Donkin on the 10th October, 1809, that Dickinson's machine had just started up, and showed him a sheet of paper which had been made on it. Donkin said that it was by no means good, and appeared to be full of small rolls or lumps, and he thought this would always be the case, from the nature of the invention. He wrote, however, that Elliot appeared to be considerably alarmed that it might prove superior to the Fourdrinier machine.

On the 16th October, Donkin saw Henry and Sealy Fourdrinier, and told them the particular improvement to the paper-making machine about which he had spoken previously, so that he could show that he had no intention of taking any undue advantage out of them in requiring a premium. The only stipulation he made was that it should remain unknown to Didot, and that, should it prove successful, he thought he was entitled to the same advantage which Didot might eventually derive from it, but he left that to the honour of the Fourdriniers.

Elliot came over and looked at the Two Waters machine, and asked Donkin to supply him with a pair of cast-iron rollers for the second-press on his machine. Donkin gave him instructions about laying steam-pipes for heating the press-rolls. There were, of course, no steam-heated or other type of drying cylinders up to this period, nor for many years afterwards.

Bacon, of Norwich, came to Two Waters to see the machine at work, and by this time the new method of delivering pulp onto the wire, suggested by Donkin, had been tried out. This consisted of dropping the breast-roll below the level of the tube-rolls, and having the wire running up 3 or 4 in. from the breast-roll to the tubes. In his diary, Donkin goes on to say that this answered very well indeed and was a great improvement. The pulp was brought onto the wire with less velocity, and consequently the paper was a much better sheet than before. This alteration is the one which Donkin communicated to the Fourdriniers.

This improvement to the wet-end, by dropping the breast-roll and allowing the stuff to run down the projection-board, over the silk apron, and onto the wire as it was sloping upwards towards the tube-rolls, is shown in some of the drawings of machines which were in operation for many subsequent years. It is not quite certain when the breast-roll was moved up again parallel with the tube-rolls, as had been the case with the first three or four machines which were made. This practice of lowering the breast-roll below the level of the tubes is a so-called innovation of some modern high-speed machines making tissue papers.

Donkin states in his diary that on the 11th November, 1809, he entered a caveat at Mr. Pool's office against his invention for printing, but he gives no particulars as to what this invention was. Probably it was connected with Bacon's printing machine, which he was making and perfecting at that time.

Martindale, of Cambridge, was having difficulties in settling his account with the Fourdriniers, and asked Donkin to make some proposals to them to help settle a dispute between them regarding royalties on the paper which he was to have been given and also for the fixing of the machine, amounting to £340 on the paper account, and to deduct £241 from their bill on the machine account. Evidently the Fourdriniers had not, in the opinion of Martindale, supplied him with the paper which they had promised to do. They in their turn considered they had a claim against him for breach of contract. The Fourdriniers rejected Martindale's claim, when presented to them by Donkin, as being quite unreasonable. Martindale said that he did not wish to take legal proceedings, but wished to meet the Fourdriniers on friendly terms, and offered to subtract £441 from their bill and pay the remainder immediately, but the Fourdriniers would have nothing to do with this suggestion, and rejected it.

At this time a Mr. Handasyde, working for Donkin, was casting iron press-rolls for their paper-making machines. These rolls were turning out to be very much superior to the brass- and copper-rolls previously mentioned, and many of the paper-makers who had purchased the early machines were ordering second-presses to be fitted with cast-iron rolls. These rolls were turned in a lathe, and until that time the method of grinding them true had not been discovered.

5

The Chain-mould Paper-making Machine

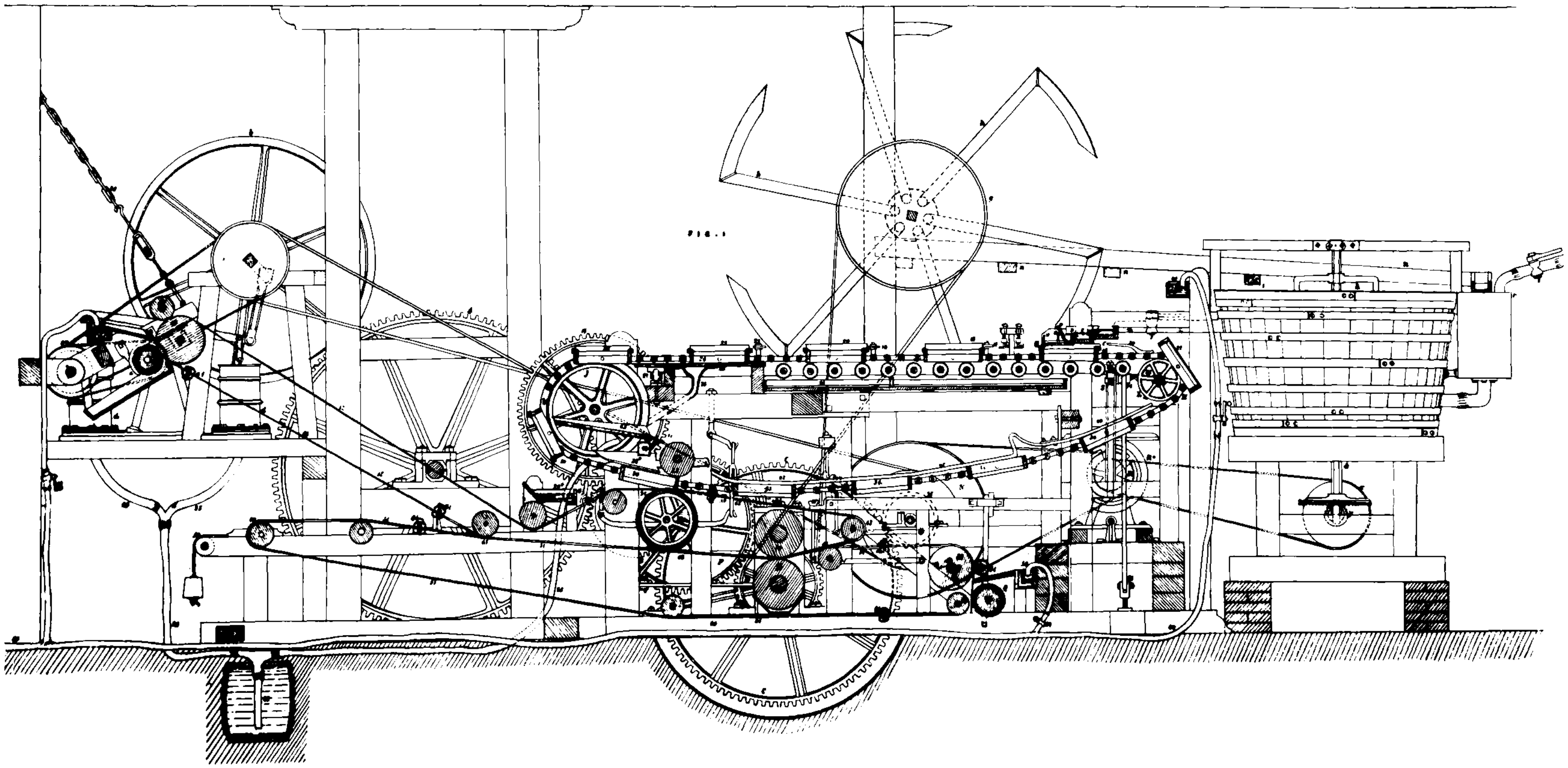
WHILE successful attempts were being made continuously, between 1803 and 1807, and afterwards, to perfect the endless-wire wet-end for the paper-making machine, nevertheless there must have been misgivings in the minds of the Fourdriniers, fostered chiefly by Didot, as to whether these were going to be a success eventually. This can be guessed from the fact that during the whole of this time they were still experimenting with an endless chain of moulds, each mould being separate and making a separate sheet. In July, 1806, Henry Fourdrinier obtained a patent, No. 2951, for the method of making a machine for manufacturing paper of an indefinite length, laid and wove, with separate moulds. The specification describing this patent was not, unfortunately, accompanied by drawings, and it did not contain a very detailed description of the machine. However, sufficient can be picked up from it to show how the machine worked.

Later, in 1812, another machine with these separate moulds carried by chains was patented, and a drawing was included with the specification. This is illustrated.

The patent of 1806 consisted of a framework containing a series of rollers on which a succession of moulds were caused to run or roll along. These moulds were hooked onto each other as closely as possible, and there was no real division of the stuff between each mould, although there were fairly big deckles which were hinged, and kept in position by springs on either side to prevent the stuff running off the moulds onto the floor. The moulds were moved on their rollers by an endless felt passing round two driving rollers, the lower one of which revolved on the wet stuff on the mould, and couched it off onto the felt, carrying it almost vertically upwards through a press. At this press the web of paper was transferred to another horizontal felt which carried it through a second pair of press-rolls, and it was then either taken off by hand or could be reeled up.

It is not very clear whether this machine became a commercial success, but probably it did not; it seems likely that there would be a certain weakness in the sheet between each of the moulds although, if these were made the size of the paper that was required, this would not be a serious matter, and the final product would be rather like the paper made on a cylinder mould machine at the present day, such as the paper used for banknotes.

This mould machine operated as follows: Immediately above the frame holding the moulds, which were hooked onto each other, was a box of stuff with a hog, or stirrer, fixed to it. This discharged stuff at a predetermined rate into a V-shaped box with a slot along the bottom, and as the wire moulds passed along driven by the felt which eventually couched the paper off, the stuff was spread on the mould from this slotted box. The whole frame, which was supported by a chain suspending the other end from a framework which carried the presses and was fixed to the floor above, was shaken laterally by a crank at the wet-end. As the empty moulds left the couching felt-roller a workman picked them up and carried them to the other end of the frame where he hooked them onto the last mould just before it passed under the stuff-box.



No. 21. Front elevation of Didot's chain-mould machine, showing the machine chests, drive and back-water lifting wheel, and the elaborate, ingenious and very costly method of traversing the separate moulds on the endless travelling chain. The drawing is by Bryan Donkin.

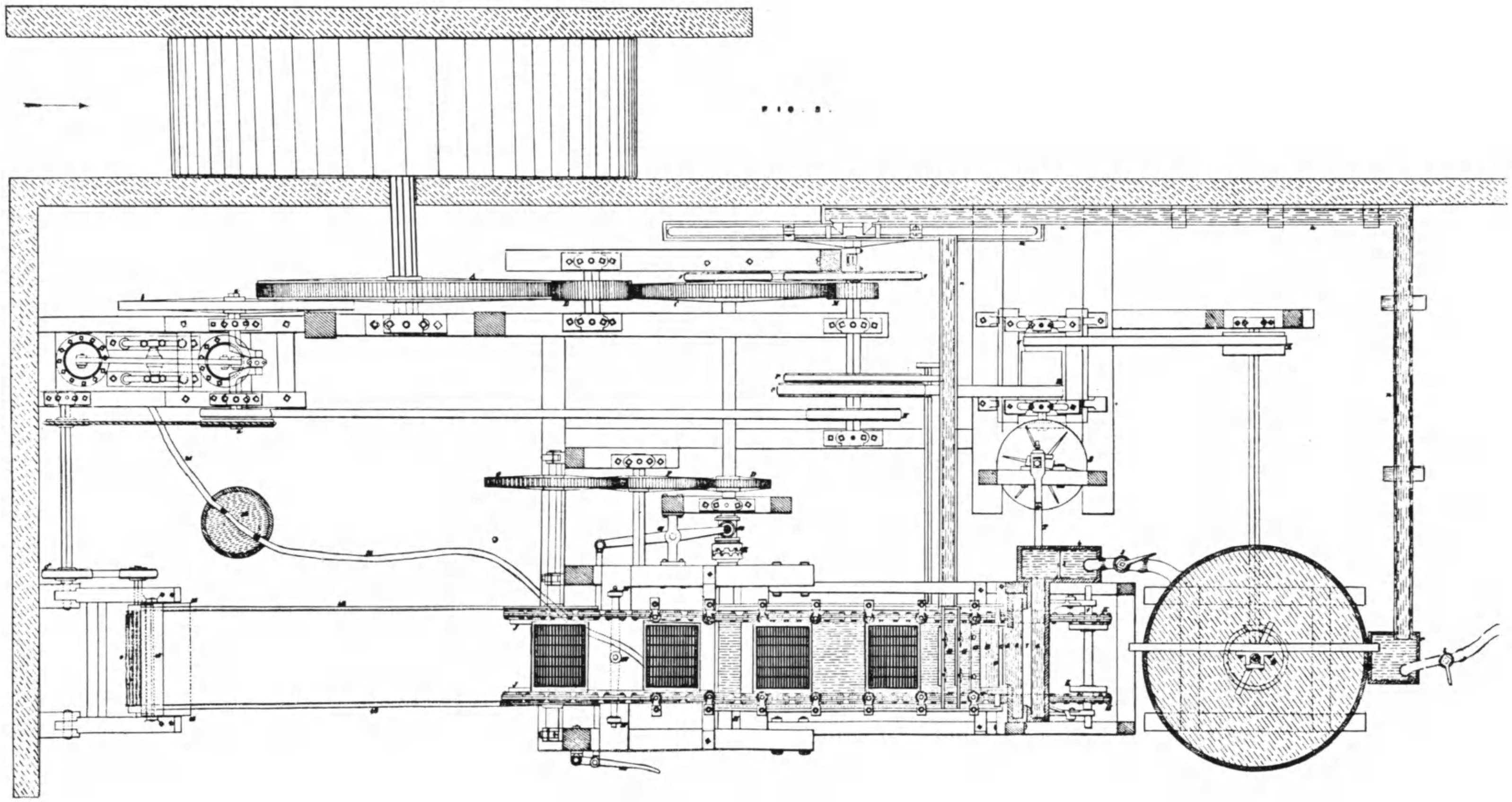
As the 1806 Fourdrinier patent for the endless chain-mould machine did not have a very complete specification, and was not accompanied by drawings, it has been thought best to describe this as further patented in 1812, with very complete drawings, and these are shown here. This extremely ingenious and very complicated piece of engineering reflected very great credit on Donkin, the maker of the machine, especially as he never really believed in it, and always insisted that it would never turn out to be as great a success as the endless-wire machine. Nevertheless he prepared the drawings and carried out the making of all the parts, and the erection of the machine, first of all for the Fourdriniers, and then, later, for their assignees, Bloxham and Abbot, and Didot. Didot was the driving force behind the efforts to perfect this piece of machinery (No. 21).

In a way it looked rather like a Fourdrinier wet-end, when seen in section. There were chests, breast- and measuring-boxes, and twelve moulds which swivelled on a roller chain, all of which can be seen in the drawing, which shows one mould lying underneath the stuff-box ready to receive its quota of pulp. The other moulds are in various positions along the horizontal frame of the machine; others are seen turning round the rolls, and one of them is just about to pass over the couching roll. The others are returning to the breast-box end. The machine was driven by water-power through the toothed wheel marked (a), which was the main driving wheel, and which gave the power to the various other moving parts of the machine. As the mould passed over the couching roll (31 on the drawing), it was taken on to a felt (42), and carried round a small guide-roll (43); and immediately afterwards came in contact with another felt (51). These two felts together carried the paper between them through the press-rolls (56 and h). The paper then continued along and passed the underside of the couch-roll (45) where the two felts left contact with each other, and the paper either stuck to the felt (42), or to the felt at (51). A workman stood at the back of roll (52) and peeled the paper off either the top felt or the bottom felt according to whichever of these it had stuck.

As will be seen from the drawing, the machine was extremely elaborate, and all sorts of devices were resorted to in order to keep the felts clean. The top- or couch-felt, which went right up to roll (46), was brushed with a brush-roll, washed with water, and squeezed by a small press-roll. It was kept tight by the massive chain with a shackle on it, which could haul it up towards the roof. The felts were also guided by having leather strips sewn to their edges, and these held the felt outwards by means of small guide-rolls (61), rather the same as those used for guiding the wires on the original Fourdrinier machines. The bottom felt also was brushed by the brush-roll, and had a water shower on it, and was pressed by roll (54) before it went to the roll (41) where it held the paper on to the bottom of the couching-felt (42). There was a backwater trough (62) underneath the horizontal chain-mould table to catch the water, and this was taken back by the lifting wheel, as in the Fourdrinier machine. The chain-mould table was shaken sideways.

It seems to be most unfortunate that no other method could be found than having a man standing taking the sheet off whichever felt it happened to stick to, especially having regard to the most ingenious arrangement of the machine in other ways.

The plan of the machine shows the complete drive from the water-wheel through to the machine itself. Various methods were used for transmitting the drive, as can be seen in the drawing (No. 22). First, there were the spur wheels, then belts or straps; a rope drive can also be seen driving the double-acting water-pump; there is a heavy dog-clutch driving the mould chain, actuated by a lever at the front of the machine. The surfaces of four of the moulds are shown passing along after having received their stuff from the stuff-box. The stuff left the chest through a big pipe feeding a levelling box at the side of the machine, flowed into the trough, and passed afterwards through a series of other boxes into a box designed to deliver the requisite quantity on to the mould. On the extreme left of the picture the wire brush roll can be seen, which was used to brush the wet-felt before it returned to take up another sheet.



No. 22. Plan of Didot's chain-mould machine, showing the water-wheel and elaborate drive and the intermittent moulds carried by the chains.

It is obvious, from a perusal of the drawing of this machine, how very much more expensive it must have been to produce than the endless-wire machine, and what a drain it must have been on the resources of the Fourdriniers, more especially as it was never a commercial success.

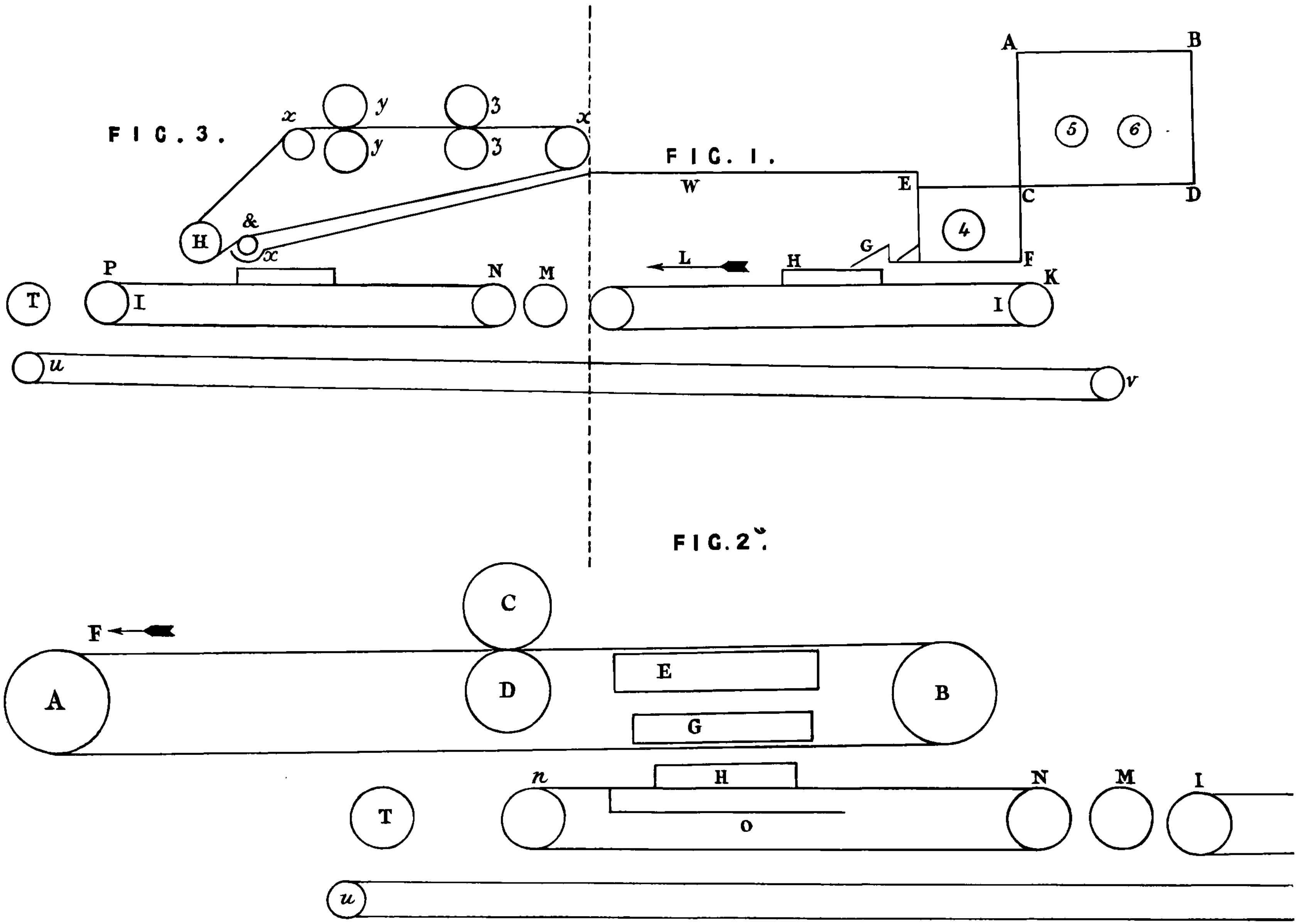
Later still, when one of these machines had been built and set up at Two Waters Mill, Donkin was asked to go and examine it and ascertain the practicability of a scheme of this sort for his firm, and to give his opinion to the assignees of Henry and Sealy Fourdrinier. He says that the machine worked, but that great difficulty was experienced in keeping the felts clean, and the machine had to be shut down after about 2½ hr in order to wash the felt. The machine actually ran for a total of 16½ hr, and much of the paper was spoiled by the irregular motion of the chain to which the moulds were attached, and by the paper being couched upwards. Donkin made experiments with the machine which satisfactorily showed that the paper would leave the moulds much cleaner if it were couched downwards. Many further experiments were made confirming Donkin's opinion. He wrote a report about the machine to Bloxham and Abbot, saying that if it were altered, at a cost of about £300, he thought it would then make paper superior to any made by hand, and that it might prove ultimately of considerable benefit to the Fourdrinier estate. He was then asked to produce a detailed estimate of the work, and to deliver it to Abbot.

At this time the Fourdriniers, who were very anxious to sell as many machines as possible, issued a further prospectus following the one they had issued in 1806. This new prospectus issued in 1813 incorporated many improvements made to the original Frogmore and Two Waters machines and is reproduced in Appendix I.

Didot seems to have been chiefly instrumental in persuading the Fourdriniers to go on with the intermittent mould arrangement or, as he called it, the "continuous mould" machine, because, again in 1817, he took out further patents for a machine which could be used either with a continuous succession of square moulds, or these could be removed if required, and underneath them was an ordinary endless wire-cloth for making the wove paper, as described in the Fourdrinier specification of 1806. Presumably one of the reasons for persisting with these chains of moulds was the fact that the dandy-roll had not yet been invented; the only kind of paper which could be made on the endless wire was "wove", whereas with this continuous chain of moulds the mould could be used like a hand-mould in that it could be covered with "laid" wire to impart the laid mark to the finished paper. It is difficult to see what other reason could have been advanced for persisting in this machine, because the ordinary Fourdrinier endless-wire machine was a success many years before 1817. Donkin showed little interest in this type of machine, but he must have spent a great deal of the Fourdriniers' money in the making of it over a period of at least eleven or twelve years.

From 1807 until 1814, while the Fourdriniers and Donkin were busily engaged with the endless-wire machine, then already known as the Fourdrinier machine, a number of other people were experimenting with machines of other types, all with the object of mechanizing paper-making, saving labour, and particularly with producing laid paper as opposed to the wove variety made on the Fourdrinier machine up to this period. We have already mentioned the Fourdrinier–Didot machine which consisted of a chain of moulds, which was devised with the object of making laid paper continuously, and it will be referred to again.

In 1807, however, Thomas Cobb, of Calthrop House, near Banbury in Oxfordshire, who had a paper-mill and made paper by hand, produced a machine for mechanizing the process. This machine consisted of the usual vat, or chest, and breast-box with a delivery-slice, and a conveyor band on which the moulds were placed. This conveyor band was worked by hand, and the mould stayed under the delivery-slice long enough to get a supply of stuff, and was then passed on. In the original model the mould was then taken off by hand and couched onto a pile, as in ordinary hand-made paper-making. Subsequently, however, Cobb added another conveyor, onto which the moulds passed, and when they reached the end of the second conveyor they came under a couch-



No. 23. Drawing of Thomas Cobb's first mechanized mould machine, in which the separate moulds are filled with stock from a tank and travel along bands in succession; the sheet is ultimately couched off onto a felt.

roll, round which was travelling an endless felt. As the moulds passed this roll, the sheet was couched off onto the felt and taken up and through two press-rolls, which squeezed the paper sufficiently dry for it to be handled. Thomas Cobb persisted for a good many years with this machine, patenting several improvements to it in 1812, by when he had got it very much more mechanized, and it was quite an elaborate machine (Nos. 23 and 24).

It had an automatically controlled supply of stuff for the mould, according to the thickness of the paper to be made, so that when the breast-box contained the requisite weight of stuff, the valve supplying the breast-box from the chest was automatically closed, and the stuff discharged onto the mould. This breast-box was quite elaborate; it had baffles in it, and means of allowing the air to escape and so prevent bubbles in the sheet of paper. The stuff passed from the breast-box onto the mould over an apron made of cloth. The moulds were carried along the machine continuously on travelling bands, in rather the same way as on his original machine, until they came to the couching roller (r). Once the mould had delivered its pulp, onto the endless felt at the couch-roll (r), it passed onto a tipping table and when the whole of the mould was on the table, the table tipped and dropped the empty mould onto a lower belt, or conveyor, which carried it back again to the other end of the machine. The frame, or conveyor, on which the moulds travelled from the breast-box to the couch was shaken laterally, just as the wet-end of a paper-making machine. In Cobb's original specification he had caused the frame to shake backwards and forwards in the direction in which the mould was travelling, but he subsequently found that this was not necessary.

A man had to be present beyond the breast-box end of the machine to receive the moulds as they were returned, and put them on the conveyor again to take them under the breast-box. The moulds were sprayed with fresh water on their way back, to wash them so that they were clean enough to receive a fresh supply of paper-stuff on their next journey.

The wet-felt was washed by shutting down that part of the machine which actuated the moulds and breast-box while the wet-felt and presses continued to run, and the felt was then washed with sprays of water at intervals.

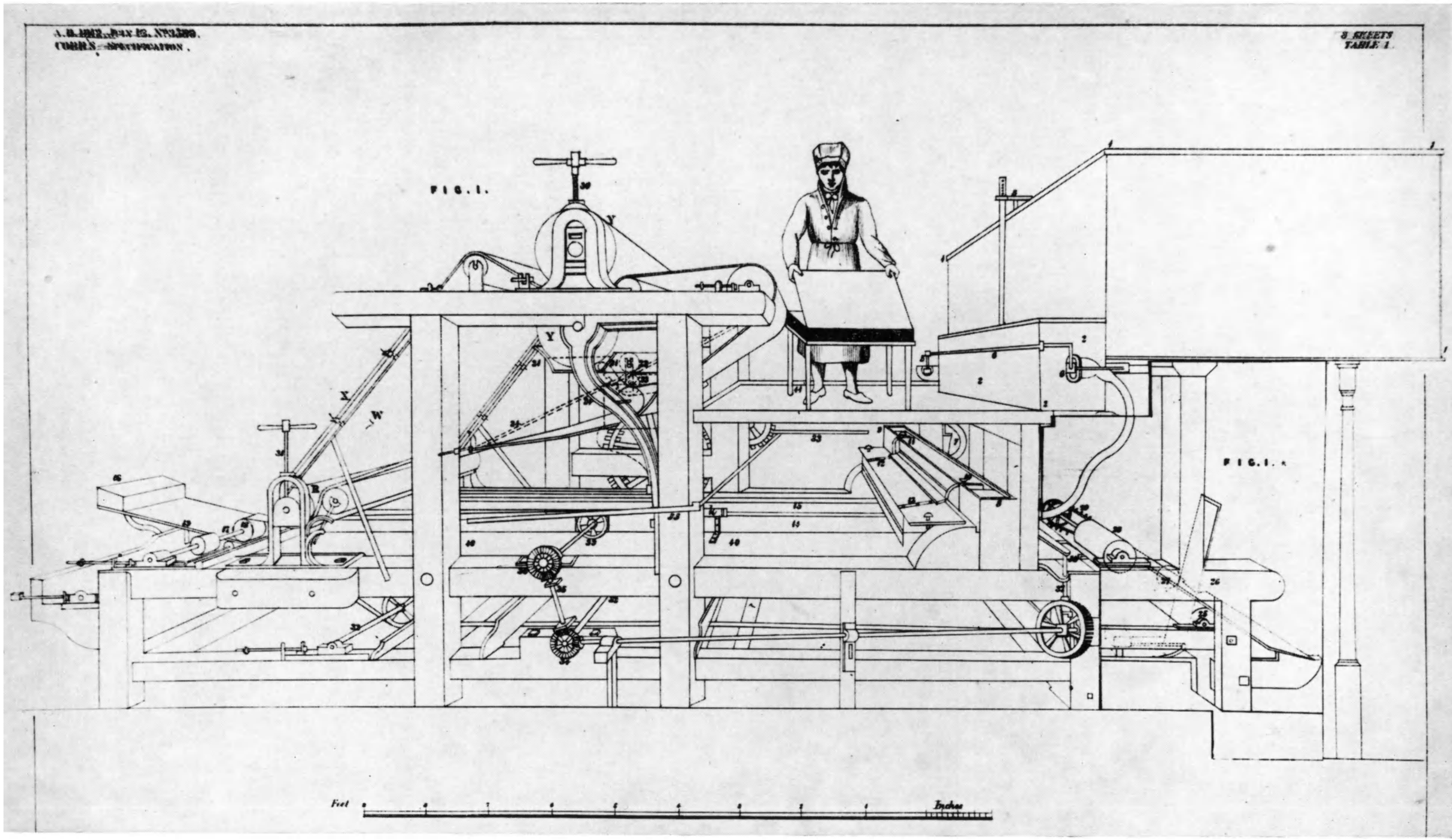
The right-hand of the illustration shows that arrangements were made for putting the moulds back onto the travelling band automatically, thus doing away with the necessity of having a man there to do it by hand.

When the machine was started up a man placed the moulds in succession onto the machine. When the whole of the machine was full of moulds, there was a continuous operation, the moulds passing along the conveyors to the couch-roll, where the paper was taken from them onto the felt, up through the press-rolls, and then off the felt by the operator on the platform. The moulds then returned continuously by a lower conveyor, and were put back into circuit automatically.

If wide moulds were used, making two sheets, or rather double moulds, then it was necessary to have two workmen to take off the sheets and lay them.

This was a very ingenious machine, and must have taken a great deal of developing by Cobb, but it does not seem to have had a very long or successful life, probably owing to the greater success achieved by the Fourdrinier machine. In some respects it bears a resemblance to the Didot–Fourdrinier mould machine, but cannot in any way be said to have been a copy of it.

John Dickinson's mould-machine was patented in 1809. Didot appeared again with a new specification in 1812, and Thomas Cobb a second time, with further improvements in mechanizing this machine, also in 1812. As these attempts to make paper continuously by all these varying methods were taking place during the evolution of the Fourdrinier machine, it is appropriate to describe them at this stage, to keep the sequence of events correct, as they, to some extent, had a bearing on the development of the continuous-wire Fourdrinier machine. They were, however, the only machines on which laid paper could be made until the invention of the laid dandy-roll a good many years later.

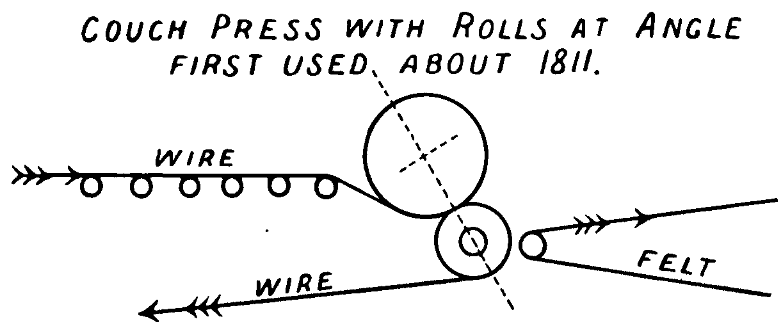


No. 24. Thomas Cobb's improved paper-making machine, using mechanical moulds, on which one sheet is made at a time. The machine is completely automatic and very ingenious. No handling of the sheet is necessary—until it is pressed and ready to be air-dried. The wet press part works in the same way as that on a Fourdrinier or cylinder-mould machine. The used moulds are washed and returned automatically to the front of the machine ready to fall into place for use again.

The continuous chain-mould machines were eventually given up, and never seem to have been a commercial success. John Dickinson's cylinder-mould machine, however, was the exception, for it did have a great success eventually, and became the forerunner of the multi-vat-board-machines of to-day.

In 1809 the Fourdriniers continued to lose money, to the amount of £5635, in their paper-making machine business, and a Commission in Bankruptcy was issued on the 8th November, 1810, under which C. A. Bloxham, son of their former partner, and a person called Abbot, were appointed assignees on their behalf.

Up to the year 1811 two wires had already been used on the wet-end of the Fourdrinier paper-making machine, one above the other, the sheet of paper being held between them, and subsequently couched from the rolls around which the wire returned onto an endless felt. This arrangement, in consequence of the fact that it did not get rid of sufficient water, caused endless breakages of the paper, but notwithstanding the inconvenience of this arrangement, the machine was considered a practical success. Donkin, who was at this time frequently visiting Two Waters and watching the working of the machine with his foreman, was sitting in his room in the Bell Hotel one evening when the following idea occurred to him. He wrote: "By placing the couch-rolls at an angle, instead



No. 25. Bryan Donkin's staggered top couch-roll arrangement. This was a most important discovery on the part of Donkin and led to vastly improved performance of the paper-making machine, higher speeds and the elimination for good of the top wire, which had always been a source of trouble and expense. This staggering of the top couch-roll is invariably used at the present time.

of vertically one over the other, so that the upper one should bear slightly onto the web before receiving the full pressure between the rolls, thus causing more water to pass from the sheet of paper, through the wire, the effect would be that the sheet would be stronger and less liable to break in passing the couch-roll." This trial was made at once, as it was not wished that Didot should be present, and with great exertion this alteration was made in the middle of the night, and the mill started. The noise, however, woke Didot, who at once appeared on the scene.

"This rearrangement of the couch-rolls proved perfectly successful, and, as was fully expected, the individual referred to (namely, Didot) tried to claim credit for this important invention, but in this he was not successful."

The inclined arrangement of the couch-rolls, or staggering, had also another very beneficial effect, in that it enabled them to do away with the upper wire, which was inconvenient and very expensive. From this date the machine was definitely a practical success. This was one of the more important of Donkin's many strokes of genius in the evolution of the Fourdrinier machine.

During 1811 Donkin was making many visits to paper-mills and quoting prices for converting hand-made paper-mills to machine mills. By this time he had taken over completely this kind of work from the Fourdriniers, and they had to be paid a royalty on the machines, and another on the paper made. Of this latter royalty it is known that the Fourdriniers got very little.

In 1811 the first paper-making machine to be installed in a mill in the north of Scotland was erected by Lewis Smith at Peterculter near Aberdeen. Smith was the son of Bartholomew Smith who came from England to start paper-making at Peterculter. The mill employed fifty workpeople and ran day and night, being only stopped for oiling and washing up.

Didot at this time sent to M. Berthe in France full particulars of the 1808 Fourdrinier machine, and asked him as Didot's agent to patent it. Berthe did so, but as Didot did not appear in France within two years he authorized Berthe to have two machines constructed according to the plans and instructions he had sent, and to sell them in order that Berthe could have remuneration for the expense he had incurred in taking out the patents. The machines were made by an engineer named Calla in Paris in 1814 and 1815. One machine went to Sorel and one to Dreux under the direction of Grevenich, an associate of Berthe.

Longman and Dickinson bought a Fourdrinier machine and erected it at Apsley Mill in 1812.

Joseph Wright, of Marlow, was very anxious to have a machine, and when he had had Donkin's quotation he would not give him a final answer about whether he would accept the quotation or not unless he could have an assurance that he could have a machine 6 in. wider than the one running at Elliot's mill at Chesham! In those early days paper-makers were evidently trying to steal a march on their competitors by having wider machines when possible. The Fourdriniers, however, had set a limit to the width of the machine, based on the practical experience they had gained, and Donkin would not alter the width without the Fourdriniers' permission, or rather without the permission of the receivers, or assignees, of the Fourdriniers.

Swann, who had one of the earliest machines running at Eynsham, near Oxford, asked Donkin at this time to arrange some alterations to his existing machine, and to examine Wolvercote Mill in preparation for erecting a machine there. Meanwhile, Bloxham, junr., the son of the original Bloxham who had been a partner of the Fourdriniers, and also a Mr. Abbot, had been appointed to carry on the Fourdrinier business during the bankruptcy of the Fourdrinier brothers. They asked Donkin to let them have a statement of his account with the firm of Fourdriniers, and also that with the assignees of the Fourdriniers. Abbot said that he would go through the account and that it would be settled immediately, and he agreed to take the three wires which Donkin had on hand for the Two Waters machine.

Donkin gave Henry Fourdrinier an estimate of the cost of making four different sizes of paper-making machines.

At about this time Donkin went to Two Waters, at the request of John Dickinson, to examine the state of the Grand Junction Canal and its locks. Dickinson had been having trouble with the Canal Company, as their canal leaked and lost water, and the Company was taking water from the river Gade, thus robbing Dickinson, and the other mills, of water. While Donkin was at Two Waters about the canal matter he went to the mill and saw the Didot chain-mould machine working on stuff prepared from canvas, making, he says, very good paper. It was also tried with an engine of fine stuff, but Donkin reported: ". . . from its being beat too short and holding very little water, it was not made well." Donkin also observed that the machine would do better if the deckles were altered, and he reported to Abbot that the experiment with the chain-mould machine had, on the whole, been a success.

The first Fourdrinier machine to be sold by Donkin to France was erected there in 1815, at Annonay, for M. Canson. The two or three machines which had been built there by French engineers, to drawings supplied by Didot, had not been a success.

In 1814, when twelve machines had been constructed on the improved principle, as was described in the prospectus of 1813, and machine-made paper was becoming fairly well known, the Emperor Alexander the First of Russia, whose dominions had then recovered from the invasion of 1812, came over to England for the peace festivities, and heard of the invention of the paper-making machine. He approached the Fourdriniers with a view to introducing the machine into Russia. Accordingly, an agreement was drawn up under which Henry Fourdrinier agreed to permit the use of two of his machines (which were erected under the superintendence of one of his sons) in the Imperial Paper Mill at Peterhoff for ten years at a royalty of £700 per annum. The agreement further provided that Fourdrinier should, from time to time, communicate, free of charge, particulars of any improvements that might be made. In pursuance of this latter clause one of his sons went to Russia as late as 1824 to give details of something new that had been added in the meantime, although not a farthing of the stipulated £7000 had been paid, nor had the machines themselves been paid for; this debt was never discharged.

6

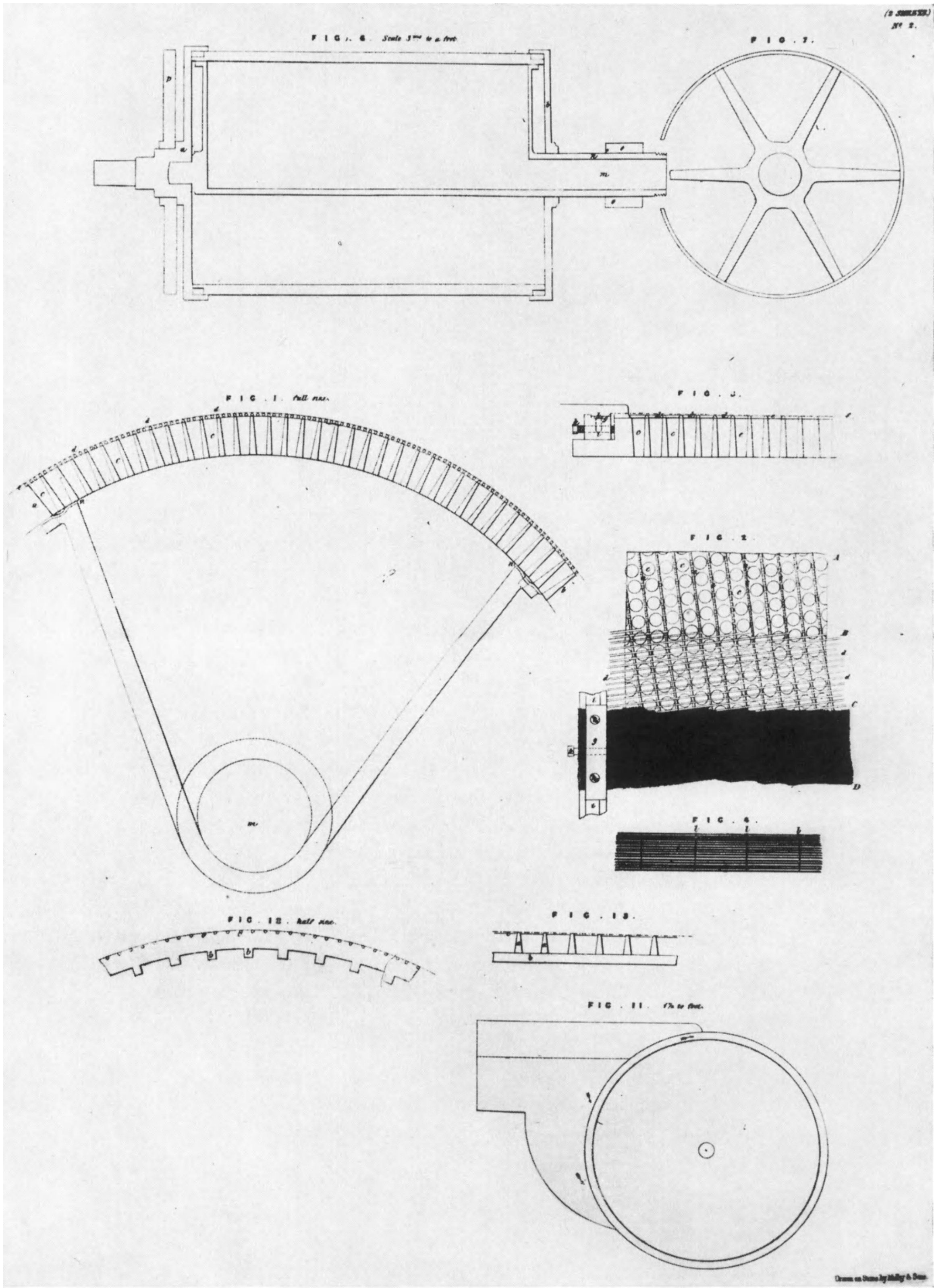
The Dickinson Cylinder-mould Machine

JOHN DICKINSON patented his cylinder-mould machine on the 19th July, 1809, and this became the prototype of the vast multi-cylinder board machines now in use throughout the world. Although the machine was originally intended as a competitor of the Fourdrinier machine and failed in this in the early days, it continued to be developed, and must be considered as a very important step in the progress of paper-making.

The principle of the original machine of John Dickinson was exactly the same, in so far as the formation of the sheet is concerned, as that employed on the cylinder-mould machines of the present day. It is interesting to note that Dickinson soon saw the advantages of a two-ply paper, achieving this object in two ways. First he made a thin roll of paper, then he unwound it and passed it through a press in contact with another sheet of paper from a mould-machine, combining the two in a wet state. Later, he put two moulds on his cylinder-mould machine, and made a two-ply sheet in the same way that it is made today.

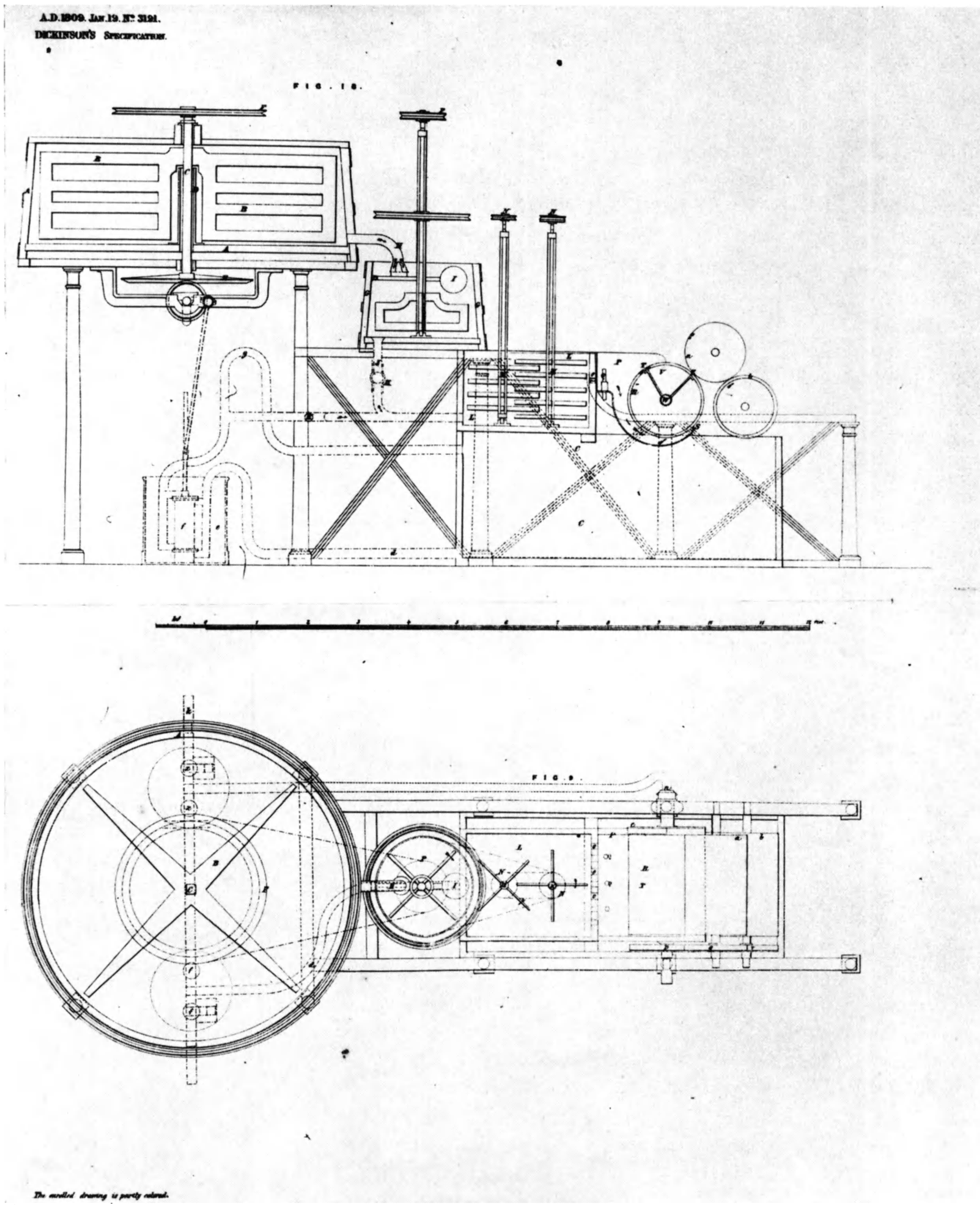
His first machine consisted of a strong, hollow cylinder built up as shown in the drawings. He laid stress on the fact that it must be very strongly constructed so as to stand the pressure of the couching roll. The cylinder-mould had to be covered with a woven wire cloth, with apertures communicating with the internal part large enough to permit easily the passage of water, but calculated to intercept the fibres of rag pulp. The cylinder had to have broad flat rings, of different widths, in order to vary the proportion of the surface which was left uncovered, provided that the same cylinder was intended for making different widths of paper. The body of the cylinder could not be made of wood, because it would be liable to warp, nor of iron because that would rust. Dickinson used a polished brass cylinder. This he turned in a lathe to make a spiral groove, with the threads about ½ in. apart and 1/25 in. deep, and drilled holes in the metal between the grooves, all as shown on the drawing. He then fixed a backing wire over the cylinder, and onto this he fixed tightly a cover of woven wire. He kept the cylinder-mould cover in place by rings screwed into position at each end (No. 26).

Figure 1 represents a transverse section of a segment of the cylinder, showing the holes and cross-wires. Figure 2 is the plan of a portion of the external surface of the cylinder, the top part of which shows the holes without the cross-wires, and the groove turned in it. Lower down the cross-wires are shown. These were soldered or otherwise fastened into the ends of the cylinder. Again the cylinder is shown covered with the wove wire cloth. Figure 4 shows how the mould could be covered so that the sheet would eventually have the appearance of a sheet made on a laid hand mould. A triangular trough, or receiver, closed at the end, was fixed inside the cylinder so that the upper edges touched the inside, and of such a depth that the bottom was about level with the centre of the cylinder, so that when it was fixed and the cylinder turned round, every part of the upper edge rubbed against the inside of the cylinder, which had to be perfectly smooth. In Fig. 1 a section of



No. 26. Detailed drawings of the components of John Dickinson's cylinder mould machine. The design of the cylinder mould and vat or "back" are shown; also details of the construction of the cover.

this trough is shown which has an orifice at one end at the bottom, marked (m), and at the points (n-n) it comes into contact with the internal surface of the cylinder. Figure 6 is an outlined vertical section of the whole cylinder, in which the trough is represented fixed in the inside of the cylinder, with the orifice (m) and the pipes communicating with it.



No. 27. Elevation and plan of John Dickinson's complete cylinder mould machine.

The axis of the cap (a) at the end of the cylinder was supported in a bearing and had on it a cog-wheel (p), by means of which the cylinder was made to revolve. As it turned round it rubbed against the upper edge of the trough, which remained fixed and received any water that passed through the upper part of the surface of the cylinder and carried it off through the orifice end. Figure 7 is a front view of one of the caps, or cylinder ends. Number 27 is a sectional elevation of the machine erected and ready to make paper, and a plan of the same machine.

In the drawing Fig. 18 and Fig. 9 (A) is a circular stuff-chest into which stuff was emptied from the engine; (B) is an agitator consisting of a number of arms connecting with a spindle (C) which passed up through a tube (D) in the centre of the chest. This was turned by a bevelled cog-wheel (E), and kept the stuff in motion in the chest, and also, by means of the two riggers (F-F), drove another small agitator in the smaller vessel (G), which was for the purpose of receiving the stuff from the first chest, and it was conveyed through the pipe (H), the aperture of which was opened or contracted by means of a conical valve, on the principle of a ball-cock, so that as the vessel filled with stuff it gradually closed the orifice. By this means the stuff in the smaller vessel was kept to the uniform height so that the discharge through the pipe (J) at the bottom was always the same.

The large chest (A) could be of any shape or dimension, and agitated in any convenient manner. The smaller chest (G) was circular, about 18 in. in diameter, and the same depth. The use of this was to cause a uniform discharge, which would not take place if the stuff were to pass from the large chest without any intermediate vessel, because its passage through the pipe would be more or less rapid, according to the height of the head. This was practically the same as the head-box on a modern paper-making machine, where the height of the stuff is kept constant by overfilling the box and allowing any surplus to overflow back into the chest. In the pipe (J) there was a cock (K), by means of which the quantity of stuff required to make the paper was permitted to pass. When it was found what proportion of stuff was required, no variation in the supply took place. The best valve for this purpose was one which left an opening for the stuff which was nearly round or square, so that the stuff would not lodge. As the stuff passed down the pipe (J), past the valve, into the pipe below, it met a rapid stream of water which diluted it, and it actually began mixing with the water in that pipe.

When making paper on the cylinder-mould, about four times as much water was needed in the pulp as was used on the endless Fourdrinier-type of paper-making machine wire.

From the vessel (L) the pulp flowed through the pipes (O-O) into the vat (P) which was called the "back". (Q-Q) were waste-pipes for adjusting the height of the head, or, in other words, the level of the pulp. (R) was the cylinder-mould already described, revolving in a clockwise direction. The water was constantly flowing through its surface from the point (S) to the point (T), that is to say through every part covered by the pulp, and as it passed through the fibres of rag were left on the surface, so that they were gradually accumulating on every part of the surface of the cylinder during the whole of its passage, and when it emerged from the pulp at point (Z) the quantity required for the composition of a sheet of paper was collected. This was a continuous process as long as the motion was continued with a uniform supply of pulp.

It was necessary to remove as much water as possible from the wet web of pulp on the mould before it could stand any pressure. This was where the trough (V) came into operation, connected to a pair of double-acting pumps (X-X) placed in a cistern of water under the chest. When these pumps were started, the air contained in the triangular space enclosed between the trough and the cylinder-mould was immediately drawn out, so that atmospheric pressure was exerted upon the surface of the cylinder covered with pulp which was thereby rendered nearly impervious to the air. The immediate effect produced was the squeezing out of the water and the laying of the pulp in a compact state on the surface of the cylinder, so that the paper could not be distorted at the point

(Z) by the pressure of the solid roller (a). This part of the process was called the "pneumatic pressure". The periphery of the roller (a) moved at exactly the same rate as the periphery of the cylinder (R), and in the direction mentioned in the drawing, that is, anti-clockwise. The roller was made to fit in between the caps or brass ends of the cylinder-mould, so that it only pressed on the paper-pulp covering the surface of the cylinder-mould. The surface of the couch roller (a) had to be smooth so that the paper adhered to it instead of sticking to the cylinder-mould (R); it was then led round to undergo a second pressure between the roller (a) and the roller (b), the latter having a porous surface, so that the paper was produced sufficiently dry for leading off to be cut.

Dickinson stated that:

> . . . independent of the quality of the materials, the strength, smoothness and beauty of papers depend upon the arrangement of the fibres of rag of which it is composed. In a well-made sheet of paper the fibres are arranged in a horizontal and parallel direction; and a paper-maker describing such a sheet of paper would say that the stuff was "well shut", which quality all paper must possess in a greater or lesser degree, as otherwise the parts of the sheet will scarcely cohere together, the surface will be rough, the thickness uneven, and the paper devoid of beauty, and not useful. In the modes of paper-making exercised hitherto, this indispensable quality has been obtained by shaking the mould or wire on which the pulp is settling, as in the case of the Fourdrinier machine, so that as the water runs off, the fibres are laid flat on the surface of the wire, and arranged in a parallel direction. Making paper by the machinery above described, that is, the cylinder-mould, the stuff is perfectly well-shut without any shaking, and the quantity of water forced through it may be adjusted accordingly; and as the thickness of the paper depends upon the quantity of fibres left on the surface of the cylinder by the water flowing through it, this principle affords the means of regulating it with great precision.
>
> It will be seen that the fibres of rag being deposited gradually in a longitudinal direction by means of the friction which takes place upon the cylinder, in consequence of its motion being in an opposite direction to that of the stream of pulp, the effect of which is to smooth down the fibres of rags as they are laid upon the cylinder; and it is necessarily continued during the whole time of the formation of the paper, and must be uniform throughout every part of it.
>
> The reason for introducing so large a quantity of water into the pulp is in order that every fibre may be afloat separate, and at liberty to take a direction according to the influence of these causes.
>
> It is to be observed that in making paper by this method, after a certain quantity of fibres are deposited on the surface of the cylinder it renders the passage of the water and the accumulation of more fibres so difficult that without a considerable height of pulp the pressure will not be sufficient to force the water through the cylinder and the fibres of rag lying upon it, the consequence of which would be that the fibres of pulp accumulated on the surface of the cylinder would be washed off by the pulp, or very much disturbed before they arrived at the point (T), which is the level of the pulp in the back. To obviate this it will be necessary to increase the pressure of the atmosphere to the weight of the water, in making thick papers. The couching roller (a) ought to press on the cylinder-mould (R) about the point which is over one side of the trough (V), that is just about the end of the suction period. The couching roller (a) should not be fixed in bearings, but should be pressed down on the cylinder by weights suspended on each end of the axis, which may be adjusted according to circumstances; and in all cases the principal pressure should be on roller (b). All the water which passes through the cylinder is returned through the pipe (K) back into the vessel (L) where the pulp is mixed with it by means of the agitators (M).

In other words, it was a sort of closed back-water system with the water being continuously circulated round in order to dilute the pulp coming from the chest (G).

As regards the diameter of the cylinder-mould, 15 in. was considered sufficient for making a paper equal in substance 17 × 22–20 lb per ream. The thickness of the paper made on the cylinder-mould could be adjusted in various ways; first by using a cylinder of different diameter; secondly by accelerating or retarding the speed of the cylinder; thirdly by varying the proportion of the surface of the cylinder covered with pulp; and fourthly by varying the consistency of the pulp.

The peripheral speed of the cylinder on the first cylinder-mould machine was 36 ft/min. The friction between the cylinder and the "back" was relieved by either a piece of woollen felt or leather.

From the foregoing description of the machine, taken from Dickinson's specification of 1809, it is quite obvious that the board-machines of today are almost exactly the same in principle.

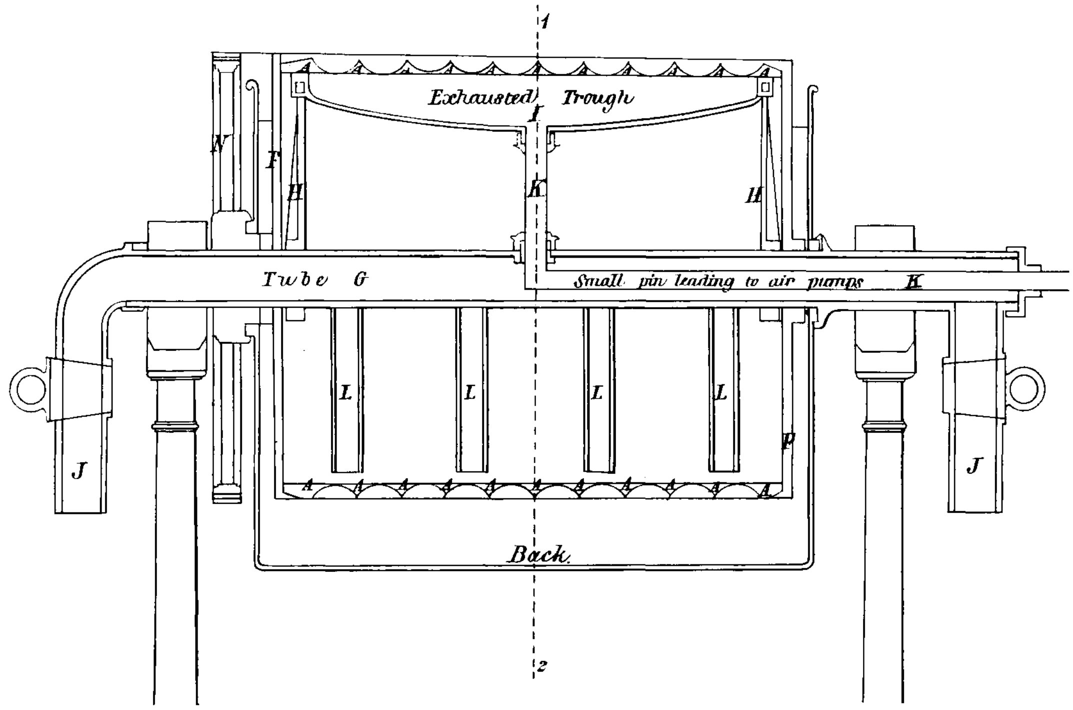
By 1811 Dickinson had improved his cylinder-mould machine very considerably; he had altered the construction of the cylinder-mould so that water could more readily pass through from the outer covering of wove wire into the exhausting trough, and so out of the cylinder. Instead of drilling a series of holes, he cut a series of notches round the periphery of the brass cylinder.

The second improvement made by Dickinson relates to the passage of water through and out of the cylinder. No. 28 shows the form of the "caps" which are marked (F). These were actually the ends of the cylinder. They had a hole in the middle, through which the tube (G) passed; this was fixed and formed an axis to the cylinder. There was an opening in the upper part of the tube (G), through which the small pipe (K) passed, and which communicated from the exhausted trough (I) with a pair of double-acting air-pumps, or an exhausted air vessel. The aperture where the pipe (K) communicated with the exhausting trough (I) passed through the tube (G), which was made air-tight by joining screws, as shown in the drawing. Otherwise the aperture where the pipe (K) passed out of the end of the tube (G) was airtight. The tube (G) was intended for letting out the water from the inside of the cylinder instead of running out at the end, as in the original machine. The pipes (L) were open at their lower end and soldered at the upper end into the tube (G), which had no opening except through the cocks (J-J), the orifices of which were below the mouths of the pipes (L); consequently the whole together would act as a siphon and empty the cylinder as low as the mouths of the pipes (L). The idea of this part of the apparatus was that the water inside the cylinder might be kept to any level between the bottom of the pipes (L) and the height of the pulp on the outside of the cylinder by the cocks (J-J) being regulated. The pressure of the head of pulp on the cylinder, and the quantity of water forced through it, were adjusted accordingly, and as the thickness of the paper depended upon the quantity of fibres left on the surface of the cylinder by the water flowing through it, this principle afforded the means of regulating it with great precision.

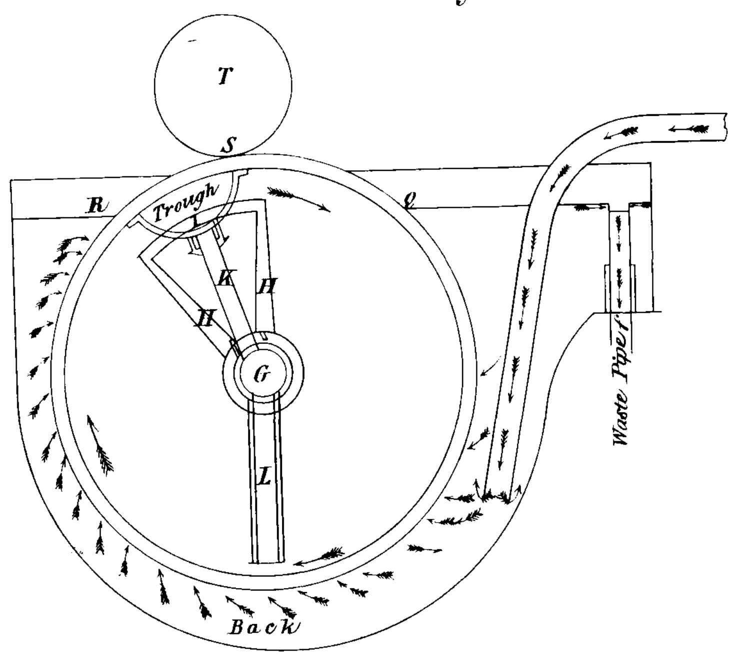
The third improvement claimed related to the construction of the "back", or vessel containing the pulp for supplying the cylinder. Originally the cylinder rubbed against this so-called "back", but in this case the cylinder turned round in it without touching it. Leather rings were used to prevent the pulp and water escaping between the ends of the cylinder-mould and the "back". It will be seen from No. 28 that the cylinder-mould was immersed in the stuff and revolved in an anti-clockwise direction, and it was in a position to receive stuff all the way round from (Q) to (R); and at the point (S), after the pulp collected on the cylinder had passed over the trough and been sucked nearly dry, it was led off the cylinder by couching roller (T), to which it adhered.

Dickinson stated that the exact shape of the "back" was immaterial, and that the method of driving the cylinder was not very important either. He said that the "back" could be of wood or metal, but he made use of copper in order to remove friction between the "back" and the cylinder, and to have as much of the cylinder as possible in contact with the pulp, so that the quantity necessary for the formation of the sheet might be collected on it in a shorter space of time than in his original patent, and consequently the machine could be run faster.

Longitudinal Section of Cylinder



Transverse Section of Cylinder



No. 28. John Dickinson's improved cylinder mould machine. It will be seen that the main improvement is the introduction of vacuum into the inside of the cylinder at a point after the sheet has been formed, and just before the couch roll. The object of this was to extract more water from the web and thus enable it to be couched more easily and at greater speed.

The fourth improvement made in this second attempt was in the couching of the paper from the cylinder. Instead of the brass roller used originally, he had a roll covered with several turns of woollen cloth, rather like a jacket, and constructed so that the surface was moderately soft and elastic. This couching roller (T) only pressed on the cylinder by its own weight, or, if absolutely necessary, equal weights were suspended at each end of it on the spindle.

The fifth improvement was simply the application of the method of using an endless felt on the Fourdrinier machine between the presses, and is shown in No. 29 marked (M). This felt ran round the couch-roll, by the pressure of which the paper adhered to it at the point (S). The paper was carried round with the felt and received two subsequent pressures between the press-rolls (V) and (W), after which it was reeled off for cutting. The reason he used two pairs of press-rolls was so that the pressure could be applied more gently to take out a given amount of water than would be the case if only one lot of press-rolls were used. As a result of the two lots of press-rolls the machine could run faster. The pressure on the first press-rolls was controlled by weights hung on each end of the spindle of the top roll. On the second pair of press-rolls the pressure of the top roll on the under roll was actuated by screws. He also had to use a short endless felt in order to prevent the paper sticking to the top roller (V). The felt used was a fairly long one, and it had to be washed on its way back to the cylinder-mould couch. This was accomplished by spraying water on it as it passed over the roll (Y), and then passing it between two squeeze-rolls (Z) on its way back, for squeezing out the surplus water. This particular machine, described and illustrated, ran at 48 ft/min and upwards.

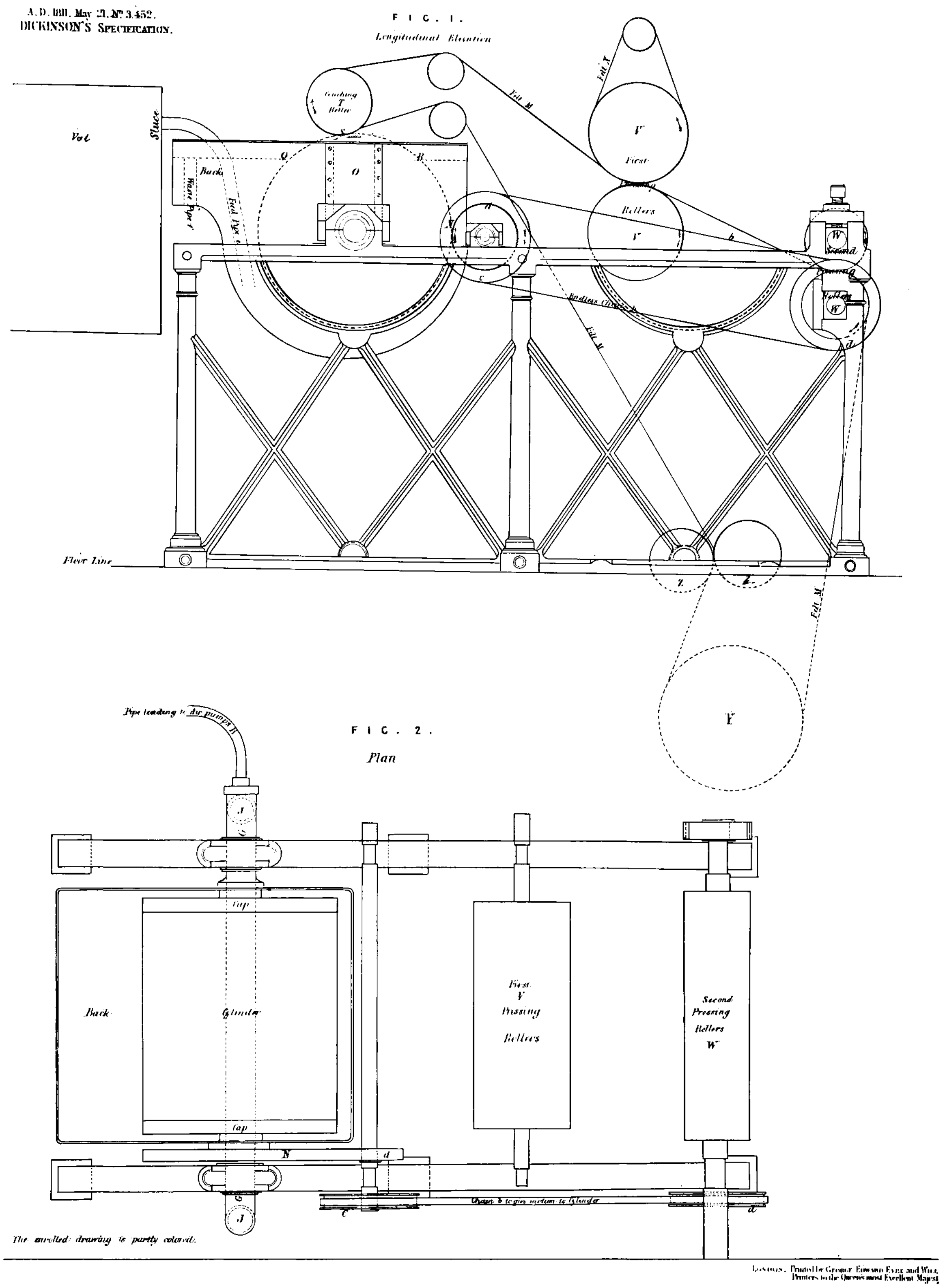
Dickinson contrived to make paper of different colours, or with two sides different, with this machine, by dividing the "back" into sections by partitions, and he could get stuff of different colours into these. The colours actually ran into each other slightly where the partitions came, as these latter could not be made to touch the cylinder, otherwise the paper would have been divided. If paper of more than two different colours was needed, there had to be correspondingly more partitions, vats and feed pipes, with a waste-pipe between each partition to keep the stuff between each at the same level, and to prevent the colours running one into the other.

During 1813 it was quite obvious that a lot of trouble was being experienced by employers of labour owing to the formation of some type of union, whereby the men were very difficult to handle. Strikes were very frequent, and the men's claims for better pay and conditions were looked upon with great alarm by the manufacturers. Donkin has this to say about it:

> I attended the committee of the Machinists' Society for the purpose of consulting upon the best means of opposing the present application to Parliament for an amendment of the Statute of Elizabeth relative to apprentices and trade. I agreed to procure a private interview with Mr. Vansittart and to ask his advice; and in the meantime to endeavour to awaken the attention of other trades, and to procure their co-operation as well for the above purposes as also for calling the attention of the legislature to the present state of the various associations of the journeymen under the colour of benefit societies, and to consider the propriety of petitioning Parliament for the repeal of the Statute of Elizabeth altogether.

About this time there was a fair amount of activity in connection with Didot's mould machine for making laid paper on continuous moulds, which has been mentioned several times; and there is a note to the effect that Farey was paid £60 for making the drawings to accompany the specification for the patent for the laid paper-making machine by Bloxham and Abbot, the assignees of the Fourdriniers.

In June, 1813, Aubrey who had worked for Donkin was offering to make paper-making machines for paper-makers at a cheaper price than Donkin's machine. Evidently Aubrey was trying to infringe the patent, for he had no permission from the assignees of the Fourdriniers to make the



No. 29. Elevation and plan of Dickinson's improved cylinder mould machine, showing two sets of pressing rollers, the first press having a short top felt, the second continuing to carry the web of paper, and then passing through squeeze rolls on its way back to the couch roll. The presses were driven by an endless chain.

machine, and they gave Donkin an assurance that they would not encourage Aubrey. On the other hand, they seemed to think that they could not refuse to allow a purchaser to get his machine made how he pleased, provided he paid all the royalties due to the Fourdriniers. One of the people who had been offered a machine at a much cheaper price was a Mr. Smith from Durham, who asked Donkin if he was prepared to reduce the price of his machines to make them as low as those which had been offered to him. Donkin informed him that there would be a reduction in the price of the machines, approximately £75, but this was due to alterations and simplifications which would be made in the construction of it. Smith told Donkin that he had received a much lower offer from Aubrey.

The new prices at which the Fourdrinier machines were to be sold at that time are those given in the prospectus of the Fourdriniers (see p. 255), and were agreed to in the presence of Bloxham, Abbot, Henry Fourdrinier, Ellis, Charles Fourdrinier, and Didot, but Smith would not agree to take a machine at these prices and to be obliged to pay the royalties for three vats. Eventually Abbot and Bloxham told Donkin that they had never given their consent for anyone but him to make the machines, and that they would not do so; and they accepted Donkin's new prices for the wove machines of different widths. These were inserted in the new prospectus which was sent to the printer in July, 1813.

There does not appear to be any record that Aubrey made any machines for anyone, even at his cut prices. A certain amount of interest was shown in the laid mould machine and a number of paper-makers went to Two Waters to see it in operation, among whom were Mr. Balston, Mr. Rouse and a Mr. Wise.

Shortly after the prospectus was issued, Donkin paid a visit to Lancashire and booked an order for a 46 in. wide machine from Livesey, of Prestolee, near Bolton. This machine was to be ready in less than six months, that is, by the 1st June, the order being placed at the end of January; Livesey's millwright was a Mr. Thompson, of Bolton. On his way back to London from Manchester, Donkin called at Birmingham, and got an enquiry from Whitmore for a paper-making machine to make paper from tarred hemp ropes, the stuff to be beaten in the engines with very hot water, in order to render the tar miscible. It was during this visit to Birmingham that Donkin spent some time with James Watt, who was 84 years old and still in possession of all his faculties. They discussed steam engines. On his way back to London he called at Wootton Wawen and saw the Wrights and the machine which he had built for them, and got a bill from them for the balance of his account for it. He also called at Phillips' mill at Lyttleton and took the necessary dimensions of the building, etc., for the reception of a paper-making machine he had on order for Phillips. He also saw another mill on the river Avon belonging to Lloyd, for which he was promised an order for a paper-making machine, but none of the machinery for the mill had yet been installed. The machine-house, according to Donkin, was excellent for housing a machine, and was 70 ft long by 20 ft wide.

Martindale, who had had a machine some time previously, does not seem to have been so successful with his, and gave Donkin orders to advertise his mills and estate for sale by private contract.

Donkin was called in by a Mr. Rowland, who had a paper-mill, regarding the erection of a gunpowder-mill which he thought was too near. Actually the gunpowder-mill was 186 paces from the gate of the paper-mill, but no conclusion seems to have been come to regarding safety.

Among other paper-mill activities of Donkin was the receivership of Bacon's mill at Taverham in August, 1816. There were several thousand reams of paper in stock; and besides this Donkin told Burgess, the manager, to work up all the stuff in the chest, and also the wet rags, and finish up by making the stock into a paper which could be sold. There were also two weeks' wages to be paid, amounting to £80. The mill was capable of making fourteen or fifteen engines of stuff per day on the paper-making machine. Bacon was in partnership with Wilkin in this mill, and Wilkin's private estate was mortgaged to Gurneys for £10,000, there was a bond for £2000, a debt of £2500, another debt of £4000, one of £2400, and one of £900, so the paper-makers seem to have been in rather a bad way.

Donkin made another visit to the paper-mills in Lancashire in December, 1816, after his visit to Telford at the Caledonian Canal, and saw both of Livesey's machines running at Prestolee, near Bolton. There was also another machine at James and Francis Wrigley's, Bridge Hall, Bury, and another one belonging to J. and C. Crompton, at Farnworth, near Bolton. Donkin says that Livesey's machines were both at work and doing very well, but the shake on the machine making white paper was out of order; the other machine was making large packing-paper, called "Manchester Paper", and this paid very well.

Unfortunately, Donkin still had to wait for some of his money from Livesey, who could not meet the bills due for it, but these he promised to meet in a month.

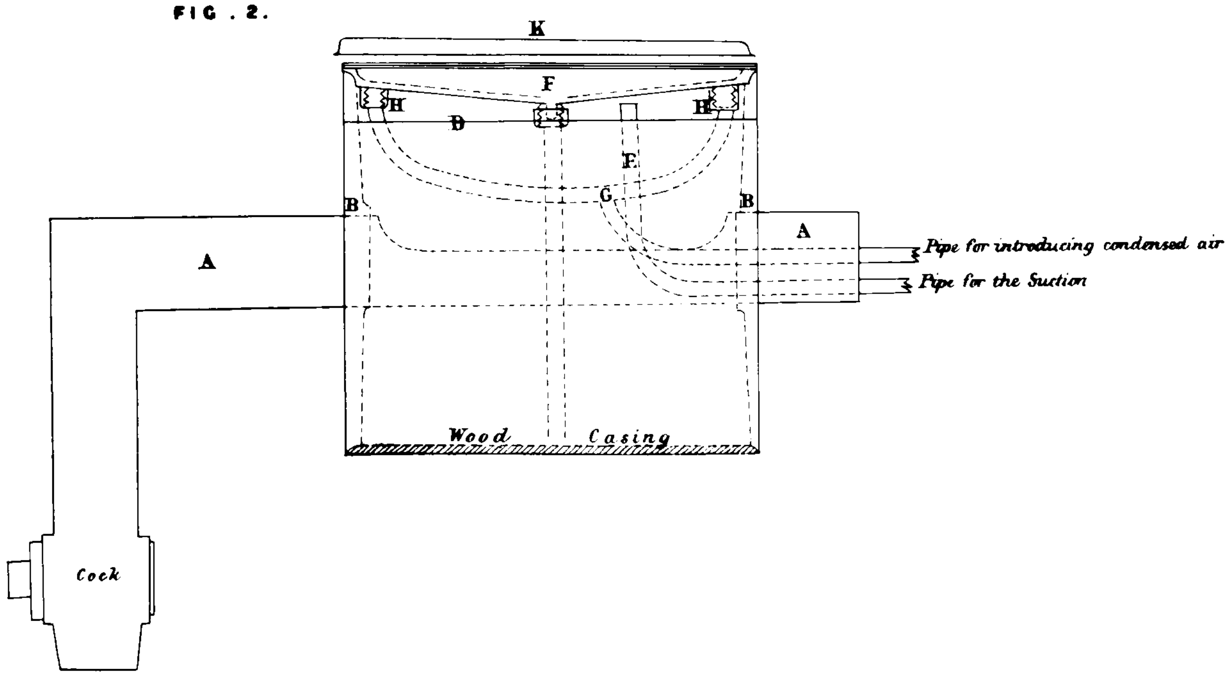
There seems to have been a serious lack of capital about this time and Donkin always seems to have been chasing money and renewing bills.

On his way back from Manchester just before Christmas Donkin called at Birmingham and visited Messrs. Dow and Gold's mill at Aston Furnace, and found his mechanic, Chappell, and his son, John, putting up the paper-making machine. A 24 h.p. engine had been erected with the idea that it would eventually drive four paper-making machines. Donkin says "the steam engine is made extremely rough and put up in a very slovenly manner".

This is the first mention of a steam-engine being used in a paper-mill.

About 1814, John Dickinson, in collaboration with his younger brother George, made some further improvements in his cylinder-mould machine, mostly connected with the shape of the trough, and also with the methods of passing the water out from what virtually was the suction-box. He had by this time found, however, that he was having difficulty in getting the web of wet pulp

FIG. 2.



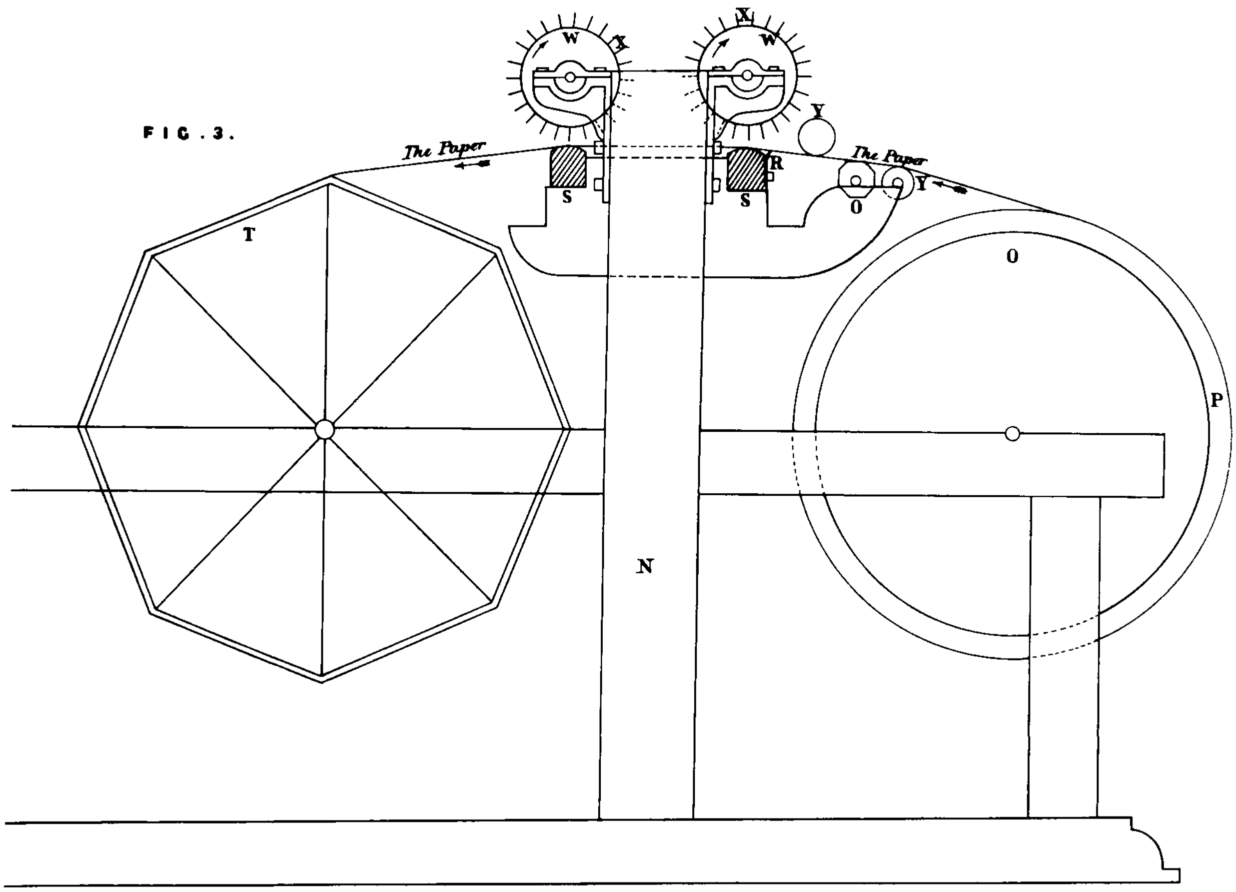
No. 30. Further improvement to Dickinson's cylinder mould machine. This consists of an arrangement to blow the web off the cylinder mould, after the suction box has sucked water out of it. There are, in fact, two boxes fitting close to the inside of the mould: one to exert suction and the second to allow of air being blown against the inside of the cover in order to help to release the web ready for the couch roll to pick it up.

to couch properly off the roll, so he invented a blowing arrangement of compressed air to force the paper off the cylinder at the point where the couching took place. This is shown in Fig. 2 of the drawing No. 30, and is marked (F); so that in order to make the paper he was sucking water through a suction pump, pressing the water through by a couch, at the same time putting air into another box in the inside of the cylinder-mould to ease the sticking of the web and allow the couch to pick it off.

Another improvement was the washing of the surface of the cylinder after the pulp had been couched off it by means of a water spray-pipe placed immediately after the couch-roll; washing of the mould was done with clean spring water which was not allowed to mix with the white-water in the mould, so he fixed a small trough inside, in which he could collect the clean spring water and run it away to waste. In order to seal these various boxes Dickinson had them covered with wood, and relied on perfect fitting to make the joint between them and the inside of the cylinder-mould.

Along with this specification Dickinson patented another piece of apparatus to go onto the reel-up of the machine, the purpose of which was to pick lumps off the surface of the paper. It sounds rather a crude way of getting rid of imperfections in the paper. The paper was reeled up on the machine in its wet state, on the reel (O). When this reel of paper was full it was taken and put into a frame, as shown in No. 31. The paper was first led over the small octagonal roll, marked

FIG. 3.



No. 31. Scraping and cleaning equipment invented by John Dickinson for removing knots and heavy dirt from paper as it was being wound up. As no strainers or knotters had by this time been used, there was a great deal of knots and lumps as well as much dirt in and on the surface of the paper which was usually scraped out by hand before the paper was polished.

(Q), which was covered with felt, and revolved in the same direction as the paper, about 300 r.p.m. The paper was next laid over the straight-edge (R), which was fixed to the side of a piece of wood (S); and being drawn tight over it, it forced the knots to project from the upper side of the paper. It was afterwards led over the cushions (S-S), which were pieces of wood rounded on the upper side and covered with felt or woollen cloth. The paper was then reeled onto the roll (T), which was driven so that it could draw the paper at the rate of about 40 ft/min.

The rollers (W-W) each had about 24 bars of very thin sheet-iron on them, as shown in the drawing, and marked (X-X). These rolls revolved in the same direction as the paper, at about the rate of 250 r.p.m., the extremity of the bars or teeth lightly brushing the paper. It was intended that the second roll should touch the paper rather harder than the first. There were two small guide-rolls (Y-Y) which were fixed so that they could be raised or lowered so as to adjust the friction of the paper against the steel knives. The octagon reel for reeling the paper upon was preferred on account of the angles being obtuse, so that it drew the paper uniformly over the cushions.

It is well known that, in making paper by machine, grit finds its way to the side of the sheet next to the wire on which the paper is made, and the knots are usually found on the upper side. The intention of this process was to remove the grit by the friction of the small octagonal roll, and scratch the knots off by means of the bars in the rolls. This seems a rather crude way of removing grit and knots from paper, but in those days there were no strainers or sandtraps yet available for this purpose.

From all these inventions it is obvious that John Dickinson was an extremely ingenious man, and spent a great deal of time and thought on perfecting the cylinder-mould machine.

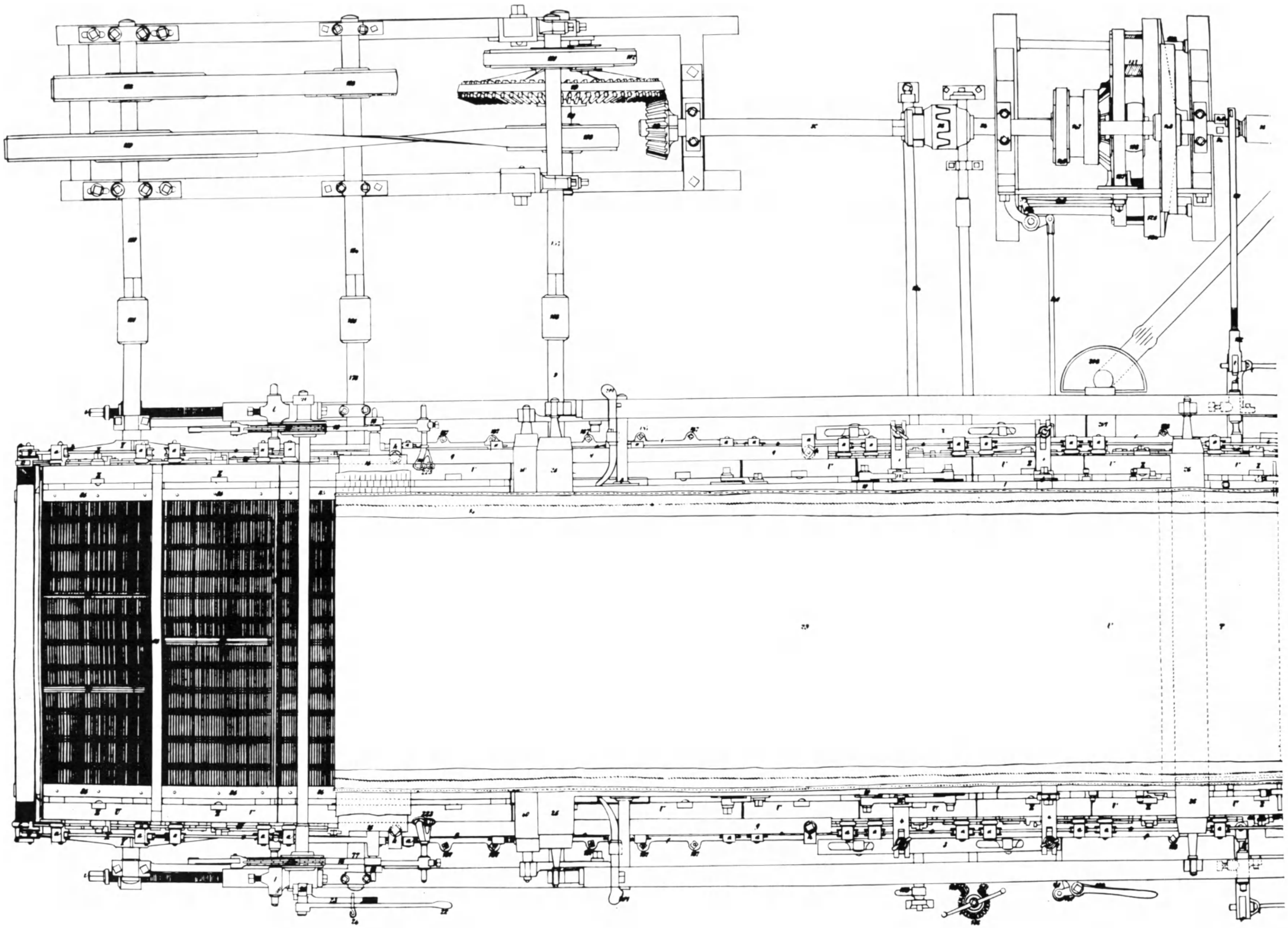
7

The Chain-mould and Fourdrinier Machines combined

WE have already referred to Didot's persistence with the chain-mould machine, which was never successful. By 1817 he was still busily engaged in trying to make a success of it, and to try and surmount the objections of Donkin and others to the machine of 1812, he produced a composite machine, combining both the chain of moulds and the endless wire machine of the Fourdriniers, which had already achieved success. This composite machine was even more complicated than the other one, and provided for the use of the machine to make paper in single sheets, on laid moulds, or, if wove paper in a continuous length was required, then the moulds were taken off, and the machine contained, underneath these, an endless wove wire cloth, as in the ordinary Fourdrinier machine. The construction of the machine, however, was different in that breast-roll and chest were in the middle of the machine; the wire and moulds travelled to the left and delivered their paper to a couch-roll, which picked it up onto an endless felt, and this carried it high above the machine back over the breast-roll and over the chest to the presses and reel-up. The whole of which can be seen in the drawings (Nos. 32, 33, 34 and 35) illustrating it. Didot describes the machine in his own words thus:

> In the first place I cause the prepared paper-stuff or pulp to be delivered upon the surface or surfaces of the moulds, which moulds are carried continually forward by means of two endless revolving chains, with which the said moulds are connected. Thus forms such pulp into sheets of paper of any required length. Secondly, I also occasionally change the parts of the machine so as to make the paper upon an endless revolving web of wire, thus making one machine to serve both purposes.

As will be seen from the drawing, when it was used as a chain-mould machine for laid paper, it had a better chance of making endless paper than the previously described machine under the patent of 1812. The reason for this was that the moulds were made to touch each other over the whole length of the machine while they were in the horizontal position. The paper web was couched off the moulds on to a wet-felt while in the horizontal position, which took the continuous sheet back over the machine to the presses, whereas in the other machine the moulds were not continuous, but followed each other at some distance apart along the chain. It seems likely that a really continuous sheet could not have been made by these moulds, as the laid wire cover could not have been completely continuous on account of the joins between the moulds. There is no record as to whether continuous laid paper was actually made on this machine; the only thing that is quite certain is that the machine was never a commercial success, and was never proceeded with. It was,



No. 33. Plan of part of Didot's composite machine, showing various possible arrangements of different sized moulds and the complicated drive.

however, an extremely ingenious conception, and the ordinary endless-wire frame, built in underneath the chain part, can be seen in the drawing, and would probably have worked quite well.

In order to alter the machine to make a wove paper on the endless revolving web, the endless chains and moulds were taken away by removing the nut uniting the screws of the chain. It was also necessary to substitute two movable troughs, shown on the drawing by dotted lines, for the one through which the pulp passed down to the surface of the revolving moulds. In other words, there had to be an extension of the trough which fed the mould to carry the stuff right down to the much lower level of the wire at the breast-roll. The breast-roll was situated on a lower plane than the tube-rolls, and the stuff ran onto the wire as it was passing from the breast-roll to the first tube-roll. The endless wire was driven, as usual, by the bottom couch-roll. The wire passed from the couch-roll under a brass fixed return-roll, over a movable stretch-roll, and under another return-roll, back to the breast-roll. The breast-roll was fixed to the shaking-bar.

From the breast-roll, the wire passed over a brass guide-roll, and over thirty-eight tube-rolls. The pivots of these rolls turned in holes made in brass plates, through to the iron plates, which were screwed to the ruler-bars by adjusting screws.

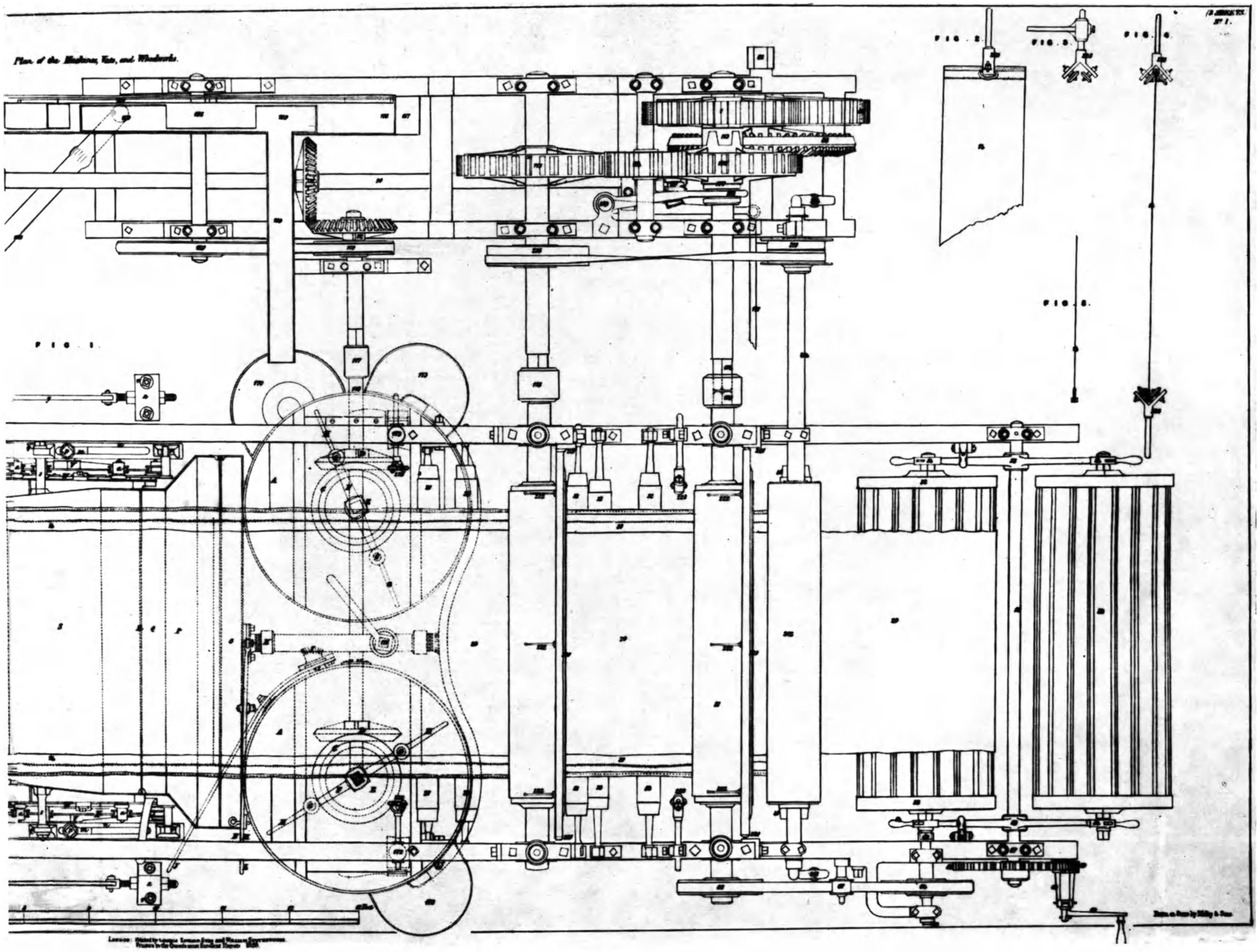
The wire then passed over five other larger brass rollers, which were hung in screw-hooks to the ruler-bar, and onto the couch. The dickles were next lowered down to the revolving wire upon their four regulating screws. The dickle-pulleys which drove the dickle-straps had also to be lowered. The top couch-roll, shown by a dotted line, was lowered down onto the wire, and this was accomplished by sliding it down slots in a vertical bracket. A shower of water was directed onto the wire, in order to wash it on its way back to the breast-roll.

It is stated in the specification that in some cases it was expedient to dry the paper as fast as it was made. For this purpose a hollow cylinder was provided, into which steam could be admitted through the pipe at one end of it, and allowed to escape through a hollow shaft and pipe at the other end. Although this was only a very small steam-heated cylinder, smaller in diameter than the press-rolls, nevertheless, it would appear to be the first time that there was any mention of drying the paper by means of heat on the paper-making machine itself. It can be imagined that very little drying would be accomplished at this cylinder, in spite of the slow speed of the machine. The idea, however, was there.

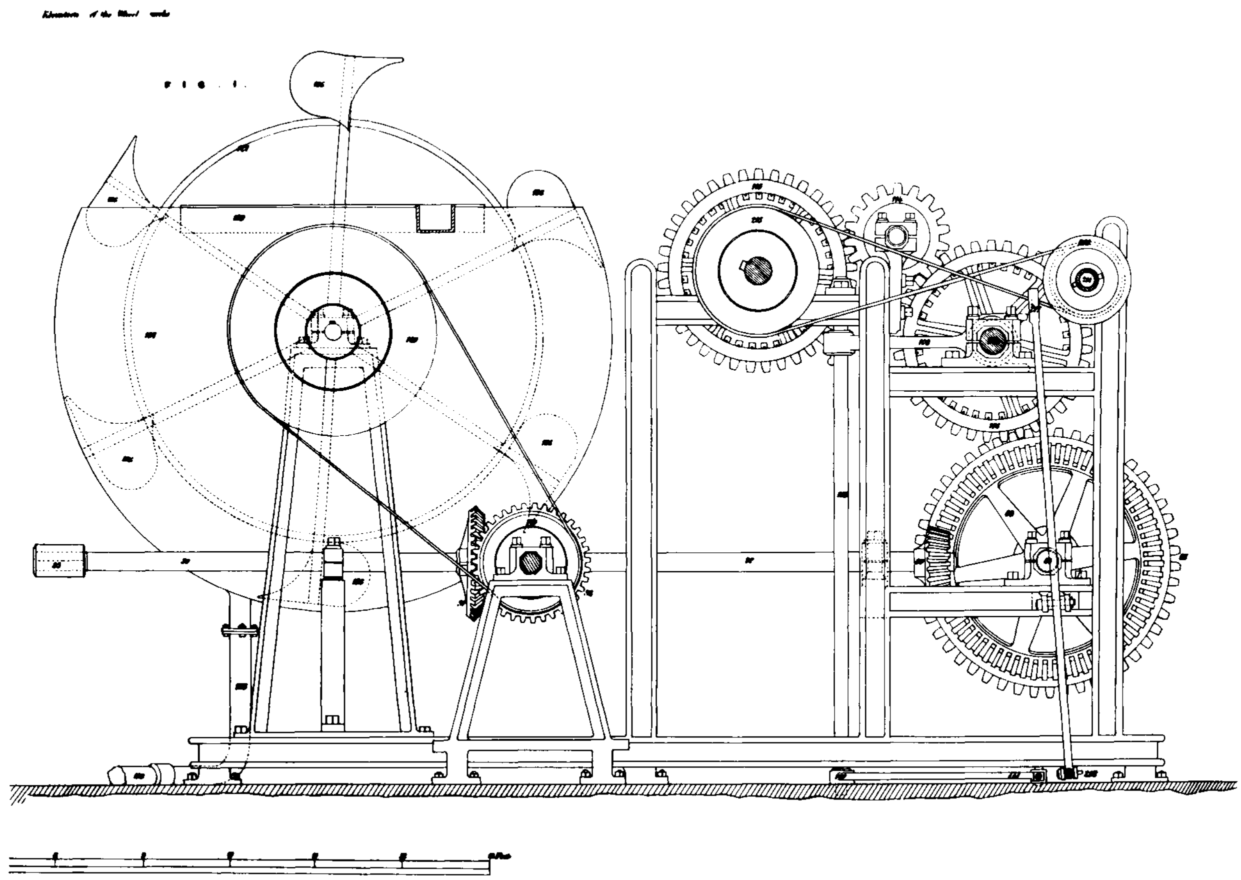
On this complicated machine the endless web of paper, after passing through the couch-rolls, adhered to the felt, which took it up and away over the wire, and down to the first press which was beyond the chests. There it left the wet-felt and passed on to a second felt, and through the second press. It then passed over the heated cylinder, and was wound on the reel-up, Nos. 34 and 35. The operation of this very complicated machine can best be understood by a careful study of the drawings. It will be readily appreciated, when examining this drawing, together with the earlier one, that a very great deal of the Fourdriniers' money must have been expended on this complicated piece of mechanism, and it is most unfortunate that it was never made into a commercial success.

Donkin himself had no confidence in its ultimate success, but there is no doubt that he helped Didot very much with all the details of the engineering work required, because this machine can be seen to be full of ingenious engineering devices and Didot himself was nothing of an engineer. There were times when Donkin himself admitted that the machine might work if various alterations were made, and these alterations *were* made from time to time, culminating in the final machine of 1817 which we have just described.

The real reason for the persistence with this type of machine, by Didot and others, was, of course, that there was still a demand for laid papers, or papers of the old hand-made type. Printers had not, however, very long to wait for these from the paper-making machine, because it was only a few years later that the dandy-roll was invented, which enabled laid papers to be made on the Fourdrinier wire machine.



No. 34. Didot's composite machine, plan of breast roll end, chests and presses, hot cylinder and reel-up drums, also bevel and pinion wheel drives at back side of machine.

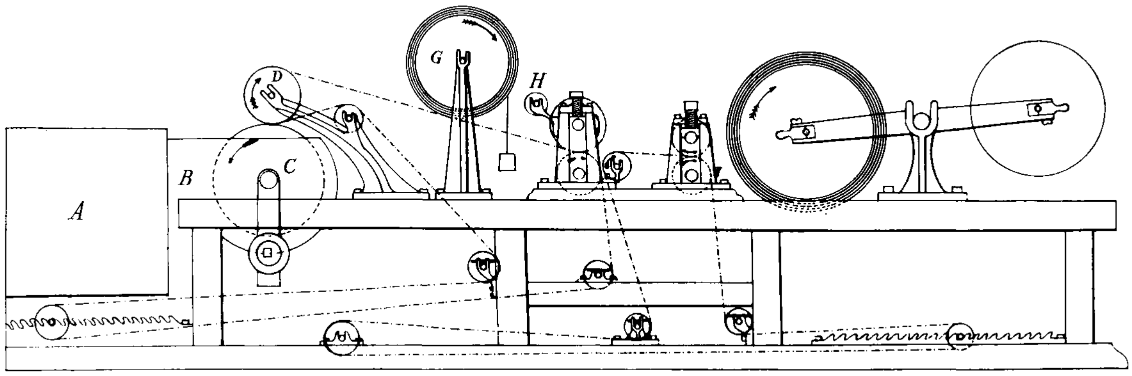


No. 35. Sectional drawing of the backwater lifting wheel and pinion wheel drive on Didot's machine.

By 1817 John Dickinson had further improved his mould-machine, and was making two-ply paper on it, but with only one mould. His method of operation was as follows:

He first filled a reel with very thin paper, and reeled it up as wet as possible from the machine. He then suspended this reel of paper over the machine which was making a thicker paper on the mould principle and while this latter paper was in a wet and pulpy condition, the end of the thin paper was laid upon it and conducted with it to the press-rolls, which pressed the two papers together and united them as one. The action of the press-rolls drew on the thin paper with the other, and thus unwound the suspended reel so that the process of combining continued until the reel of thin paper was finished. The empty reel was then removed and a full one substituted in its place. This is shown in elevation in No. 36, in which (A) is the vat, (B) the copper back, (C) the cylinder working in the vat and making the paper; (D) is the couching roller, and from this the web of paper was taken on an endless felt going round the couching roller. The paper, when detached from the making-cylinder, adhered to the felt and travelled with it to the first pair of press-rolls (F). The reel of thin paper is marked (G), and it can be seen to be suspended above the felt. The end of the paper is shown descending to the press-rolls where the pressure of these rolls caused the two wet-webs to unite.

Dickinson found that there were two precautions particularly necessary to prevent the paper wrinkling; one of these was to have a small and very light guide-roll (H) near the upper press-roll, so that the paper, when unwinding from the suspended reel, turned the guide-roll. The other precaution was to have a means of holding back the suspended reel so as to produce some tension



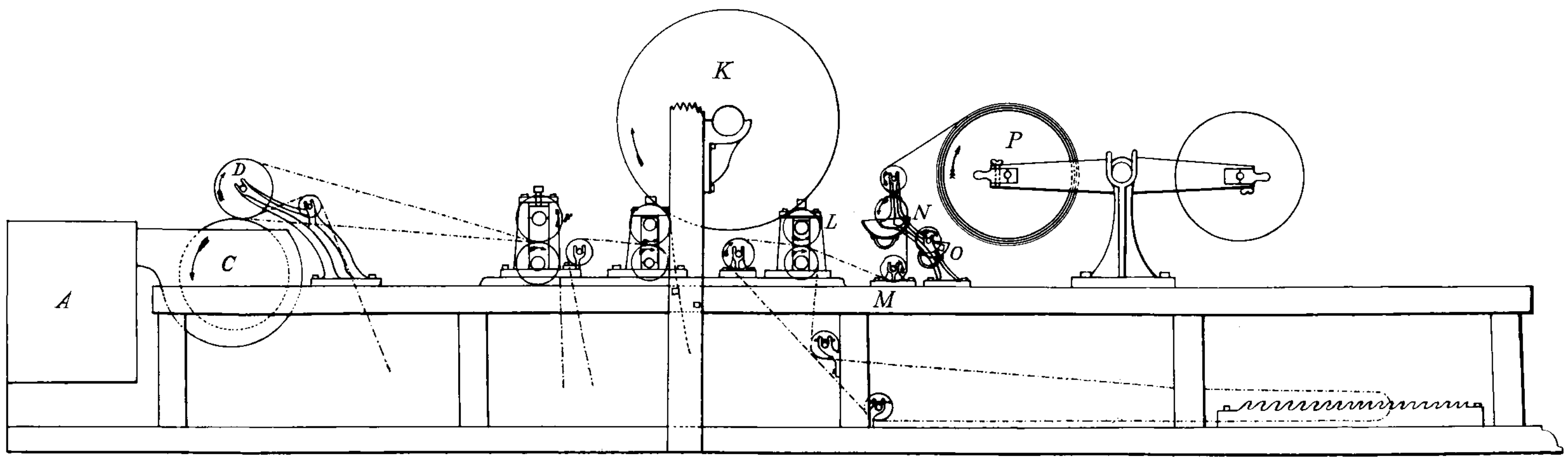
No. 36. John Dickinson's machine for making two-ply paper. The machine is a normal Dickinson cylinder mould machine with two presses, two wet felts and reel-up. In order to make a two-ply sheet, a reel of paper (G) which has already been made is suspended in brackets above the wet felt which carries the sheet being made, and the paper from this reel is unwound and laid on the sheet being made. Both are passed through the presses. The pressure causes the two wet sheets to adhere to each other, and thus they can be dried together.

on the thin paper; in other words, he had to put a drag on the roll. The paper was taken from the combining press to the second press on a felt. It left the felt at the second press and was then reeled up in the ordinary way.

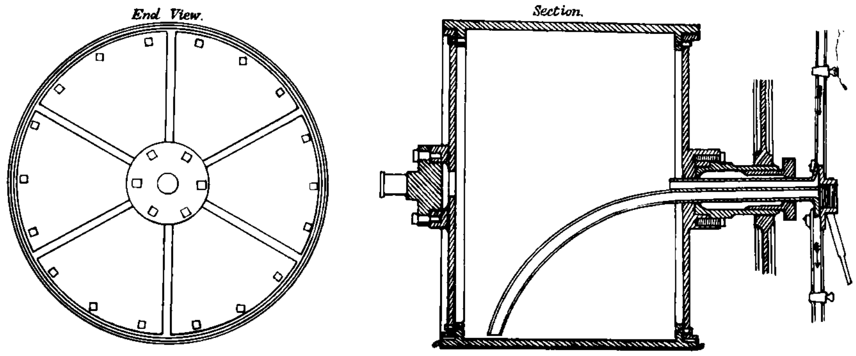
In this specification of 1817 Dickinson also described his method of tub-sizing on the machine, and incidentally the first mention is made of a drying-cylinder heated by steam, although Didot, about the same time, had a small hot cylinder on his dual-purpose machine. This drying and tub-sizing was done on a machine which was the ordinary Dickinson mould-machine, with a second pair of press-rolls squeezing the paper very hard so as to get out as much water as possible. The paper was then led round the large drying cylinder (K), which was heated by steam. The construction is also shown in the illustration. The steam-heated cylinder was intended to evaporate the water left in the paper after the second press. By the time the paper arrived at the third press-rolls (L), which came after the drying-cylinder, it was nearly dry, so there was no humidity in it perceptible to the touch. The paper then passed round the small guide-roll (M), and upwards between the two sizing-rolls (N and O), after which it was wound up on the reel (P) driven by a slipping or friction mechanism. The process of sizing was done by allowing the top and bottom rolls to revolve partly immersed in the baths of size, thus transferring the size to the paper as it came in contact with each roll in turn, and the surplus was then squeezed out by means of the top press-roll. There were pipes, pump, and size boiler, all fitted near the machine to keep the size trough supplied with size at the correct temperature.

The paper, by contacting each of these sizing rollers on both surfaces, was sized on both sides, then any surplus size was squeezed out before the paper was reeled up. The size bath and the path of the paper are shown in the drawing. It may be noted that although Dickinson used a large steam-heated drying cylinder on this machine, it was not covered with a felt, as in the later patent of Crompton, which will be described shortly. Dickinson described his steam-heated cylinder as being of cast iron or other metal, as shown in No. 38. The cylinder had to be bored out, in order to get equality of thickness of the surface and even drying. He sealed the joints between the cylinder ends and the surface of the cylinder by means of iron cement. A pipe was introduced for bringing steam into the cylinder, and another pipe for conveying away the condensed water. By carrying the pipe nearly to the bottom of the cylinder the condensate was practically all blown out by the pressure of steam in the cylinder.

At this time Dickinson was having trouble from knots and dirt in the paper. In order to eradicate



No. 37. John Dickinson's cylinder mould machine with two presses, steam heated drying cylinder, felted third press, tub-sizing plant and reel-up for making, partly drying and tub-sizing in one continuous operation. This is the first time that a drying cylinder has been used on a machine, and the first machine to be equipped with tub-sizing plant.



No. 38. Drawing showing details of construction of the drying cylinder, also inlet for steam and outlet pipe for condensate. This same arrangement is used at the present time.

these he invented a most elaborate strainer and breast-box placed at the beginning of the ordinary mould-machine, in which (R) is a vat of the usual kind with agitators. The stuff was first delivered from the chest into this vat where it was considerably diluted with back-water. By driving the agitators fast, the stuff was thoroughly mixed with the water before passing out at (S) into the vessel (T), which was about 3 ft 6 in. wide, with another vessel or boat-shaped contrivance (V) inside it, fitting neatly against the sides of the outline shown in the drawing. The purpose of this internal vessel was to direct the course of the diluted pulp in its progress from the vat (R) to the vat (A), and the arrows show how the pulp descended. It travelled along under the bottom of the vessel (V), rose up at the other end, and flowed into the vat (A), where it was again agitated, previous to its arrival at the making cylinder. The bottom of the vessel (T) was an inclined plane. At the end farthest from where the stuff entered there was a recess with a cock at the bottom of it which was used for cleaning out from time to time.

The object of this apparatus was to ensure that any wood or cork, or any other substance which would float on the pulp, would stay in the vessel (T) and would not descend and travel under the bottom of the vessel (V), hence these contraries were kept from getting into the paper. Any sand or grit, or other substance heavier than water, would sink to the bottom and remain there. Rag knots, being not much heavier than water, in the course of passing along the bottom, gradually settled. Most of them would sink into the recess and could be drawn off, with other heavy dirt, after about eight hours' work, from the cock at the bottom. The object of having this separate inner vessel was in order that it might be raised or lowered according to whether it was necessary to run the machine fast or slow, depending upon the amount of dirt it was found necessary to catch.

This machine made paper 2 ft 4 in. wide, and had three picking rolls, already described under a previous John Dickinson specification, which were to brush the underside of the paper to remove knots, etc. Dickinson found this precaution particularly necessary on account of the fact that he used his paper for making pasteboard, and the knots were very objectionable.

In order to expedite the drying of the paper so that he could make it into pasteboard immediately, he put three drying cylinders of different sizes on this machine. These are marked (K) in the drawing. The paper was led over these without any felt, and then reeled up in the usual way.

In 1817 Thomas Gilpin and Company, of Wilmington, Delaware, U.S.A., started up a machine to make endless paper in their mill on the river Brandywine. This machine seems to have been a cylinder mould machine, possibly on the lines of Dickinson's machine. Very little is known about it. One thing is certain, however: that the early American paper-makers using machines preferred the cylinder mould machine to the Fourdrinier type for very many years.

Donkin took out a patent in Germany on April 23rd, 1818. This was for Prussia, and was for fifteen years. A company was formed in Berlin, called Patent Papierfabrik and a machine installed. No other machine was erected in Prussia for the time covered by the patent, but this first machine worked till 1877, when the firm failed. The machine was bought by Kraft and Kunst, of Berlin, who re-erected it, and it was still running in 1913!

After the Dickinson drying-cylinders on his mould-machine came the complete dryer-part invented by Thomas Bonsor Crompton, of Farnworth in Lancashire, in which not only drying-cylinders were used, but also dry-felts. Up to the time of Crompton's patent, most paper had been dried by air in lofts, after having been cut into sheets which were very badly cockled and irregular in shape, due to expansion and contraction. It was in order to try and improve this flatness of the paper and increase the drying capacity that Crompton invented the dry-felt. As already mentioned, even Didot had had a drying-cylinder, and John Dickinson had as many as three on some of his machines, but he had not used a dry-felt.

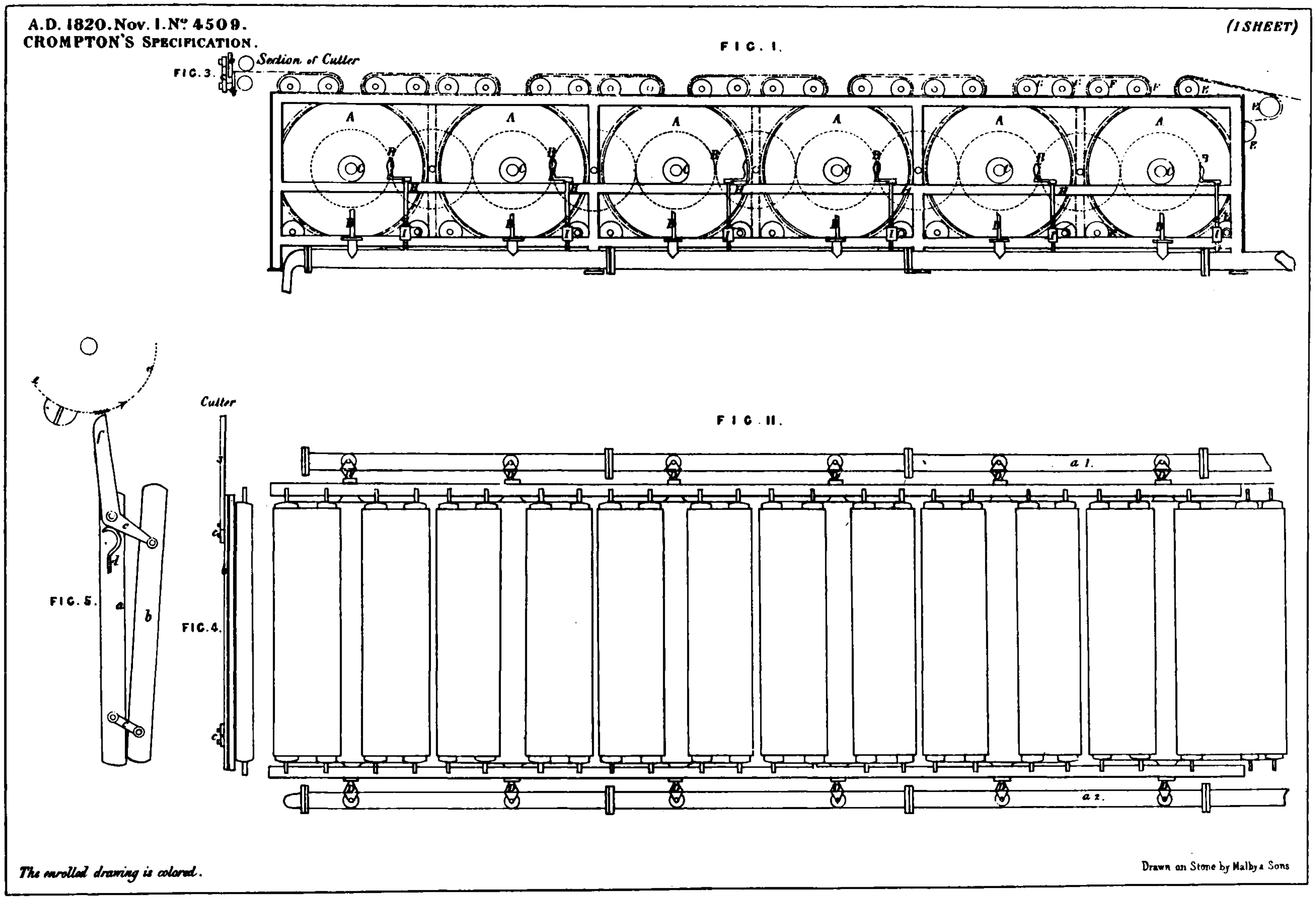
The principle of Crompton's drying-machine is shown in the illustration No. 40, and will be seen to be almost identical with many dry-parts used on paper-making machines at the present time. In fact, there has been quite a definite move to go on to single-tier drying for some classes of paper instead of the double-tier drying which has been in use for many years.

Crompton drove all his drying-cylinders by means of spur wheels, and he had no separate felt-drying cylinders. There were tightening-rolls for the felt, and when this method of drying was adopted very great improvements took place in the drying of paper. Although the patent states that any suitable material could be used for the felt, Crompton used a felt made from a linen wrap and a woollen weft, which he found to be the most satisfactory. The illustration shows the lead-rolls for the paper, and also for the return of the felt. He used a very big proportion of the surface of the drying-cylinder for drying the paper, more, in fact, than is commonly used on many paper-making machines today.

It has been said that Crompton first got the idea of drying paper over cylinders from the drying of textiles, and that in fact he actually took a roll of wet paper to a textile mill where he had it run over the textile drying-rollers. This fact may have influenced him in inventing the use of the textile material as the felt to hold the paper against the hot cylinder. Although Crompton invented the drying-cylinder in 1820, paper-making machines were still usually sold in two halves for another thirty or forty years. It was the common practice to buy a paper-making machine, which consisted of chest, wire-part, presses and reel-up, separately from the drying-machine; and also, often, to order a drying-machine at the same time. But they were always treated as completely separate items in the order, and it was not until about 1860 that a paper-making machine was presumed to include the drying-machine as well. His claim was as follows:

> The invention I claim consists of conducting the paper by means of cloth or cloths against the heated cylinders, which cloths may be made of any suitable material, but I prefer it to be made of linen warp and woollen weft, and this cloth is shown in the drawing (No. 40).

The paper was also shown and he regulated the rollers for the purpose of preventing the paper from being creased by expansion, or broken by contraction. The cylinders (A) were driven by a spurred gear, one wheel was fixed on the axis of each cylinder, and there were other wheels intervening to connect the whole together. The power for driving them was applied to any of the above wheels, shown in dotted circles (B). (C) were the centres of the cylinders, which have apertures to receive the valves which conduct the steam from the pipe into the cylinders, where it was condensed, and it was then carried off by the pipe (D), No. 40. (E) were the lead rollers which were attached to the first cylinder which conducted the endless felt which covered the whole of the rollers and most of the cylinders, and the felt carried along with it the paper around the periphery of the



No. 40. Crompton's drying machine, with six cylinders, for drying paper continuously. This is the first drying machine to be patented and used with woollen felt to hold the paper against the cylinders during drying. This is a very well designed arrangement of drying cylinders, in single tier, which makes full use of the drying surface of the cylinders, and many similar drying machines are still in use at the present time. Crompton's patent also included a cutting device at the end of the dryer, for cutting the web of paper into sheets.

cylinder, until it arrived at the rollers (F), where the paper left the felt and continued forward to the rollers of the second cylinder, and so on, to any number of cylinders that were found necessary. (H) were screws with handles which acted on the pivots of the rollers (I) for the purpose of tightening the felt in order to prevent the forcible breaking of the paper by expansion, or the injurious effect frequently produced by rapid contraction (cockling).

It was some time afterwards that two-tier cylinders were used, but Crompton's system must have been a tremendous advance in the drying of paper, and in reducing the cost of dealing with it after it was made, when compared with taking it off wet and cutting it wet, and then drying the sheets in lofts.

Crompton patented at the same time, and in the same specification, a cutter which could be attached to the end of the machine, to cut the paper, as delivered, into sheets of any given size. This patent was granted on the 28th April, 1821, and it had been applied for in 1820, on November 1st.

The Culter Paper Mill, which we have mentioned earlier as being the first mill in Scotland to have a paper-making machine, was sold by Lewis Smith to the Irvines, who installed a second machine in 1821.

It is recorded that Gilpin's Mill at Wilmington, Delaware, in which he had installed a cylinder mould machine, was entirely destroyed and carried away by a great flood of the river Brandywine in 1822. Also, in this same year, John Ames, of Springfield, made a cylinder mould machine. It is not known whether this machine was copied from Gilpin's mould machine which had been installed some years previously. It was in this year, 1822, that a Mr. Pirie put the first paper-making machine in at Stoneywood near Aberdeen, and thus started the well-known paper mills there, which are still in operation. Donkin also sold a machine to Heilbronn at Wurttemburg.

The sketch, No. 41, of a Fourdrinier type machine was made by Colonel P. M. Taylor, of Dickinsons, at Apsley Mill in 1823.

A paper-mill was built at Hadley Falls, on the Connecticut river, in Massachusetts, for making newsprint on a paper-making machine, but the paper it made was only of poor quality.

One of the earliest machines for the drying of paper on a Fourdrinier type of machine was that supplied by Donkin to Messrs. Rauch in 1823. The drawing shows three cylinders at the bottom and two at the top, with felts to all cylinders (No. 42).

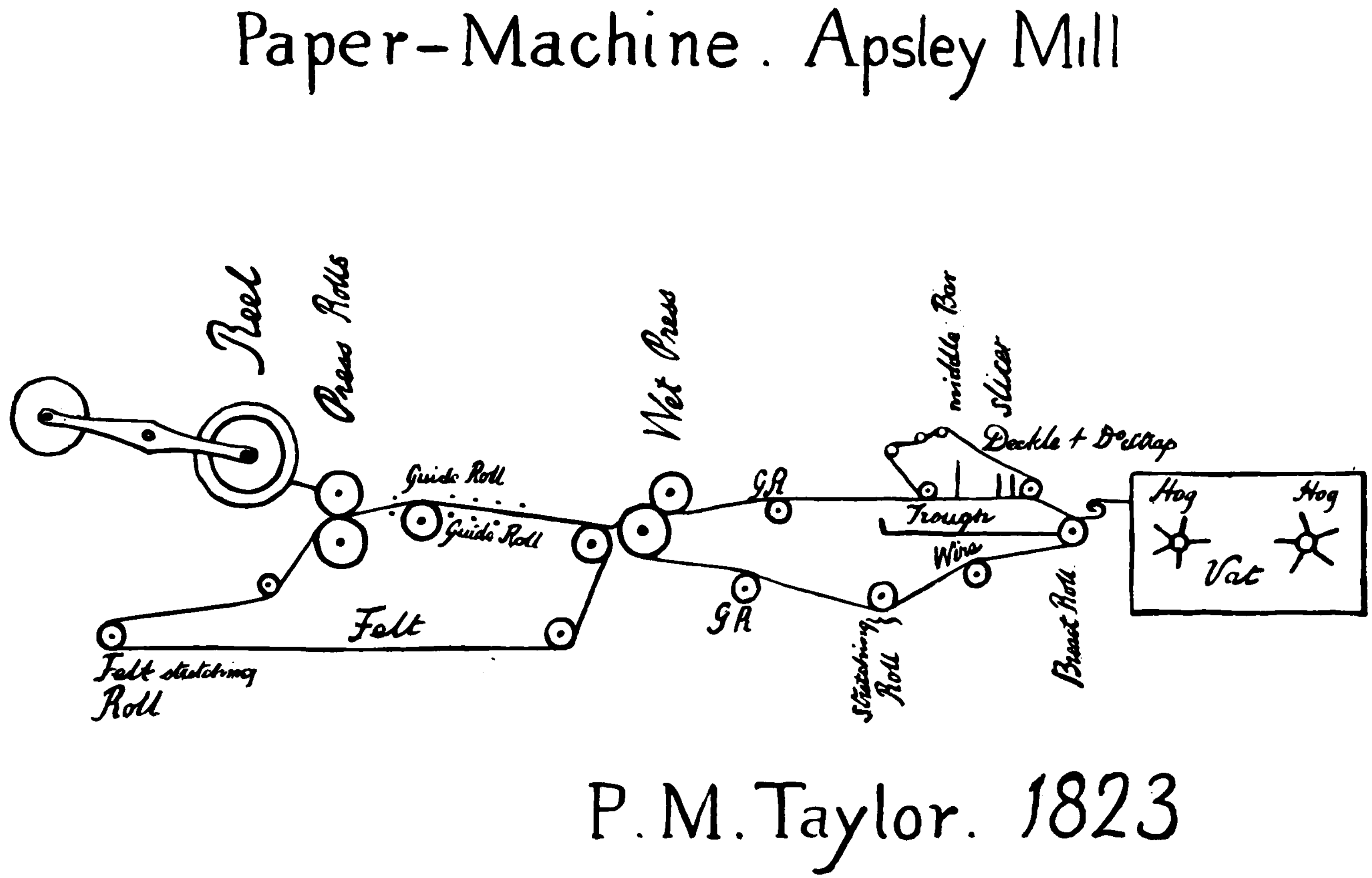
The first cylinder received the paper from the press over a lead-roll, or leading-in cylinder, and it was then carried round the first drying cylinder, which had hollow felt rolls with metal ends, and these rolls appeared to be constructed of iron and brass, and not from wood as were the later ones. The paper passed up to the top drying cylinder, against which it was pressed by a press-roll; and there was another press-roll pressing the paper to the cylinder before it came down to the third cylinder, which was not felted. The paper then passed up again to the fourth drying cylinder which was not fitted with any press-rolls, and came off at the bottom of this after nearly completing the whole circumference of it, and into the fifth bottom dryer, after which it went onto a double cylindrical reel-up, as opposed to the square or hexagonal reel boxes which were in use on the later machines of this early period. This reel-up provided for the paper to be wound up on a drum, and when this was full it was swung out of place on levered arms, and an empty drum swung into position.

The cylinders were heated by steam, and driven by toothed wheels.

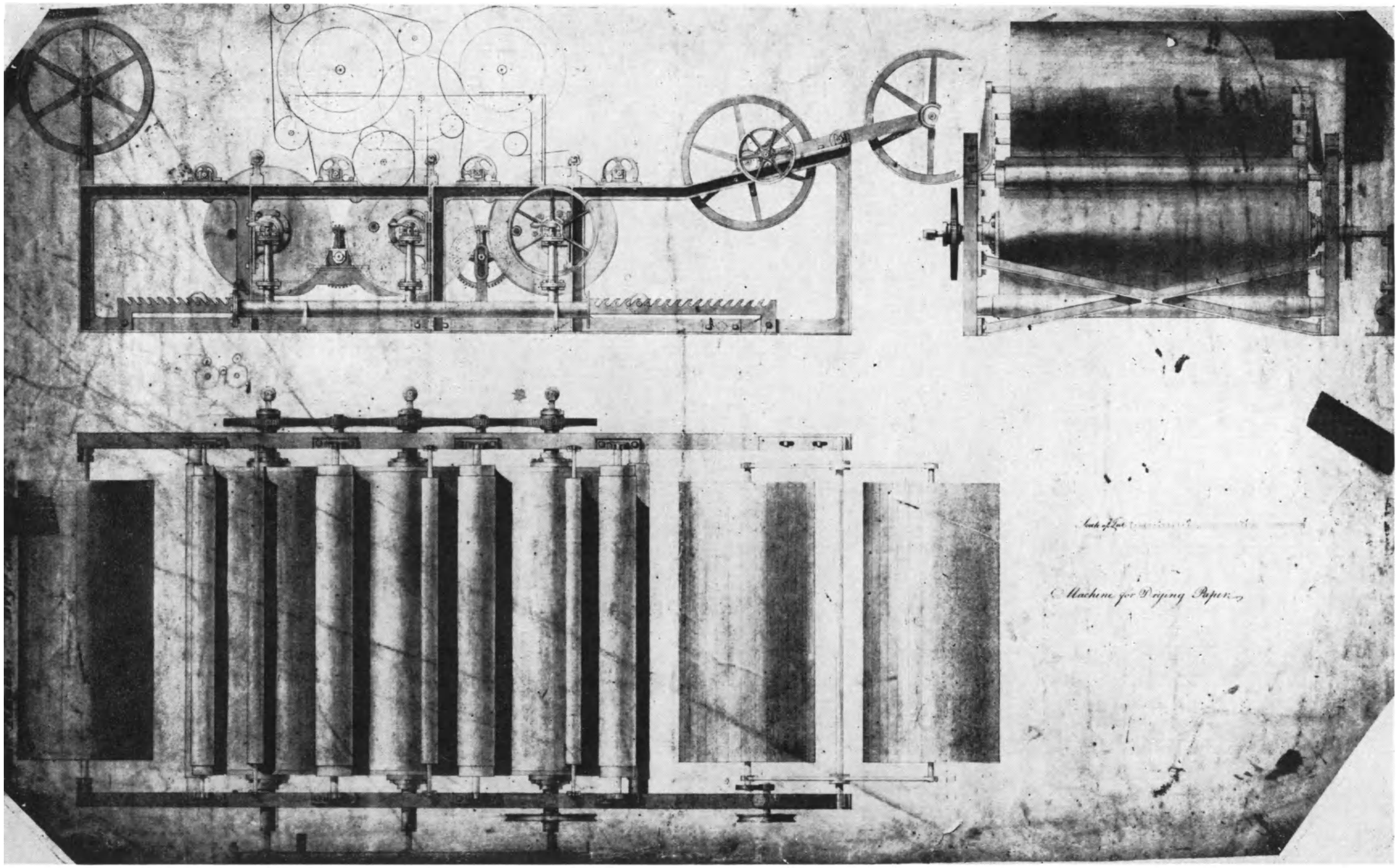
Between the bottom and upper cylinders there were three large-diameter rolls, the function of which was not quite clear from the drawing. They were probably used for taking the dry-felt from one bottom cylinder to the next.

Stretch rolls were also provided for the felt.

The steam entered through the journals at the front of the cylinders, and the condensed water came out at the back.



No. 41. Sketch by P. M. Taylor, Manager of Dickinson's mill, of the Fourdrinier type paper-making machine put in by John Dickinson at Apsley Mill. This machine has very short deckle straps and no drying cylinders, but guide rolls are shown on the wire and felt, and there is first mention of a slicer (slice) of which two are shown.



No. 42. Donkin's first drying machine, with stacked dryers following on the Crompton patent, which Donkin opposed. This arrangement adopted by Donkin probably surmounted the difficulty of infringement of the patent, and led to the general adoption of double tier drying throughout the paper trade, a system which has endured up to the present time. In this first machine there are "two up and three down". The reel of wet paper from the paper-making machine is supported at the left-hand end of the dryer in the illustration, and the paper is led through the dryer by felts. The felt stretchers can be seen at each end of the dryer, and consist of a series of teeth, into which the felt stretch roll journals can be fitted. Steam is admitted to the drying cylinders at the rear of the machine, and the condensate leaves the cylinders at the front side. The machine frame is of cast iron. This dryer was made for Rauch of Heilbronn, in Germany, in 1823.

In 1825, Samuel Denison, of Leeds, described as a whitesmith, and John Harris, also of Leeds, a paper-mould maker, invented a new type of mould-machine for making paper continuously. This machine was rather on the lines of John Dickinson's machine which was patented in 1809, but it worked in a different way, as will be seen by reference to the drawing No. 43. The drum itself had a laid cover which was made by placing a number of copper wires or very thin rods, with notches on them, close together, and soldering them to the edges of the drum. In the drawing the flow box is shown containing the pulp, which was considerably diluted and kept at the desired level so that when the machine was at work it flowed over the curved side of the flow box at (A) onto the revolving cylinder-mould (C). A hog (B) was made to revolve in order to create agitation and prevent the fibres from settling to the bottom of the flow box. The rotating mould acted like a sieve, and as it turned round clockwise in the direction of the arrow the pulp was deposited on it. It will be noticed that the mould revolved in the opposite direction to that of Dickinson's and that it was only in contact with the pulp in the flow box for a very short distance, whereas Dickinson's actually revolved immersed in the vat, and could pick up the fibres over quite a considerable part of the circumference. In this machine the pulp ran onto the mould, the water immediately drained through the wire and the bars of the mould where the paper was formed. The continued turning of the mould brought this wet web in contact with an endless felt (D) which, owing to its greater attraction for the wet pulp, caused the pulp to stick to it. The pulp was thus removed from the wire of the cylinder and carried forward between the top felt (D) and the bottom felt (H), as can be seen in the drawing. While the pulp was being carried between these felts, it passed between a pair of wet-press rolls (F), where it was subjected to pressure, in order to consolidate it. It then passed between two further press-rolls (G), called the "dry rollers", where greater pressure was applied. From thence the paper, in a comparatively dry state, was taken to a rotating vane (L), where it was reeled up in a sort of lap form. When this vane was fully loaded with paper, it was removed and another substituted in its place, in the same way as the machine-roll was moved on the other paper-making machines at that time.

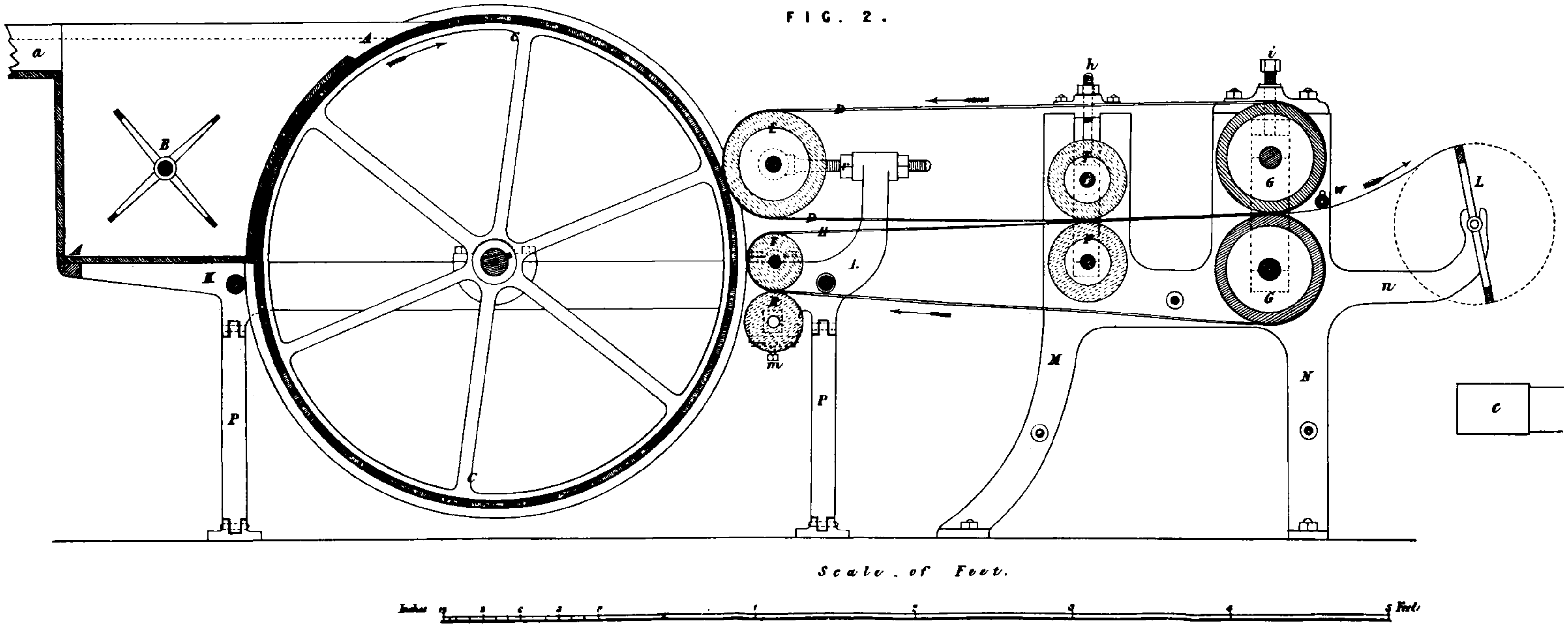
After the removal of the sheet the cylinder-mould revolved in a tank of water which served to wash off the fibres which adhered to it so that it was ready for receiving the pulp and water from the flow box next time round. The cast-iron frame, on which the roll revolved, was jointed to facilitate the lateral shaking motion considered at that time to be essential in the making of paper. This was effected by a crank and rod, or by any of the other usual means of applying shake.

The machine differs in this respect from Dickinson's machine, where no shake at all was applied. The roller (E) on this machine was called the "combing roller," because it took the paper off the mould, and its action is similar to that which we now call couching. The roller (E), as will be seen, was provided with a screw so that the pressure of the roll on the revolving drum of the vat could be altered. In the same way, the press-rolls (F and G) were also provided with tensioning screws so that the pressure could be altered as desired. There was also a small dancing roll (W), which helped to remove the paper from the top felt (D) before it went onto the reel-up at (L).

As will readily be understood, the felt (H) became very wet because all the water squeezed out by the presses fell onto this felt on its return journey. In order to squeeze some of this water out there was a press-roll (R) which squeezed against the first felt-roll carrying the felt (H) and caused some of the excess water to be squeezed out and run away to waste. In order to get the felts clean and remove any fibre which adhered to them, small rotating brushes, which are not shown in the drawing, were kept in contact with the felt.

This machine appears to have been a working model, and from the description it apparently was quite successful, but there is no indication that it was ever adopted generally by paper-makers.

FIG. 2.



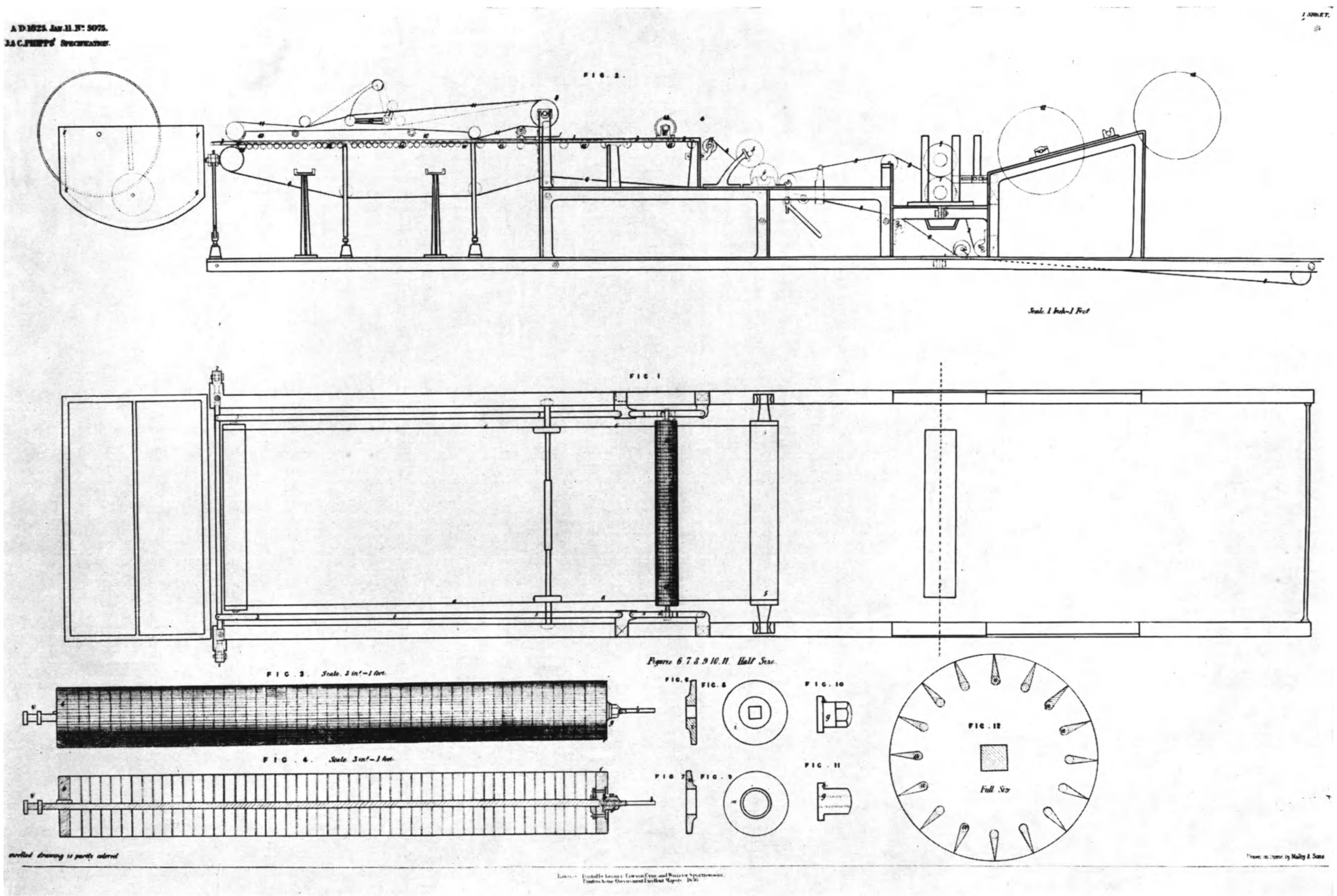
No. 43. Denison and Harris' cylinder mould machine. This machine works without the conventional vat, and in its place it is fitted with a flow box, which discharges stuff onto a small section only of the cylinder mould at (A). The level of the stuff in the flow box is kept constant by admitting at (a) only as much stuff as the cylinder mould removes at (A). There is an agitator in the flow box to keep the fibres from settling out. The cylinder, which is covered with laid cloth, enabled paper resembling the laid paper of the hand mould to be made. The formed sheet was couched off the cylinder mould by couch roll (E) onto the wet felt (D), to which it adhered until it reached the first press rolls (F) where it came in contact with a bottom felt (H). The sheet passed through both first and second presses between the two felts, and was then reeled up at (L). The bottom felt, which would be carrying more water than the top felt after the presses, passed between squeeze rolls (I and R) on its return.

8

The Invention of the Dandy-roll or Riding-roller

THE dandy-roll was invented, or rather patented, in 1825 by two brothers, John Phipps and Christopher Phipps, of the parish of River, in the county of Kent, who were paper-makers. They called their invention "an improvement in machinery for making paper". The first dandy they made was a laid one, and the sheet of laid wire cloth was made in the same way as that for a laid mould; in fact, the inventors of the dandy obtained their laid wire cloth from a firm who made paper-moulds, although they do not mention the name of the firm. Dandies were made in various widths, according to the width of the paper-making machines on which they were to be used, and they were also made in various diameters, mostly very small by our standards, that is from about 4 to 6 in. There was a spindle running right through and wooden ends were fitted onto the spindle to support the ends of the roll. The spindle was $\frac{5}{8}$ to $\frac{3}{4}$ in. square. At one end there was a collar bearing and at the other end a plain bearing. These fitted into the forked stands or carriages which can be seen in the drawing. These carriages were fixed to the stationary part of the frame of the machine. The ends of the roll were made of wood, such as elm or ash, and the wooden ends were from $\frac{3}{4}$ to 1 in., varying according to the diameter of the dandy. On the bigger dandies thicker wood was used. Two brass plates with square holes cut in them, corresponding to the size of the squares on the spindle, were clamped on either side of the wooden ends by screws. The other end of the roll had a round hole cut through the wood.

The laid wire covering was made by laying parallel wires side by side, holding them together by means of two twisted wires. These wires received one twist between each of the straight wires and held them together at certain fixed intervals, forming what is known as the chain-lines in the sheet. A sheet of laid wire was made of sufficient width so that when it was wrapped round the cylinder it would just fit. The twisting wires from one end were twisted round the last laid wire of the other end of the cover, thus making a complete cylinder of laid wire on the roll frame. The body of the roll was made in much the same way as any dandy-roll is made at the present time. In order to keep it perfectly cylindrical in shape, narrow tubes of copper or other metal were fitted inside the roll, rather like the brass rings in a modern dandy. These served the same purpose as the wooden bars in hand-moulds, which had a number of small holes drilled in them, in order to drain the water. The rings were held in position by sewing them to the twisting wires, in the same way as a sheet of laid wire is sewn to the wooden bar in a hand-mould. The rings were sewn in position before the laid cover was fastened onto the wooden ends of the roller. The laid wires were fastened to the wooden ends by a thin strip of sheet copper, securing the ends of all the laid wires to the wooden end of the roller (No 44.)



No. 44. Details of construction of the dandy- or riding-roller patented by J. and C. Phipps. This was the first satisfactory attempt to make laid paper on the Fourdrinier paper-making machine. The drawings show how the dandy was built up and how the laid wire cover was supported. The illustration also shows a complete paper-making machine of the period with staggered couch and lever for pressing the felt against the bottom couch roll to transfer the sheet from wire to wet felt. The dandy-roll is in the same position on the wire as is usual at the present time, but there are as yet no suction boxes.

The Phipps brothers made dandy-rolls from 4 to 12 in. in diameter, the larger rolls were used on thicker papers because of the extra weight they exerted. The dandy was fixed in the brackets so that the whole of its weight rested on the stuff on the wire, and it was the contact with this which caused the dandy-roll to revolve, as is, of course, the common practice at the present time.

No mention was made of the wove dandy in Phipps' specification of these rollers, and they were simply called "cylindrical rollers" or "riding rollers". There is very little difference now in the appearance of dandy-rolls, after a hundred and twenty-five years have elapsed, except that they are made of different materials and are better finished, and advances have been made in the manufacture of laid rolls by the introduction of the plate-laid roll. Nevertheless, there are still laid-rolls made today in which the laid wires are held together by the twisting wires in exactly the same way as were those in 1825.

While it is quite certain, from the records at the Patent Office, that the Phipps brothers were the first people who patented the dandy-roll, it is claimed that John Marshall, of Dartford, was the first person to make one. What is known, however, is that John Marshall was a maker of paper-makers' moulds at Dartford and it has been stated that he was an apprentice to the firm of Bryan Donkin and Davies, who were mould-makers at Dartford at the end of the eighteenth century. As already mentioned elsewhere in this book, Donkin served his apprenticeship with John Hall. When he had finished that, he started up a mould-making business, and was later joined by Davies.

The history of Bryan Donkin and Company shows that John Marshall was one of their apprentices, and that he carried on the business and founded the firm of that name, which has continued through succeeding generations to the present day as makers of paper-moulds and dandy-rolls for watermarking machine-made paper.

Another account has it that John Marshall founded the firm in the year 1792, and this puts it a little earlier than could have been the case if the story of his being apprenticed to Bryan Donkin and Davies was true. Actually Donkin was financed to the extent of £350 by John Hall, of Dartford, in 1798, to enable him to start the mould-making business, and in 1799 Davies joined him in partnership. It is also on record that they sold £175 worth of moulds for hand-made paper to Cray Mill, on account of John Hall.

John Marshall first made his dandy-rolls, or "riding rollers" as they were called, in the year 1826, that is, one year after Phipps—but by that time he had an extensive business at Dartford, for the manufacture of moulds for making paper by hand; and in fact there is on record an order from Messrs. Henry and Sealy Fourdrinier for moulds in January, 1805.

Messrs. T. J. Marshall and Company, the present firm of dandy-roll makers, which was founded by John Marshall, are in possession of a book containing entries to the effect that John Marshall received orders for dandy-rolls from most of the early paper-makers. There are, moreover, the following early entries in the book:

		£	s.	d.
J. Hall and Son, Cr.				
Jan. 19th, 1827.	To two carriages for a riding roll		9	6
M. Towgood, Dr.				
Jan. 20th, 1827.	To a wove riding roll, carriages, etc.	8	7	6
J. and C. Phipps, Drs.				
July 26th, 1827.	To a laid riding roll	10	5	0
T. Nash, Dr.				
June 16th, 1828.	To a wove riding roll	8	16	6
T. Weedon, Dr.				
Sept. 24th, 1828.	To a riding roll	5	0	0

		£	s.	d.
C. Magnay and Sons, Dr.				
Dec. 24th, 1828.	To a riding roll with case, 3*s.* 6*d.*	6	1	6
J. and C. Phipps, Drs.				
Jan. 15th, 1829.	To a riding roller covered with a 60 hole wire 5 ft 1 in. between the shoulders of the bars and 5 ft $3\frac{1}{2}$ in. of bearings	3	0	6
	To case		4	6
	(This was a wove roll)			
John Dickinson, Dr.				
Jan. 20th, 1829.	To a riding roller 5 ft full between the shoulders of the bars and 5 ft 6 in. between the bearings	4	18	0
	To case for ditto		4	6

From these very early proofs that dandy-rolls were being made by John Marshall, it is very interesting to note that Messrs. J. and C. Phipps were ordering rolls by 1827, and also in 1829, from John Marshall, although they had patented the roll themselves in 1825, and we have already mentioned earlier in the book that John Phipps had one of the first Fourdrinier machines.

The John and Christopher Phipps, mentioned in connection with the first patent of the dandy-roll, were very considerable paper-makers, besides being stationers in the city of London. They had offices in Upper Thames Street, and two mills at Dover, one of them called River Mill and the other Crabble Mill. They continued to operate these mills for a very long time, at least until 1866.

John Phipps patented the method of putting the horizontal lines in writing paper by water-marking, so that people could write straight, before the days of the paper-making machine, and had hand-moulds constructed so that lined paper could be made to help in teaching children to write properly. Christopher Phipps also invented marking paper by embossing, that is, putting a design on a piece of paper, and then putting a plain piece of paper against it, and passing the two sheets through a plate-glazing calender.

The names of other early well-known paper-makers occur in Messrs. Marshall's ledger, particularly those of Messrs. Towgood, who, of course, had St. Neots Mill, and John Dickinson, of Croxley, as well as Nash, and Weedon and Son, of Temple Mills. It seems quite possible that John Marshall might have manufactured rolls for J. and C. Phipps under their own patent. It is even possible that they purchased the laid cloth from Marshall for the purpose of patenting the original roll, as they were paper-makers and not mould-makers. One thing, however, is quite certain: the firm of T. J. Marshall and Company has a longer connection with the paper-trade with their moulds and dandies than any other firm in the world, except Portals of Laverstoke.

On John Marshall's trade card, he claims himself that he was the inventor and manufacturer of watermark rolls for paper-making machines.

In 1826 Canson, of Annonay, in France, who had put in the first Donkin–Fourdrinier machine in 1823, put a suction box under the wire of his machine and applied suction, as already done by Dickinson in his cylinder mould. Canson did not patent this method of removing water, but kept it a secret for six years.

It was also at this time that Donkin supplied the first paper-making machine in Denmark, for a mill at Frederiksborg owned by the Drewson family who got a state loan for the purchase of the machine and a 20 h.p. steam engine. It will thus be seen that Western European countries were beginning to be interested in making paper by machinery, although France only had four machines, in spite of the original idea having come from there.

The first Donkin-built machine to be installed in America was started up on 24th October,

Trade card and bill head of John Marshall, claiming the invention of the dandy-roll in 1826.

1827, by Henry Barclay at Saugerties, New York. The machine was built at Bermondsey and shipped to America. It had a wire 60 in. wide. The mill was owned by Beach, Hommerken and Kearney. The machine was started running by Peter Adams, who afterwards founded the Peter Adams Company in Buckland, Conn.

Davidson, of Mugiemoss, Aberdeen, built a machine which he copied from the Donkin machines, and installed it in his mill in 1827. He also built and installed another one in 1844.

We have already described Crompton's patent of the drying cylinders using dry felts in 1820. It was not known who made the felts of linen warp and woollen weft for him. Fortunately, however, Messrs. James Kenyon and Son have in their possession a weaver's book recording felts made by some of their weavers for paper-making machines, and dating from January, 1827. From this it seems evident that Kenyons were certainly among the first to make paper-makers' felts of various kinds. There is also a diary kept by Kenyon himself, with entries from the latter part of the eighteenth century, and with detailed entries from 1834 to 1839. From the diary it is clear that felts were being made for various types of machines. Warps were sent out from the factory at Bury to weavers who at that time were weaving cloth in their own homes. Beside the entry of the warp in each instance is the name of the weaver to whom it was sent, and it is also evident that all the warps were made from linen.

Kenyons commenced the mechanical spinning of yarn in 1820, a date which coincided with the start-up of Crompton's drying machine using a dry felt.

A table of paper-making machine felts in 1827, made by Kenyons, is reproduced here.

It is evident that even in those early days paper-makers were having felts made to their own specifications, as they are frequently referred to in the weaver's book by the name of the paper-maker for whom they were being woven. The list is a selection from the entries in the weaver's book, to show the various types of felts and the sizes.

List of References to Felts for Paper-making Machines or for making Paper by Hand (taken from a weaver's book of James Kenyon and Son for the period from January, 1827, to December, 1830)

Date sold:	*Description:*	*To whom sold:*
Feb., 1827	Fine felting.	Appleton.
Mar., 1827	Coarse felting 50 in.	Thos. Hughes.
Mar., 1827	6 fine felts.	Smith and Ingle.
Mar., 1827	6 fine felts.	Livesey and Co. (and Saxons.)
Mar., 1827	6 coarse felts.	Smith and Ingle.
Mar., 1827	Felting.	Thos. Hughes.
Apr., 1827	Felting 48 in.	Henry Cooke.
May, 1827	Appleton's fine felt 54 in.	Jno. Appleton.
May, 1827	Appleton's fine felt 64 in.	Jno. Appleton.
July, 1827	Paper felt.	Thomas Hughes.
July, 1827	Seddon paper felt 39 in.	Robert Seddon.
Sept., 1827	48 in. felting Wm. Walker.	Walker, Liverpool.
Sept., 1827	6 Walker felts.	Wm. Walker and Sons.
Oct., 1827	6 comn. machine felts for Livesey (66 in.).	Livesey and Co.
Oct., 1827	18 in. jacket.	John Livesey.
Oct., 1827	6 Crompton middle felts.	Livesey and Co.
Feb., 1828	6 Livesey's coarse machine felts.	——
Feb., 1828	Robt. Walker fine felting 72 in.	——
Feb., 1828	6 Crompton's coarse felts.	——
Feb., 1828	6 Ibbotson and Livesey fine felts.	3 Ibbotson. 3 Saxon.
Mar., 1828	8 Smith and Ingle and Saxon coarse felts.	4 Smith and Ingle. 4 Saxon.
Mar., 1828	16 in. jacketing.	——
Mar., 1828	14 in. jacketing.	——
July, 1828	2 Crompton drying machine felts.	J. and T. Crompton.
July, 1828	3 superfine felts.	——
Nov., 1828	3 drying felts (2 felts 42 ft 1 felt 55 ft.).	

All these paper-makers had Donkin machines.

Date sold:	*Description:*	*To whom sold:*
Dec., 1828	16 in. jacketing.	——
Jan., 1829	2 fine felts, Crompton.	——
Feb., 1829	6 Crompton fine felts.	Jno. and Thos. Crompton.
Feb., 1829	6 Ibbotson fine felts.	Jno. Ibbotson.
Feb., 1829	6 Ibbotson coarse felts.	Jno. Ibbotson.
Mar., 1829	2 felts 80 in. Crompton.	Jno. and Thos. Crompton.

Date sold:	*Description:*	*To whom sold:*
Apr., 1829	McDonnell thin drying felts (50 ft × 57 in.).	M. MacDonnell.
July, 1829	Drying felt 48 ft × 60 in.	B. Sullivan, Dublin.
July, 1829	3 fine felts Sullivan.	B. Sullivan, Dublin.
July, 1829	Drying felt Crook and Dean 48 ft × 54 in.	Crook and Dean.
Aug., 1829	4 Crook and Dean fine felts.	Crook and Dean.
Sept., 1829	6 fine felts not ordered 22 ft × 52 in.	2 felts McDonnell. 1 felt Smith. 3 Henry Cooke.
Mar., 1830	6 felts 22 ft × 52 in. "These were not regular in the weaving. Some finished a foot longer than others and 1½ lb difference in the lots."	3 Smith and Co. 3 Crook and Dean.
June, 1830	6 fine felts. "These were right and very nice ones."	Crook and Dean.
June, 1830	One drying felt. "This was just right every way."	
June, 1830	Two rope felts, Ibbotson. "These were too narrow laid in the looms."	
Nov., 1830	Felts McDonnell 21 ft × 54 in. "These were rather too long for 21 ft. 1 wough shorter would have done."	

It was in this year, 1827, that Tidcombe started to build paper-making machines at Watford. Some of the cylinders of his early machines are still in use at the present time.

In 1826, Lewis Aubrey tried to obtain the laid mark in paper by having a wire made with intermittent warp wires of a very much thicker gauge, in order to produce those transversely large watermark lines which are the characteristic of laid paper. This, however, does not appear to have have had very much success, or to have been adopted generally by paper-makers.

In 1828, James Palmer, of Mile End, in the county of Middlesex, a paper-maker, made another attempt to solve the difficulty which had hitherto been experienced of getting water out of the paper web while on the wire. It will be remembered that a top wire travelling round several rolls had been used in the original Donkin machine, before the couch-roll, in order to get water out. Then came the laid dandy-roll, patented by John and Christopher Phipps, of Dover, also paper-makers. Until that time, however, nobody had thought of using a wove roll. In 1828, James Palmer invented the wove dandy-roll, and claimed for this that the object was to help in removing as much water as possible from the web of paper before it reached the couch-roll. It will thus be seen that, as in the case of the hand-mould, which had been invented a thousand years previously in China, the first moulds were laid and the first dandy-roll was a laid roll. It was some years after this that the first wove roll was used on a paper-making machine. Although Palmer was granted the patent for the wove roll in 1828, Marshall had been selling wove rolls in 1827.

Palmer constructed his roll very much in the same way as rolls are made today. First he put onto a wooden mandril the cross wires which were to form the support of the roll. Then he put a spiral wire round these, and tinned the spiral wire wherever it touched the straight wires, in order to make it rigid. He then proceeded to put another laid wire across the spiral wires and tinned these by soldering, so that he had a very strong framework. These final laid wires, which were the third set of wires forming the body of the roll, were also bound together with two sewing wires, at about 1 in. apart, in the same way as in making a laid mould. He then brazed the whole together and took out the mandril. When he had obtained the framework of his roll, he next sewed together a sheet of wove wire, to fit the roll exactly. He then put in the ends, which were made of brass, and drew the wove cloth over the complete framework, so that he had a complete wove dandy-roll of very strong construction.

It will thus be seen that first of all came the laid roll, in order to press water out of the paper and give a laid mark which was required by printers who were accustomed to having paper made by hand on laid moulds. Later we got the wove roll, the avowed object of which was to press water out of the web. So far, no mention has been made of watermarking by putting devices into the paper, such as had been done for hundreds of years on the hand-mould, and it seems rather surprising that these did not follow immediately upon the introduction of the dandy-roll.

Still further efforts were made by paper-makers to express more water from the pulp before it came to the couch; and again, in 1830, there was another invention of what was practically speaking the same kind of dandy-roll that had already been invented, made by John Wilkes, who was a partner of Donkin. This roll was several inches wider than the wire, about 7 in. in diameter, and it resembled somewhat the plate-laid dandies in use at the present time; it was in fact a spiral laid roll. This roll was placed across the machine in much the same position as the dandy-roll is placed on modern machines; and almost immediately under it, but slightly nearer the breast-roll, was a large tube-roll which helped to give some pressure for removing water, which was the desired object of the roll.

Sometimes two of these riding rolls were used, the second one being nearer to the breast-roll. This is quite common practice on many machines making fine tissue papers at the present time, especially where the wove roll is running immediately in front of a laid roll.

Actually, when Wilkes patented his roll he made provision to exhaust air from it, in order to have a kind of suction-roll, but apparently this was never used because the roll itself performed satisfactorily the function for which it was intended. This roll took the place of the original wire or felt which used to be allowed to revolve above the wire, before the couch, on the earliest of the Fourdrinier paper-making machines, and it overcame the so-called "water-galling," which was what we should call crushing at the couch. As just mentioned, there were other rolls made before Wilkes got his patent, but his roll appears to have been much heavier, and probably it gave better results, particularly as he had a roll underneath the wire, which would make it into a kind of press. In order to keep this perforated roll clean, there was a copper spray-pipe laid across the machine, perforated with a large number of holes, and these discharged water onto the outer face of the dandy-roll, or riding-roll, in order to wash it and keep it clean during the whole time it was on the machine.

9

The Dickinson Suction-roll and other Developments

WHILE the development of the Fourdrinier paper-making machine was making good progress at this time, and large numbers of the machines were being made by Donkin, further patents were obtained which had quite an important bearing on the evolution of the machine.

George Dickinson, of Buckland Mills, near Dover, came forward with his patent in 1828 for shaking the wire-part up and down vertically instead of sideways, but this does not seem to have caught on very well. He states that, as a paper-maker, he had made many experiments with both types of shake, but that he found he got very much better results with the vertical up-and-down motion, which is described and shown in the accompanying illustration (No. 45). The machine-frame, which was made of timber, was pivoted at the point (C), and this part of the frame held the suction-roll (B), probably what we would call the bottom couch-roll, which drove the wire.

There were other features about this machine which will be described later, and which were quite revolutionary. The shake itself was given by means of a crank at (H) and a rod which was fixed at the bottom of the frame (F). As this crank revolved, the whole of the wire-frame, containing the breast-roll (A), tube-rolls, wire-return roll, and the roll (B), was shaken vertically up and down; most of this motion was at the breast-roll end, the motion dying out at the roll (B), in much the same way as the shake dies out where the frame is pivoted on a horizontally-shaken wet-end.

George Dickinson mentioned in his patent that more water could be taken out by making the wire, with the web of paper on it, to pass over a box from which air had been exhausted, but he did not show this box on the drawing. In a way, his method of taking the web off the wire was rather like that used today—the vacuum transfer—except that he had no vacuum on this part of his machine. The wire came along from the breast-roll (A) and passed over the suction-roll (B), but only over about a quarter of the circumference of it. The wire then left the suction-roll (B) and passed between the top and bottom coucher, marked (W-W), where the couching took place, the web being taken off and transferred to the felt (r). In other words, Dickinson had an additional roll in his machine, which was not commonly used on these early paper-making machines, nor is it used in this position on paper-making machines at present. This was the first suction-roll.

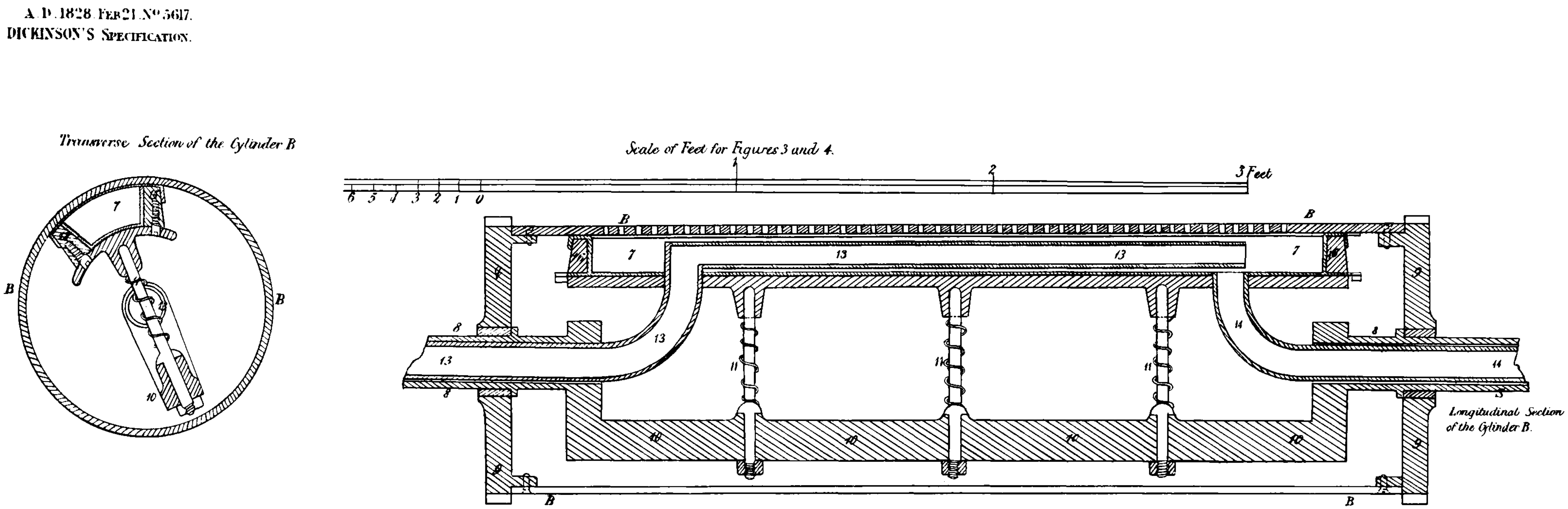
Dickinson mentions that he transferred the pulp from the chest (l) onto the wire by means of a leather apron which carried it some distance over several of the tube-rolls before it was allowed to run on the wire, and also that he drove the deckle-strap by means of a spur-wheel which engaged the toothed wheel on the suction-roll (B). The deckle-straps were held down onto the wire by the brass deckle-plates (K). He arranged the deckles so that they could be pushed in if required when the sheet was narrower than the full width of the machine. He mentions also the slice in this specification for the first time, and says it was a thin board fixed "endways upwards across between" the deckles (k), so as to leave a narrow space between its lower edge and the surface of the wire for the pulp to flow through, along with the moving wire. The lower edge of the slice dipped into the pulp and tended to diminish the waves formed on the surface of the moving pulp. The slice also prevented any bubbles of air, caused by agitation of the stuff, pouring out over the leather apron onto the wire.

It will be appreciated that the provision of the slice was a very important improvement at the wet-end of the machine, and it may be said that it was used for at least a hundred years after he invented it and, in fact, is still used on many paper-making machines at the present time, in spite of the subsequent introduction of the flow-box or projection-slice, which is a misnomer.

Perhaps the most revolutionary part of George Dickinson's machine is, however, the roll (B), to which we have already referred, the suction-roll. This roll is shown in detail and in section in No. 46, and it will be immediately apparent to those who are conversant with suction-rolls today that it is definitely the forerunner of the modern suction-roll. In its design it is almost identical. This suction-roll does not seem to have been generally adopted by paper-makers at the time, and there is no record of any of the later Donkin or Bertram machines being equipped with it, or any of the machines made by Tidcombe of Watford. It is only 75 to 80 years afterwards that we find the introduction of the suction-couch and suction-press on paper-making machines.

George Dickinson describes his suction-roll in the following words:

> The circumference of the roll is pierced with a great number of small holes disposed at regular intervals. It will, therefore, admit water to drain through the film of pulp or half-formed paper which covers the endless web when it passes over the roll. The water passes through the holes which are pierced in its circumference, into the inside, where it is received into a trough (7), No. 46, fixed within the roll, and from that internal trough the water is carried away by a drainpipe which is conducted through the hollow axle (8) on which the roll revolves, and to cause the water thus to drain through from the paper to the inside of the roll, the interior of the trough is kept partially exhausted by air, by the continued action of air-pumps worked by the machine (which are not shown in the drawing). A portion of the air being drawn from the internal trough, the elastic pressure of the air which remains in it is rendered less than that of the external atmospheric air, which is in contact with the outside surface of the film of pulp or half-formed paper upon the endless wire, and consequently that paper is pressed down upon the wire by the excess wherewith the pressure of the atmosphere predominates over the pressure of the air remaining unexhausted from the internal trough. This difference of pressure tends to squeeze out the water from the paper, and it passes through the wire-cloth to the inside of the roll, and is received within the internal trough, from whence it drains away by the drainpipe which passes through the axle.
>
> The construction of the roll and its internal trough is explained in No. 46. (B) is the circumference of the roll, which is made of brass or copper, pierced with a great number of holes, which are about a quarter of an inch in diameter, and arranged at distances of 3/8ths of an inch apart, centre to centre. The centres of every three adjacent holes form the three angles of an equilateral triangle, each side of which is 3/8ths of an inch long. The ends of the roll are closed by two circular plates, or wheels (9), which have projecting rims entering a little way into each end of the roll, fastened thereto by screws through the centres of the wheels. The axle (8) is not straight, but bends down in the middle part (10) in the manner of a crank within the roll, as is shown in No. 46. And into this lower part (10) three straight iron pins (11) are fixed so as to stand up therefrom. Their upper ends are fitted into sockets formed at the underside of the internal trough (7), and



No. 46. Sectional drawing of George Dickinson's suction-roll, showing the holes drilled through the shell, separate exhaust pipes for water and air, also the spiral springs for holding the suction box close against the shell. The small drawing shows the design of the suction box in cross-section.

> spiral springs are coiled round the pins to act beneath these sockets, to urge the trough (7) outwards from the centre of the roll, and cause the edges of the trough (7) to apply closely to the internal surface of the roll with a sufficient force to make them fit closely. The bottom of the trough (7) is made of metal, the sides of the trough are made of wood, the internal surface is lined with leather, as are the edges (12 and 15) in No. 46, and the leather is turned over the upper edges of the sides of the trough. The upper edges of the ends of the trough are also covered with leather at all the parts where they apply to the interior surface of the roll, in order to make a close joint thereto, and to prevent the entrance of any air into the trough, except that which may pass through the paper.
>
> On each end of the trough (7) are pipes (13 and 14). Pipe (13) is the air pipe, and pipe (14) is the water pipe, so that the air and water are separated. These two pipes (13 and 14) are smaller than the hollows in the ends (8) of the axle. The water pipe passes down on the outside of the roll, and the lower end of it is open and dips beneath the surface of the water which drains through the pipe into a small cistern placed on the ground at the side of the machine to receive the water. The water in the cistern prevents external air entering at the open end of the pipe.

There were two air pumps with a $3\frac{1}{2}$ in. bore and a $7\frac{1}{2}$ in. stroke, and they were combined together so that they acted alternately with a reciprocating motion transmitted by suitable levers from a crank on the spindle, turned by a belt and pulley fixed to any convenient part of the main driving part of the machine. The air pumps did twelve strokes per minute each, so that they exhausted twenty-four times the capacity of the barrel per minute.

Dickinson ran this machine at 25 ft/min, making paper 3 ft wide. He was also able to vary the speed of the air pump by having three different positions for the belt on the pulleys. He goes on to state that the speed of the air pump, in order to give adequate suction in the trough, would depend upon the thickness and quality of the paper, its width, and the speed at which the machine was running. He also provided movable deckles (16) in the box, so that they could be pushed in or out according to the width of paper being made. This was checked by referring to the distance which the deckles on the wire had been pushed in.

As will be seen on the drawing (No. 45) the suction-roll (B) had no top press-roll, and the wire still continued beyond it and passed through couch-rolls (W).

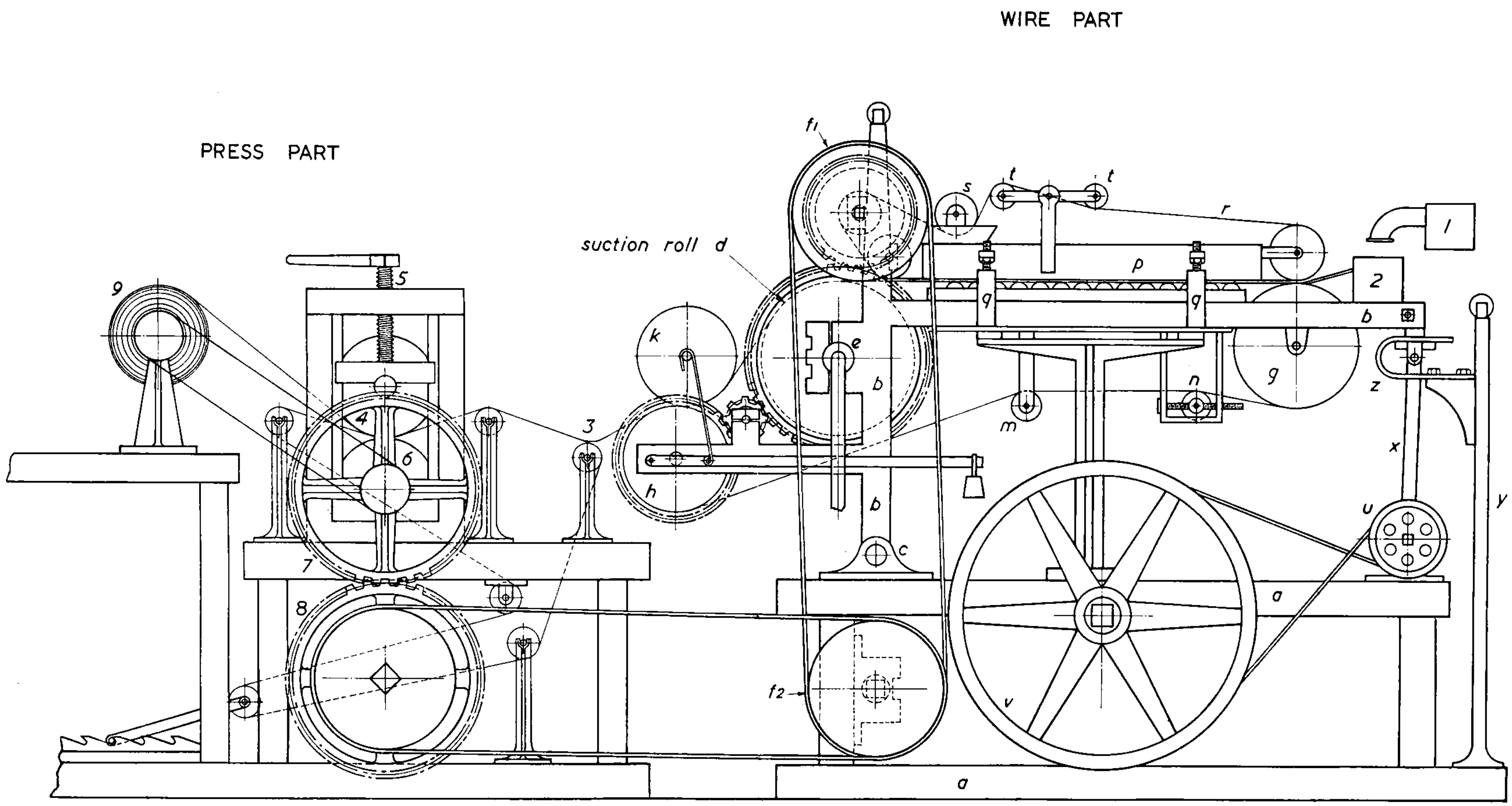
The wet web of paper was taken off the lower couch-roll and put onto the felt (r), the wire continuing back over the two wire return-rolls, the roll (x) being movable horizontally by a screw, in order to guide the wire. The top couch-roll could have pressure put upon it by a lever and weight, which was hooked onto its axle, and it also had a doctor for taking off stuff if it should stick to the top roll. The second press part and reel-up were almost exactly the same as was commonly used on other paper-making machines around that time.

There is no doubt that George Dickinson was a very clever paper-maker and designer of paper-making machines, as several of the things he mentions in his patent specification are now in common use, more particularly the slice and the suction-couch. His method of shaking the wire frame in a vertical direction has not been adopted and, so far as is known, is not in use anywhere at the present time.

Two paper machines were sold by Fourdrinier to the Czar of Russia in 1814.

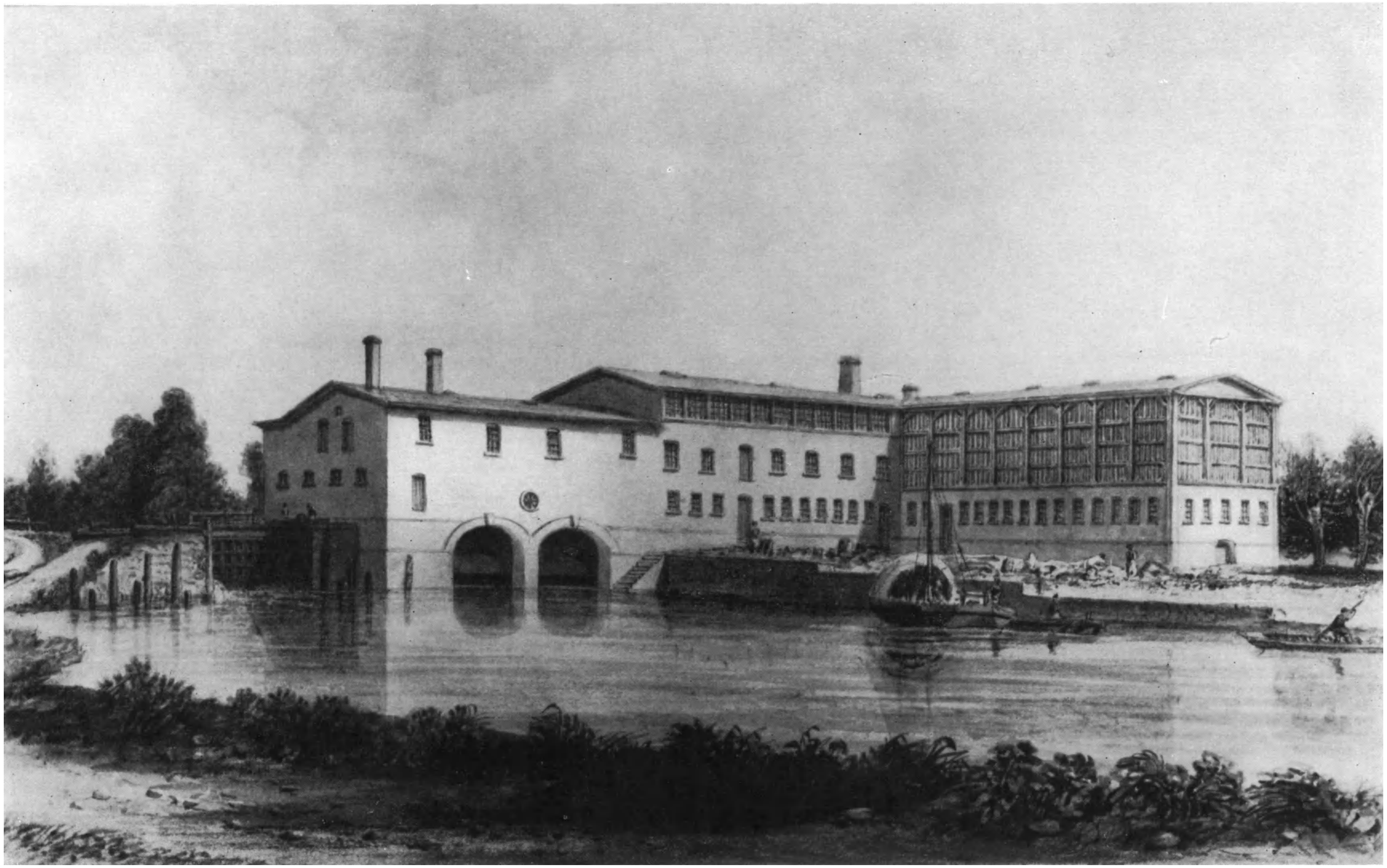
In 1829, John Dickinson, described now as of Nash Mill, in the parish of Abbots Langley, Hertfordshire, paper-manufacturer, patented his process for taking the paper in reverse direction through a second press. He said that this method of pressing could be used either on a mould-machine or on an endless-wire machine, and the machine shown in the attached drawing is one of Dickinson's patent mould-machines (No. 51).

Dickinson gave two-sidedness, common in papers led through straight presses, and leading to

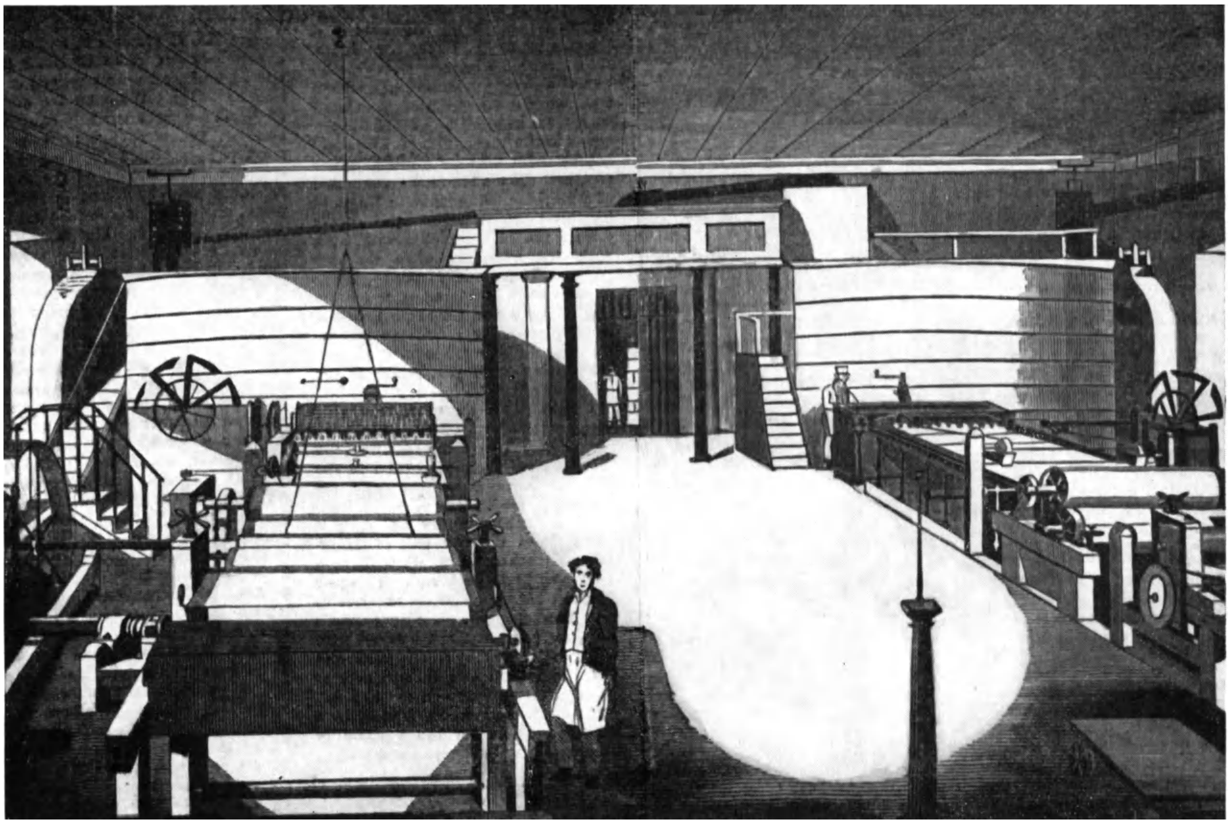


ELEVATION OF G. DICKINSON'S PAPER MACHINE, 1828

No. 47. Another view of George Dickinson's paper-making machine, taken from the back side, and showing the exhaust pipe (e) leading down from the suction-roll. The lever and weight to exert pressure from the top couch roll is also shown, also the wire guide roll, on the return (n). The top roll of the suction press is driven by a belt, and the top roll drives the suction-roll by cog-wheels.



No. 48. Engraving of the paper mill at Sandford-on-Thames in 1828. The mill was driven by two very large water-wheels and there was a drop of 9 ft. The lock for navigation is next to the mill, and occupies the place latterly taken for a turbine, when the lock was removed to its present site many years later. The paper-drying lofts are very extensive, even for a mill making hand-made paper. Some of the buildings are still in existence in 1967.

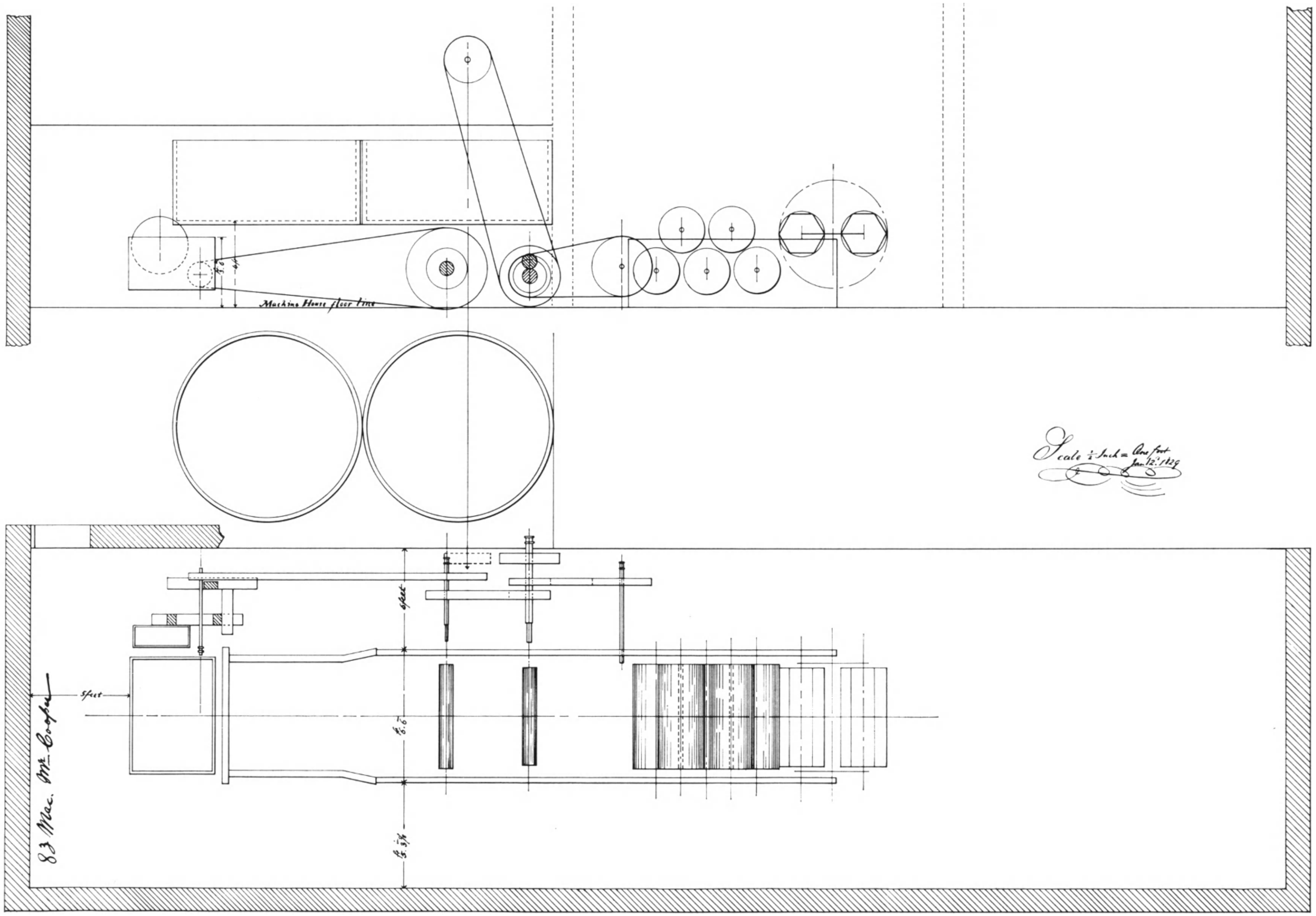


No. 49. The two paper-making machines made by Bryan Donkin for the Fourdriniers and sold to the Czar of Russia in 1814 for the Imperial Paper Mill at St. Petersburg. The artist's impression, though crude, shows for the first time right- and left-hand machines installed in the same machine house. These were apparently the first paper-making machines exported from England. They had a dryer section added by William Reed in 1825.

trouble in printing, as the reason for the new patent. He thought it would be a good idea to reverse the paper therefore, and give it a polished surface on the underside also. To carry out this operation he took up a great amount of room, as will be seen on the drawing, and he also used four long felts. The first wet-felt brought the wet web from the forming cylinder in the vat between the first press (a-a). The paper was then taken off the felt and passed round the small roll (c) and then onto another felt. As it was carried down on this felt it came in contact with a third felt and passed round a roll near the bottom of the frame between the two felts, one shown by a dot-and-dash line, and the other by a continuous line. When the paper travelling between the two felts came to the little roll (x) it was found to be sticking to the top felt, and this felt carried it up and through the second press (d). It then travelled round a further roll onto another felt (f), which took it down to a lead-roll (g), from which it passed to the three drying cylinders. It is difficult to understand why he should have needed so many felts. It may have been that he had plenty of room, and by using the long felts he was able to run them a much longer time before they needed to be washed.

The use of the reversing press was immediately taken up by other manufacturers, and it subsequently became almost universal practice.

In order to get as high a finish as possible on the paper through the presses, Dickinson heated the two top press-rolls by steam, and removed the condensed water in the same way as from drying-cylinders.



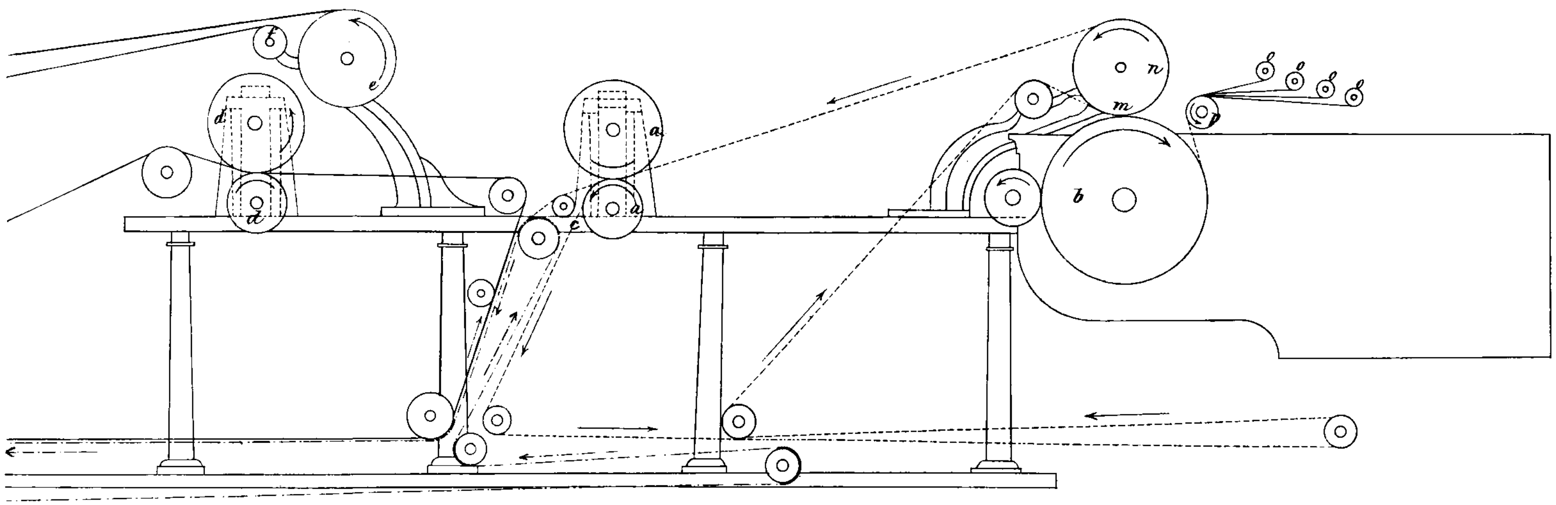
No. 50. Sketch by Bryan Donkin of a paper-making machine for Mr. Cooper in 1829. This machine has a large breast-box, one wet-press and five drying cylinders in tiers and large reel-up skeleton drums.

In this same specification as the reversing press, and illustrated on the same drawing, is Dickinson's method of introducing threads of silk or cotton into the paper to make the security papers for which his name became famous, particularly in the case of the Mulready envelope. This, too, was the forerunner of the paper with threads which are now to be found in many banknotes.

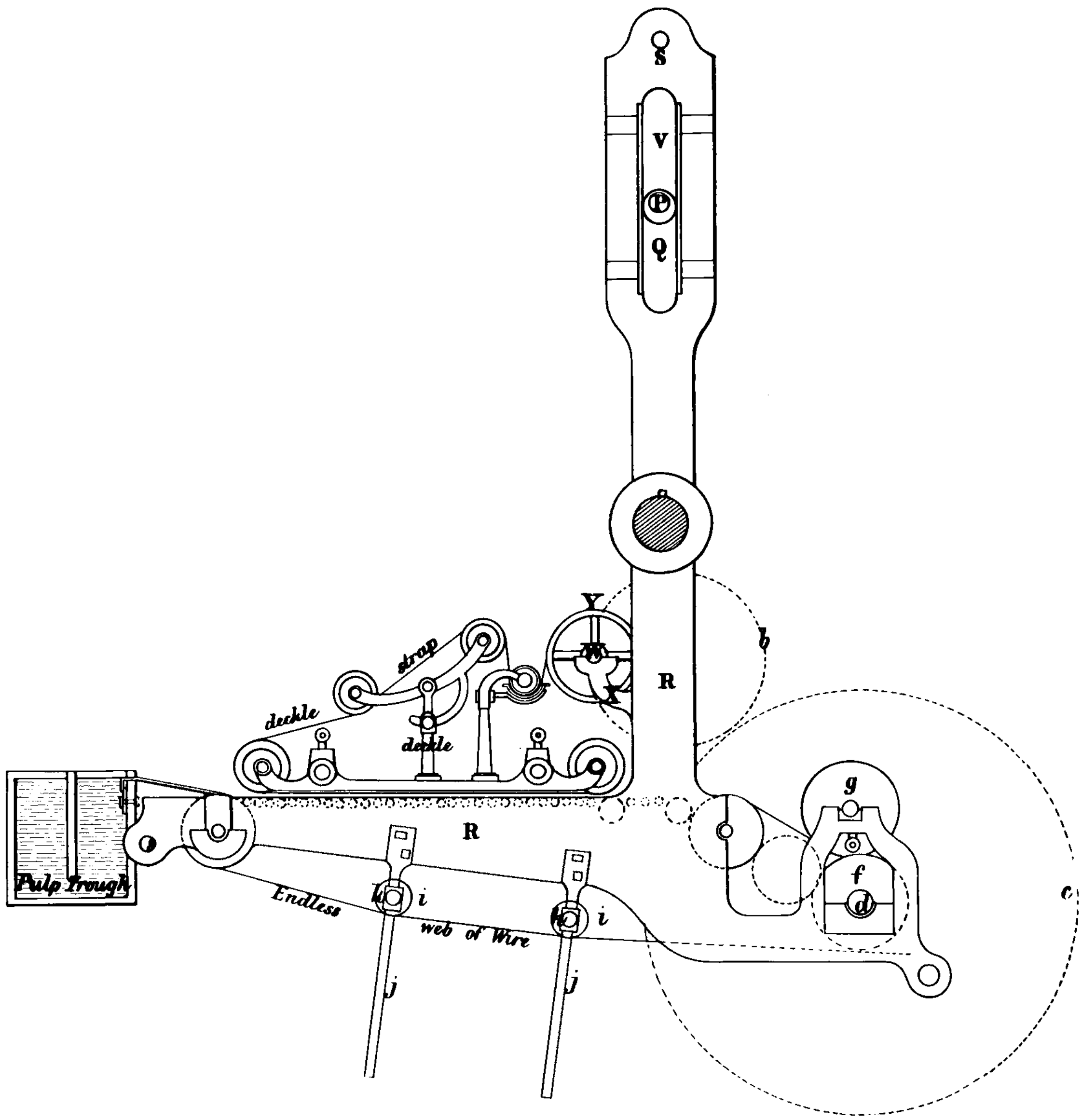
The method of putting in these threads was as follows: There were bobbins of the various kinds of threads, marked (o), which were filled with the thread it was desired to incorporate in the paper. These threads were led over a very light roll (p), in which were a number of grooves corresponding with the number of threads it was desired to have in the finished paper. These could be as close as ⅛ in. apart, but usually they were a little wider apart than this. When the machine was started up the ends of the threads were dropped into the vat by turning the roll (p) by hand, and the suction of the stuff going towards the cylinder and forming itself into a web of wet paper was sufficient to draw the threads in. These passed round the cylinder and were transferred with the paper-pulp to the top couch-roll, and after the threads had reached this point it was not necessary to turn the roll (p) any more, as the couch pressure between the cylinder and the couch-roll drew the threads off the bobbins. The position of the roll (p) could be altered and brought nearer or further away from the cylinder, according to the position which the threads should occupy in the paper. Dickinson points out that half the thickness of paper is made in the first quarter of the cylinder-mould, so that if it be desired to have the threads exactly in the middle of the paper, the threads should touch the cylinder after a quarter of its circumference had passed round the vat in the stuff.

In 1830, John Dickinson, who was a most persistent improver of his machine, started the multi-vat board-machine idea. For years he had been making paper on the cylinder-mould, but in 1830 he had two cylinder-moulds on his machine served by the same endless wet-felt (No. 52). He passed the felt between the cylinder (A) and the couch-roll (C), where it picked up a layer of paper from the cylinder. He then led the felt beween the second cylinder (B) and the couch-roll (C), and picked up a further layer of paper on the first layer, so that he had a two-ply paper. This endless felt (D) carried the double paper through the press-rolls (F-F), the top one of which was heated. These received there a light pressure between felts. The paper was then transferred to a second endless felt (G), and was given a much harder pressure at the press-rolls (H), the top one of which was also heated. The paper was then led in the ordinary way over four drying-cylinders in this instance, and it will be seen that the second drying-cylinder was bigger in diameter than the others. It is not clear whether Dickinson had yet adopted the Crompton idea of using a dry-felt on the drying-cylinder, and he certainly does not mention it.

We have already mentioned the introduction of the dandy-roll and other means whereby it was attempted to reproduce the characteristics of hand-made paper on the paper-making machine. In order to further these attempts Thomas Barratt, a paper-maker, of St. Mary Cray, Kent, in 1830 patented a new wet-end of a paper-making machine, which is illustrated in the drawing (No. 53). He suspended his wet-end from beams, and could shake it up and down, and cause it to vibrate while the machine was running. He insisted that in this way he got a better sheet formation, as did George Dickinson. The chief point of his patent, however, was that he was enabled, by the way he made up the wire, to make watermarks, such as names and devices, in the sheets of paper. He accomplished this by sewing the devices onto either a wove or a laid endless wire-cloth, in the same way as these devices were sewn onto a hand-mould. It was probably a fairly simple matter to do this on a wove wire, but it must have been rather difficult to construct a laid wire, which would have any great life when it had to turn round the comparatively small couch- and breast-rolls which he employed on his machine, and which can be seen in the drawing. He used very small tube-rolls, ⅞ in. diameter, and spaced them very close together near the breast-roll, but about ½ in. apart as they came nearer to the couch. He also placed little bars between each tube-roll touching



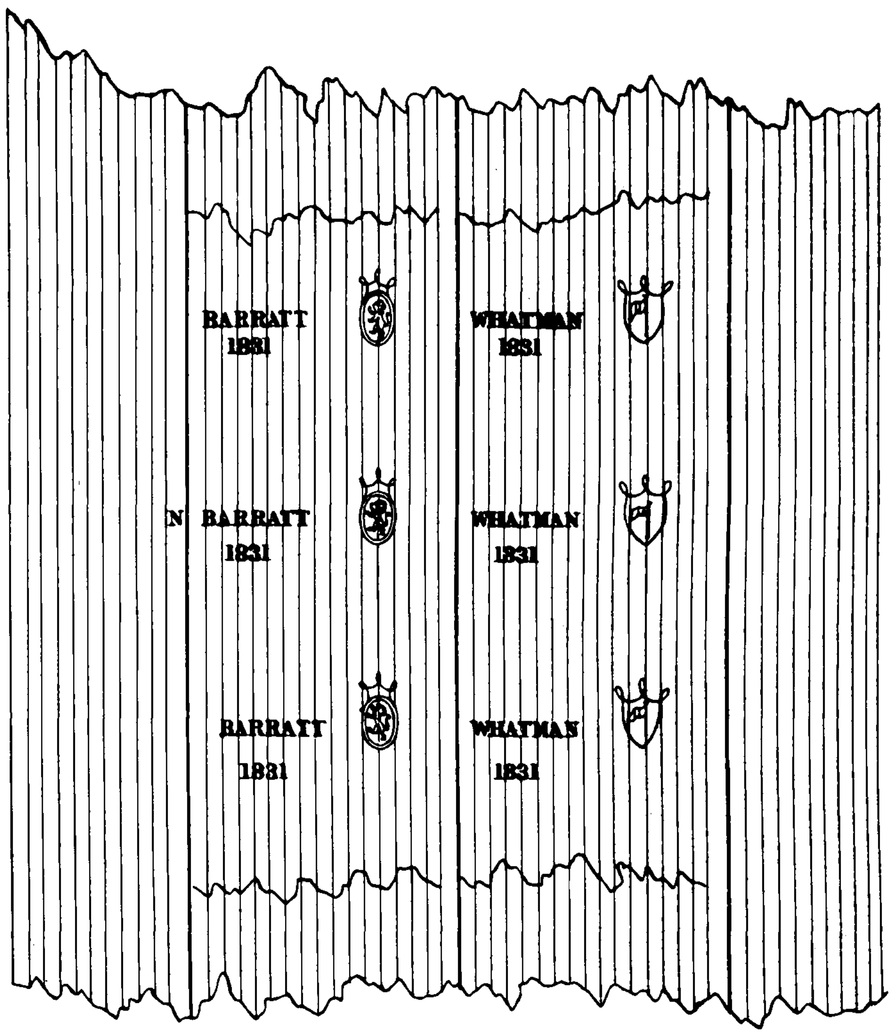
No. 51. Drawing showing John Dickinson's arrangements for a reversing press. The felt run is shown and three felts were required in order to support the web of paper between two felts as it passed from the first press on a very long run almost at floor level, before it was led back and up to the second press (d). From the second press the paper was taken round a further large roller (e) and on to a fourth felt to the drying cylinders. This extraordinary waste of space, necessitating very long felts, is difficult to understand. The drawing also shows the four bobbins delivering silk threads onto the cylinder mould for incorporating in the security papers.



No. 53. Barratt's specially designed wire part for making watermarked papers on the paper-making machine. The wire part was arranged to shake vertically up and down in rather the same way as George Dickinson's machine. The wire is led at an unusually acute angle to the couch rolls.

the wire, and in this way maintained he got better water removal. This device has been used, and is, in fact, used at the present time on some high-speed machines.

Another feature of Barratt's machine was that he had three or four deckle-straps, so that he could make sheets of different widths, or two sheets with different watermarks, at the same time, as is shown in No. 54 drawing, where the deckle-straps are represented by heavier lines, and where two sheets of foolscap are shown side by side but with different watermarks. Barratt admits that every time he had to change the make of the paper he had to put on a completely new wire with different devices sewn onto it, and he might have to have different lengths of wire for the different sizes of paper. He got over the trouble of having different lengths of wire by having two stretch-rolls (k) fixed on very long arms, so that they could be let down a long way from the machine-frame to take up the slack of the longer wire. This is quite an ingenious way of putting the name



No. 54. This drawing shows the machine wire of Barratt's machine, onto which the devices to form the watermarks on the paper are sewn, and thus form part of the wire. The wire cloth itself is of laid construction.

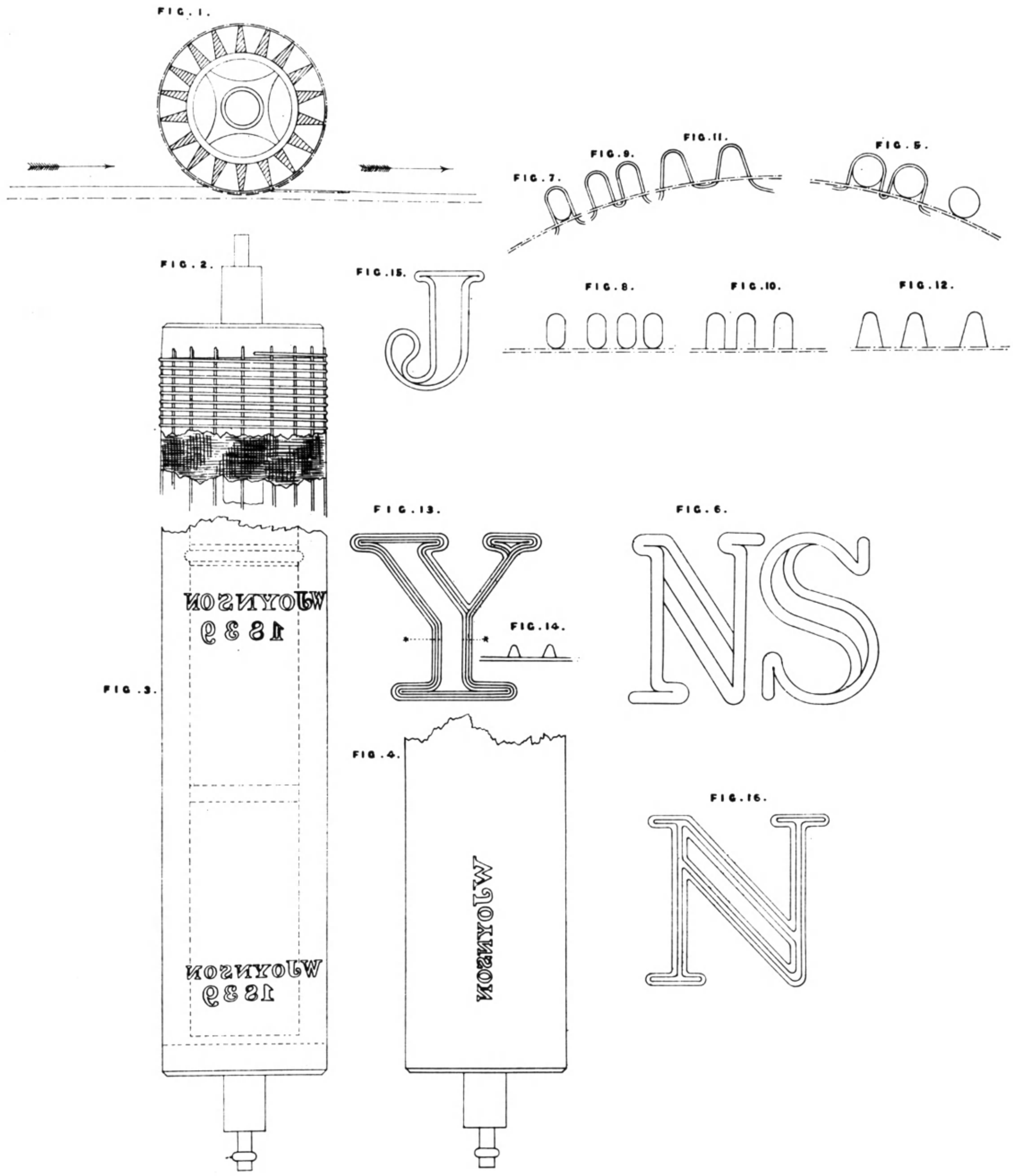
into the sheets of paper, but it must have been very expensive, and there is no evidence to show that it was ever a commercial success.

In order to facilitate the cutting of the paper to register, which is the first time this seems to have been contemplated, he had a contracting reel drum which he maintained always remained the same size as the paper which was being wound on it. It contracted to the same extent as the paper being wound on it increased, so that in the end he finished up with a roll only the same size as when he started! The roll of paper was then cut off with a knife, and when it fell away from the reel, the sheets were all supposed to be properly registered with the names and devices in the proper place in each sheet! It is not very clear how this could actually take place correctly in practice, but it is at least the first attempt at cutting to register.

It seems appropriate to mention here that it was not until nine years after Barratt's attempt to put marks in by sewing devices on the machine-wire that the problem of watermarking was actually solved. This was the invention (which he patented) of William Joynson, of St. Mary Cray, Kent, the well-known paper-maker, of a method of fixing the devices to the dandy-roll itself, thereby making the mark in the web of perer as it passed along the machine-wire under the dandy-roll.

Watermarking on hand-moulds had been practised since the twelfth century, that is for six hundred years; the paper-making machine had been invented for thirty years, and dandy-rolls for about twenty years, before anyone hit upon the idea of putting the mark in by means of the dandy.

William Joynson had evidently done a good deal of experimenting, and brought his method to perfection before he patented it, as will be seen from the drawing (No. 55). He used alternative kinds of wire, as are shown in the figures, the first being a round wire, shown in Fig. 5, than a flat wire, shown in Fig. 7, and then a wire which was round and had flat sides and base, shown in Figs, 10, 11 and 12. He got very much the best results by using wire shaped as is shown in Figs. 11 and 12, and in the letter "Y" (Fig. 13) on the drawing. The letters NS (Fig. 6) were formed of round wire,



No. 55. William Joynson's method of constructing a dandy-roll and of forming the letters and devices for fixing to the wove wire cloth of the roller.

shown in Fig. 5, and he further made his letters and figures by cutting them out of metal plates with rounded tops, tapered sides, and flat bottoms, the effect of which is shown at (N) (Fig. 16). This method, patented in 1839 by Joynson, seems to have continued to the present time all over the world.

In 1830, Richard Ibotson, of Poyle, in Middlesex, a paper-maker and one of the earliest customers of Fourdrinier since he took one of the first Fourdrinier machines to be sold, invented the slotted strainer-plate, which was a very big advance on anything that had been used for straining paper-pulp up to that time, thereby conferring a very great benefit on the paper-trade, from which it has derived much advantage ever since. Up to this time the sieves or strainers used for straining paper-pulp were of woven wire, and it can be imagined how very difficult it must have been to strain the stuff through them, when we bear in mind that up to this time the only material used in any quantity for making paper was that obtained from rags, although a little was made from straw, and even from wood-pulp. With the wove wire type of strainer there was a great tendency for the long rag fibres to clog up the holes, and they were extremely inefficient.

Ibotson made his strainer-plate by making use of bars of brass, copper or gunmetal which were about ½ in. in width, and of any convenient thickness. The upper or outside of each of these bars was as nearly straight, flat and smooth as it was possible to make it. He fixed the bars side by side to the bottom or underside of a wooden or metallic frame, of rectangular shape, so that the upper surface or flat sides of all the bars lay in the same plane, and so that the edge of each bar was parallel with the edge of the neighbouring bar, leaving between every two bars a parallel slit of about 1/70–1/100 in., according to the type of pulp which had to be strained. Ibotson said that he found from experience that the plates gave better results if the width of the bars themselves were about the same as the length of the longest fibres which composed the pulp to be strained.

When Ibotson had constructed his strainer-plate, he fixed it in a box and gave the usual jogging motion to it with cranks and cam wheels. He also constructed another strainer-plate in which each alternate bar could be moved so as to get different widths of slots in his strainer-plate to suit varying kinds of paper. This method of construction was soon taken up by other people with various modifications, but there is no question whatever that Ibotson was the first person to get the idea of substituting slotted plates for the woven-mesh straining cloth. It must have been a tremendous improvement and aid in keeping the paper-making machine running without frequent stoppages for cleaning out the strainers.

10

Progress in Paper-making, 1830-35

AN advanced type of Fourdrinier machine, with a number of additions, was introduced by Matthew Towgood and Leapidge Smith in 1830. It will be recalled that Matthew Towgood obtained St. Neots Mill from the Fourdriniers on account of the large amount of money they owed him. He was the banker who had advanced them money in the early days. Towgood took a very great interest in paper-making and, as is well known, had several mills later on, which were carried on successfully by his sons and grandsons. This machine, of which the specification was enrolled in 1830, is excellently shown in the drawing, and some of the new features may be described in detail. To begin with, he had a steam-cylinder for warming the stuff in the vat, and while it is well known that hand-made paper was usually made with stuff heated in the vat, this practice had not been adopted on the paper-making machine and, in fact, was given as one of the reasons why the Fourdriniers could save money by their endless-wire machine, in that no coals were needed to heat the vat stuff. Quite obviously, however, Towgood had realized that the stuff drained very much better on the wire when it was kept at a warm temperature, and for this reason he warmed it in the chest just before the stuff went onto the paper-making machine.

He also had a sluice-gate to regulate the flow of the stuff into a fixed trough, but the breast-box trough was arranged to shake with the rest of the wet-end of the machine. The deckle-straps were carried back beyond the breast-roll, or head-roll, as he called it. The rest of the wet-end seemed to be quite normal, with tube-rolls, deckles and deckle-straps which were driven, but he had two dandy presses, that is dandy-rolls fixed over large tube-rolls immediately before the paper came to the couch, it being intended to get as much water out of the paper as possible before the nip of the couch-roll. He also had washing arrangements to wash any stuff off the wire-return rolls, which was also a new feature, still carried out on all modern machines. His wet-press or couch was weighted with a heavy lever, and the top roll was set back in the conventional way into the wire. The paper then left the wire and went onto the wet-felt, where it was carried through the presses, which he called the upper and lower dry-press rolls. From there it was led round a steam-heated drying-cylinder which had a felt-covered press-roll immediately on the top.

The main feature of his machine, however, was his tub-sizing arrangement. This is the first time that tub-sizing is shown to have been carried out on a paper-making machine, with the paper passing through the tub in an endless web. He used three sizing-rolls, and there were two size-troughs. The paper came off the cylinders and passed over No. 1 size-roll, between it and No. 2 size-roll, round the bottom of this roll, and back between No. 2 and No. 3 rolls, then onto the drying-cylinders. Size was supplied to No. 2 roll on which there was a doctor, at the top from a vat, and to No. 3 roll at the bottom. The pressure between these three rolls could be applied according to the amount of size it was desired to leave in the paper. Towgood points out that the amount of moisture remaining in the web after it left the first drying-cylinder was important, and had a good deal of bearing on the ultimate sizing of the paper. Arrangements were made to have size always available, at a predetermined temperature, above the size-trough, and there was an overflow arrangement to receive any surplus size that was squeezed off. The latter was then pumped back to the size-supply chest.

The first drying-cylinder after the size-bath was heated by steam, but covered with felt fixed to its surface. The second two drying-cylinders were of iron, and had the conventional type of dry-felt, in the same way as those described under Crompton's patent.

Towgood stated that with certain kinds of paper it might be advantageous to reel them up after they had been sized, before they were put over the drying-cylinders. This was in order that the paper could be cut off into sheets and air-dried in a loft, as was the usual custom with most sized papers. For certain papers he maintained that equally good results could be got by drying the paper over the steam-heated cylinders shown in the drawing. He also said that with regard to the size-rollers, it was better to have No. 1 and No. 3 covered with felt to give them a soft yielding surface, and to have No. 2 with a hard polished surface. This gave the best results.

Figure 3 on the drawing shows a sizing-machine for sizing sheets of paper, patented at the same time. The operation of this is quite obvious from the drawing. The sheets of paper were put onto the endless felt, passed through the size-rollers, and then picked off and stacked in a heap ready for drying. This was supposed to be an improvement over the old method of dipping them into a tub of size. It is the method in common use today in mills making high-class papers by hand, or on small cylinder-mould machines. Towgood points out that if the drying-cylinders are driven in the usual way by toothed wheels driving one from the other, allowance must be made in the diameter of the cylinders for the shrinkage of paper.

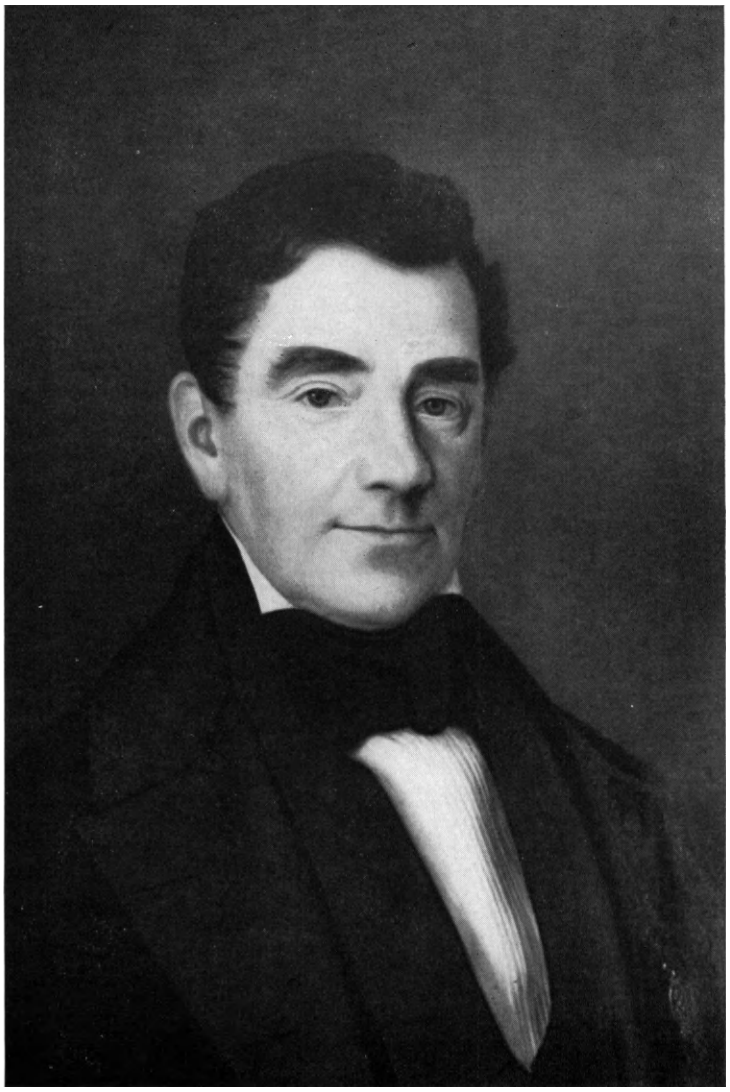
In 1829 several French paper-makers bought Fourdrinier machines from Donkin, but at least one American mill bought a machine from France; this was installed at the Pickering Mill, North Windham, Connecticut. Out of a total of sixty paper-mills in Massachusetts, only six had paper-making machines, two of which were Fourdriniers.

The Danes had started up their machine at Frederiskborg, and this having created a great deal of interest in Sweden, Sven Sunnerdahl of Klippans was encouraged to have one. He approached Donkin in 1830 and got particulars and prices. He then asked the government for a loan, which was granted and 15,000 riksdaler were advanced to the company. The order was placed with Donkin on Christmas Eve, 1830, for a wet end and a dryer, and he sent them the plans of the machine. In 1831 new buildings were erected to house the mill.

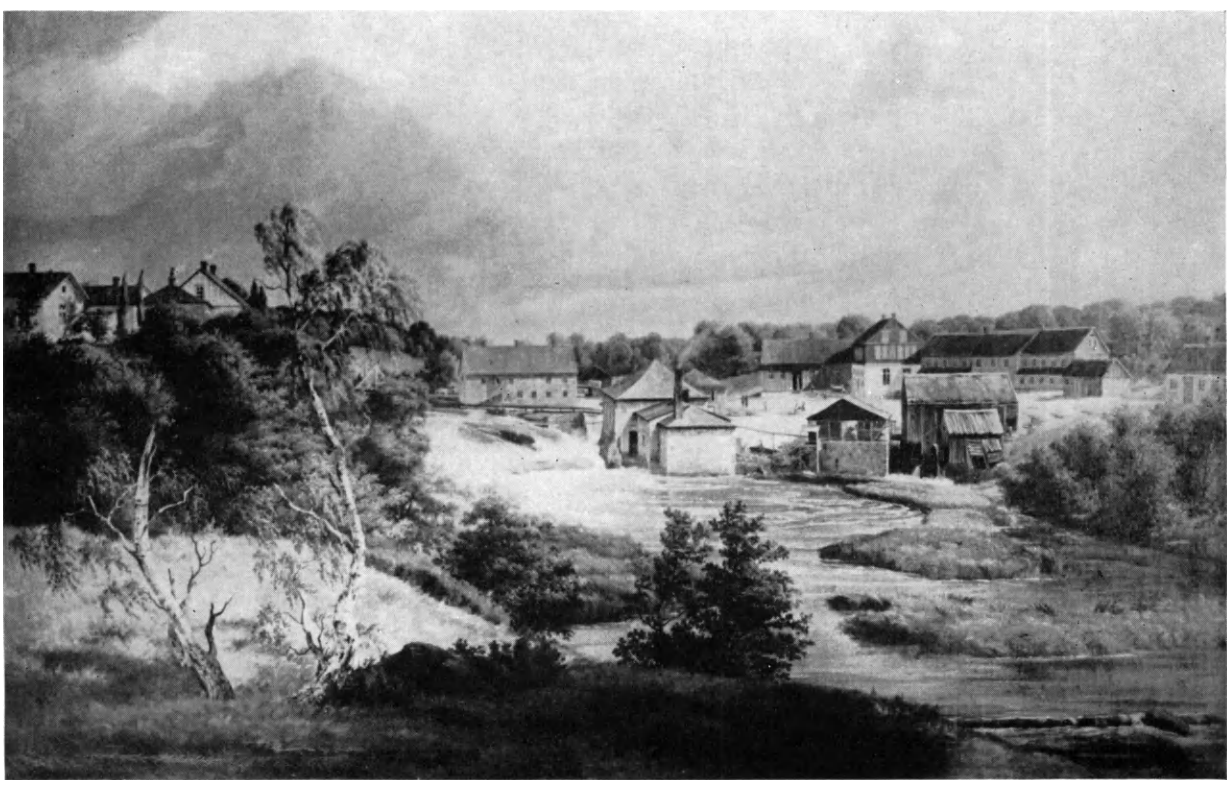
The machine, with its ancillary parts, arrived at Klippans in the autumn of 1831 and the erection of the various machines began. When the work was completed in the first half of the following year, the general construction was as follows:*

Water was led from the river along a 28 yd trough to a so-called "water works" placed in the lower floor of the beater house. The trough was supported by oak poles. The "water works" was equipped with an overshot water wheel of Scots pine running on an oak shaft. Power was transmitted from the water wheel to the four beaters, in the upper floor, by means of an oak cavity wheel fitted with a cast-iron toothed ring, a cast star wheel and two oak fly-wheels. The beater rolls were a yard wide, each equipped with fifty-four steel knives. The eighteen knives in the base plate were also of steel. Two of the beaters were intended for "seconds" or "half-stuff" and stood with their bases on the same level as the upper edges of the two finishing beaters, which stood nearest the side of the paper-making machine. This arrangement enabled the half-stuff to be dropped in easily. In addition to the beaters (Hollanders) two large stuff chests and a large reservoir with a strainer for jet water were also placed in this upper floor.

* This account is taken from a translation of the Klippans book.



No. 57. Sven Magnus Sunnerdahl who bought the first paper-making machine for Sweden from Bryan Donkin and erected it at Klippan Mill in 1830, thus starting the great paper-making industry of Sweden.



No. 58. Klippan Mill, Sweden, about 1840, enlarged to take the first paper-making machine.

From both the finishing beaters, the mixture was dropped via a trough to the machine house and down into two large stuff chests equipped with agitators. Meanwhile water from the reservoir was led around and about in copper or lead pipes fitted with metal stop-cocks for the various needs of the mill. The stuff chests were placed on a frame three yards high made of oak poles and beams and stretching the whole width of the house. They were so arranged that they stood below the beaters. From these chests the stuff was led through copper pipes, with metal taps, to a large lead-lined vat. From here, the pulp mass flowed in an even stream out onto the paper-making machine.

The formation and further processing of the paper on the first Klippans machine was normal for a machine of the period.

The brass wire was 9 m long and the deckle straps were of leather. The machine was supplied with a dandy-roll. It was quite usual at this time for a paper-making machine to end at the reel-up after the presses, but Sunnerdahl's machine comprised a dryer part of five drying cylinders. When the paper had passed over the drying cylinders it was led through glazing rolls or calenders and then reeled up.

The paper was cut off the reel-up drum and laid on a cutting table, where it was prepared for further cutting up into sheets.

The total length of the machine was 12½ m and about 2 m in width, and could make paper 1½ m wide.

The machine was driven by an iron overshot water wheel 3 m in diameter, and power was transmitted from the shaft of the water wheel to the various sections of the machine through hemp belts.

In order to prevent the water wheel icing up during the winter it was housed in the machine house, and enclosed by pine boards.

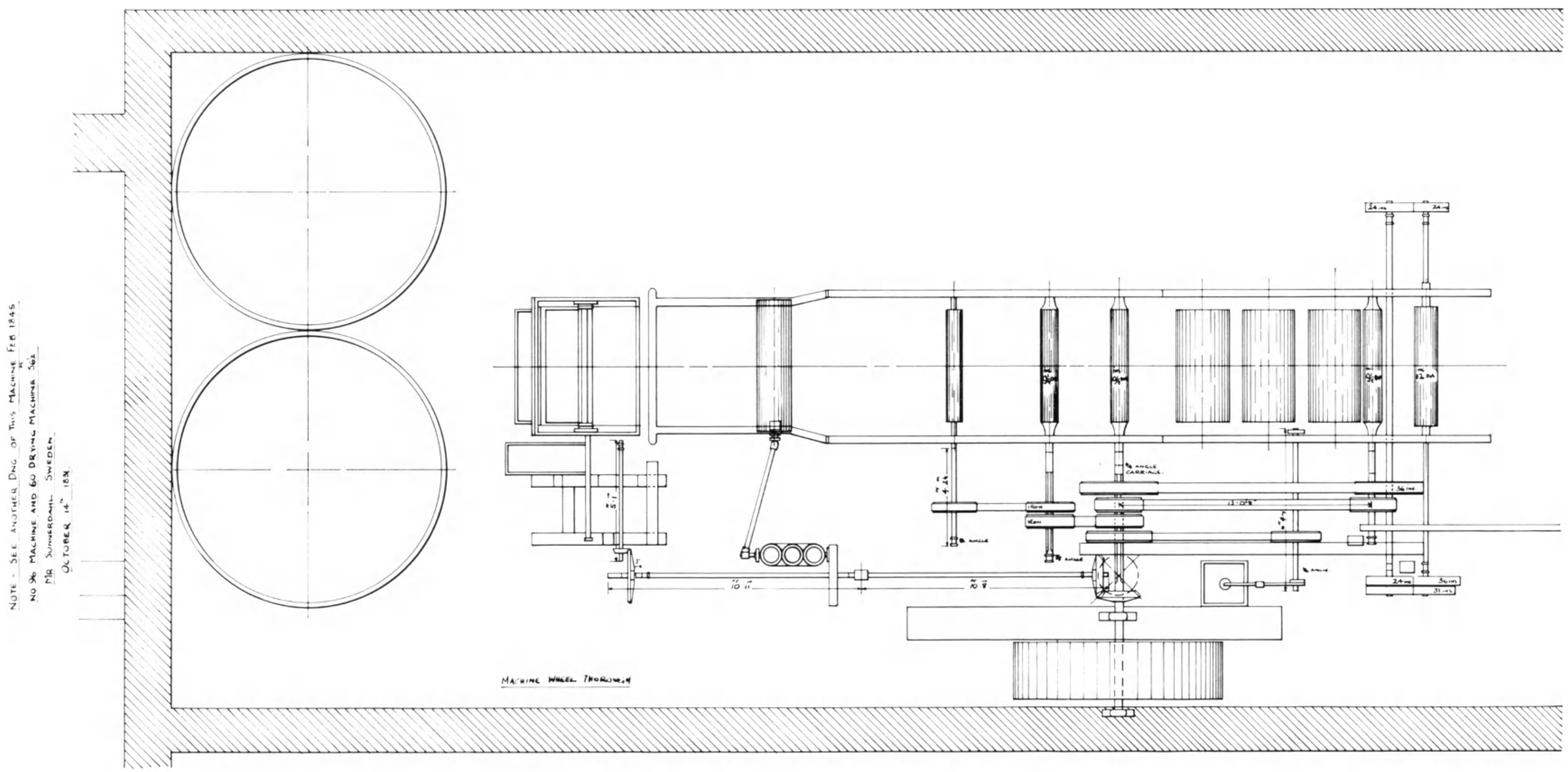
A boiler house was built nearby for the sole purpose of supplying steam to the drying cylinders of the machine.

The machine started up on the 20th June, 1832. The following description of the staffing of the mill was translated from the Klippans book:

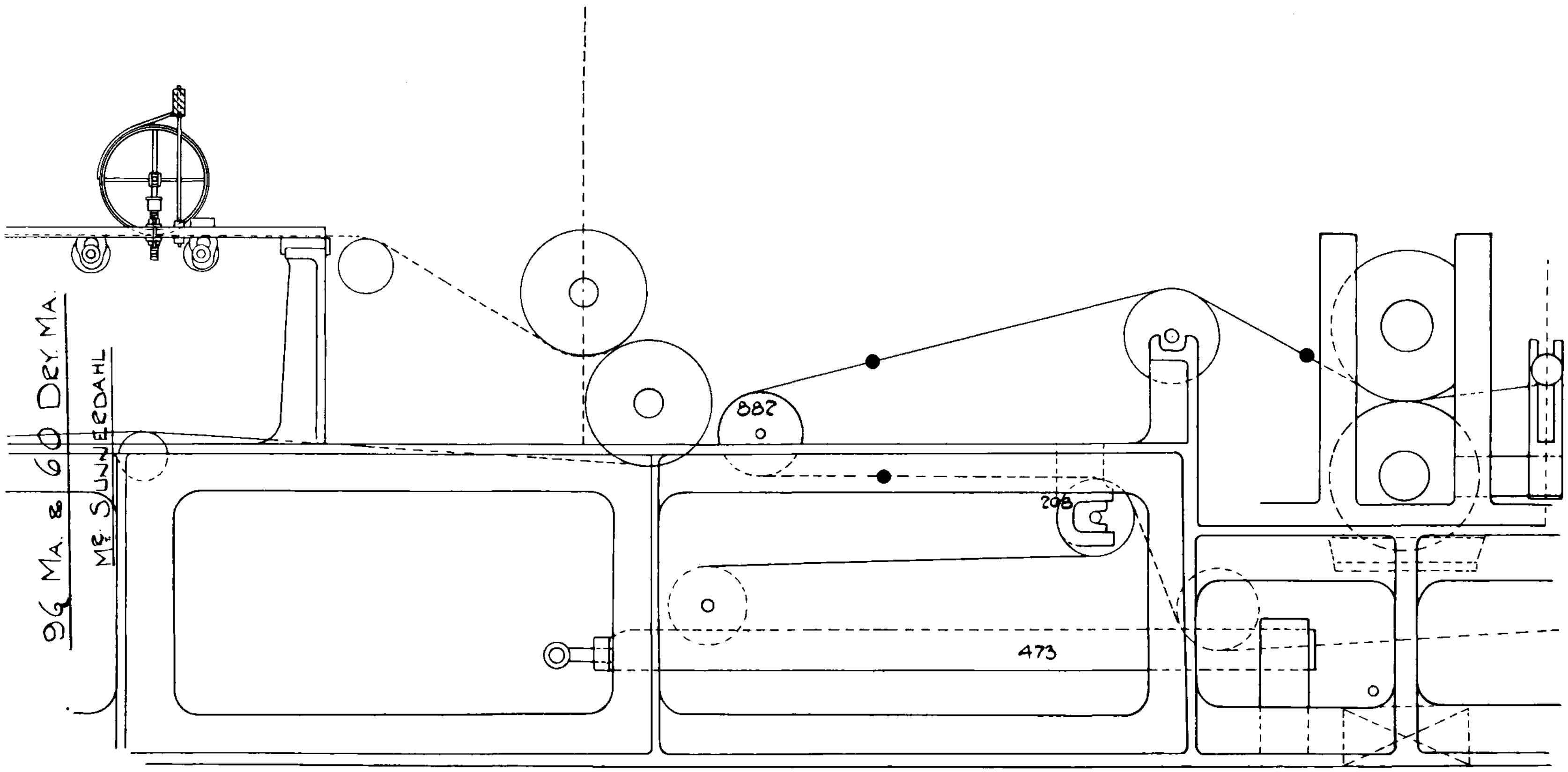
Skilled, knowledgeable men from England naturally co-operated in the erection of the machine and the technical management of the mill lay in foreign hands for many years. After an attempt with Johan Larsson as mill manager and a former needle-maker as first machine-man it was announced in 1833 that William Howard was engaged as paper-maker and mill manager at Klippan. He was appointed through the co-operation of the supplier of the machine Messrs. Bryan Donkin and Co. William Howard was followed in 1838 by John Howard, probably a brother to William, and after his death in 1840 H. A. Lincke became paper-maker. From the middle of the 1840's the Danish-born Teodor Danielsson held the post of mill manager. The type of work called into being by the paper-making machine was quite separate and distinct from the traditional guild-like work of the hand paper-maker. Those workers who, for the first twenty years, had charge of the paper-making machine, had only in rare exceptions had any previous experience of paper-making. As superintendent of Klippans plant the Danish born A. E. Leidesdorff, a former needle-maker, was appointed in 1832 and simultaneously Magnus Olsson and J. Dreyer were appointed as workers, the former appears to have been a mill servant, the latter an apprentice. Leidesdorff's management did not last long and in 1833, when the paper mill had an English manager, the paper-making machine was run by five, later six, men. With great conscientiousness these men carried out their duties and Sunnerdahl expressed himself in 1835 in the following words:

"During the recent past I have been able to assure myself that those persons to whom I have entrusted the management and supervision of this paper-making machine have made great endeavours to acquire skill and accuracy and a proper understanding of the manipulation of the machine."

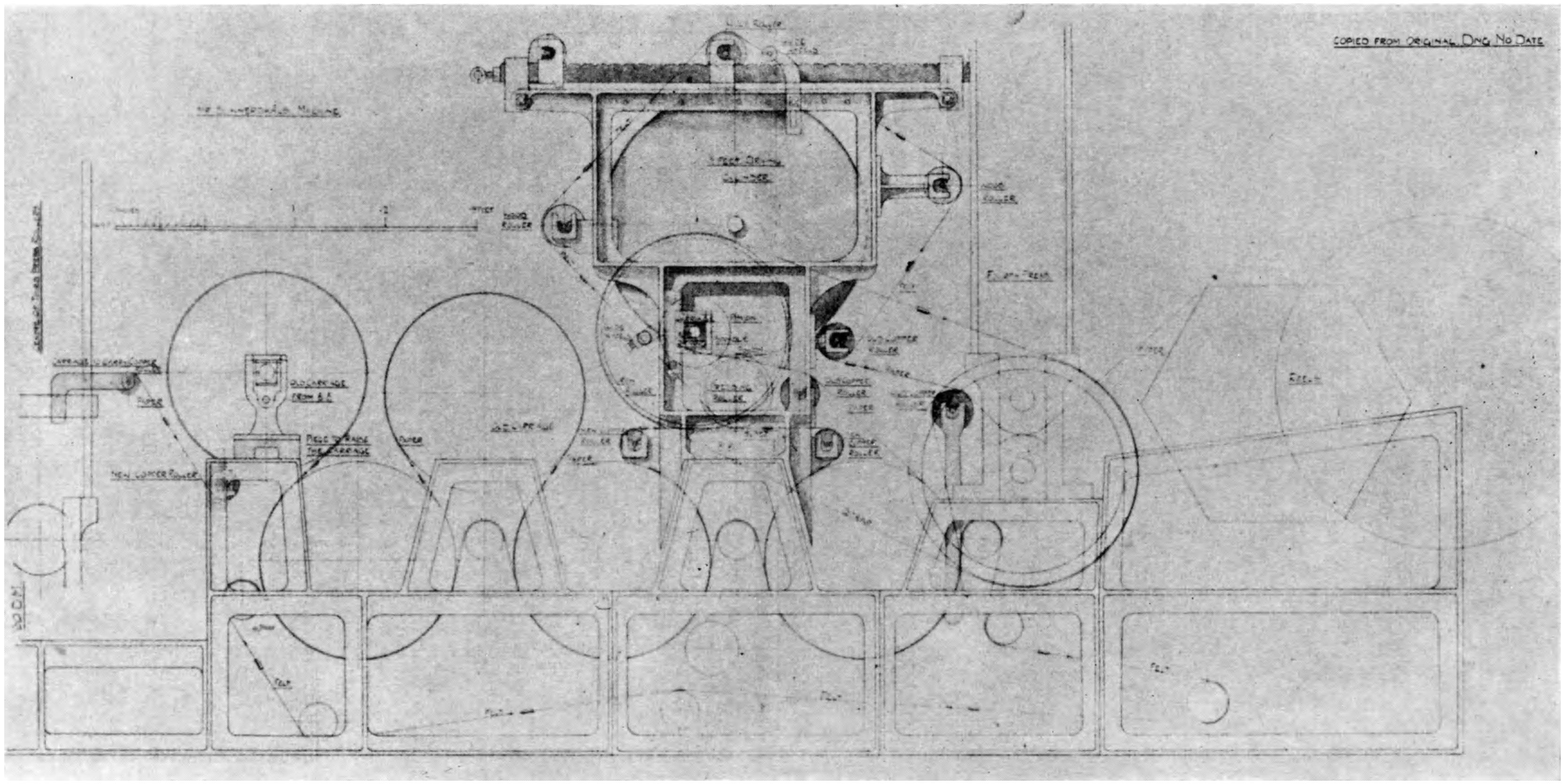
Ten years later the same employees were still at the machine.



No. 59. Donkin's No. 96 paper-making machine for Klippan Mill, 1830.



No. 60. Drawing by Bryan Donkin and Company of the couch and press part of the machine for Mr. Sunnerdahl, January, 1831. This drawing shows a dandy-roll with wiper cloth, and is the first intimation that the cloth was used on the dandy in the early days of the paper-making machine.



No. 61. No. 60 dryer part of No. 96 paper-making machine supplied by Bryan Donkin and Company to Klippans in 1836. This is apparently an alteration to the original dry part. A three-feet diameter drying cylinder has been added, together with a press-roll and alterations to the gearing.

The paper-making machine was, in the beginning, kept running only during the day time, but Sunnerdahl soon tried to install continuous running, and for this purpose extended the beater house. When the employees had acquired sufficient experience, an attempt was made in 1835 to begin continuous operation and this succeeded so well that in the same year Sunnerdahl considered himself strong enough to claim that "stoppages in the continuous running of the machine night and day throughout all week days during the year neither can, should, nor may take place". In this connection he appointed Jeppa Strômberg and Magnus Olsson as machine-men with the duty of "managing and maintaining this my valuable paper-making machine and to supervise the making of paper therefrom". The division of their working day so that "they carry out their duties a half-day each" was left to themselves to agree upon. As recompense for their work the mill owner gave them "an ample income and amenities", an annual wage of 500 riksdaler in cash together with free house-room in a new house specially built for them and further he undertook to keep a cow fed for them and to supply them with firewood. These conditions were confirmed in a legal contract for a period of "six consecutive years".

By means of the paper-making machine Sunnerdahl achieved a considerable increase in production while the number of employees increased only very slightly. Increases in employees were confined to those engaged on work preceding and following the making and drying, the greater part of the work that was formerly carried on by twenty-five journeymen and apprentices, and so also the hanging and taking down of paper in the drying room, which was now carried out by six workers at the machine. Production on the machine during the first six months was 6677 reams. This increased in the following year to 19,716 reams and increased year by year so that from 1840 it consisted of 35,000–40,000 reams. Thus whilst before 1832 the annual output was about 13,000 reams with a payroll of about sixty persons, twenty years later the annual production was nearly 40,000 reams but the number of employees had increased only to about one hundred. The great advantage in labour saving might be even more apparent if a truer comparison could be made. Machine-made paper could be produced in any size then used and the ream figures include large quantities of bigger sizes than could be produced by hand. In addition there was a considerable saving in raw materials as the thickness of the paper could be better controlled on the machine than by hand.

The financial crises which during the 1850's and 1860's had caused such havoc with the steady development of the commercial world seemed, to a large degree, to have bypassed the paper-making world and left this undisturbed. The business had developed to such a degree that Bock (successor to Sunnerdahl) considered that owing to the increased demand for the mill's products he could build a second machine at Klippans. This, bought in 1873,* was supplied, as was the first machine, by Bryan Donkin and Co. of London and had a working width of 193 cm. In connection with this development the power available was increased by the installation of a water turbine of 100 h.p. This, with other re-building and extensions during 1871 to 1873, together with other improvements, gave to the paper mill the outer appearance which, to a large extent, it retained until the opening of the twentieth century.

The machine at Whitehall Mill in Derbyshire, it is recorded, made a roll of paper 4 ft wide and 13,000 ft long.

A firm of engineers in Connecticut, named Phelps and Spafford, were now making paper-making machines, George Spafford having erected the Pickering machine.

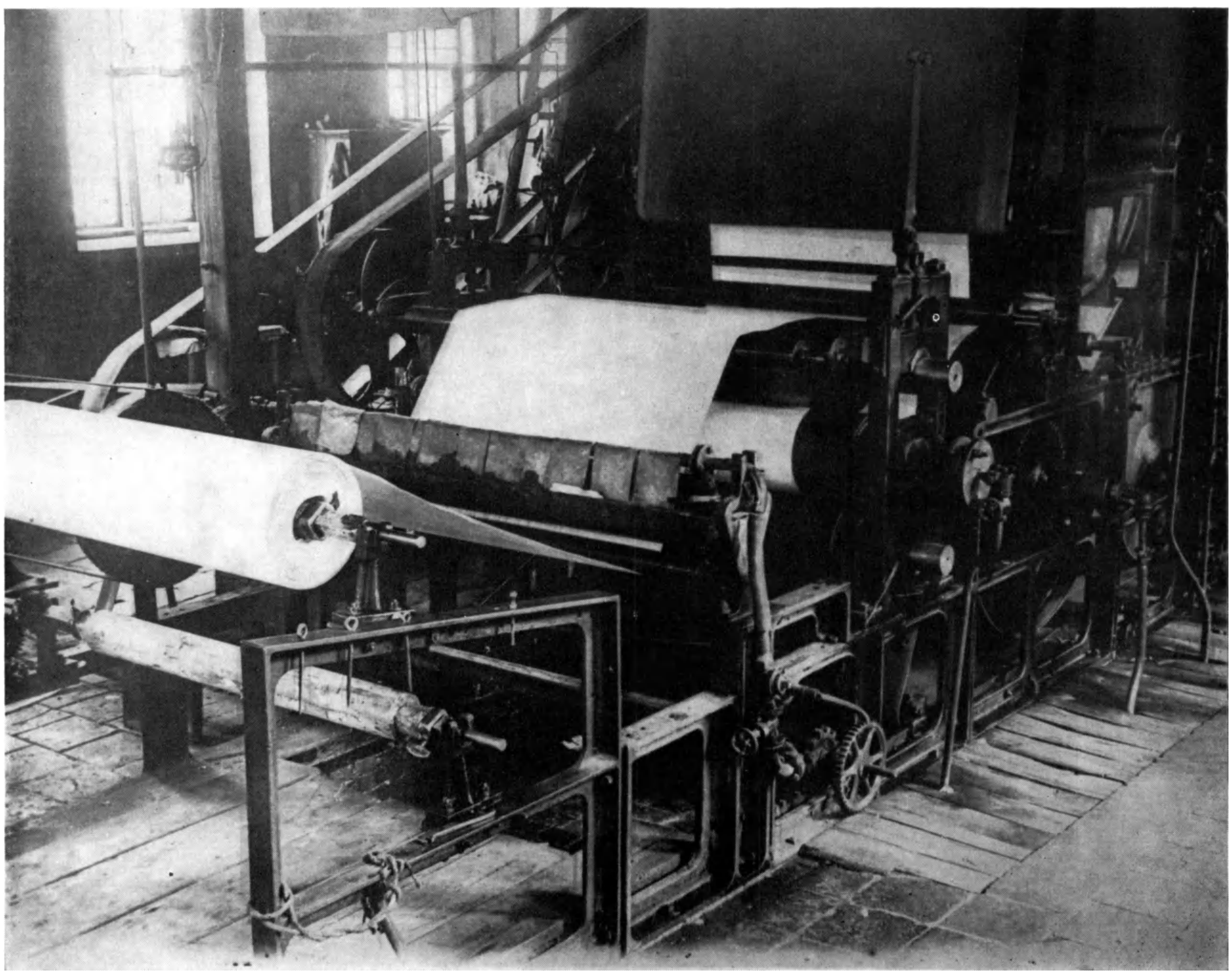
Thomas Barratt, who became well known for his work in connection with water-marking, also found a very useful method of grinding cast-iron press rolls. He drove the rolls in contact with a stream of water running on them, and thus got a far better fit than had been possible before in a lathe. This discovery was of a very great benefit to paper-makers, and made the presses on the

* The 1873 machine is illustrated in this book (facing p. 234).

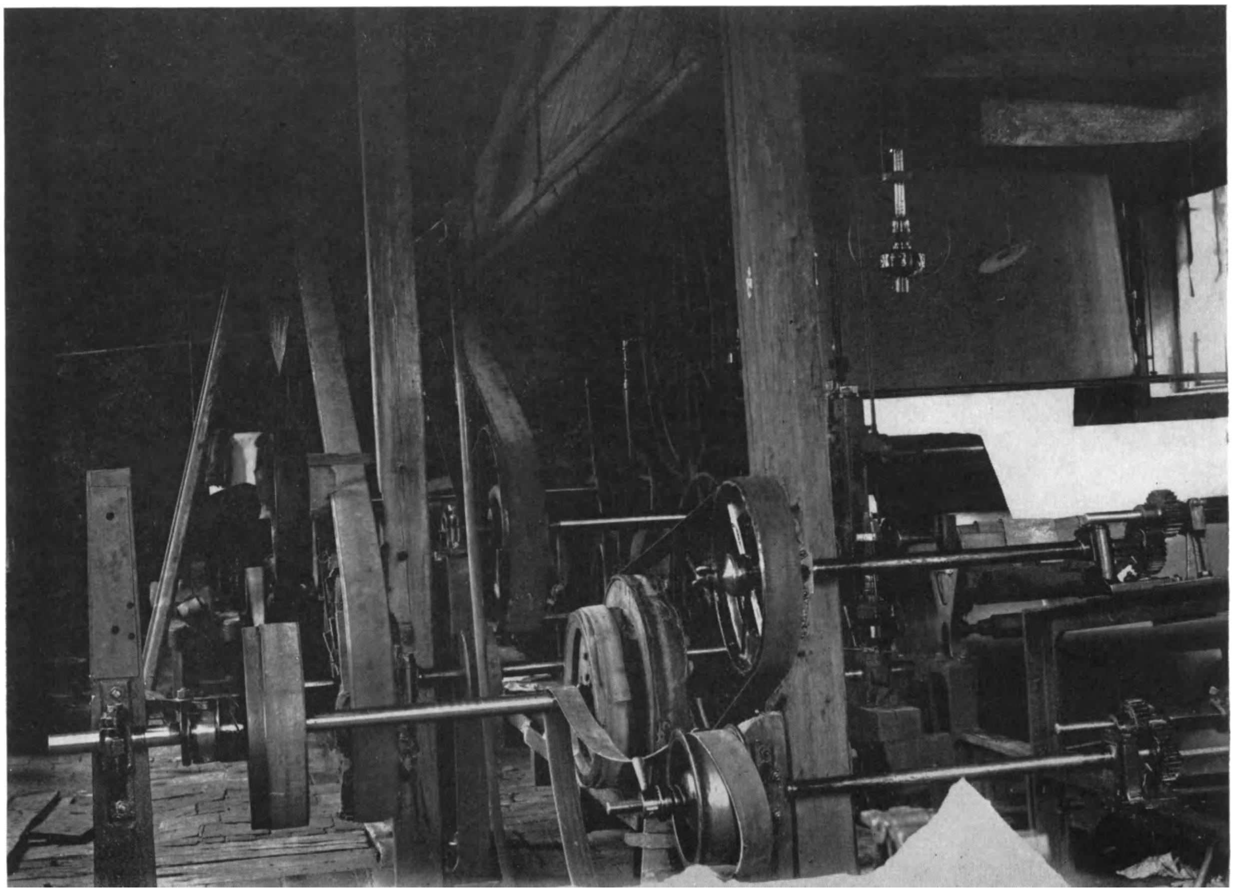
machines very much more effective, and the paper was much more evenly dried. It was quite common practice to grind press rolls and also the press rolls on M.G. cylinders in water, as recently as 1920.

The inward-flow revolving drum strainer patented by John Dickinson in 1832 was almost the same in design as most strainers of the present day, except that it was rather small in diameter, being only about 15 in., but it had slots instead of mesh wire. The following remarks were made about it shortly after it was put into use:

The pulp being diluted to a consistency suitable for the paper-making machine, is delivered into a vat, of which the level is regulated by an overflow pipe so as to keep it fairly full. From this vat there is no other outlet for the pulp except through the wire-work periphery of the revolving drum, and thence out of each of its ends into troughs placed alongside, from which it is conducted to the machine destined to convert it into the paper-web. The revolving drum is constructed somewhat like a squirrel-case.



No. 62. Dry end three-roll calendar and reel-up of the original Bryan Donkin machine of 1831 at Klippans, still running in 1898.



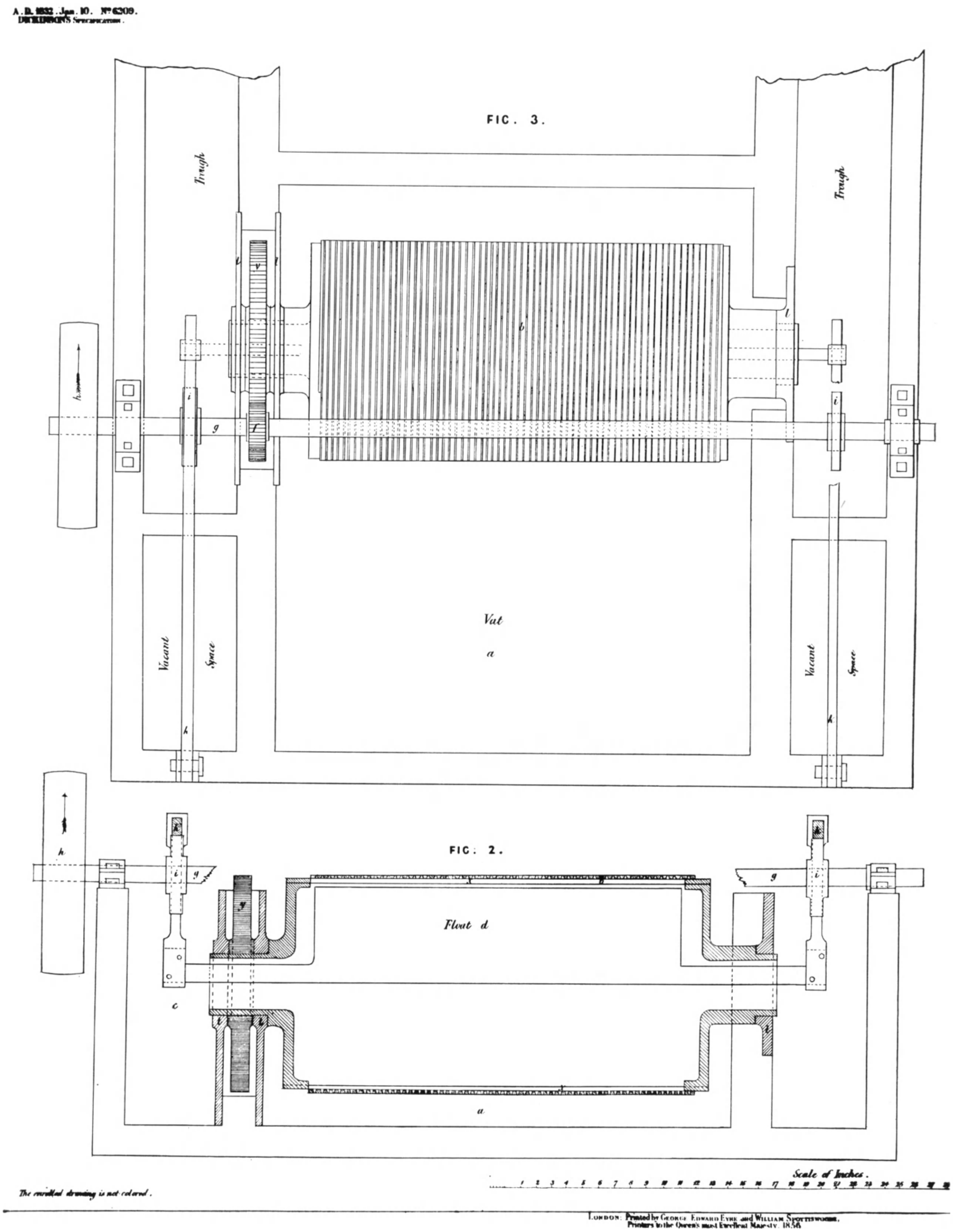
No. 63. Belt drives of dryers, calender and reel-up on No. 1 machine at Klippans in 1898. The machine was by this time sixty-seven years old.

Dickinson describes his patent strainer as follows, referring to the Figs. 1, 2 and 3 in the illustrations (Nos. 64 and 65).

Figure 1 is a longitudinal section; Fig. 2 a transverse section; and Fig. 3 a plan; and in all three the same letters are used for reference to several parts. (a) represents a shallow vat in which the revolving drum (b) works. The pulp, diluted to that consistency which suits the paper-making machine it is intended to supply, is delivered into the vat, and the level of it is regulated by means of a waste, so as to keep the vat nearly full; and from this vat there is no other outlet for the pulp except through the periphery of the drum (b), and out of each end of it into the trough (c), through which it is conducted to the paper-making machine. The drum (b) is constructed like a squirrel-cage, or circular hoops on an endless spiral wire attached to transverse metal bars (x), and is so formed that the spaces between the hoops, or between each spiral ring of the wire, are sufficient to allow the passage of the fibres of pulp, but narrow enough to intercept the knots and other substances which it is desirable to keep out of the paper.

For making fine papers it is found practicable to pass the pulp through spaces 1/150th part of an inch wide, and even less, but the drum must, in other cases, be formed with wider apertures, as for coarser papers the fibres are longer, and in some cases they require to be twice the width specified above.

It has been before mentioned that the pulp enters the drum only through the periphery, the



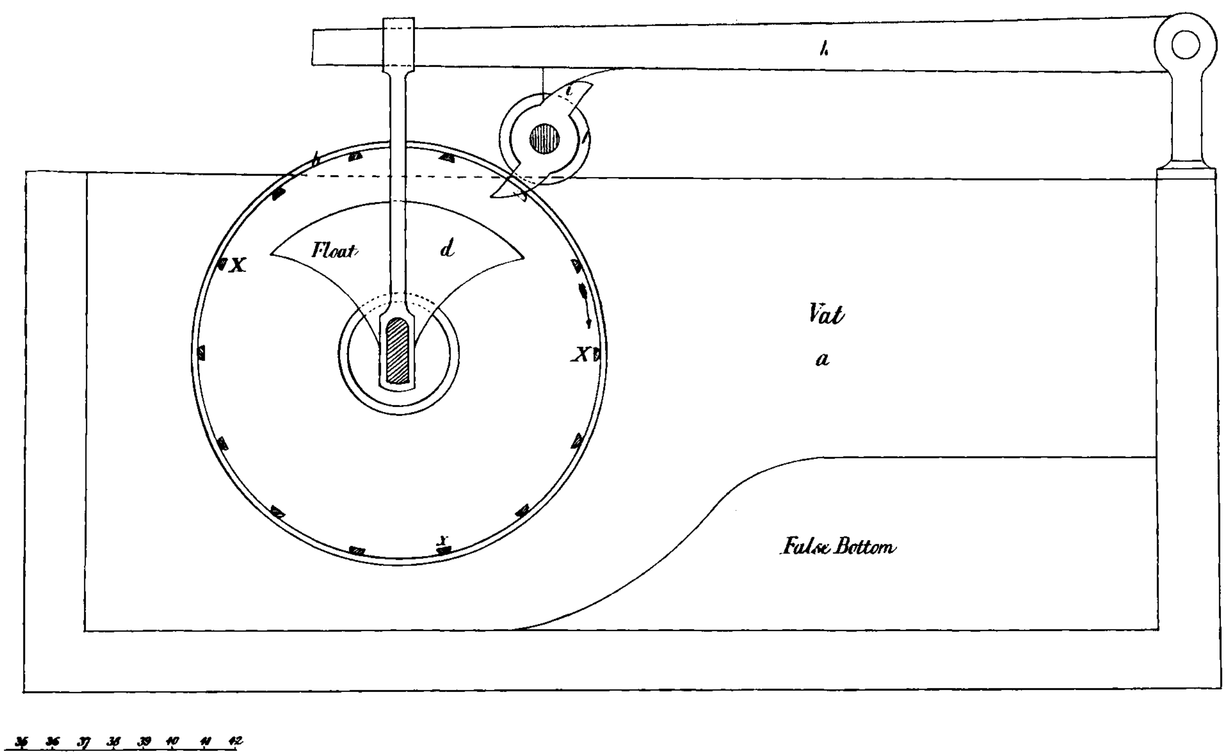
No. 64. John Dickinson's full-drum, inward-flow, revolving strainer. This very advanced form of strainer or knotter patented by Dickinson in 1832 was the forerunner of the strainers in use at the present time, and it had everything which the most modern strainers now have, except that the engineering technique now has advanced very considerably so far as the actual construction is concerned. It was about seventy years after Dickinson's patent before other patents were taken out for the same type of strainer, and in the interval many very inefficient strainers were used on paper-making machines, mostly of the flat type. Dickinson appreciated the value of "inward-flow" and of the ebb and flow caused by the float or flapper, and he must have been able to make much cleaner paper than his competitors.

ends being solid, except the axis, which at each end consists of a large tube through which the pulp flows out. The hoops of wire, of which the periphery is formed, are about 3/8th of an inch wide on the outer surface, and about one quarter of an inch thick, and the inner surface, which comes against the transverse bars, is only about one quarter of an inch wide, so that the apertures towards the inside of the drum are wider than they appear externally.

The best mode of forming these drums is by a spiral wire drawn to the shape above described, and wound round, and attached to the transverse bars.

The pulp would naturally accumulate on the surface of this drum, and almost immediately stop up the apertures between the wires, but this effect is prevented by the agitation of the pulp in the interior of the drum, produced by the rapid and constant up-and-down motion of the float (d). This instrument is of the shape described in the section Fig. 1 and is nearly long enough to reach from end to end of the drum inside. It is hollow, but made water-tight, and formed of strong copper, and has a metal bar through it with an arm projecting from each end, to which is fixed a strong link, and by these links it is hung to two levers (k) in such a way that the levers, in moving up and down, raise and depress the float, but in all cases without bringing any part of it into contact with the drum. I call this a float, but it is intended, with the links and levers to which it is fixed, to be much heavier than water, so that after being elevated by the levers, it may sink suddenly by its own weight when it is no longer supported. The range of up-and-down movement given to this float should be about $1\frac{1}{4}$ in. and the rate of movement about 80 or 100 alternations per minute, and this, by suddenly checking the flow of pulp through the apertures in its descent, or rather reversing the flow which in its ascent prevents any lodgement of the fibres of rag.

FIG. 1.



No. 65. Details of the float or flapper of Dickinson's inward-flow revolving strainer, showing cams for jogging the float inside the drum. Dickinson immersed the drum much deeper in the stuff in the vat than is usual nowadays.

This is the reflex action given to all strainers at the present time, but this movement is usually achieved nowadays by having the flappers or agitators outside the drum itself, and in the vat.

The drum (b) has a toothed wheel (y) fixed on the tube part of one of the ends, and working between two metal flanges fixed to the wooden side of the vat for the purpose of keeping the pulp away from the wheel which is made to revolve by a pinion (f) fixed on the spindle (g) which goes across the vat, and is fixed by two plummer blocks on the outside of the troughs, and has a rotary motion given to it by the rigger (h), by means of a strap from any convenient power at the rate of 40 or 50 rev/min. This spindle has also fixed upon it two double eccentrics (i), so that in every revolution it twice lifts these levers, and at the same time raises the float (d). Dickinson says that the diameter of the drum (b) is not very important, but he found 14 in. the most convenient size. The length of the drum must be regulated according to the size of the machine it is intended to supply with pulp, but he found that a drum 4 ft long in the grooved part was sufficient to supply a machine of the largest size in ordinary use, that is, one capable of making 4 ft 6 in. width of paper. The metal flanges (l) are firmly fixed to the sides of the vat (a) with a water-tight joint, and form the bearings in which the drum works.

Figure 2 shows the shape of the slots through which the fibres pass, and how the narrow slot on the periphery widens out towards the inside of the plate. There is no doubt that this was a very advanced type of strainer for 1832, and strainers for the most part, for another fifty years or more, were not nearly so well designed as this one of Dickinson's. It seems very strange that very inefficient flat jog knotters should have been in general use until about 1900, or even later, when the inward flow revolving strainer already existed. Many modern strainers are almost an exact copy of this original patent of John Dickinson.

About this time the French paper-makers began to install paper-making machines to supersede the making of paper by hand.

In 1832 in Scotland there were fifty-seven paper-mills operating, thirty-three of which were entirely given to the production of hand-made paper. Twenty-three mills had paper-making machines, seven of them having two machines, the rest one each. Many of these mills are still operating at the present time under the same names. Alexander Cowan had four mills, one for hand-made paper only; the other three had paper-making machines, Valleyfield having two. Alexander Pirie had two machines at Stoneywood; Edward Collins had three machines and four vats at Dalmuir; James Brown had two machines at Esk Mill, Penicuik; Charles Davidson had a machine at Mugiemoss, Aberdeen; and Robert Tullis had a machine at Auchmuty Mill. These mills were making a wide variety of papers, from writings, printings, news and cartridge, to browns and greys.

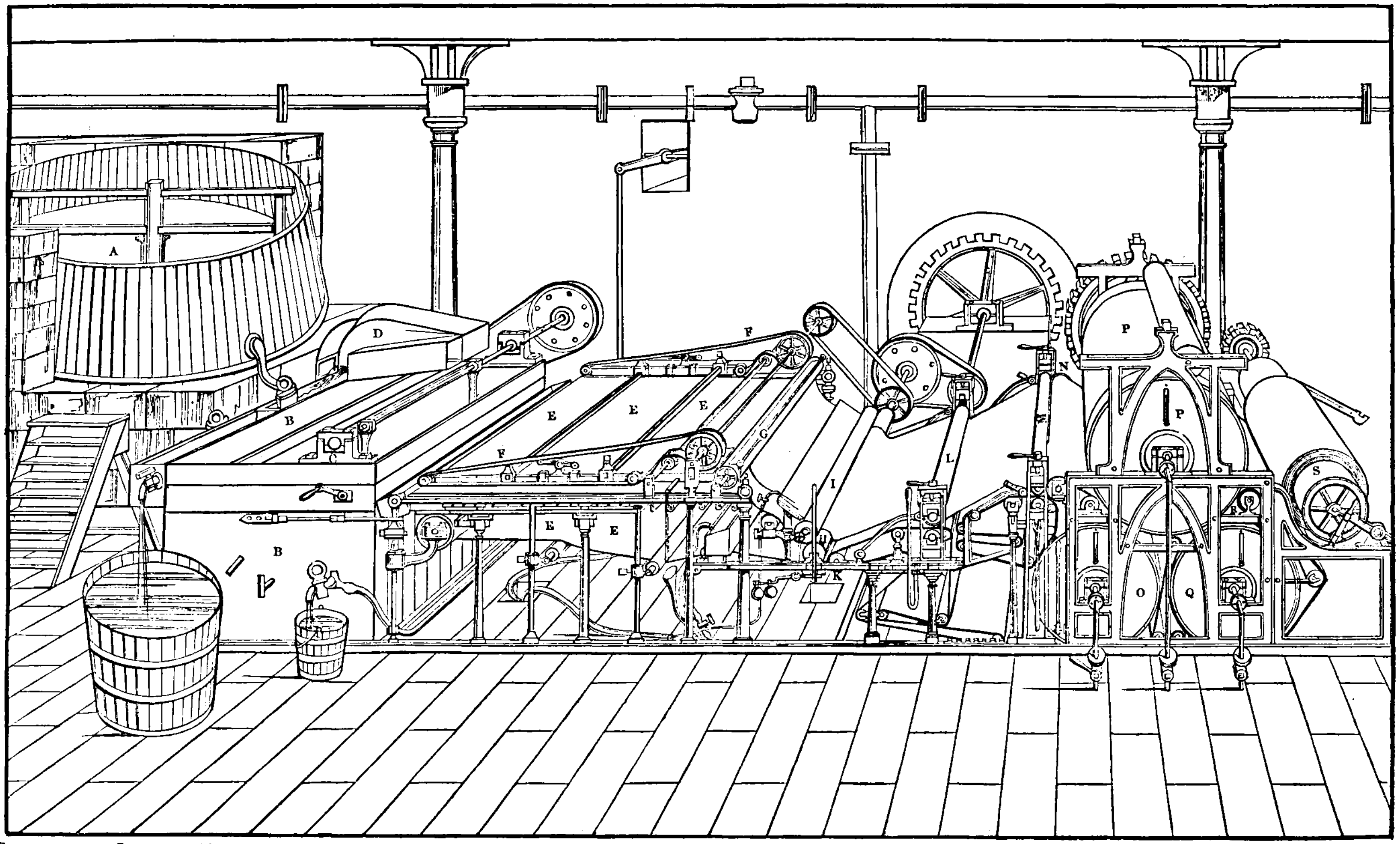
In 1833, George Dickinson, of Buckland, near Dover, in an attempt to get over the inconvenience of not being able to make satisfactory laid papers on a Fourdrinier-type machine, maintained that all paper made up till this period on a Fourdrinier machine had, in spite of the laid dandy, been wove paper, although several attempts had been made to produce a wire-cloth which would give a laid mark in the paper. These were not successful, on account of the fact that the wires would not last any length of time. Dickinson maintained that in making a laid paper on a hand-mould the mould was shaken horizontally backwards-and-forwards, the direction of the shake being transversely across the direction of the chain wires. In a new patent he arranged for the chain-lines to run parallel to each other in the machine direction, and in order to make the wire flexible he joined the laid wires with threads of yarn, silk or cotton, or even worsted, suitably twisted or plaited, as a substitute for the fine wire which is used in binding the laid wires together to form a laid mould. In the drawing (No. 67, p. 130) Fig. 1 shows how the wire was made, and he claimed that this method of keeping lay wires in position enabled him to have a flexible wire which would pass round all the rollers on the paper-making machine. His wire was very short, being only about 12 ft long

Paper Mills in Scotland in 1832 with Paper-making Machines

			Machines	Vats	
Alexander Pirrie	Stoneywood	Stoneywood, by Aberdeen	2	0	Printing, etc.
Alex. Irvine and Co.	Coulter	Culter, by Aberdeen	2	0	Cartridge, grey and brown.
Robert Tullis and Co.	Auchmuty	Auchmuty, by Kirkaldy	1	0	Writing, printing and cartridge.
James Craig	Newbattle	Newbattle, by Dalkeith	1	0	Printing and coloured.
Edward Collins	Dalmuir	Dalmuir, Dumbartonshire	2	4	Superf. and 2nd writing, printing and music, plate drawing, blotting and coloured.
Phillip Caddell and Co.	Auchindenny	Auchindenny, by Dalkeith	1	0	Writing and printing.
William Brookes	St. Leonards	Lasswade, by Edinburgh	1	0	Writing and printing.
Alex. Cowan and Son	Low Mill	Penicuik, by Edinburgh	1	0	News and other printing.
Alex. Annandale and Son	Polton Mill	Polton, by Dalkeith	1	1	Writing and printing.
John Cameron and Co.	Springfield	Springfield, by Dalkeith	1	1	Printing and mill boards.
James Brown and Co.	Esk Mill	Penicuik, by Edinburgh	2	0	Writing and printing.
Young, Trotter and Son	Broomhouse	Broomhouse, by Dunse	1	3	Chiefly news and other printing sorts.
Ebenezer Martin	Mill Bank	Ayton, Berwick-shire	1	0	Coloured, cartridge, brown and pressings.
Elizabeth Wilson	Dalbettie	Castle Douglas	1	0	Brown and grey.
George Laing and Co.	Balerno Mill	Balerno, by Edinburgh	2	2	Brown, cartridge and binders' boards.
Russell, Kerr and Co.	Kinleith	Kinleith, by Edinburgh	1	0	Printing, brown and coloured.
Alex. Cowan and Son	Kates Mill	Collinton, by Edinburgh	1	0	Printing.
Alex. Cowan and Son	Valleyfield	Penicuik, by Edinburgh	2	0	Superf. and 2nd writing and printing.
Charles Davidson	Muggie Moss	Muggie Moss, by Aberdeen	1	0	Brown and grey.
Edward Collins	Dalmuir	Dalmuir, Dumbartonshire	1	0	Brown, grey, cartridge, calender and coloured.
James M'Robie	Airthrey	Bridge of Allan, Stirling	1	0	Brown and grey.
James Watson	Townhead	Kilsyth, Stirlingshire	1	0	Brown and grey.
James Walkinshaw	Overton	Overton, by Greenock	2	0	Cartridge linings, danny blue and brown.

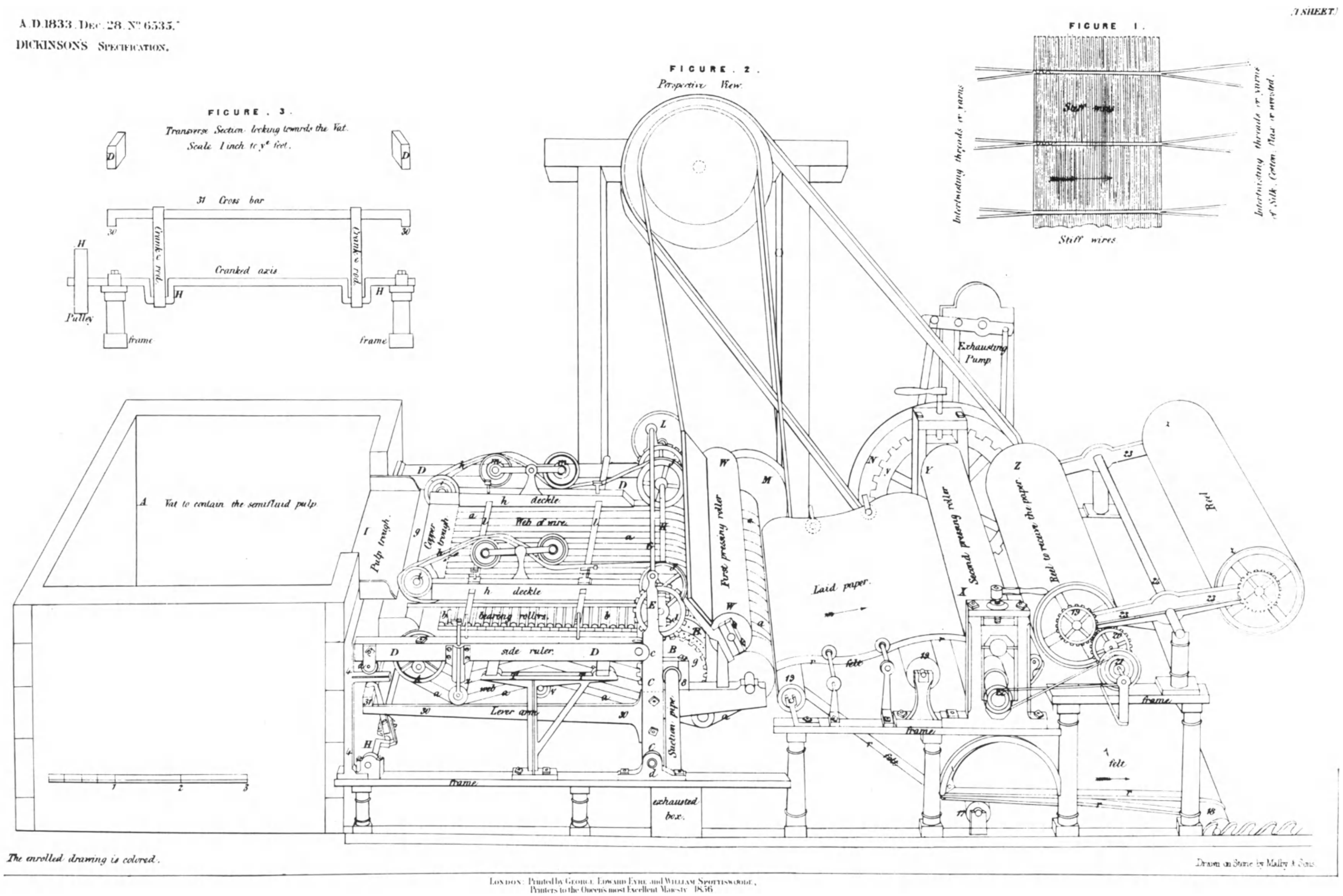
before it was joined together, so that he only had a making length of about 4 ft. In this machine, as can be seen in the drawing Fig. 2, he also had a forward and back shaking motion of the wire, instead of the horizontal shake which was a feature of the Fourdrinier machine.

Also incorporated in this machine was his suction-couch, which has been described elsewhere, which was combined with a press-roll set off at an angle from the couch, and bearing on a second press-roll, or wire-return roll, before the web was led off onto the felt, where it is shown marked as "laid paper".



References to the Parts of the Machine.—A Chest.—B Vat, 4 feet by 5.—C Sifter.—D Lifter.—E Endless wire, 5 feet wide.—F Deckel straps.—G Dandy, a wire cylinder.—H Lower roller of endless wire.—I Roller pressing upon H.—K First roller to the endless felt.—L First pair of pressing rollers.—M Second pair of pressing rollers.—N Roller receiving the sheet previous to its coming upon O.—O First hot cylinder.—P Second hot cylinder.—Q Third hot cylinder.—R Felted Cylinder.—S Ree.

No. 66. Isometric drawing of a complete paper-making machine of 1833.



No. 67. Drawing of George Dickinson's complete paper-making machine for making laid paper. This small and compact machine contains the suction-roll (B) patented by Dickinson in 1828, and this is situated under the wire, before the couch or "first pressing roller." The web of paper is reeled up wet, ready to be dried. The suction or "exhausting pump" for the suction-roll is shown at the back of the machine. The suction-pipe from the suction-roll is shown on the front of the machine.

Dickinson said that while his patent wire could be used on an ordinary Fourdrinier machine, he did not advise it, and he recommended that it should only be used on a machine made to his new design.

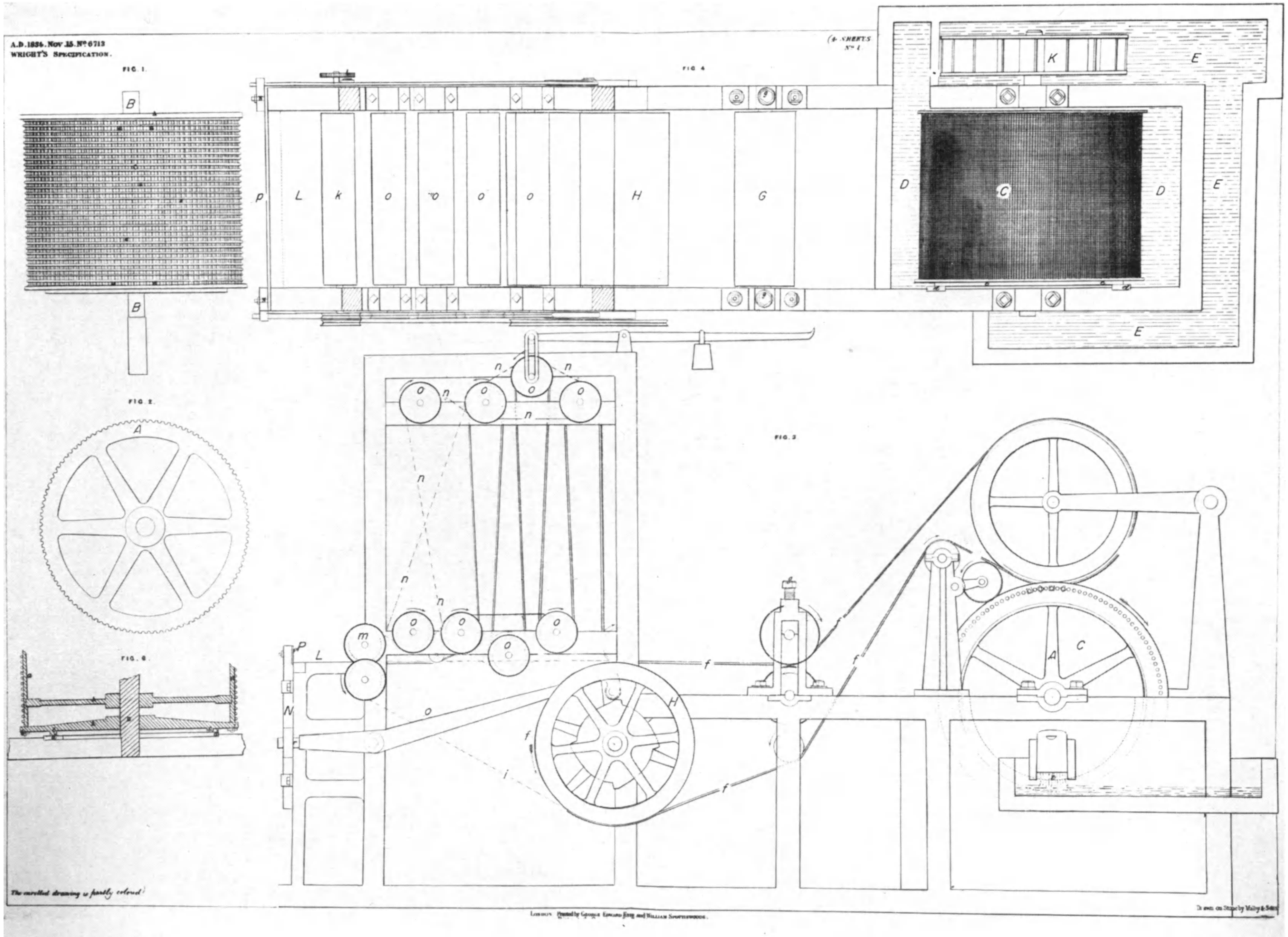
On the suction couch-roll, marked (B) on the drawing, he had slight grooves cut to correspond with the chain-lines of the wire, and so protect them from damage when passing through the press. This method also kept the wire running true, and stopped it from moving about laterally on the machine; but instead of his usual up-and-down shake motion, or the usual horizontal motion given to the Fourdrinier machine, he shook the wire backwards-and-forwards very slightly between the breast-roll and the couch-roll, so that it became tight and slack at regular short intervals all the time the machine was running. This was in order to imitate as closely as possible the shake of the hand-made paper-maker.

The drawing itself is self-explanatory, and it is not necessary to describe it in any great detail. It has the ordinary vat, the pulp trough, and the copper projection-board to let the stuff down onto the wire; it has ordinary deckles and tube-rollers, called "bearing-rollers", and side rulers; there is then the suction-couch (B), the top couch-roll (W), and the wire-return roll (a). The web then passes onto the felt, through the second press, and is subsequently reeled up on a change-over reeler. The "exhausting" pump for the suction-roll is shown at the back of the machine, and the suction-pipe can be seen coming out of the end of the roll (B) into a water-box. Figure 3 is a drawing of the shake motion which controlled the breast-roll, and shook the wire backwards-and-forwards towards the pulp vat and couch alternately.

It is not clear whether this machine was ever much of a success, although there is no doubt that George Dickinson was an extremely ingenious paper-maker, and certainly had good sound reasons for his inventions. He must be given the whole of the credit for inventing the suction-roll, which was not used to any great extent for nearly a hundred years afterwards, and without which many modern paper-making machines would be of very little use.

Lemuel Welman Wright, of Chelsea, who described himself as an engineer, patented several interesting things in connection with the mould-machine, which had been invented and quite successfully developed by John Dickinson. One of the most interesting things in Wright's patent was the construction of the cylinder-mould (No. 68). This was made in the form of what we should now call an extractor-drum (C). It had one end closed and the other end open, and it was sealed around the periphery by a sealing band which joined it to the vat. This prevented any water and stuff from the vat getting into the open end of the cylinder. The open end was connected to a trough, so that the water, which had passed through when the pulp had been deposited on the outside of the cylinder, might pass away. The flow of the water was regulated by a sluice or cock. This limited the flow of water from within and regulated the pressure on the outer surface of the cylinder. The cylinder was driven by a travelling endless felt which passed between the cylinder-mould and the couch roller, then between the press rollers and over the driving wheel (H) which drove the whole machine. The sluice regulating the flow of water from the interior of the cylinder-mould into the trough is shown in the drawing, Fig. 3. This water was used again for diluting the stuff in the vat, into which it was lifted by a bucket wheel.

An unusual feature of this machine was the method adopted for drying. The paper was led up and down over a series of small rollers, in much the same way as tub-sized paper is often dried at present. These rollers are shown in the drawing, marked (o). As the paper passed up and down between these rolls, a current of hot air was blown through the box in which the whole of the drying-rollers were situated. The box was open at the top and bottom to allow free circulation of air. Wright maintained that satisfactory drying was carried out in this manner, and that when the paper passed over these rollers it enabled cutting off on the flat table (L) in the drawing, by means of a knife (p) dropping down on it as it passed along the table. The length of the sheet to be cut



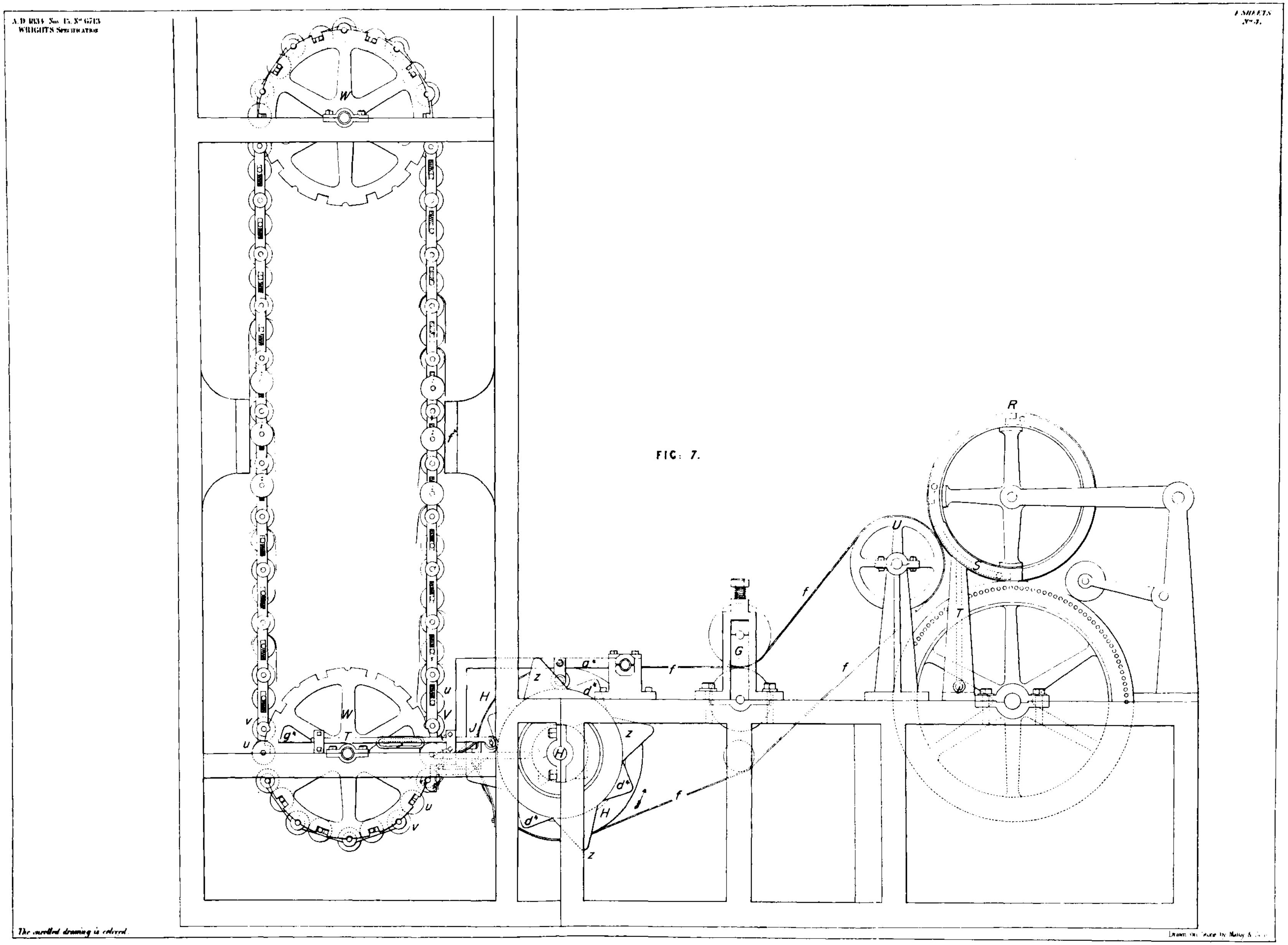
No. 68. Plan and vertical sectional drawing of Wright's patent cylinder-mould machine, which has a vertical dryer for drying the paper web continuously.

could be regulated by the levers and cams on the main driving wheel, so that a predetermined length of sheet could be cut off. If the width of the cylinder-mould was greater than the required width of paper, ribbons of thin webbing were fastened round the cylinder-mould to cover up a portion of the wire-work, and so make a narrower sheet of paper.

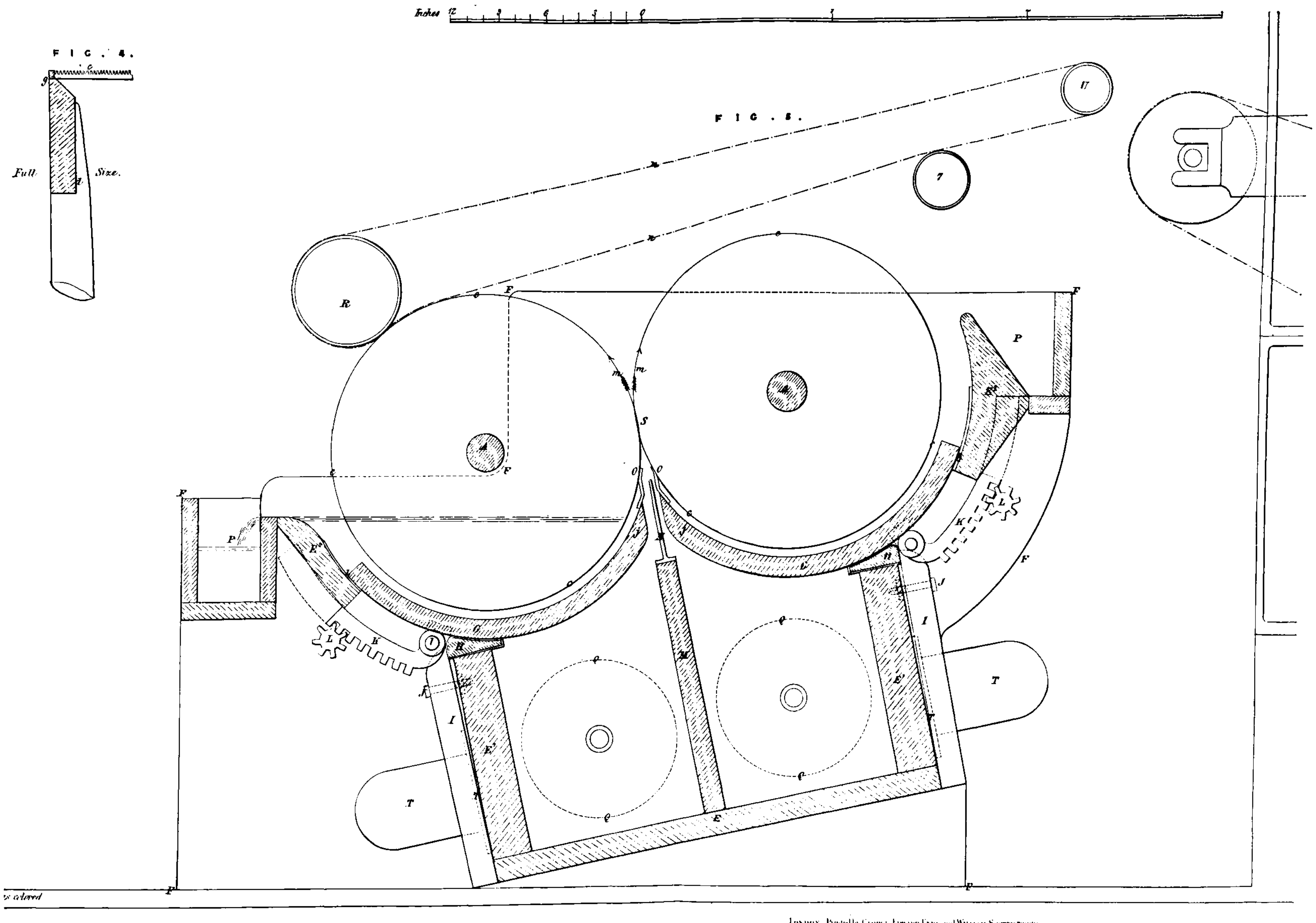
Wright could also arrange his cylinder-mould for forming paper into separate sheets by fixing wires around the mould and across it, so that the stuff did not form there. This method has been adopted on modern mould-machines making banknote and similar types of paper. He also made a modification to his original couching-cylinder, or roll (Fig. 7, No. 69). In this instance he covered the top couch-roll (R) with wire-cloth, and picked up the web of paper from the cylinder-mould onto the wire-covered couch-roll, which in turn passed it over onto the felt-covered roll (U) in the drawing. He applied suction to this top couching-roll (R), and it thus became a *suction transfer-roll* for taking the sheets of paper off the cylinder-mould and passing them onto the felt. He made the suction transfer couch-roll of segments, so that the air was drawn intermittently through it and it could be adjusted so as to suck up each separate sheet from the cylinder-mould, as the sheet passed onto its periphery, the vacuum dropped while the sheet was passed onto the wet-felt passing round the roll (U). This was an ingenious arrangement of the cylinder-mould machine, and seems to be the first mention ever made of the suction transfer roll, which has become quite a common feature, but only very recently, on modern machines. As the sheets of paper adhering to the felt passed through the rolls (G) they were pressed, and water was removed; they then passed on the felt round the roll (H), which was actually the driving roll of the machine, and were doctored off by a steel doctor blade (j). This doctor directed the separate sheets to a series of what were called "pinching rollers", which were formed into an endless chain. These pinching rollers were mounted in pairs, where their axles turning in two endless chains (V) extended over two pairs of notched wheels (W). The axles of the lower rollers (v) of each pair formed the bolts of the links of the chain. The axles of the upper rollers turned in brass boxes capable of sliding in the slots of the links, having small spiral springs in the slots to keep them down. The upper roller (u) had to be raised the moment that the sheet of paper passed down the inclined plane (j) from the doctor, so that it might be gripped between the two rollers (u) and (v). The sheets were carried round the drying apparatus until they came back to the bottom wheel of the chain, where they were automatically released and discharged from the machine. The endless chain carrying the sheets was enclosed in a chamber in which warm dry air was circulated in order to dry the sheets of paper as they passed round.

In 1834, John Donkin, the oldest surviving son of Bryan Donkin, made some improvements to the vat or cylinder-machine. It will be remembered that John Dickinson had already made a machine with two separate vats and two separate cylinder-moulds, with the idea of bringing together two sheets of paper, and joining them at the press to make a two-ply sheet. This was the beginning of the multiple-vat board-machine.

John Donkin, in his patent of November, 1834, however, made a modification to this. He arranged that the two cylinder-moulds were situated in the same vat, so that they could almost touch each other, and when the web of paper had formed on each of these cylinders, the two webs were brought together by gentle pressure where the two peripheries of the cylinders met, at the point (S) on Fig. 5, No. 70. The drawing shows how this arrangement worked. The two moulds operated in two vats which could be separated, and in which two different coloured paper stocks could be used, or two different qualities of stuff. The vats were sealed against each other at the point (o). One cylinder-mould was situated rather lower than the other, so that the sheet should be formed on this mould first and be in position when the other mould delivered its sheet on top of it. The height of the stuff could be regulated by racks altering the height of the stuff in the vat. When the two sheets had been formed and had come together at (S) they were carried forward still on the outside of the cylinder-mould (F), and couched off at the couch-roll (R), afterwards taken through

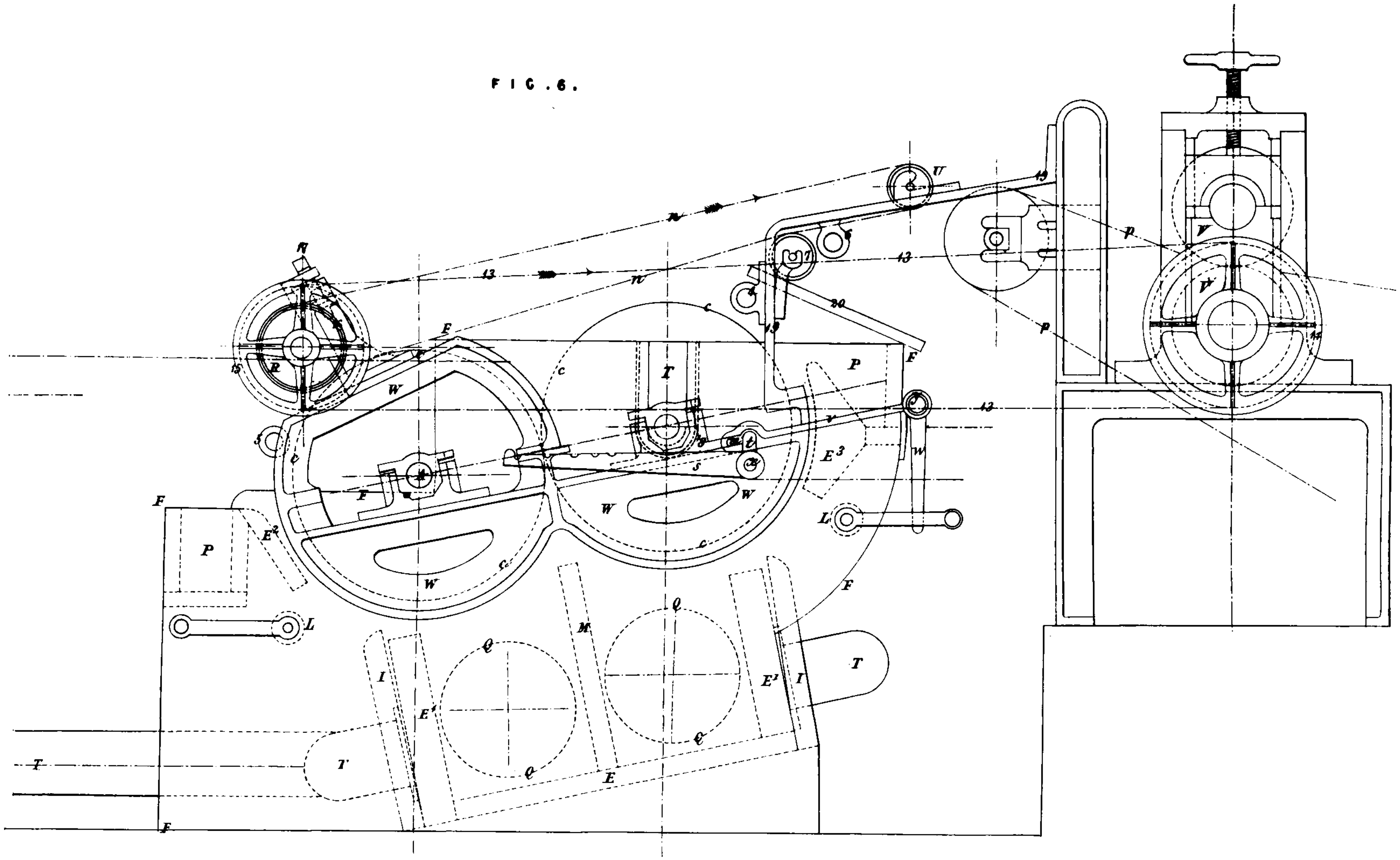


No. 69. Vertical section of Wright's cylinder mould machine showing chain dryer for drying single sheets. This drawing also shows the suction couch roll (R) for picking the sheet off the mould and transferring it to the felt passing over roll (U).



No. 70. John Donkin's doubie cylinder-mould machine showing the two vats and two cylinders touching at (S); couching roll (R) for removing the duplex sheet and passing it on the felt (n) to roll (U) whence it was transferred to the press part of the machine.

FIG. 6.



No. 71. Donkin's double cylinder-mould machine showing felt runs and press part.

a press, which is shown in No. 71, and then onto the usual drying apparatus. This consisted of drying-cylinders, which were in general use on paper-making machines by this time.

This machine, in common with many other inventions of this early date, does not seem to have been put into operation on a commercial scale, as nothing more is heard of it, but it is reasonable to suppose that it would have worked, and in fact Donkin said that it performed quite satisfactorily. This method was abandoned in favour of the Dickinson method, which was developed further than his original patent in which there was only one mould, until there were many moulds, and then the multi-vat board-machine by the end of the nineteenth century, on much the same lines as it is in operation at the present time.

There is a notebook of Bryan Donkin and Company covering the period 1833 to 1840, with details of many pieces of machinery made for paper mills at home and all over Europe, and including water wheels and many alterations to existing machines.

Facsimiles are shown (No. 72) of pages from his book, giving the calculation for the drive of No. 66 drying machine, and calculations for Messrs. Smith and Menier's Mill in 1836. Among many other jobs in 1836 was one for supplying a water wheel for Lefebre's paper-making machine. This wheel was 20 ft in diameter and had a circumferential speed of 4 ft/sec. The machine speeds were to be from 9 ft/min to 53 ft/min.

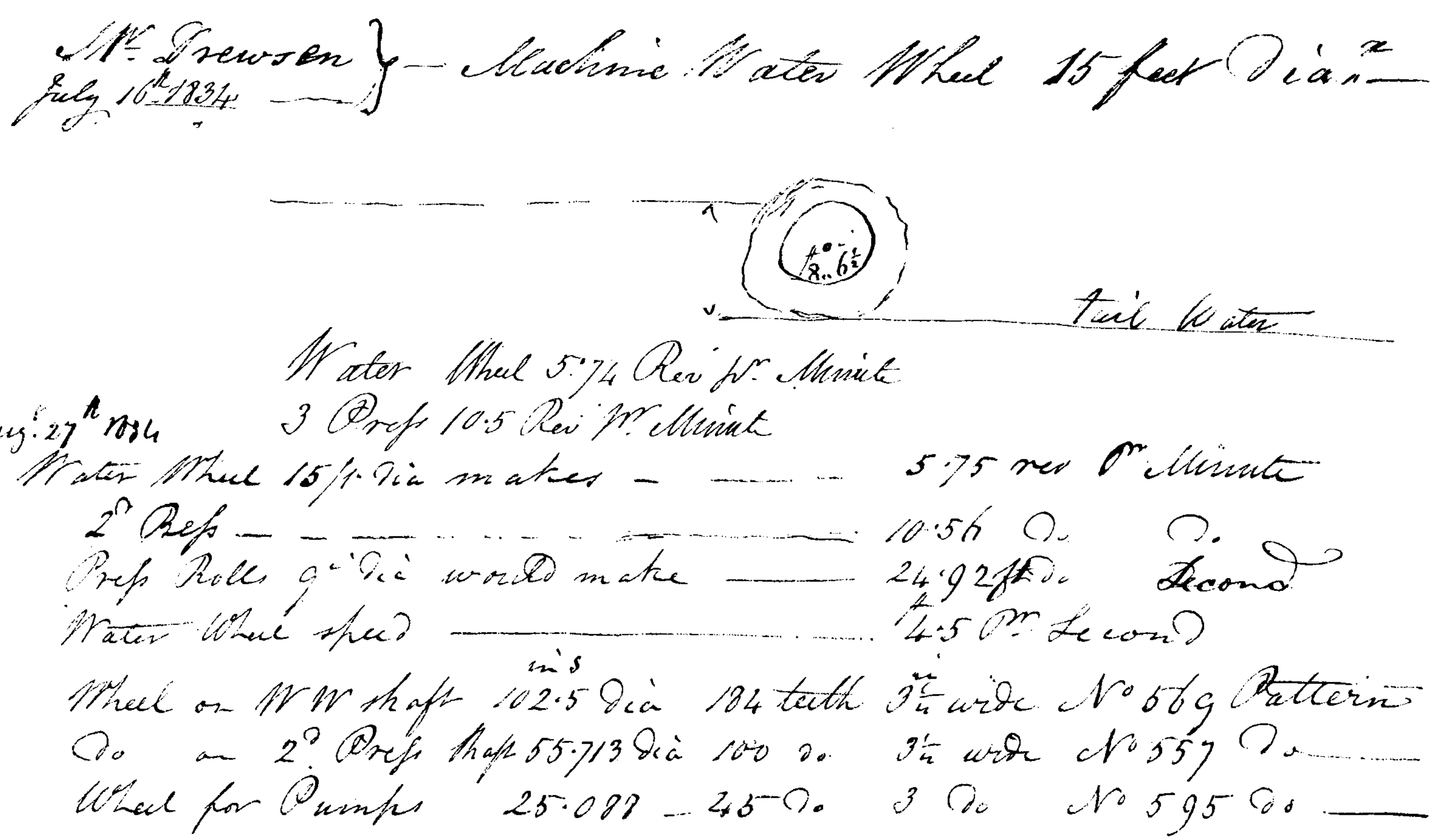
Although all the notes made by Donkin during his visits to various mills do not entirely refer to the development of the actual paper-making machine, nevertheless they give an indication of the development of the mills to keep pace with the greater output brought about by the development of the machine, and of the methods being employed to prepare rags and straw and also sizing. The actual figures, showing the practice at the various mills, are a valuable record of the progress being made in all branches of paper-making at this time.

Simpson, of Maidstone, said that a beating engine which would give 100 lb of paper from rags would only give 70 lb from straw. A machine wire would 40 tons make of straw paper and last seven weeks. The two beaters could give 180 engines a week, or each beater would be emptied ninety times in a week. The number of hours is not stated, but the stuff could not have had very long in the engine.

In 1835, John Dickinson patented the u e of magnets for removing metallic particles from paper-stock on its way to the wire. He arranged a sand-trap with a fairly wide thin sheet-copper bottom, so that the stuff flowed at a depth of about 1½ in., rather more slowly than had been the general practice in bringing the stuff onto the wire on other machines. He put rows of horseshoe magnets very close to, and underneath, the copper bottom of the sand-trap or trough, and caused the particles of metal to be held firm by the magnets on the bottom of the copper trough while the paper-making machine was working. As soon as the machine was stopped, the magnets were removed and the metallic particles washed away. He maintained that a very large amount of metal was trapped in this way, which had previously got into the paper. These horseshoe magnets have been used in quite recent times in sand-traps for the same purpose.

About this time Dickinson also tried to get over the difficulty of having so many of the fibres laid the same way, parallel to each other, on the cylinder-mould. In order to solve this problem he caused the stuff to enter the vat at the side of the mould in a series of pipes, and to be fed along channels at right-angles to the surface of the cylinder-mould at a fairly good speed, so that the fibres would not have time, before they were sucked onto the wire of the mould, to align themselves parallel. This method has not been in general use on cylinder-mould machines, so it can be presumed that it was not found to be entirely satisfactory.

Donkin was supplying paper-making machines to Sweden in 1836. One machine went to Lessebo, one to Gryksbo, and one to Holmen, so it is obvious that his export trade must have been considerable.



Mr. Drewsen } — Machine Water Wheel 15 feet Diam —
July 16th 1834

Tail Water

Water Wheel 5·74 Rev per Minute
Aug. 27th 1834 3 Press 10·5 Rev per Minute
Water Wheel 15 ft Dia makes — 5·75 rev pr Minute
2d Press — 10·56 Do Do
Press Rolls 9 in Dia would make — 24·92 ft Do Second
Water Wheel speed — 4·5 pr Second
Wheel on W W shaft 102·5 ins Dia 184 teeth 3¼ wide No 569 Pattern
Do on 2d Press shaft 55·713 Dia 100 Do 3¼ wide No 557 Do
Wheel for Pumps 25·099 — 45 Do 3 Do No 595 Do

No. 72. Pages 138 to 141 present facsimiles of pages of Bryan Donkin's notebook for the period 1833 to 1840. The book contains many calculations of the speeds and sizes of water-wheels, beaters and paper-making machines. On page 139 is the calculation for driving No. 66 drying machine and on pages 140 and 141 are the calculations for Messrs. Smith and Menier's water-wheel to drive beaters and paper-making machine.

Calculation to drive No. 66 Drying Machine

Dia. of Pinion on driving Spindle to Drying Machine = 10·22 ins. – 25 teeth
Dia. of Rigger on Do – Do — Do — = 26·875
Dia. of Second Press Cylinder — — = 9·125
Dia. of Drying Cylinder — — — = 26·33
Dia. of Wheel on Do Do — — — = 27·75 – 78 teeth

10·22 : 9·125 :: 26·875 : 24
9·125
26·875
45625
63875
73000
54750
18250
10·22)245·234375(23·9955 say 24
2044
4083
3066
10174
9198
9763
9198
5657
5110
5475
5110

26·33 : 27·75 :: 24 : 25·21 ins.
27·75
24
11100
5550
26·33)666·00(25·21
5266
13940
13165
7750
5266
4840
2633
207

Required dia. of Rigger of 2nd Press = 25·21 ins.

No. 72 (*continued*)

Mess^rs Smith & Meyner 17th May 1836

Water Wheel 20 ft dia^r 8 ft Wide outside Overshot

four Engines 2 Washers 2 Beaters

2 fly Wheels

the speed to be got by two Motions

Speed of beater 127 revolutions p^r Minute

(speed 3½ ft per Second as near as can —

3·1416
18
4 | 56·5488

14) 60 (4·28 number of revolutions of Water Wheel Machine)
56
40
28
120
112
8

Paper Machine Wheel 18 ft dia^r

spur Wheel 138 teeth on W W Shaft

55 do — shaft

$428 \times \frac{138}{55} = 10·7$ rather too fast —

rough calculation

No. 72 (*continued*)

continued

Dia of Water Wheel 20 ft
spur wheel on do —— 90 teeth
Pinion —— 49 do
Large Wheel —— 152
Pinion —— 49
fly wheel —— 208
beater pinion —— 25 speed of beater say 172

$$172 \times \frac{25}{208} \times \frac{49}{152} \times \frac{49}{90} =$$

3.1416
20
62.8320 circumference of W W

172
25
860
344
4300
49
38700
17200
210700
49
189630 0
84280 0
2845440 | 1032430 0 | 3.62
8536320
17879800
17072640
8071600

208
152
416
1040
208
31616
90
2845440

62.8
3.6 number of revolution Pr Minute
3768
1884
60 | 226.08 | 3.7 feet Pr Second of Large Water Wheel
180
460
420
40

No. 72 (*continued*)

In England the paper duties were reduced from threepence to three-halfpence per ream on the accession of Queen Victoria in 1837.

Holland was very slow in putting in a paper-making machine and, for many years after the introduction of the paper-making machine into France and Germany, retained the old hand-made methods, although Germany had its first paper-making machine in 1818, and was supplying the Dutch market with machine-made paper. Germany was in fact supplying one of the Dutch newspapers, which had the largest circulation, with all its newsprint in 1839.

In 1837, however, the van Gelders decided to put in a paper-making machine, and eventually ordered one, with its various auxiliaries, through a Rotterdam engineering firm. This firm ordered the machine in England, but unfortunately not from Donkin, the original makers, and after numerous difficulties the machine was erected in a mill "Het Fortuin" at Zaandyk in November to December, 1838. This machine was to make heavy wrapping paper 60 in. wide, and a second machine was intended to be ordered which would make white paper.

One of the English workmen who came to erect the machine for the van Gelders also showed them how to make engine-sized paper, as, naturally, tub-sizing was still being used for the hand-made papers. This seems to have been the first time that anybody in Holland knew anything about sizing in the stuff, although Illig published his invention in 1806. The recipe was to boil 138 lb of rosin with 56 lb of soda in 150 gal of water for five hours.

The van Gelders paid very dearly for their courageous step of ordering a paper-making machine. Difficulties first arose with the suppliers of the machine, as they had ordered it from an engineering firm in England which had never previously built one. Then they were in trouble with complaints and obstruction from a neighbouring paper-mill, chiefly due to their emission of black smoke. The expensive machinery proved most costly to operate, and consumed enormous quantities of fuel. They were very heavily booked with orders, but in spite of this they lost large sums of money from 1839 to 1843, and it may be said that this machine nearly ruined them.

However, in 1845, the three eldest sons of the older partners took over from their fathers the old mill "De Eendragt" and erected in it another paper-making machine for making wrapping paper. They formed a partnership which they called "Van Gelder Zonen", and "emerged triumphant from the battle with steam power".

It was really the introduction of steam in place of windmills which had been one of the major causes of the elder van Gelders' difficulties, as they were in constant trouble over black smoke.

In 1848 there were only four paper-making machines working in Holland, whereas in England there were over a hundred. It will thus be seen that during the first half of the nineteenth century Holland lost its leading place in world markets as a supplier of paper on account of its hesitation and delay in adopting the new paper-making machine.

11

Improvements to Fourdrinier Machines

THE Fourdrinier firm of wholesale stationers was in 1838 operating under the name of Fourdrinier Hunt and Company, and continued to do so until 1902, when Lepard and, Smith purchased the firm's stocks of paper and the right to use their watermarks.

Culter Paper Mills were sold in 1837 for £10,000, and there were two paper-making machines, one 7 ft wide and quite new, the other, older machine being 6 ft wide and described as being equal to new, had been entirely rebuilt and brought up to date in 1836. These two must have been the widest machines at the time, although the wires would not be quite so wide as the size stated for the machine.

It is not generally known that John Marshall, the dandy-roll maker, was also making paper-making machines for export. It appears that he did not want other engineers in England to know that he was making paper-making machines. It is quite clear, however, from the following letter written by Marshall's son, that the latter was selling equipment other than machine wires to mills on the Continent. It is fair to assume that when he was journeying abroad selling paper-making machine wires, he saw the opportunity of selling paper-making machines as well, because his firm would have an intimate knowledge of the wet ends of Fourdrinier machines.

Copy of trade letter to John Marshall—dandy-roll inventor—from his son:

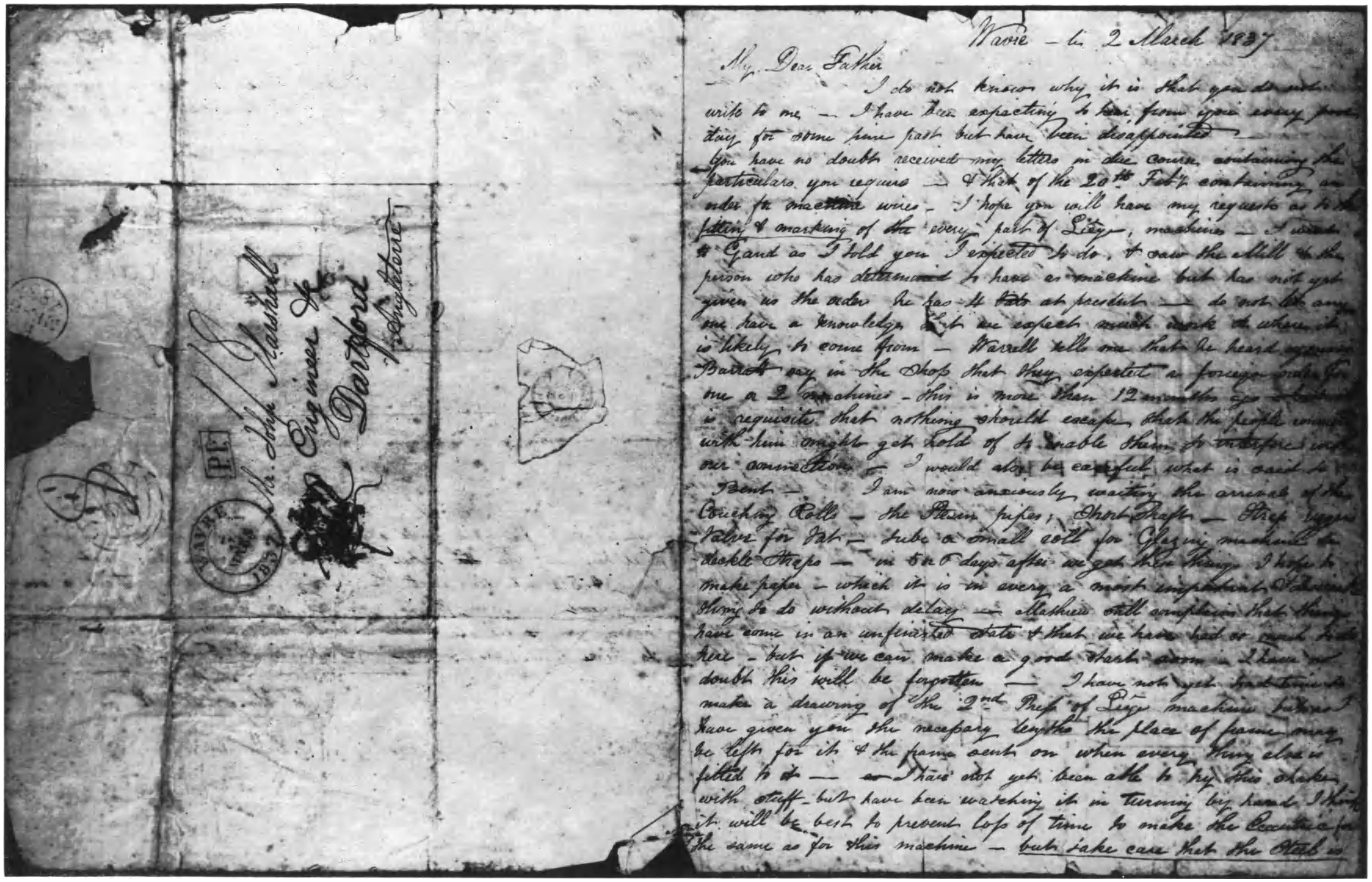
Wavre,
2nd March, 1837

My Dear Father,

I do not know why it is that you do not write to me—I have been expecting to hear from you every post day for some time past but have been disappointed.

You have no doubt received my letters in due course containing the particulars you require—and that of the 20th February containing an order for machine wires—I hope you will have my requests as to the fitting and marking of every part of Liége machines—I went to Gand as I told you I expected to do, and saw the Mill and the person who had determined to have a machine but has not yet given us the order. He has four vats at present—do not let any one have a knowledge that we expect much work or where it is likely to come from—Warrell tells me that he heard young Barratt say in the shop that they expected a foreign order for one or two machines—this is more than twelve months ago—but it is requisite that nothing should escape that the people connected with him might get hold of to enable them to interfere with our connections—I would also be careful what is said to Bent.

I am now anxiously waiting the arrival of the Couching Rolls—the Steam pipes, short shafts—strap riggers—valve for vat—a small roll for Glazing machine—deckle straps—in five or six days after we get these things I hope to make paper—which it is in every way a most important and



Mr John Marshall
Engineer &c
Dartford
Angleterre

PE

HAVRE 1837

Havre — le 2 March 1837

My Dear Father

I do not know why it is that you do not write to me — I have been expecting to hear from you every post day for some time past but have been disappointed — You have no doubt received my letters in due course containing the particulars you require — & that of the 20th Feby containing an order for machine wires — I hope you will have my requests as to the fitting & marking of the every part of Liege machine — I went to Gand as I told you I expected to do, & saw the Mill & the person who has determined to have a machine but has not yet given us the order he has 4 vats at present — do not let any one have a knowledge but we expect much work & where it is likely to come from — Warrell tells me that he heard [illegible] Barrett say in the Shop that they expected a foreign order for one or 2 machines — this is more than 12 months ago [illegible] is requisite that nothing should escape that the people [illegible] with him might get hold of to enable them to interfere with our connections — I would also be careful what is said to Bent — I am now anxiously waiting the arrival of the Couching Rolls — the Steam pipes, Short Shaft — Stop [illegible] Valves for Vat — Tube & small roll for Glazing machine & deckle Straps — in 5 or 6 days after we get these things I hope to make paper — which it is in every a most important [illegible] thing to do without delay — Mathieu still complains that things have come in an unfinished state & that we have had so much [illegible] here — but if we can make a good start soon I have no doubt this will be forgotten — I have not yet had time to make a drawing of the 2nd Press of Liege machine but as I have given you the necessary lengths the place of frame may be left for it & the frame sent on when every thing else is fitted to it — as I have not yet been able to try this shake with stuff — but have been watching it in turning by hand I think it will be best to prevent loss of time to make the Eccentric for the same as for this machine — but take care that the [illegible]

No. 73. Facsimile of a letter from John Marshall's son to his father, proving that Marshall not only made machine wires and dandy-rolls, but that he also made and exported paper-making machines.

desirable thing to do without delay—Mathew still complains that things have come in an unfinished state and that we have had so much to do here—but if we can make a good start soon I have no doubt this will be forgotten—I have not yet had time to make a drawing of the second press of Liége machine but as I have given you the necessary lengths the place of frame may be left for it and the frame sent on when everything else is fitted to it—as I have not yet been able to try this shake with stuff but have been watching it in turning by hand I think it will be best to prevent loss of time to make the eccentric for the same as for this machine—*but take care that the steel is . . .*

Letter addressed:

Mr. John Marshall,
Engineer, etc.,
Dartford,
Angleterre.

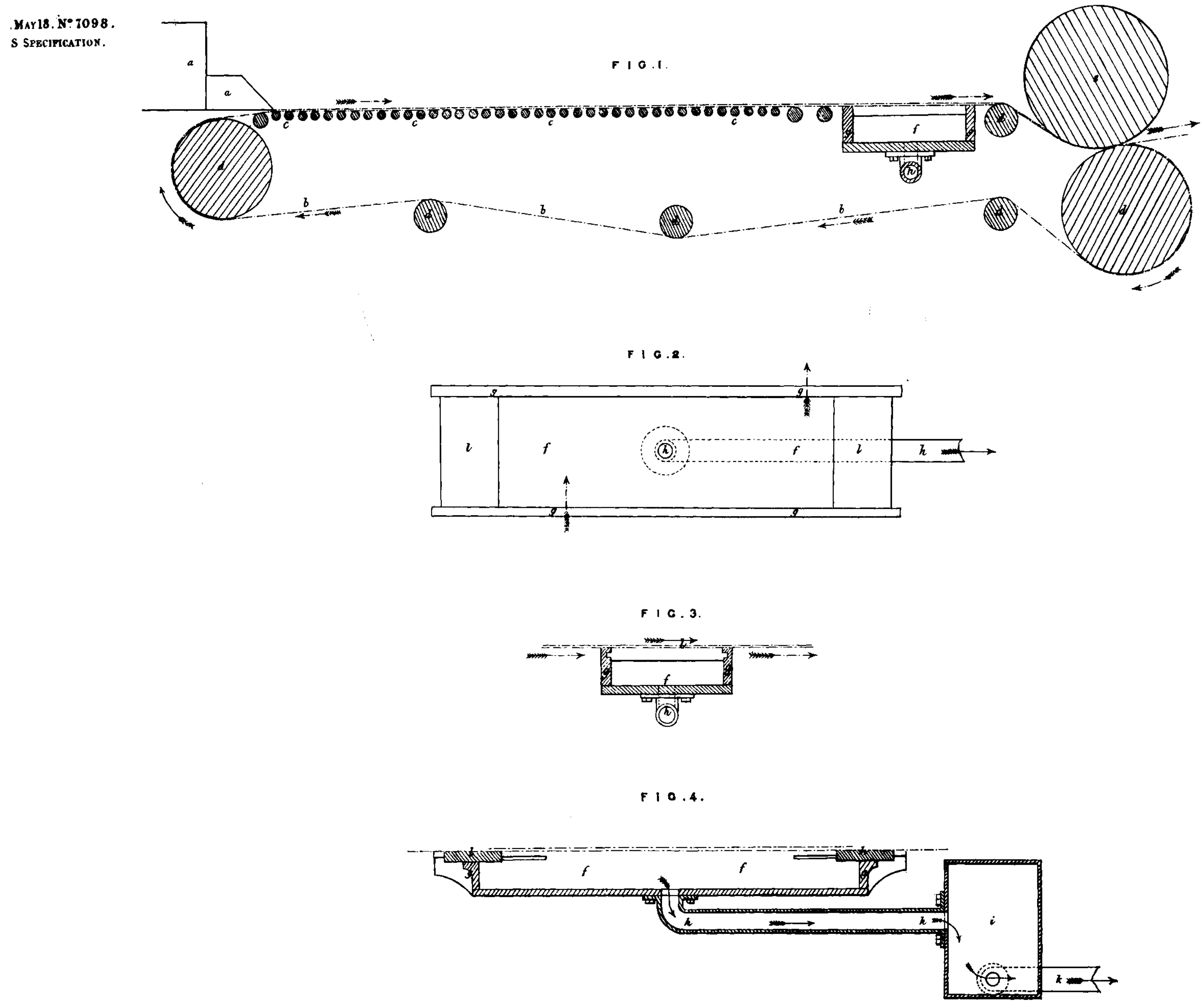
The suction-box applied to the Fourdrinier machine, and placed under the wire, was first patented in Britain by James Brown, paper-maker, of Esk Mills, Penicuik, Scotland (now called "The Paper-making Town"). This was in 1836.

Vacuum boxes of various types had been used before, but these had mostly been used on cylinder mould machines. Where they had been used on the Fourdrinier-type of paper-making machine, they were inside a perforated roll (suction-roll). Brown's invention was, in fact, the first flat suction-box applied to a Fourdrinier wire-part. Nowadays it is common practice to use a large number of boxes with perforations or slots in them, but many mills still continue to use the open type of box, especially on fine papers, and these give excellent results, probably better than the others.

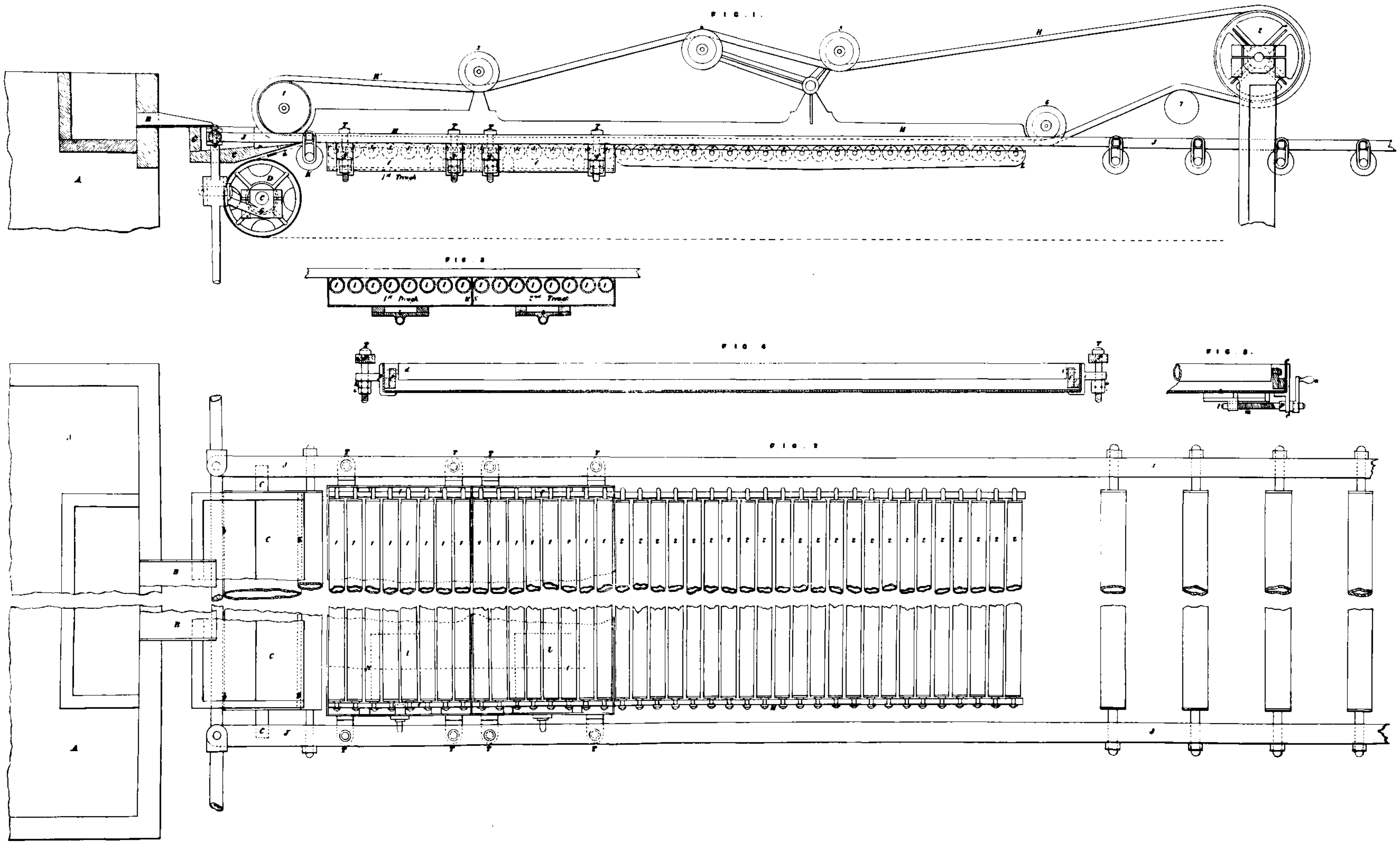
Brown's invention is shown in the drawing No. 74. In Fig. 1 there is a normal Fourdrinier wet-end with one large vacuum-box. Figure 3 is a section of the box, and Fig. 4 is also a section showing how the water and air are brought out from the centre of the box to the vacuum-pump. It will be observed that in this particular Fourdrinier wet-end the breast-roll is lower than the tube-rolls, and the wire rises up to a large tube-roll before it reaches the small tube-rolls and the point at which the pulp passes onto the wire. Movable slides were provided for changes in deckle.

In 1838, Thomas Sweetapple, of Colteshall Mill, Godalming, Surrey, invented and patented the forming-trough, or forming-board as we should now call it. He argued that when the stuff on the ordinary Fourdrinier machine ran off the apron onto the wire, the water left the fibres too quickly, and the sheet was not properly made. In other words, the fibres did not have a long enough time floating in water under the influence of the shake to felt properly together and make a "well-shut" sheet, as he called it. He therefore fitted two troughs immediately after the first wire-lead roll following the breast-roll (either one or both of these troughs could be used) in order to get much better formation of the sheet of paper, as the wire-frame was under the influence of the shake and only very little water escaped, mostly over the tops of the boxes and over the edge. Each box was fitted with a valve so that more or less water could be allowed to drain away if necessary, and also for emptying and cleaning out the boxes when the machine was shut down.

The whole wet-end is shown in Fig. 1 of the attached drawing No. 75. There is the usual trough (B) for allowing the stuff to flow into the breast-box (C). The breast-roll in this case was fixed at a very much lower level than the first wire-lead roll, and the apron was attached to the breast-box and carried forward over the first tube-roll of Sweetapple's patent box. The rest of the wet-end was quite normal, there being ruler-bars, or frame, to which the tube-roll supporting racks were fixed, and also, in this case, the boxes themselves. The tube-rolls in the boxes had their own separate racks, with bearings in which they revolved, and the boxes were placed very close together so that the space between all the tube-rolls, marked (l), was approximately the same. After the boxes, the



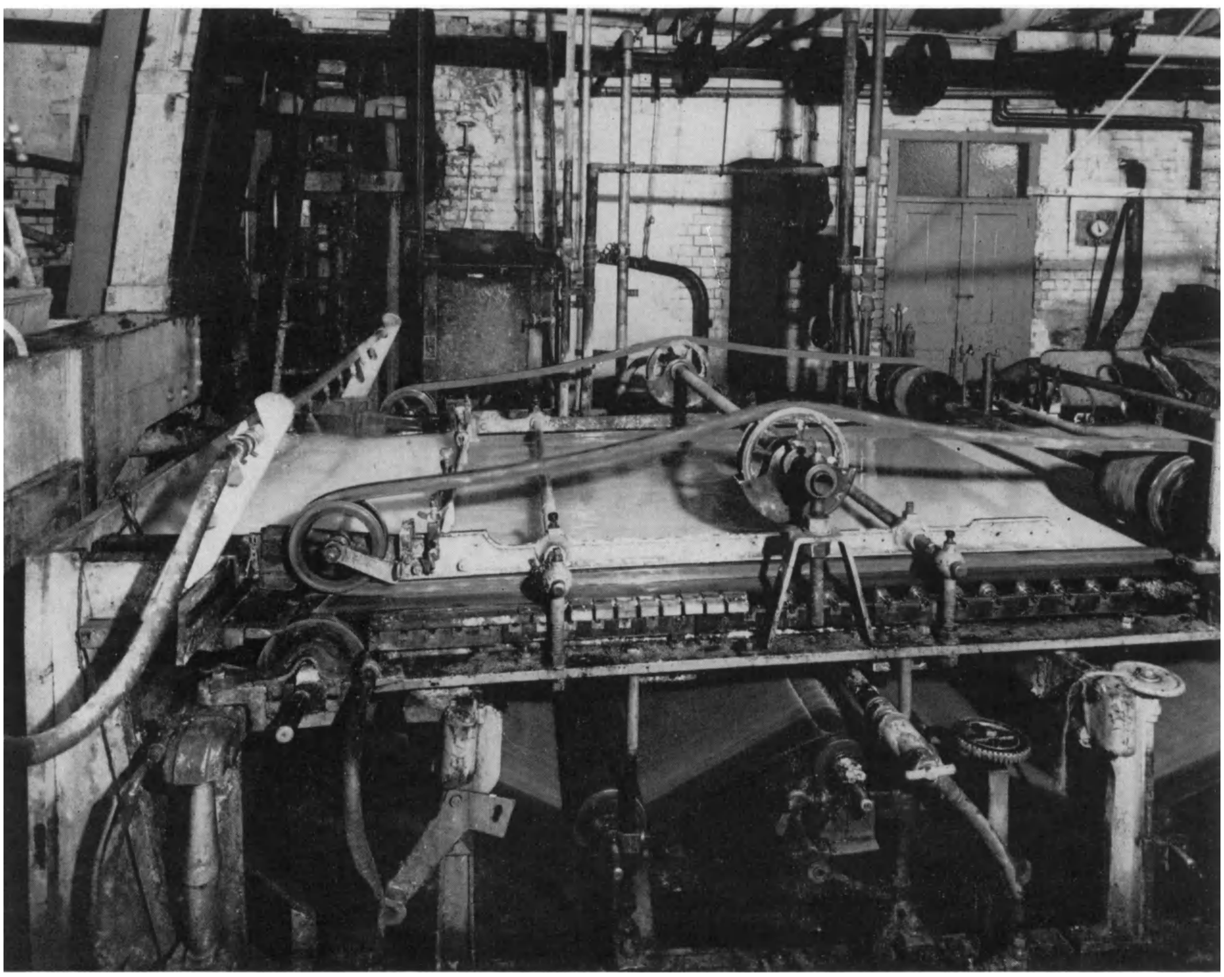
No. 74. Drawings of Brown's arrangement of the first flat suction-box to be used on a Fourdrinier paper-making machine in Britain. The drawings show the position of the box under the wire and also details of the suction-box.



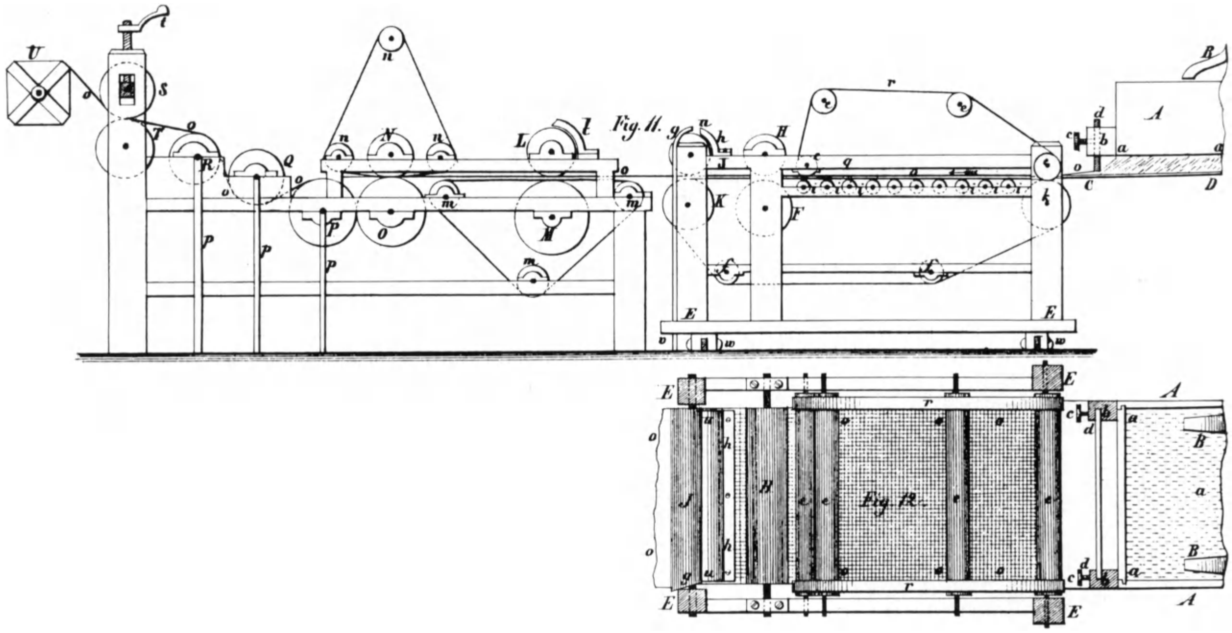
No. 75. Thomas Sweetapple's forming trough in elevation and plan on a paper-making machine and details of the forming troughs.

tube-rolls operated in the ordinary way until most of the water was out, and until the deckle-straps left the wire. The wire was then supported on further tube-rolls of bigger diameter, and spaced much farther apart. This was an extremely interesting invention because only very recently similar boxes are being used, in which the tube-rolls revolve, with the very same object, and also forming-boards are in use which have virtually the same effect on the paper formation as did these boxes of Thomas Sweetapple, a hundred and twenty years ago. Donkin mentions in his diaries, when referring to some of his new machines, that the buyer wanted "Sweetapple's invention" in the wire-part.

John Evans, who was a paper-maker in Birmingham, succeeded in producing a vacuum in the suction-box under the wire by other means than the very costly air-pumps which had been used hitherto. He considered these to be very expensive in capital expenditure and also very costly to run and maintain on account of the wear. He therefore produced a very ingenious suction-pump, which is shown in the drawing No. 78. He led the pipe from the suction-box into a vessel which was divided into three tubes or pipes, marked (d) in the drawing. One of these pipes came up beyond the water level in the tanks (a, b and c). These tanks contained water which was put in to begin with, and



No. 76. Sweetapple-type forming-troughs, identical with those in Sweetapple's patent drawings of 1838, working on a paper-making machine at Melbourne Mills of Australian Paper Manufacturers in 1953. The machine was built by Redfern, Smith and Law, of Bury, in 1871.



No. 77. König and Bauer paper-making machine about 1838. This drawing, showing elevation and plan of the German machine, shows two presses at the wire, and two felted wet presses, the first with the felt below and the second with the felt above the sheet. At the breast-roll end there is a "projection slice" for levelling out the stock as it flows from the breast-box to the wire. The drawing is from *Die Papierfabrikation von Dr. W. A. Rüst*, 1838, Berlin.

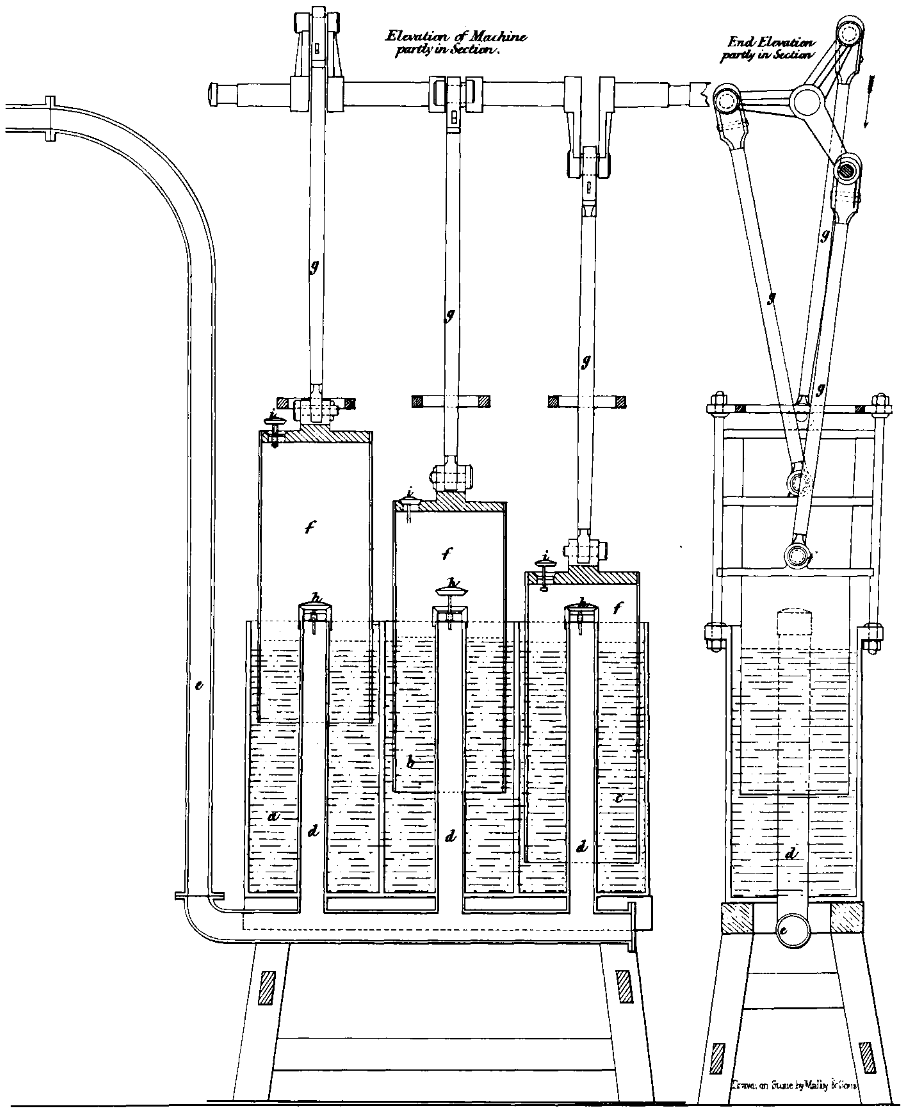
at the top of each of the pipes (d) there was an inlet valve (h). There were three movable cylinders which were partly submerged in the water, and which were moved up and down alternately in the tank of water by means of a crank-shaft. The operation of drawing air from the vacuum-box was as follows: when the machine started up, the crank-shaft was started, and the cylinder (f) began to move up. This caused a vacuum and lifted the inlet valve (h) so that air from the suction-box came into the inside of the cylinder (f). When this cylinder reached top dead centre, the inlet valve closed, and the exhaust valve (i), situated at the top, opened, and as the cylinder came down, the air from (f) was exhausted. This reciprocating movement continued so long as the crank-shaft worked, and drew air from the suction-box.

Evans maintained that he got quite sufficient vacuum in this way to dry the paper as it passed over the suction-box on the machine and that it was inexpensive to buy and cheap to maintain and run.

The first paper-making machine in Norway was supplied by Donkin in 1838 for Bentse Brug (No. 79).

One of the few things patented by Bryan Donkin, of Fort Place, Blue Anchor Road, Bermondsey, was a means of getting dirt and grit out of paper-stock before it went onto the machine. It was in the nature of a sand-trap, and it is fully explained in the diagram No. 80. Figure 1 is a plan of the troughs carrying the stuff towards the paper-making machine, and the pear-shaped marks in the drawing are holes sunk in the bottom boards of the sand-trap. The actual shape of these holes is shown in Fig. 3, which is a cross-section of the board in which the holes were made. As the stuff passed along, diluted ready for going onto the wire, particles of sand and grit were trapped in these small oval holes, and prevented from getting into the paper. This was quite a new idea for catching sand, although of course many different systems have been in operation since, chiefly the ladders and pieces of rough felt laid in the bottom of the sand-traps which were fixed in the stuff-troughs.

The boards were loosely fixed in the bottom of the sand-trap, and kept from floating by lead weights placed on each of them. Thus the boards could easily be taken out for cleaning. Each of

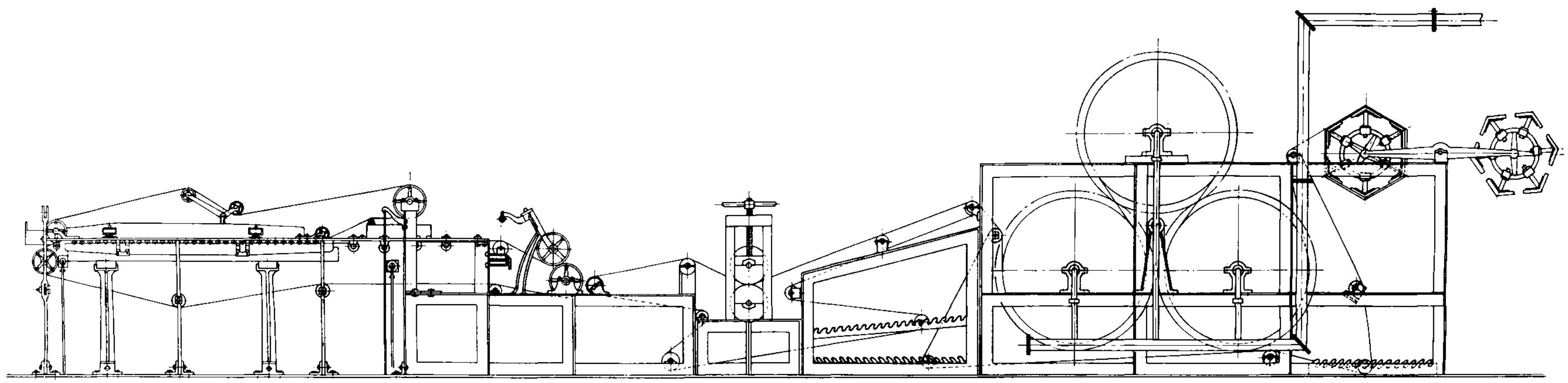


No. 78. Sectional elevation of Evans's three-throw suction-pump, which he used in place of the more usual air-pump, for extracting air and water from the suction-boxes.

the separate boards shown in the drawing was 3 ft 3 in. long and 15 in. wide, and $\frac{3}{4}$ in. thick. Donkin maintained that this was sufficient for ordinary average stuff on a paper-making machine 50 in. wide, but that it might be necessary to have a longer sand-trap if the stock was unusually dirty and the rags of very poor quality.

He arranged matters so that by having a stuff-gate at the end of each of the troughs, these could be taken out in turn without interfering with the output from the paper-making machine. In other words, one section could be shut off and the stuff passed along the other two if it was necessary to clean them without stopping the machine. This is a very ingenious type of sand-trap, and Donkin maintained that it was most satisfactory in operation on the paper-making machines which he made.

In 1839, Thomas Bonsor Crompton, of whom we have already heard, was impressed by the difficulties of getting a completely regular vacuum by the usual types of plunger-pumps which had been employed up to that time for obtaining a vacuum in the boxes under the wire, and he conceived the idea of using a centrifugal air-fan in place of the reciprocating pumps hitherto in use.



No. 79. The complete paper-making machine supplied by Bryan Donkin to Bentse Brug, Norway, in 1838. This is a conventional machine, without a dandy-roll and with one straight wet-press and three drying cylinders. This was the first paper-making machine to be erected in Norway.

FIG. 1.

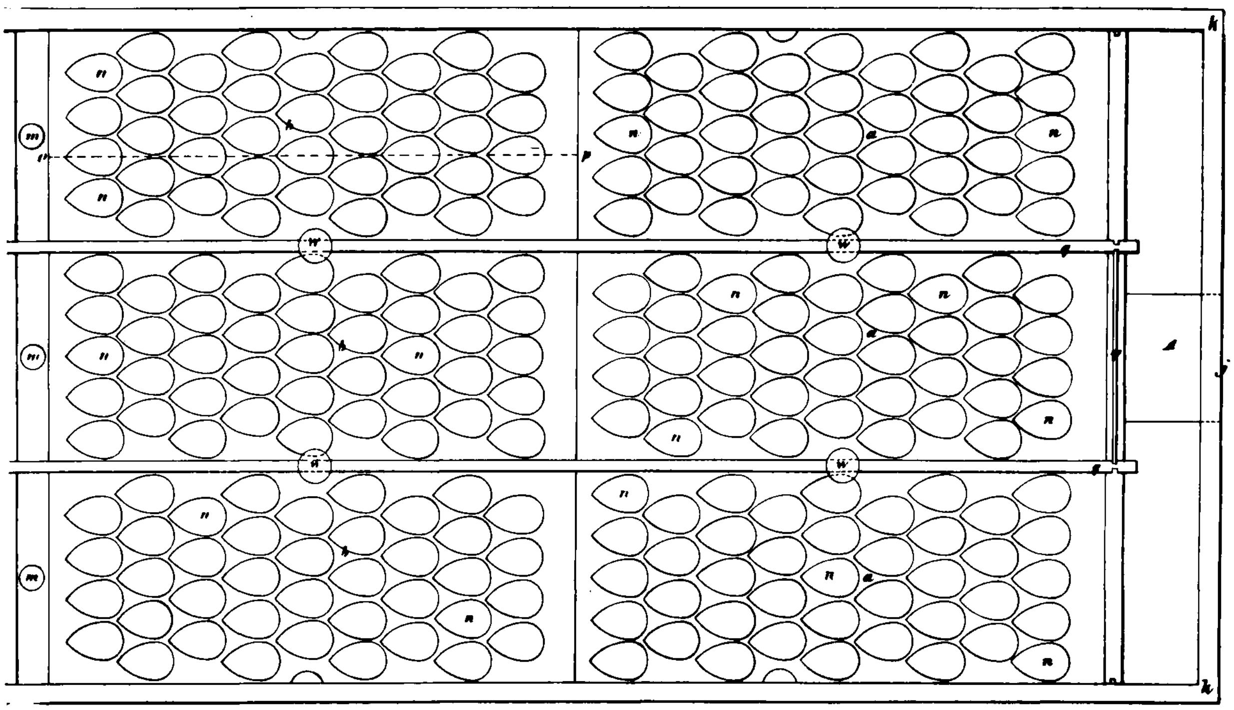
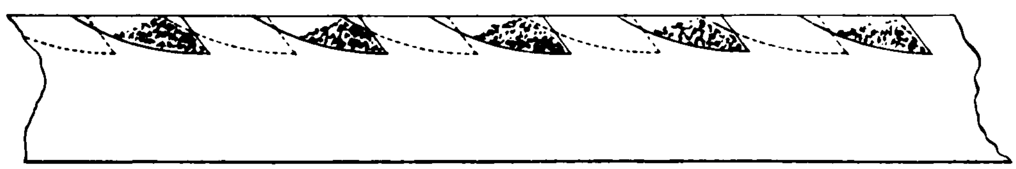
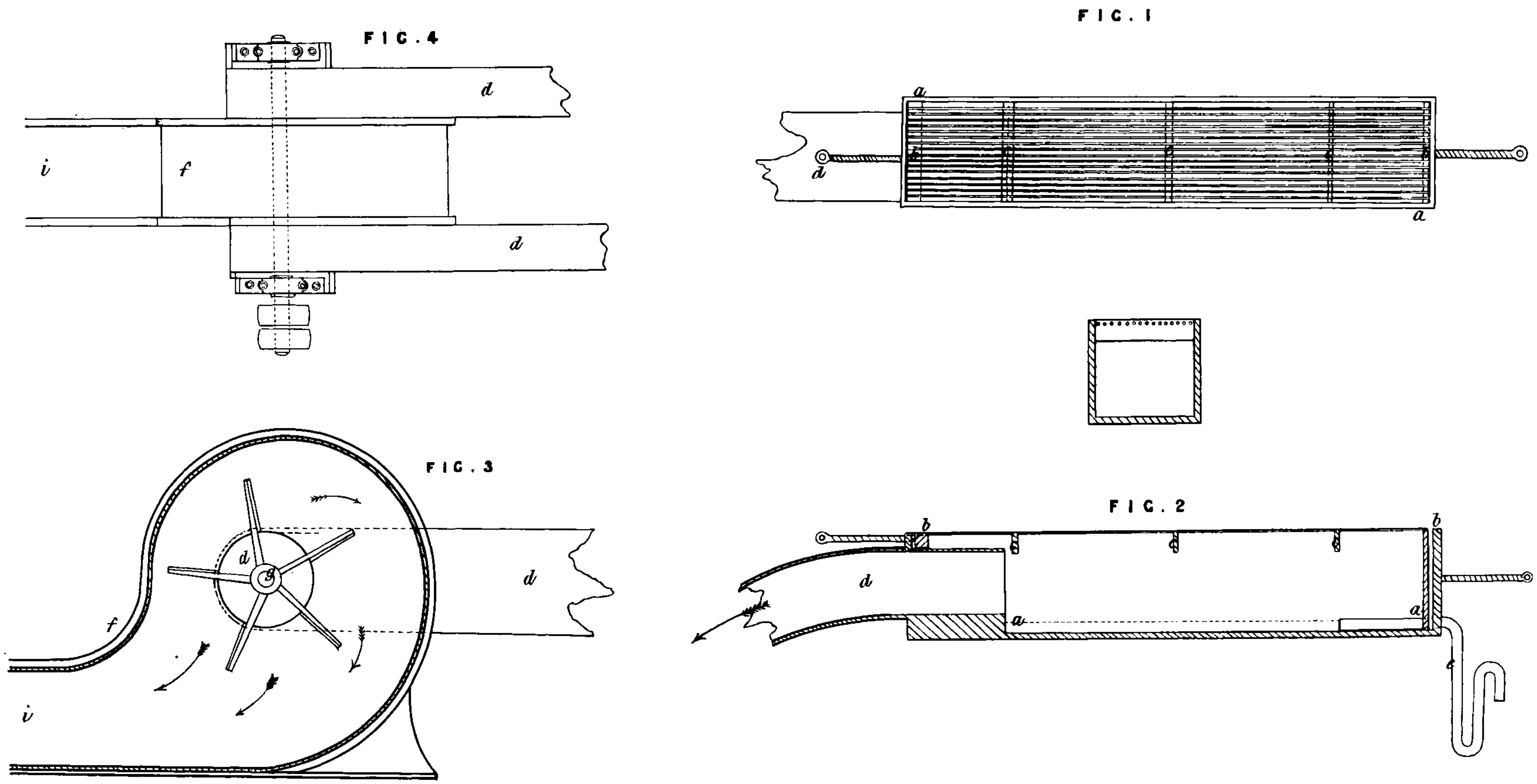


FIG. 3.



No. 80. Plan and section of Donkin's sand-trap for removing heavy particles from the paper stock before it reached the paper-making machine.

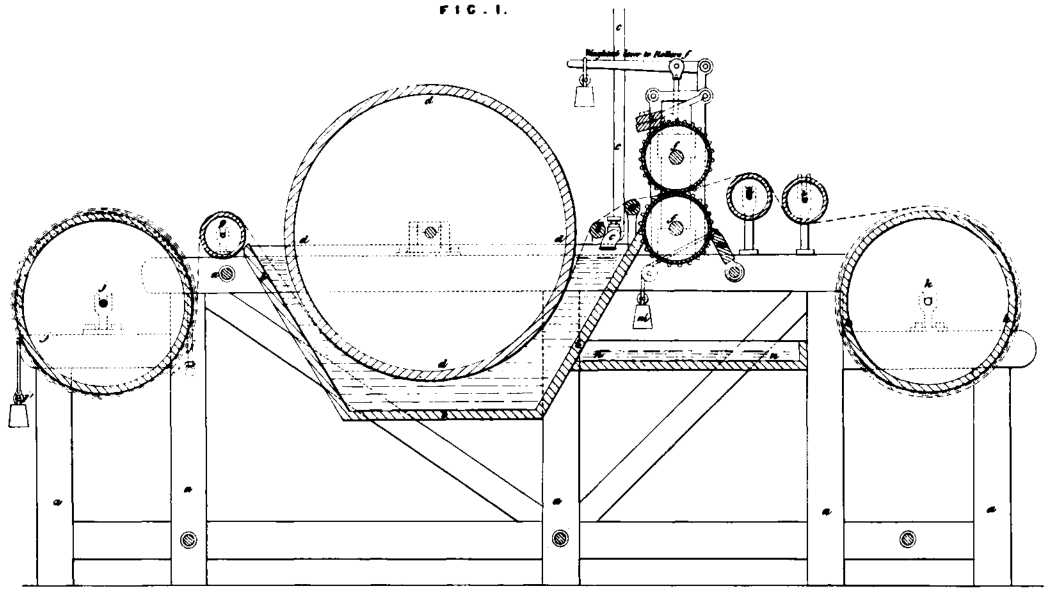
This was the forerunner of the present-day centrifugal pumps which are in common use for this purpose. He employed an air-fan in a casing, as shown on the drawing Fig. 3, and insisted that it should have an odd number of vanes. This fan was attached to the suction-box which had two movable ends (b-b) which could be slid in and out according to the width of the paper being made. The top of the suction-box was covered with round metal rods supported at intervals across the box. The seals on the sliding ends were made of leather to stop the leakage of air, and there was a siphon-pipe (e) at the end of the box, through which the water could find its way, instead of being drawn into the fan. Crompton said that the fan might be placed in any position, but it was desirable to avoid any bends in the pipe between the vacuum-box and the fan itself, and he revolved the fan at 1200 r.p.m. with a water siphon to indicate the pressure which was varied according to the speed of the fan employed (No. 81).



No. 81. Crompton's centrifugal fan for removing air from the suction-boxes on the paper-making machine. This suction-box top consisted of metal rods to support the wire and let the air and water through. The design of the fan is shown in Fig. 3, and the siphon pipe (e) for removing water and so reducing the load on the fan is shown at the end of the box, Fig. 2.

In 1839, Robert Gill Ranson, of Ipswich, paper-maker, and Samuel Millbourn, foreman to Ranson, patented a tub-sizing and air-drying plant for a paper-mill, which is practically the same as those in use in paper-mills at the present time. The machine consisted of two separate parts: one, the sizing-machine itself, and the other, the air-dryer. Whereas nowadays it is quite common to combine the size-bath and the air-dryer, nevertheless there are still some mills which conduct the two operations separately. In this particular patent the sizing-machine is shown in No. 82, Fig. 1, where

FIG. 1.



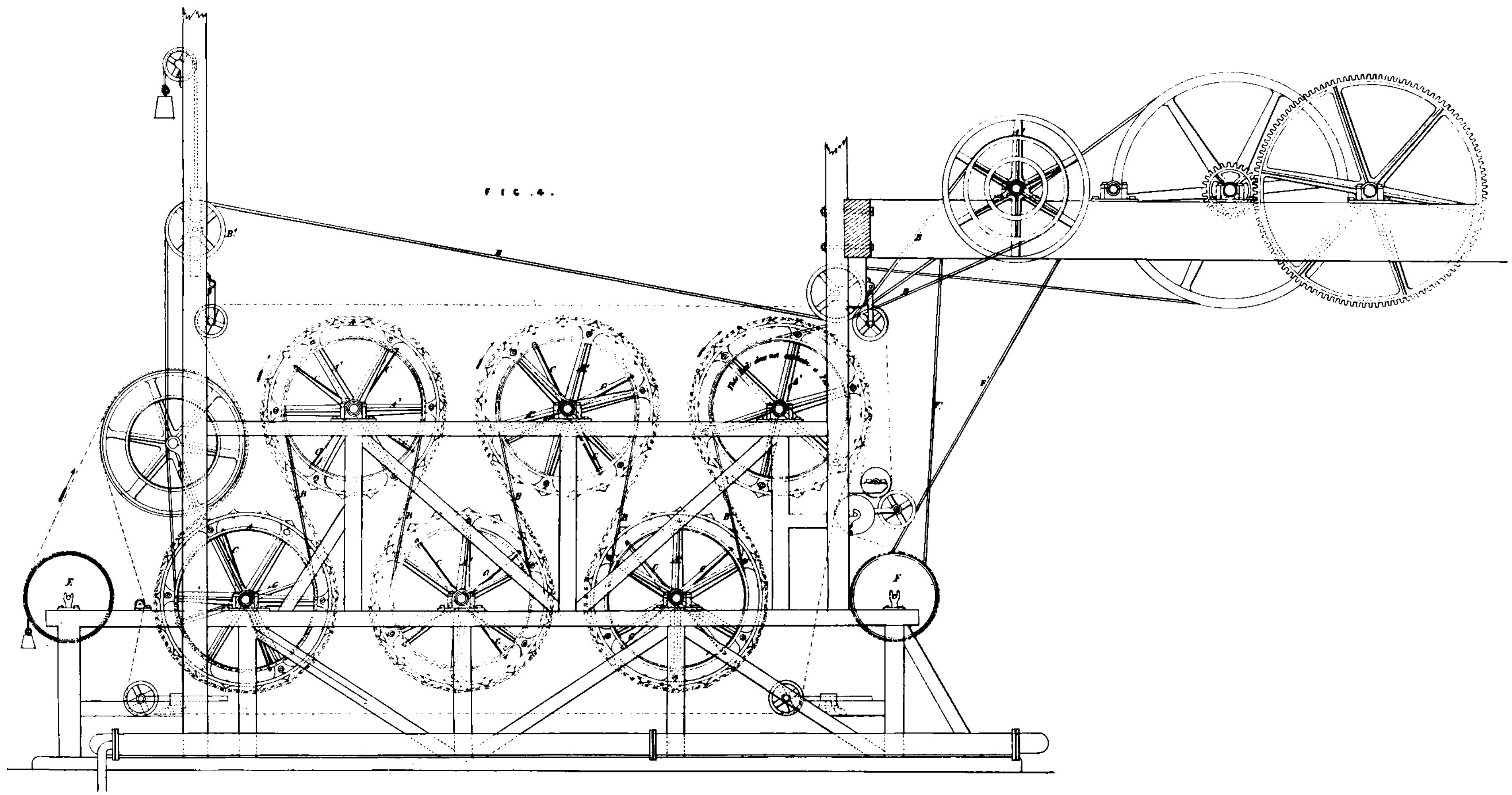
No. 82. Ranson and Millbourn's tub-sizing machine, showing the size vat and large copper covered cylinder for holding the web of paper underneath the size in the vat. The squeeze-rolls, each with a doctor to remove surplus size and other things from the rolls, have weighted levers for altering the pressure. There is also a dancing-roll just before the reel-up to assist the paper to wind up evenly on the reel.

the paper was unwound and passed through the size-bath, being either of plain copper or sparred with copper rods. After the paper had passed through the size-bath (b), it went through the press (f-f) to squeeze out the surplus size, and the pressure on the squeeze-rolls could be adjusted by weights on levers. The paper then passed round the two guide-rolls, and was wound up on roll (k) ready to be dried.

The animal size was kept at a temperature of about 60°F, and the vat was kept full of size by the workman who had a supply in a tank ready to run it in as was necessary.

The revolving cylinder in the bath was always well below the surface of the size. They stated that they preferred the solid copper cylinder rather than the cylinder built up of metal rods, as they got better sizing results. The squeezing-rollers (f-f), for taking out the excess size, were also covered with copper. They were very accurately turned so as to press equally on all parts of the paper and leave the size spread evenly over the whole of the sheet. One of the small rollers, immediately before the reel-up, acted as a dancing-roller to help the paper to wind up evenly on the reel (k). Each of the press-rolls (f) had a doctor to clean off the surplus size and anything else which might adhere to the surface. The draws throughout the machine were adjusted by belts and tapered pulleys, in order that the tension everywhere should remain constant. This appears to be the first mention of the use of tapered (cone) pulleys on a paper-making machine.

There was a most ingenious friction reel-up arrangement on this machine, so that the paper would not drag as the reel got bigger. It was worked by having a jockey pulley on the belt, which



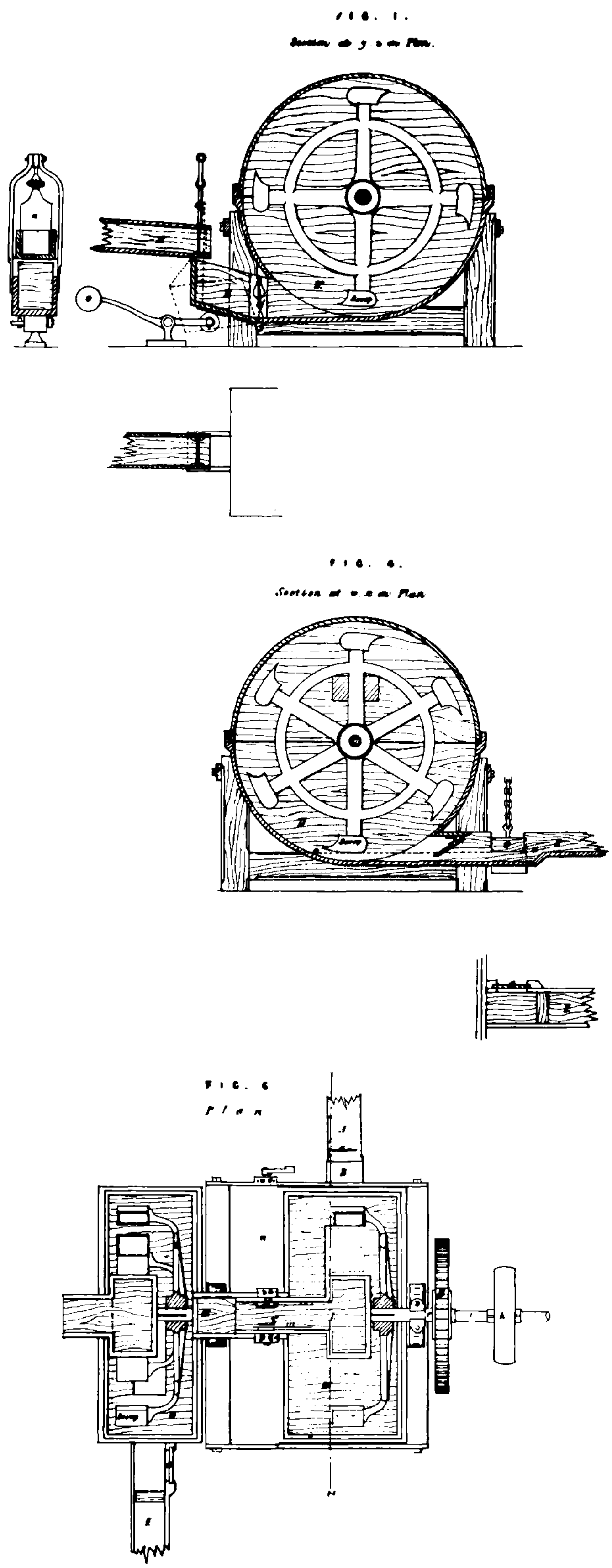
No. 83. Ranson and Millbourn's air dryer for drying the sized paper. The sparred drums are driven by endless tapes and have fans revolving inside to assist in keeping the air circulating. There are heated pipes underneath the machine which caused warm air to ascend and absorb the moisture driven off from the size on the paper.

drove the reel-up (k) from the pulley, which was attached to the squeezing-rolls. It is stated in the specification that the belt which drove the pulley (s) had a weighted pulley resting thereon, by which the band was held sufficiently to wind on the paper as it was delivered from the pressing-rollers, but would not injuriously drag on the paper, as the diameter of the reel (k) increased. The endless belt slipped on the pulley.

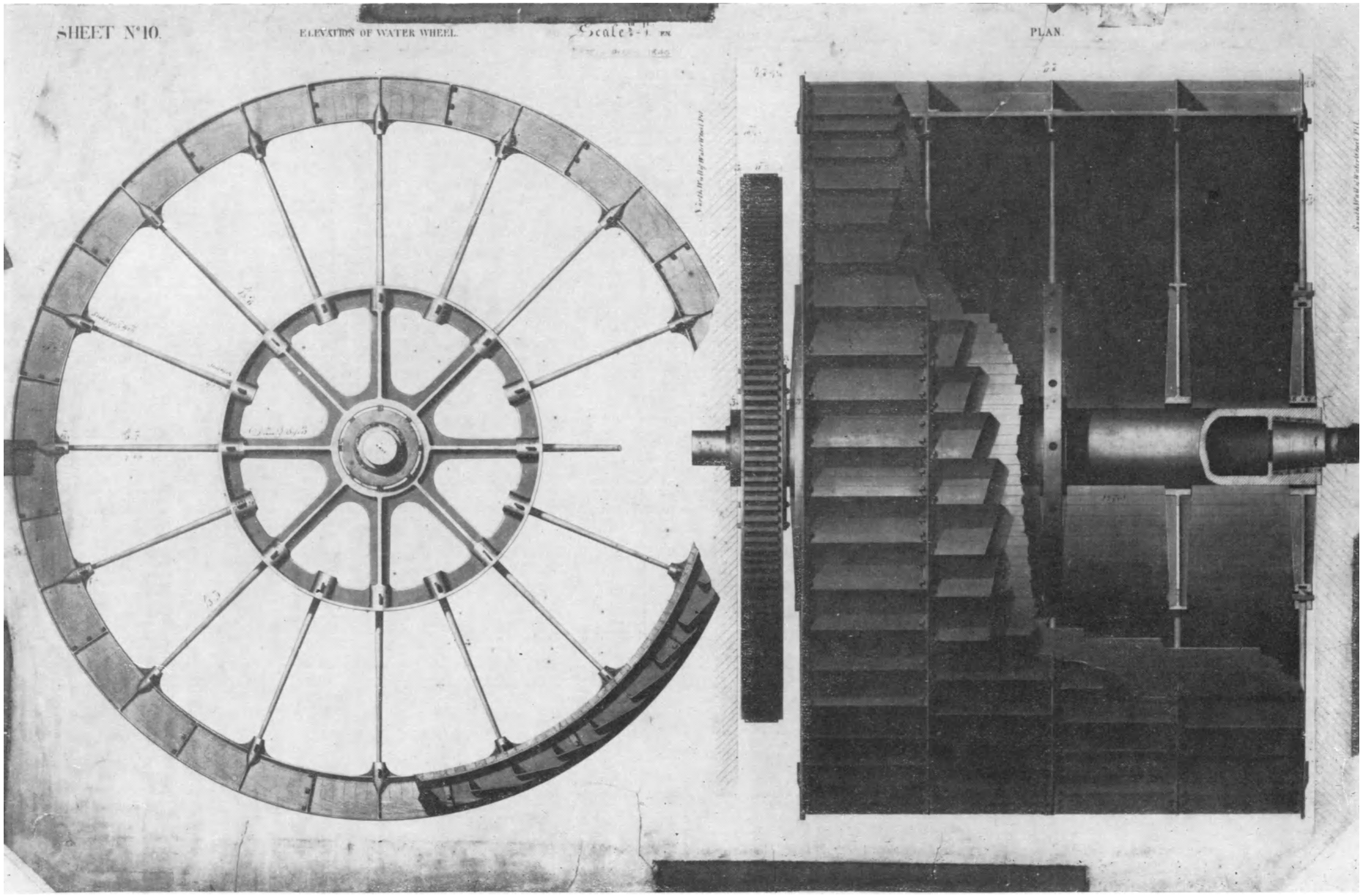
The second part of this invention (No. 83), which concerned the drying of the paper, consisted of a frame on which were mounted a number of sparred drums or cylinders with revolving fans inside them, and along the floor, underneath the machine, were steam-pipes. This arrangement is much the same as is employed on many air-drying plants at the present time. The sparred drums themselves were driven by an endless band, as were also the fans. The paper was led over the drums by tapes, both underneath it and on the surface, and the spars on the drums at (A) were usually covered with felt to prevent the surface of the paper being marked. The revolving fans were driven at a very high speed compared with the speed of the sparred drums, and by this means the heated air coming up from the pipes underneath the machine was projected outwards against the surfaces of the paper passing over the machine, and thus the moisture was carried away and the paper was dried. The temperature which was found to be most suitable was about 90°F, but this depended upon various other considerations, and Ranson and Millbourn stated that they preferred to dry at as low a temperature as possible, as this gave the best sizing results, which is also the custom at present. Means were provided for driving this machine at varying speeds according to the thickness of the paper which it was necessary to dry.

In 1840, Charles Edward Amos, of Great Guildford Street, Southwark, millwright and engineer, patented a number of inventions in connection with paper-making, and some of these show that he had a wonderful appreciation of what was required. He is also very well known for his work on paper-cutters, some of which have been in use until very recent times. He stated in his specification that it had long been a cause of complaint that the slightest deviation or irregularity in the speed of the paper-making machine caused a corresponding difference in the weight or thickness of the paper. No method, so far as he was aware, had hitherto been employed to deliver the pulp and back-water in quantities exactly corresponding to the speed of the paper-making machine. This regulation had always been carried out by hand. In consequence of this he stated that although a ream of paper may be found of the required weight, yet on dividing the ream and weighing the sheets separately, they may be found to be of various weights and thicknesses. In order to obviate this inconvenience he invented a consistency regulator for delivering a proper proportion of pulp and back-water according to the speed of the paper-making machine, and he called this a "pulp regulator". It is described as follows (No. 84):

> The stuff is let out of the chest through the chute (A) in Fig. 1 into the weigh-box (B), and when sufficient quantity of pulp is admitted to overbalance the power of the weighted lever (c), the box then descends and closes a slide or valve (a) in the chute, and prevents for a time any further flow of pulp through the chute (A). The box is fastened to the scoop-case (B.1) by loose leather- or rubber-cloth joints to admit of motion in the arc of a circle. The backwater is collected in the usual way by the dipping-pan, and flows from thence through the chute (E), Figs. 4 and 6, into the scoop-case. The quantity so discharged is regulated by a sliding shutter which can be raised or lowered at will. In order that paper may be made of any required weight or thickness, the machine must be adjusted in the following manner: If the paper is required to be made thinner, the receiving chute (L) must be moved towards (M). Then a portion of the pulp from the scoops working in the case (B.1) will fall down into the scoop-case, and the pulp and backwater may thus always be delivered into the case (D) in quantities equal to the speed of the paper-making machine.



No. 84. Amos's consistency regulator, showing the feed from the chest and the scoop wheel for lifting the stuff from one part of the regulator into a trough to convey it to the other half, the backwater having been already added in the first scoop tank. By moving the trough horizontally to left or right the amount of stuff falling into it from the scoops could be regulated and thus the amount of stuff passing to the paper-making machine could be increased or reduced.



No. 85. Typical Bryan Donkin water-wheel of 1840 for driving a paper-making machine. The elevation shows how beautifully these wheels were constructed, and the plan shows the "buckets" and internal shaft.

Amos also sought to make a strainer which would run continuously without frequent stops for cleaning, or at any rate which would run for very long periods. He said that in sifters or strainers made on the usual plan, it was customary for the pulp to flow onto the strainer-plates, and by giving these an up-and-down motion the pulp passed through the plates downwards by gravity, aided by the head of a few inches difference in the level of the pulp. There was always a quantity of grit or sand in the pulp, however carefully prepared, which choked the strainer-plates, and after they had been working a short time, the knots, that had been previously strained and kept back, began to flow over the top of the strainer-plates and thereby spoiled all the stuff that went on to the paper-making machine. In consequence of this it was common practice to shut the paper-making machine down, clean the strainer, and then start up again. In order to remedy this defect, he made a strainer working on an entirely different principle, which is shown in the diagram, No. 86. The main feature of this consisted in having a piece of board (C), which formed an airtight joint by means of rubber or leather insertion between the board and the strainer vat. This wooden flap (C) was raised and lowered by a crank, and thus caused an undulating movement of the water and pulp in the box passing through the plates, by the pressure of the atmosphere and the head of pulp and water in the box (A). The knots, grit, etc., were thus left behind in the box underneath the plates (B).

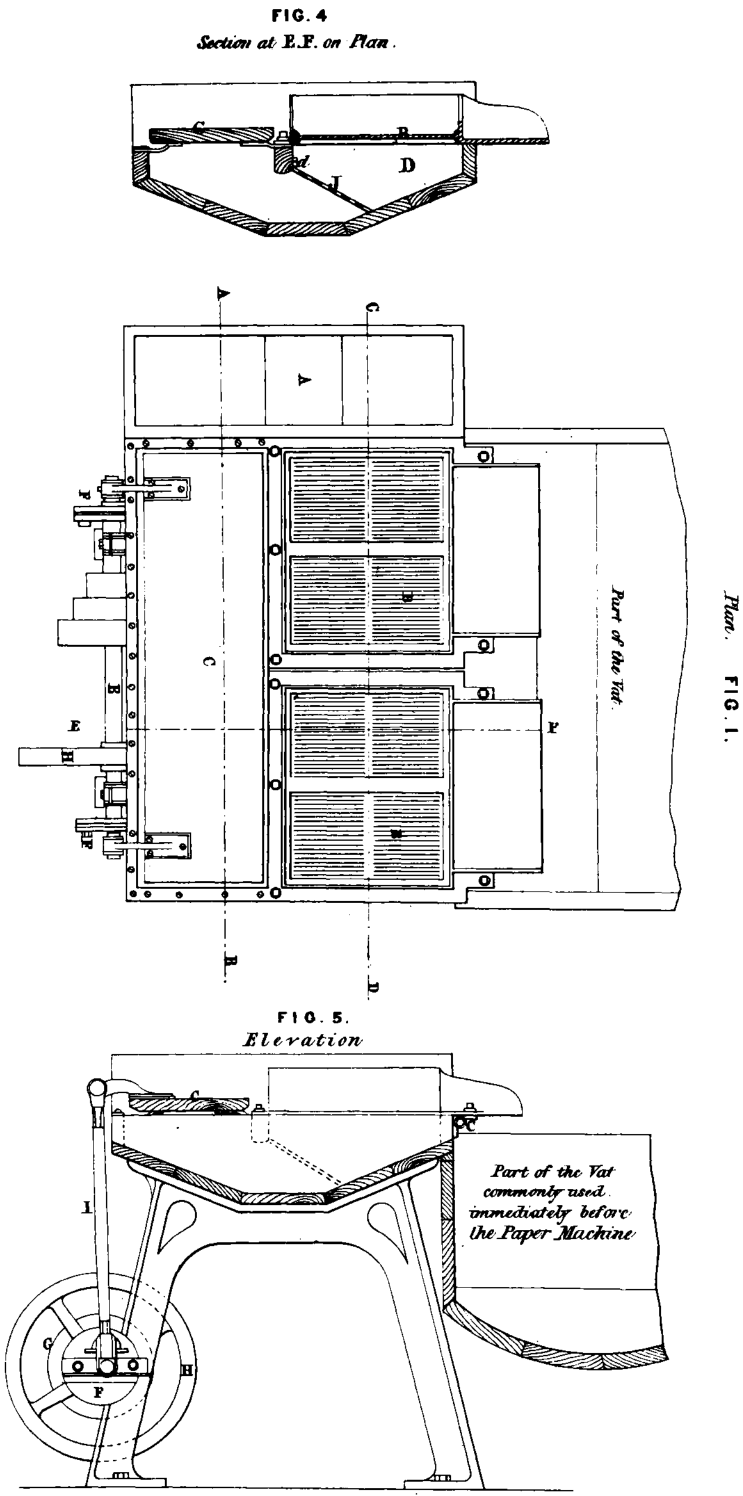
(J) is a copper or brass plate perforated to prevent the pulp settling or subsiding at the bottom of the box (D), and this was achieved by the pulp passing and re-passing through the holes formed in this plate. The strainer-plate and the plate (J) also could, if required, be hinged to the box so that they could be turned up for cleaning.

The difference between this strainer and many others which were in use at the time was that the strainer-plates themselves remained stationary and did not jog up and down, while the ebb and flow of pulp was induced by the clapper.

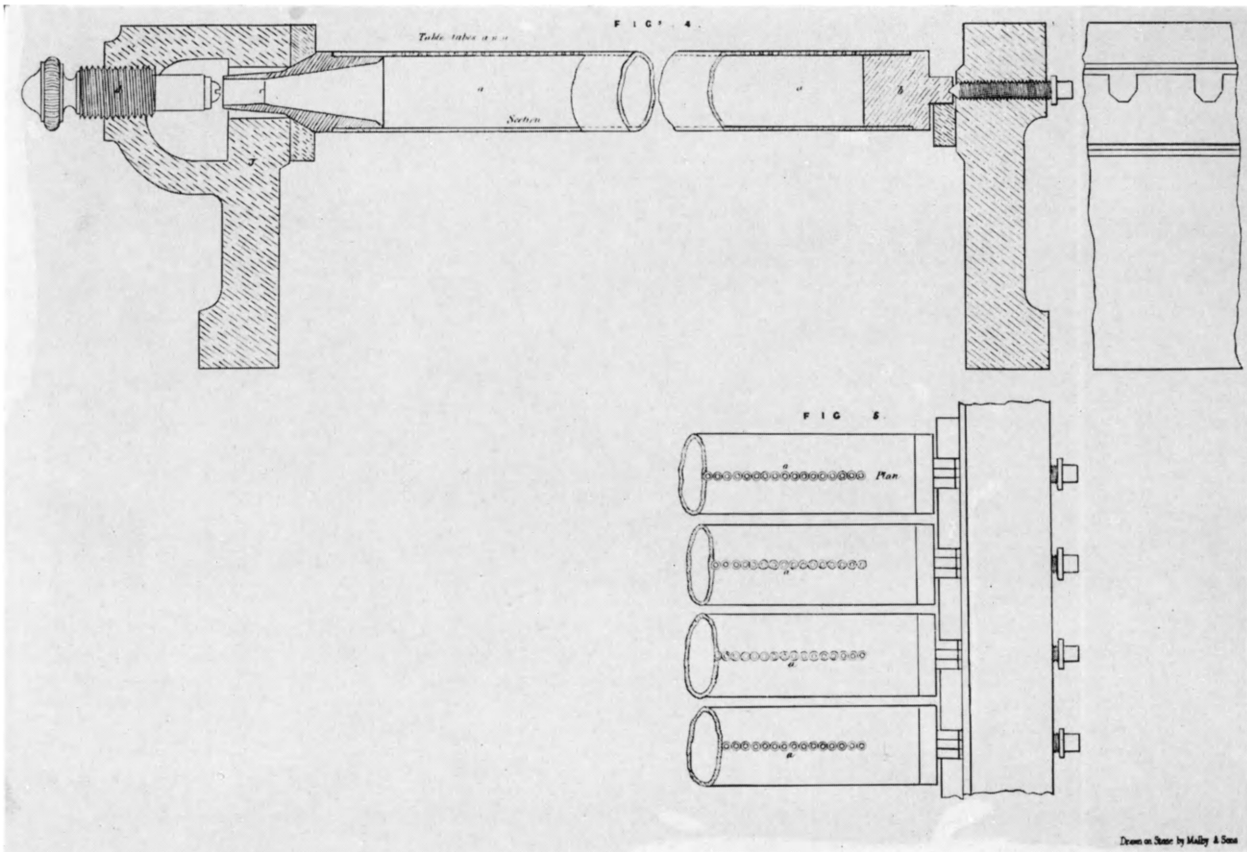
In 1840 Amos took out another patent, in connection with the tube-rolls. Up to this time all the tube-rolls had revolved in bearings, and assisted in withdrawing the water by the fact that they touched the underside of the wire. Amos, however, conceived the idea of having fixed tubes perforated with a number of countersunk holes on the top. These were fixed into the frame at one end, but open at the other end to a trough or pipe into which the water, on leaving the underside of the wire and passing through the countersunk holes and thus into the tube, could pass away. In some cases he actually had a suction-pump creating a vacuum inside the tubes. He had an arrangement whereby each tube could be plugged up from the outside of the frame by means of a screw, in order that all or any selected tube would not withdraw water through the countersunk holes. This is interesting as at the present time many experiments have been made with stationary tube-rolls and bars, whereby the revolving tube-roll is dispensed with and the wire supported by other means. The drawing shows the tube and how it was fitted to the frame (No. 87).

Amos appears to have been the first man to run the wire uphill from the breast-roll towards the couch, and he had very good reasons for his patent for doing this, and it is perhaps as well to give his own words describing the specification:

> Paper made on the ordinary Fourdrinier machine has a disadvantage arising from the lower side of the pulp being formed first into paper while the upper side is in a fluid state, the water having to pass through the paper previously made, thereby disturbing the fibres and not producing so even a surface as might be wished. To obviate this I employ a modification of my previous machine, illustrated in Fig. 1 (No. 88), which shows a side elevation of a machine with a sloping wire . . . but in this instance the shake of the table is given in the same direction as that in which the wire travels and as was described previously, instead of having a side-shake, as in the Fourdrinier machine; and the breast-roll end is placed lower than the couch-roll end of the machine. The table of the wire will form an inclined plane



No. 86. Plan and section of Amos's flat strainer, showing his method of obtaining an ebb and flow movement to the stuff on its upward passage through the strainer plates, thus keeping the contraries away from the actual straining plates and enabling the strainer to operate for long periods without stopping to clean out.



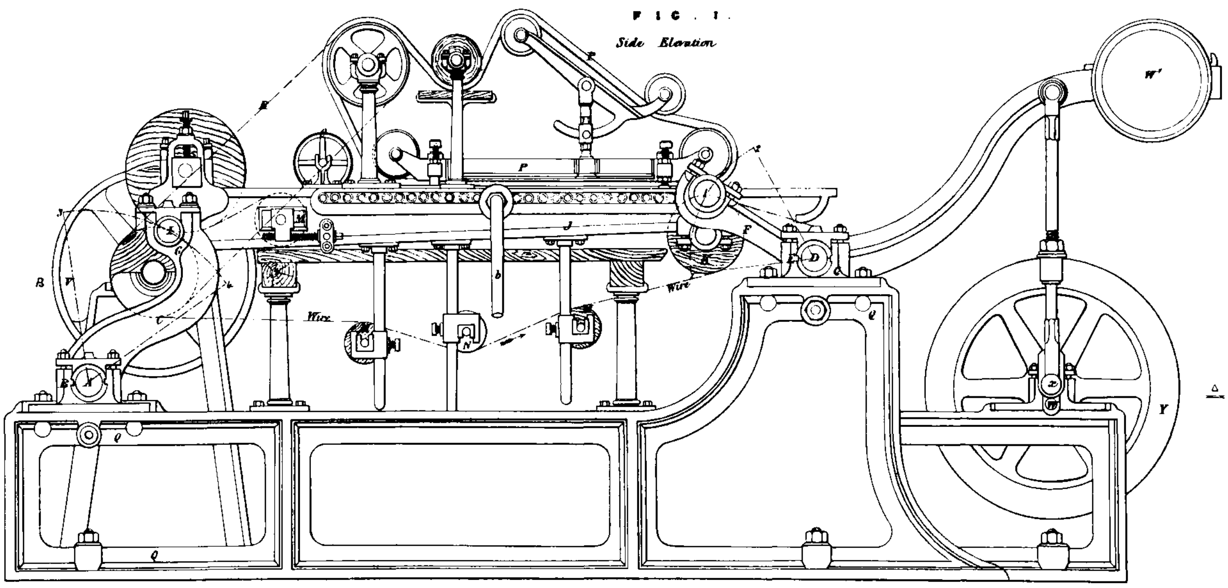
No. 87. Drawing of Amos's perforated tube-rolls, showing method of tightening the roll in its bearings, so that it would not revolve. The plug for closing the end of the roll to prevent water running out is also shown.

rising from the breast-roll, at which the pulp flows onto the wire, to the couch-roll. The water will thereby have a tendency to run towards the lower end while the pulp is carried up by the progressive motion of the wire web, and hence the paper will be formed much quicker than in the usual way. In order to alter the angle of elevation, the end of the side frame (B) and the bearings can be adjusted.

While Amos's method of shaking the wire-table never found favour with paper-makers, the sloping of the wire upwards from the breast-roll to the couch was very common for many years, and, in fact, is in use in some mills today making heavy papers from wet stock.

Amos produced another patent for drying about the same time, and in this instance he used hot air instead of steam; he goes on to describe the principle as follows:

I employ a stove or furnace for the burning of coke or coal. The gaseous products or vapours arising from combustion are received into a chest or chamber, the temperature of which is regulated by an air- or other thermometer which opens a valve for the admission of atmospheric air when too hot. When the temperature is too low the valve is shut. From this chamber, or hot-air chest, heated gases or vapours are conducted by a pipe which has other branches leading to each of the drying-cylinders, the necks of which are larger than when steam is used, for the purposes of allowing larger openings to and from the cylinders. The remaining heat is collected in pipes after leaving the cylinders, and

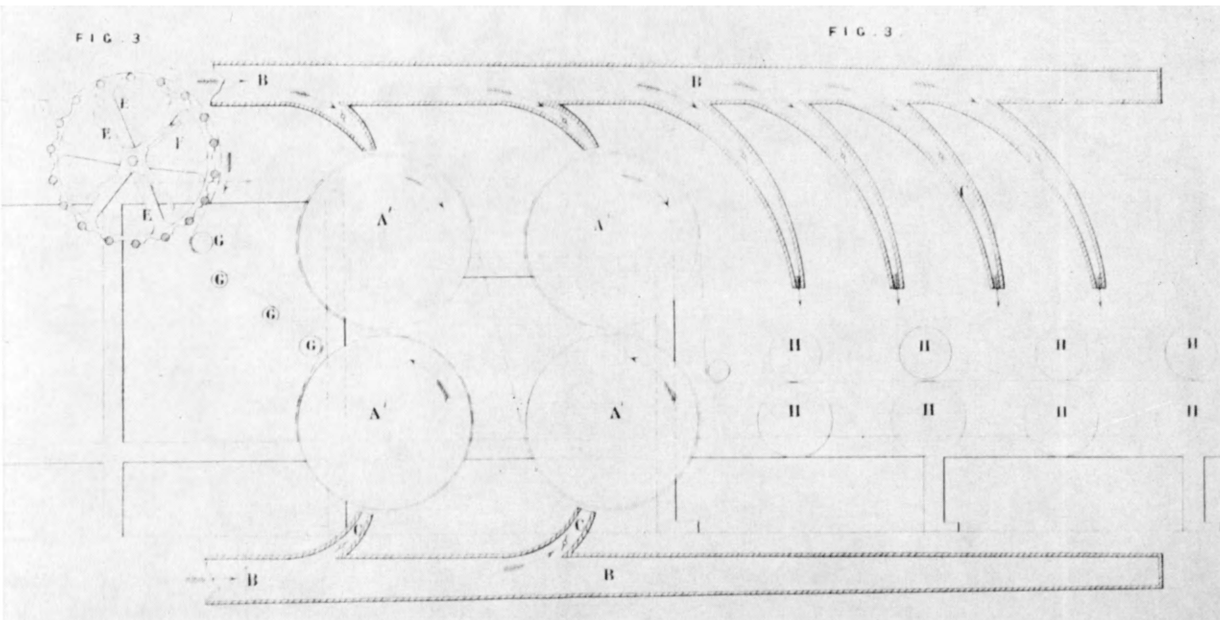


No. 88. Amos's wet-end, showing gear for shaking the frame vertically in an arc. The wire frame can be adjusted to slope upwards from the breast-roll to the couch. This wet-end also incorporates the perforated tube-rolls and the pipe (b) is shown for draining the water away from the tube-roll trough, into which the water flowed from the interior of the tube-rolls.

> may then be applied to any other purpose of drying. Circulation may be caused by a fan, by exhaustion, or by a chimney draught. The whole product of heat arising from the combustion is thus beneficially used, and the fuel thereby economized, for if steam is employed, a large portion of heat escapes up the chimney. The heat from a small coke oven can be used with the same means for regulating the temperature, and the retort for the generating of gas can be set in the coke oven, and the gas so made applied to the lighting of the mill; and the coke burnt under the boiler of the steam engine employed for working the paper-mill. Thus a uniform heat may be obtained, and the mill heated, lighted and worked with the greatest economy.

From this it will be seen that Amos had a very real feeling that the whole of the heat generated from coal could be used in a paper-mill, if the matter was given a certain amount of thought and ingenuity.

The use of hot air to augment the drying on the drying-cylinders, and also to circulate the moisture-laden air on the dryers, seems first to have been used by Thomas Barratt, whom we have mentioned before, and who was a paper-maker in Somerset. He patented his system of trunking and blowing hot air onto the paper on the drying-cylinders in 1840, and claimed that it had many advantages over the previous methods in use, which consisted simply of drying the paper through the heat of the drying-cylinders themselves without causing any proper circulation of the air in the room. If the paper was ordinary waterleaf, which subsequently had to be sized, he took it straight from the paper-making machine through the dryers, and applied hot air only, but if it had been tub-sized during its passage through the machine, he first of all passed it over a sparred drum in which a fan was revolving, and applied cool air to this before taking the sized paper into the dryers. Once it was there, hot air was applied by means of fishtail trunkings onto the paper itself as it passed over the drying-cylinders, and arrangements were also made to blow hot air onto the single-stack calenders at the end of the machine. All this can be seen in the drawing No. 89. The air could be regulated by vanes situated in each of the spouts of the trunking immediately before it was discharged onto the paper in the dryers. This system of applying air into the dryer-systems seems to have been lost sight of for very many years, and it is only in comparatively recent times that it has been reintroduced to assist and improve the drying and circulation of air on the dry part of the paper-making machine.



No. 89. Barratt's arrangement for blowing hot air into the drying-cylinder section of the machine, and also onto the calenders. The introduction of hot air increased the efficiency of the drying to a very considerable extent, and is common practice in recent years.

It was in 1841 that an Oxford graduate, returning from India, brought with him some thin opaque paper, presumably hand-made, and gave it to the Oxford University Press. They printed twenty-five bibles on it, and it caused quite a sensation on account of its extremely thin substance and good opacity. The paper was reproduced on a paper-making machine at Wolvercote Mill, near Oxford, which had one of the first Donkin Fourdrinier machines, and the paper was known as Oxford India Bible Paper.

During 1842 and 1843 Donkin and his son John made extensive trips to the Continent, including Germany, Austria, Switzerland and Italy. Among the mills they visited were those of Schoeller and Hoesch, to whom they quoted £300 for a large water-wheel to drive four beating engines, but if it were made large enough for driving six engines the price would be £400. Donkin advised against putting in a wheel for six engines as there was not sufficient water. Hoesch recommended the adoption of adjusting pieces on the lip of the strainer in order to control the stream of stuff according to the width of deckle. This was to do away with the practice of putting lumps of stuff in at each side to narrow the slot. This stuff washed away gradually, causing lumps in the paper, and waste. Hoesch had also adapted a piece of wood in front of the strainer, which could be raised or lowered so as to keep the strainer always full of stuff, and prevent splashing. Donkin thought both these ideas were good.

Messrs. Hoesch enquired the price and particulars of the Wilson ream cutting machine.

Donkin and his son also visited Maurenbrecher at Gladbach, near Cologne, who had already ordered a machine from an engineering firm at Liége.

Peoch, also of Gladbach, wanted a machine to make the output from eight beaters, but was in difficulties with a quarrelsome neighbour over water, as he wanted to join three falls into one. He thought Donkin's price for the machine was very high, but he seems to have wanted all the latest improvements and a width of $59\frac{1}{2}$ in., for which Donkin wanted £75 extra. Donkin undertook to prepare and submit a plan of the whole mill if Peoch would undertake to order from them the main part of the equipment. The beating engines were to be of stone, which seems to be the normal practice in Germany.

The Donkins went to Baron Herding's mills at Heidelberg, and saw the English manager Rowland, with whom they stayed. There were four paper-mills. The upper one had a 44 ft wheel, overshot, driving six small engines through wood bevil gears, each holding 60 lb of rags. There was an old paper-making machine in very bad order, the dryer part of which had small copper drying cylinders. The second mill, where Rowland had his house, had a 48 ft wheel and eight engines, but the wheel never drove more than four satisfactorily. This was a hand-made paper-mill, and there was no paper-making machine. The third mill had only two engines for preparing half-stuff, and a 20 ft fall.

The lowest mill, which housed the new machine, had two overshot water-wheels of wood, each 25 ft in diameter, driving the beating engines, and the wheels were assisted at the other end of the main driving shaft by a 14 h.p. steam engine. According to Donkin, however, there was neither water nor steam power enough to drive properly the six engines which were connected to the shaft. The new paper-making machine was driven by a water-wheel, for which the water was brought from much higher up the stream. Baron Herding went over the mill with Donkin and enquired for a price for a three-roll press (calender), the Sweetapple forming troughs, and the stuff-regulating apparatus (consistency regulator). He also wanted a price for a complete new paper-making machine to embody all the latest improvements and additions. Donkin advised that if the Baron put in the new machine, it should be erected alongside the present one in the same machine house. Herding also ordered six sets of circular cutters. Rowland, the manager, told Donkin he would be glad to find a new situation if Donkin could find him a suitable one. He would even take Russia or Spain if he could be paid 5 per cent on the profits!

On Thursday, 22nd September, the Donkins called on Rauch, at Heilbron, who was one of their best and oldest customers. When they visited the mill they found that Rauch was making a new machine for himself, but wanted Donkin to supply some of the parts. Donkin advised Rauch to have a third press, and also a three-roll calender at the end of the dryer. They also required the Sweetapple forming troughs and the consistency regulator.

Messrs. Rauch were having a great deal of litigation over water rights, and had asked the government for a decision. This they gave, and the total amount of water to which they were entitled was fixed, but the method of measuring it was in dispute. Donkin, however, measured all the water under the various conditions, and found that Rauch was using less than he was entitled to. After doing all the measuring the mill was shut down, and a great deal of water was found to be leaking through the walls, "which of course ought to be deducted from the 5100 cubic feet to get the actual quantity consumed by the wheel". Apparently it was considered that leakage ought not to count when estimating the total usage.

Donkin promised to send Rauch the formula for calculating the water over a tumbling bay and through the gate. Also the angle at which the maximum quantity of water would be discharged through the gate, and the difference in the coefficient for such angle. Donkin also promised Rauch a quotation for a Wilson ream cutter.

This Wilson ream-cutter, concerning which no drawings or particulars seem to be available, was evidently in great demand, and must have been in fairly general use. It was not patented in England.

Donkin, of course, made very many improvements to the paper-making machine and paper-mill equipment generally, but rarely patented anything himself. He seems to have had enquiries from most of the continental mills for the cutters and apparently these were eventually ordered, as reference is frequently made to spare cutting wheels being ordered.

On September 27th Donkin went, with Tanner, of Escher Wyss, Zürich, to the mill of Pustett, about six miles from Regensburg. Here Donkin advised on the water power available, the feasibility of putting in a second water-wheel to drive six more beaters and some pumps. The price quoted for the 14 ft water-wheel, shaft, plummer blocks, together with the fall-plate, gate tackle, etc., was between £700 and £750. Pustett agreed to place the order, and Donkin agreed to supply complete plans. Donkin gave the total weight as 15 tons, for import duty purposes, as Pustett was hoping to get the government to allow the machinery to be imported duty-free. No mention is made of the part played by Tanner, of Eschers, in these negotiations, although mention is made of a steam engine which Donkin said would be designed to take up as little space as possible.

From Regensburg Donkin went to Munich and on to Augsburg and Innsbruck. Here he was evidently in trouble over an account he could not get settled. After interviews with various people and some lawyers, he was advised that he should apply to Mr. Kennedy of Eschers, to settle the debt. From this it would seem that Donkin had been sub-contracting on a job which was being carried out by Escher Wyss, of Zürich. Donkin finally left the matter in the hands of a lawyer, and went on to Italy, where he called on the Jacobs who had a mill which was "going well". Donkin found no fault whatever with the mill, and got an order for a stock regulator, and quoted for a rag duster, with sketch. He also gave them particulars about water pipes for supplying water to the town, quoted them for a Wilson ream-cutter, with full particulars, and reported on the coal they were using. The Jacobs took Donkin on a boat, and they "steamed down the Lago di Garda very slowly". He then went on to Mantua.

On Tuesday, 11th October, he was at the Lima paper factory, where they were having mechanical trouble with their stock regulator, as the shafts that carried the cones, having been made too weak, were bending. Donkin also found the vacuum box in the wrong place, too near the breast-roll, and this interfered with the shake. One of the "swan neck carriages on the old machine" had broken and appeared too weak. He found that the upright brackets carrying the deckle spindles were vibrating badly, and were too weak. Donkin agreed to replace some of these parts free of charge, and make them stronger. He also found "the engine spindle brasses of the four rag engines too soft and already nearly worn out". He advised them to have round bearings as they retain the oil much better and last longer. They promised to send a plan of the shaft, etc., required for driving the polishing hammers, two washing engines, two glazing presses, etc. Donkin agreed to supply the driving gear for a pump to raise 20 cubic feet of water per minute 25 ft high by means of the fly shaft of the four rag engines, provided they would supply a correct plan of the exact position of the walls, etc. They also enquired if the plate glazing press could be made to turn both ways, to save time and labour in carrying the "books" back and forth each time. They also asked for a price of a pump for a hydraulic press, about 1 in. diameter, the press was to be about 9 in. diameter. This pump was to be driven from the shaft of the large glazing press. They enquired also the price for a Wilson ream-cutter.

From all this it would appear that the Lima mill was a good and satisfied customer of Bryan Donkin and Company.

They had a discussion about Braynes' machine, and asked Donkin for his considered opinion as to which machine they should install for making "very common papers, very quick", and also if possible for making paper for cartons (boards). Donkin seemed to think they had in mind some type of cylinder mould machine.

The lifting scoops on the stuff regulator were not big enough for the high speeds they were able to run, and they were making bigger ones themselves. They ordered "two shoes for inside the stuff chests to send the stuff into the measuring scoops from either chest".

Donkin promised a sketch showing the exact position for the vacuum box nearer the first press (couch) so that they could see if any alteration would be required to the framing of the wet-end. They were also prepared to order, on trial, new steam cocks for the drying cylinders, by Chappel, if the drawings were approved.

The middle roll of the three-roll smoothing press on their new machine was not round, presumably due to expansion. They had no time to grind it, as it took too long to fix the belts, etc., so Donkin suggested they should try driving the middle roll from the top roll by means of two pinions on the clutches, so as to do away with the shaft across the machine as well as the temporary shaft on the working side. They promised to send an exact drawing of the position of the clutches and the room for the pinions. They told Donkin to proceed with the making of the pinions. They also asked for a price immediately for a good "Stanhope" press about 75 cm × 55 cm, supposed to be the largest size available.

Donkin put a footnote at the end of his report on his visit to the Lima mills in Italy, which was as follows: "Mr. Rauch would have no objection to one [cylinder machine] being put up." They were evidently anxious to make good glazed boards for pressing cloth.

From this note it would appear that Rauch, having been one of the first to install Donkin machines and machinery, had made some conditions regarding the supply of particular machines to other European countries.

Donkin left Florence on Tuesday, 18th October, having spent a full week at the Lima mills. He went by way of Milan to Venice, and thence to Malmer's mill, where he got an enquiry for bleaching equipment for "steep bleaching", and an order for a lead pump for raising the bleaching liquor into the chests.

According to Donkin's mechanic, Whatson, the second-hand cutting machine from Chorley (Parke's mill in Lancashire) had been badly erected, and it was expected that the screw for the expanding pulley would strip.

Donkin went on to Borel's mill, where they were anxious to put in grinding equipment on the small calender rolls on the drying machine. If it was found impossible to put grinding apparatus on the present rolls, they wanted a price for a new set of rolls, with grinding shafts, driving tackle, etc.

From all these enquiries it would appear that most machines had three-roll calenders at the end of the dryer. They were also in trouble since the rolls distorted when hot, and they were being compelled to put in equipment to grind the rolls in water to keep them level, and the finish on the paper even and regular.

Borel also enquired for a price for new iron doctors on the first and second presses of his machine, in place of the wooden ones which did not work well, and also for doctor blades separately to fit the existing carriages. He asked at the same time for a price for a set of glazing calender rolls with wheel and pinion, and pinion shaft, the rest of the drive to be supplied by Escher from Switzerland. He also wanted a price for the copper plate-glazing sheets, and wanted as few as Donkin considered adequate, and as low in price as possible.

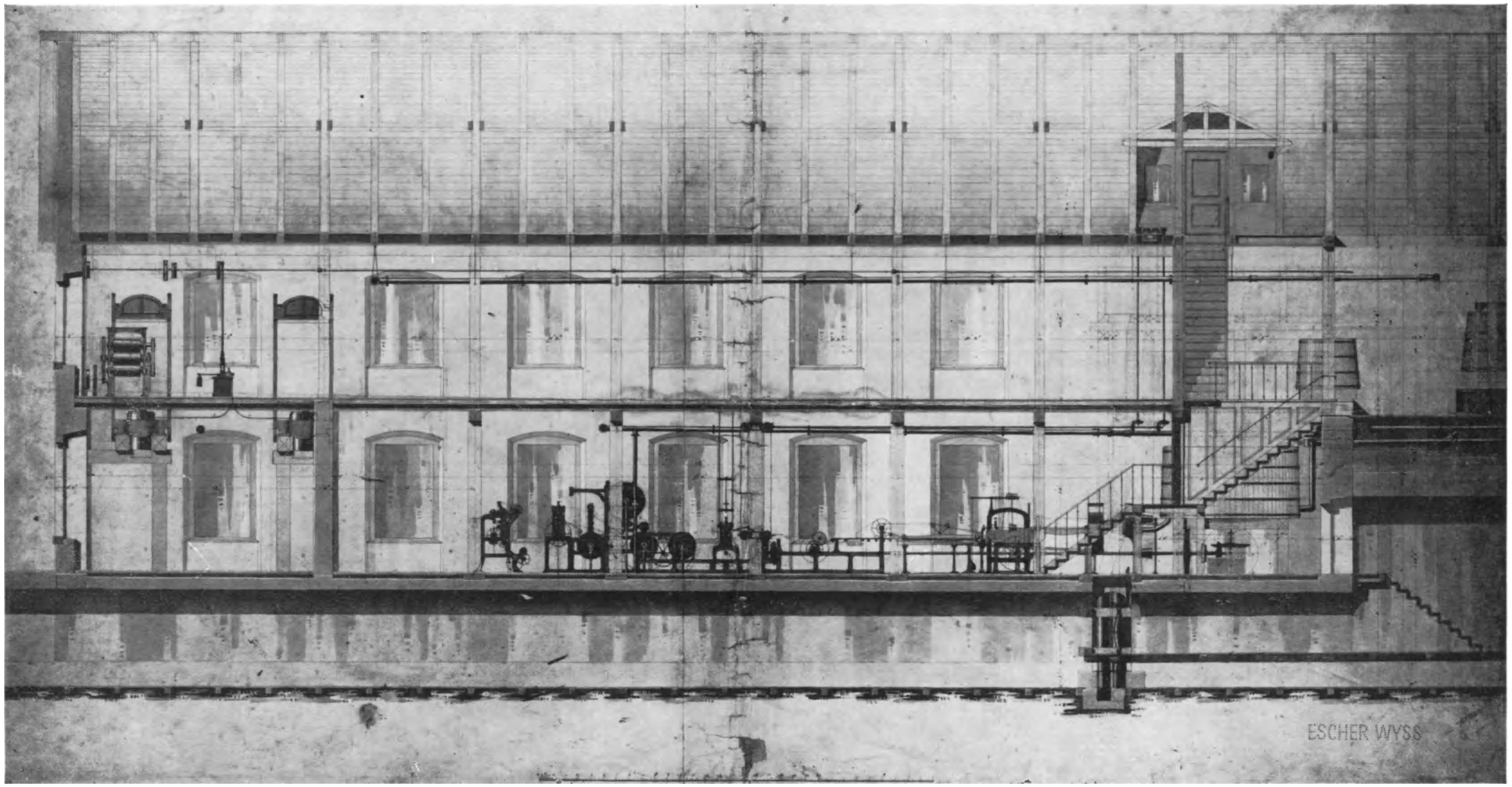
On October 30th Donkin went to Strasburg and then on to Ettlingen to see Buhl, who gave him an order for cutter knives. Buhl proposed to build a new mill with eight stone beating engines, and wanted a price for a complete new paper-making machine a few inches wider than his present one, with all the latest improvements. He also wanted to know the difference in price if the bottom press rolls were covered in copper and were 1 ft in diameter. Buhl undertook to send a drawing of the present position of his stuff chests, vat chests, etc., to ascertain if Donkin could contrive to place the measuring scoops and sand catcher. If they could be got in he would order them. He also agreed to send a plan of the fourth cylinder with four small smoothing rolls, driving shafts, wheels, etc., to see if Donkin could supply and fit grinding apparatus. Buhl drove his beating engines with a water turbine, with which he was very satisfied. His machine turbine, however, was not so satisfactory and took a great deal of water, although the supply of water was regulated by a case sliding onto the turbine to prevent its escape. The machine turbine threw the water out with great velocity, whereas the big turbine driving the beaters discharged it very quietly. In consequence Buhl was undecided whether to have turbines or water-wheels for his new mill, but Donkin expected him to choose water-wheels if they were not too expensive. Buhl also gave Donkin an enquiry for a washing drum.

On November 1st Donkin called on Bohnenberger, at Pforzheim, who wanted two vacuum boxes and equipment for his paper-making machines. He also seemed interested in another machine to make fine writing papers. Donkin told him that if he decided to proceed with another mill he would gladly come over and give him the best advice he possibly could.

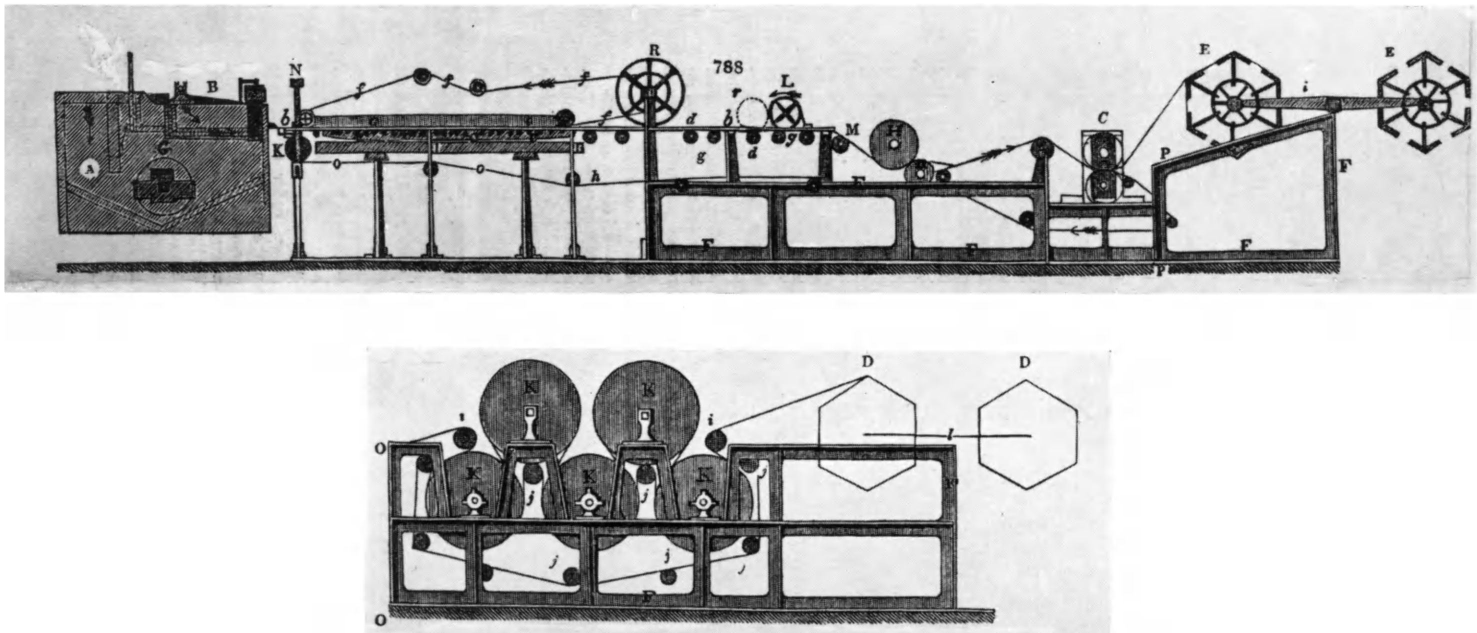
It will be agreed that these long continental trips of Bryan Donkin and his son were remarkable for the ground they covered at that time, when, to all intents and purposes, transport did not exist. In three months they visited much of Germany, Austria, Italy, and Germany a second time. They obtained many orders and enquiries, and assisted greatly in the development of the paper-making machine and paper-making generally in all the countries which they visited. They were really responsible for the establishment of paper-making by machinery in Europe, and also in the development of the far greater and more economical use of water and steam power.

Escher Wyss, who were doing some work for Donkin in Europe at this time, were also building paper-making machines, the earliest known one being of 1841, an elevation of which is shown (No. 91).

It is stated in Ure's *Encyclopaedia*, of 1843, regarding the mechanical workshops of Messrs. Bryan Donkin and Company, in Bermondsey, "that they had never seen a more admirable assortment of exquisite and expensive tools, each adapted to perform its part with dispatch and mathematical exactitude", though those who said this said they had probably seen most of the best machine factories in this country and on the Continent. "It will be appreciated," the statement goes on, "that the grand mural circle of 7 ft diameter, made by Troughton, for the Royal Observatory of Greenwich, was turned with final truth upon a noble lathe in Bryan Donkin's engineering works. These works had supplied, up to 1843, no fewer than 133 complete automatic paper-making machines, each of a value of £1200 to £2000, for different factories, not only in the United Kingdom but in all parts of the civilized world. Each machine was stated to be capable of making, under the impulsion of any prime mover, all unwatched by human eye and unguided by human hands, from 20 to 50 ft of paper 5 ft broad in one minute."



No. 91. Elevation of the first paper-making machine built by Escher Wyss of Switzerland. It appears to have a long wire, a straight press and a reversing press, four drying cylinders, a calender and reel-up.



No. 92. Complete paper-making machine illustrated in Ure's *Encyclopaedia* of 1843. This machine appears to have been built some years earlier than 1843, as it has only one straight press and no reversing press. No suction-boxes are shown under the wire, but there is a dandy-roll. The drying cylinders are shown separately, and the paper is being wound up wet, after one pressing. It is not clear as to whether the paper could be led straight from the press to the drying cylinders or whether it was reeled up wet and subsequently run through the drying cylinders.

12

Early Victorian Paper-making Machines: Modifications and Inventions

BY 1843, Lemuel Wellman Wright had moved to North Wales where he was a paper-mill engineer. He invented a number of notable improvements to the cylinder-mould machine. These are described with the help of the drawing, which explains the full set-up (No. 93).

In the first place he used the open-ended cylinder-mould which has been described earlier, but he had what is apparently the first lick-up felt to remove the web of paper from the cylinder-mould, and lead it into the nip between the press-roll (K) and the drying-cylinder (L). The design of the cast-iron drying-cylinder is interesting, being so constructed that the steam was only contained in the outer portion of the cylinder and in the spiders which went to make up the casting. The main bulk of the cylinder itself was open to the air.

This cylinder was a single or "Yankee" type, of large diameter, and the paper was stuck onto it by the wet- or over-felt as it came from the cylinder-mould. During the passage of the paper over the cylinder, it was pressed against it by three or more press-rolls, which were held against the cylinder by lever arms and weights, and were not driven except by friction against the cylinder, or rather against the paper as it stuck to the cylinder. With regard to the four rolls driven by friction on the surface of the cylinder, the two rolls marked (K) were pressing-rolls, and those marked (M) were steam-heated smoothing-rollers. In this way he made a very highly machine-glazed paper. This appears to be the first time that this type of paper was made. He claimed that the surface was far better for writing upon than that of any other paper previously made, and that for printing purposes it gave excellent impressions.

Another interesting feature of this machine was the fact that doctors were used on the cylinder. The wet-felt or over-felt was led down into a washing-trough, after it had deposited the sheet of paper on the cylinder, where it was continuously washed and battered, in order to keep it clean and open. The washing arrangements and the beating-roll can be seen in the drawing. The felt could also have its tension altered by stretch-rolls, which were operated by chains working a pulley, and a screw.

Unlike most M.G. papers of the present day, the paper made on Wright's machine, after it left the drying-cylinder, was taken through a tub-sizing bath, shown at (W) on the drawing; and from there, after sizing, it was led over a roll (w), after which it was cut off by a square revolving knife, the fly-knives being fixed to the corners of the square, and cutting the paper against a dead knife during the revolution of the knife-roll (Y). As the sheets were cut off they dropped onto a short travelling felt which carried them down and laid them on the table. This was the first "layboy" that has so far been noted in a paper-mill.

Regarding the tub-sizing, the paper did not go into the bath, but picked up its size between the sizing-rollers (U and V), the size being deposited between these two rolls, and the excess running down into the tub (W). It is not clear how the sheets of paper were dried, as they must have been damp from the size by the time they were cut and laid on the table, there being no drying apparatus provided after the tub-sizing. Presumably these sheets were hung up and loft-dried, which was quite common practice at that time.

Thomas Nash, who was a paper-maker of St. Paul's Cray, Kent, seems to have had rather the same idea as Amos about drying paper, because in 1844 he invented a means of drying tub-sized paper by hot air from a furnace in place of steam which was commonly used. His apparatus, which was very elaborate, is shown in the illustration (No. 94). It consisted of a series of cylinders with an internal stove, which had between their surface and the stove a revolving fan. The stove was supplied with hot air from a flue which passed under the dryer and then along the back where there was a pipe leading up from this flue into each of the so-called stoves situated in the centre of the cylinders or drying-drums. He appeared to rely on hot air leaving the flue and dispersing itself inside the stove (A), and when it cooled down, running back into the flue again, and eventually being taken up the chimney which was provided at the end of the flue.

The paper was led from the tub-sizer over the roll marked (w) and round all the drying-drums, the surface of which it almost completely covered. It passed down to the last dryer, and was then led back on a felt extending the whole length of the machine, supported on small pulleys. It was eventually led back again round the guide-roll, without a felt, throughout the whole length of the drying-machine, until it was reeled up on the roll (x) on the left-hand side of the machine. The paper thus made three passes over the length of the drying-machine.

It seems to have been a very elaborate and expensive piece of equipment, compared with the usual sparred-drum type of air-dryers, generally in use at that time for tub-sized paper.

It is not clear what sort of circulation this would have given, but the apparatus does not seem to have been generally adopted in the trade, although it may have been used by Nash himself at St. Paul's Cray.

It was reported in 1843 that there were three hundred and sixty-seven paper-making machines in England, Scotland and Ireland, and three hundred and fifty-nine vats for making paper by hand. The paper-making machines were mostly made by Bryan Donkin and Company, of Bermondsey, Tidcombe of Watford, J. and D. Bertram, of Edinburgh, and by a firm in Aberdeen. France had about twenty paper-making machines, mostly made by Donkin.

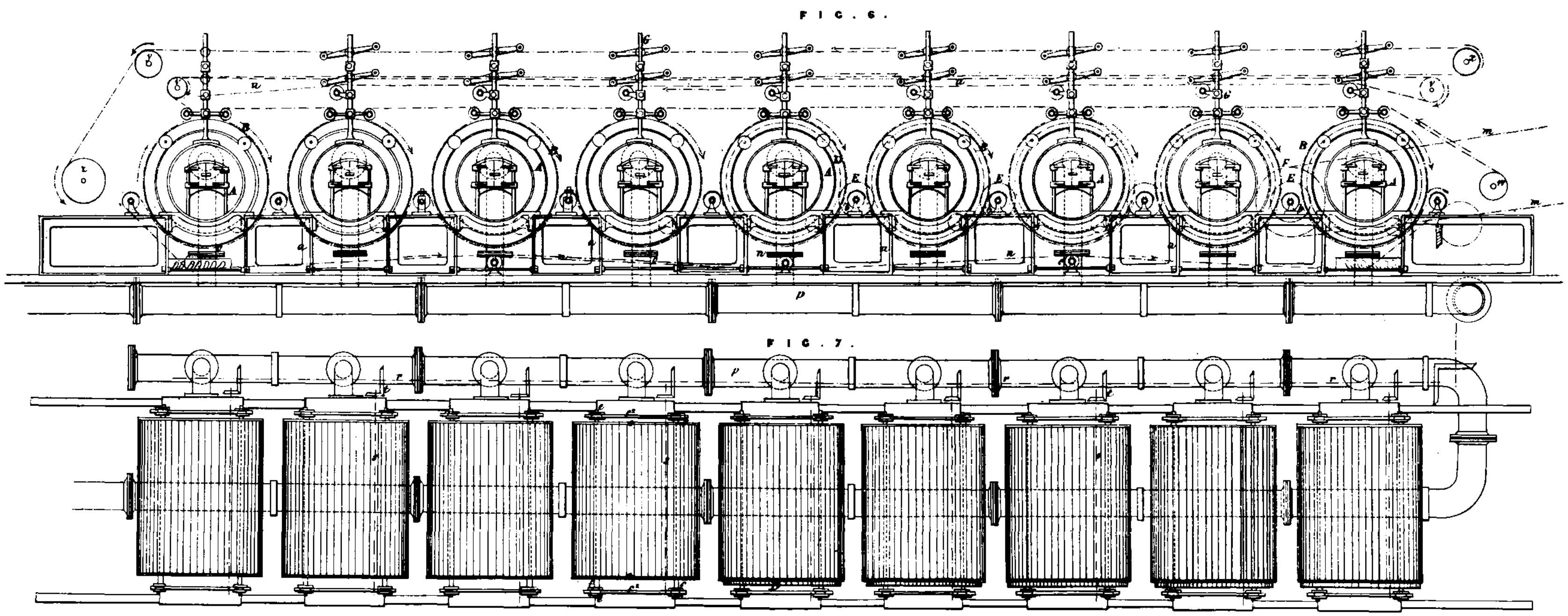
Chorley Mill was started by T. B. Parke, who installed one paper-making machine.

Austria was reputed to have forty paper-making machines, but it is not known where these were made. They could not all have been supplied by Donkin, although he had made some of them.

John Donkin left London on Tuesday, 14th May, 1843, for another trip to Europe to follow up the enquiries and orders the firm had received the previous autumn. He reached Antwerp on the 15th, and saw M. Godin, who had three Chapelle paper-making machines. Donkin saw one of these machines which was a year old. He also saw the beaters which were made at Liége. The Chapelle machines seem to have been serious competitors of Donkin at this time. These machines, made at Aix-la-Chapelle, were referred to as Chapelle machines; the name of the maker cannot be traced.

A good many engineering firms in Europe had started to make paper-making machines by this time, for Donkin's monopoly had gone. However, the locally made machines were not as good as those made in England, although cheaper because there were no freight charges and duties.

John Donkin sold a sizing process to Schoeller and Hoesch for £30. The object of this was a saving in alum and a consequent improvement in the colour of the paper. He also quoted them £140 for a cross-cutter, without circular knives, and £60 for a consistency regulator, without an agitator, for the small chest, and £25 for a washing drum. Schoeller and Hoesch were also interested



No. 94. Thomas Nash's drying-cylinder arrangement. This is the largest dryer so far known to have been made, and differs from previous dryers in that instead of the cylinders being heated by steam, each contained a stove and an internal fan for circulating the hot air.

in an edge trimmer for removing the edges on the paper-making machine while wet. Schoeller and Hoesch had a new method for putting the name in the paper other than by the dandy, which worked very well, and they promised to put the method in writing for Donkin.

Donkin saw another machine at Cologne, made at Aix-la-Chapelle, but it was not completely erected.

John Donkin, in his account of his visits to cities and mills, has a great deal to say about the scenery and show places, and does not confine himself so much to descriptions of mills and equipment, as his father did on his earlier visits. He covered a great deal of Europe, however, and visited a very large number of mills as far east as Berlin and Potsdam in Germany, also Prague and Salzburg. He had, however, a very unfortunate habit of referring to the cities and towns which he visited by the first letter of the name, which makes it very difficult to follow accurately his itinerary and also the correct geographical position of many of the mills.

On 20th May he was at the Hotel Royal, Cologne, from where he went up the Rhine to Coblenz and stayed at the Giant Hotel. He visited several other places by boat, and then went by rail to Cassel and Frankfurt. This is the first mention made in any of the Donkin diaries of a rail journey in Europe.

John Donkin visited Schriesheim, where there were the four mills of Baron Herding. The lower mill had a Donkin machine and 14 h.p. steam engine to assist the water-wheel. The upper mill had the old Donkin machine which required a new breast-roll, deckle pulleys, vacuum box, a new set of tube-rolls, third press brackets and frame, but the iron press rolls could be used again, also the wooden rolls. This machine also required a new dryer part and three-roll calender. Rowland, the manager, told Donkin that he proposed to put in another water-wheel close to the upper mill to drive four breaking engines for half-stuff.

Baron Herding saw Donkin and asked for estimates for the renewal of the parts of the old paper-making machine, and Donkin quoted £590 plus £180 for the three-roll smoothing press. He also quoted £600 for the 20 ft water-wheel to drive the four breaking engines.

John Donkin wrote to Bryan at Bermondsey and asked for sketches and drawings.

When John Donkin visited Buhl, at Ettlingen, he found that the knives which Buhl had ordered the previous year for the cutting table were too thick, and he undertook to supply new knives, thinner and longer. Buhl also ordered a washing drum and scoops for the consistency regulator. Buhl proposed ordering a cutting machine from Donkin, and enquired for a new paper-making machine. He said they would get the steam engine either from Bermondsey or from France.

John Donkin got a great many enquiries during the whole of his 1843 trip, and visited many mills. He was quoting £150 for washing engines, plus £30 if they also had a drum washer; £170 for a 300 lb hydraulic press; and £170 for cutters.

He got an enquiry from M. Moffe, of Munich, for a paper-making machine with all the latest improvements, but he wanted a guarantee of output.

He also visited the Beckischefabriek of Baron von Beck, which was a very large mill. From there he went to Berchtesgaden, which he described as a very beautiful place with wonderful views of the Alps.

While on this trip he collected a good deal of money from various customers, some in cash and some—the greater part—in bills. He also arranged for their erector, Thomas, to be financed by the various mills out of the money they owed for machinery.

At Prague Donkin spent some time at Schallowitz's mill and got some particulars of his stock preparation methods. He boiled the rags in two iron vessels, each holding 10 cwt, and used lime only—no potash—and each was filled twice in 12 hr. He then washed them in a round tank with perforated false bottom and air agitator. He bleached with liquor made from chloride of lime, prepared in a wood tank with an agitator, and allowed the rags to bleach for 2 hr in the engine when they then stood for 12 hr in wooden tanks to steep, after which the bleach had spent itself completely and he did not need to wash it out. After that the stuff was beaten ready for the machine.

In consequence of Schallowitz's hospitality, and the information he gave, Donkin presented him with "two silver sword tooth-picks".

At Berlin he saw Leinhaas and took particulars and dimensions for the new machine. He also obtained an order for a rag cutter with six knives, and a rag-duster to do 100 r.p.m. "Leinhaas keeps his bars and plates always dull to make strong paper."

Donkin reported that all the paper-making machines at Cassel, and two at Osnabruck, were in very bad condition.

Schoeller and Hoesch, of Düren, made three hundred reams of paper in a 24 hr day (day and night) at 10 lb per ream, or 3000 lb.

In 1845 Pewtress stated that at Iping (mill No. 123) they made 2600 lb of paper on a 48 in. machine in a week (for *The Times*), not including Sunday.

At Woking mill Mr. Bailey said that working day and night they made 6 tons of paper per week. The yield from low quality rags and bagging was 66 per cent. (Donkin's mechanic Bowery said they were losing 100 lb in 12 hr at the stuff pump.)

Jacob's machine (No. 130) was 72 ft long from second slice to centre of reel.

Tracing paper was made by Heath and Company in the following way: "They let down best Venice turpentine with warm turpentine in the proportion of one ounce Venice to one pint ordinary turpentine, and then laid it onto sheets of Double Crown with a piece of clean flannel, the sheets were then hung up to dry for two or three days. (Note: a small proportion of acetate of lead added helped the drying.)"

A paper-making machine working day and night required two engines (112 lb capacity) to break sufficient rags for bleaching, to supply two washing and two beating engines giving the rags a proper time in the engine for good half-stuff. But if the breaking engines were worked on Sundays sufficient half-stuff could be made with two breaking engines, after the stuff chests in the machine house are full, to carry through the week, when working only one breaker for half-stuff during the rest of the week.

Continuous working on day and night shifts seems by now to have become established practice in many paper-mills.

Donkin's engineer and erector, Bowery, reporting from Schoeller and Hoesch, Düren, in May, 1846, said that Hoesch made his thin papers from new clippings of linen. This was well boiled, and made into half-stuff which was drawn out as long as possible with a dull roll and brass plate. It was then gas bleached and carried back to the washing engine for washing out. Following this it was steeped in cloride of lime bleaching liquor for 12–15 hr and then pumped out and put in the beating engine where it was carefully beaten for 5–6 hr. The stuff was coloured with ultramarine blue, and sized with resin engine size as usual.

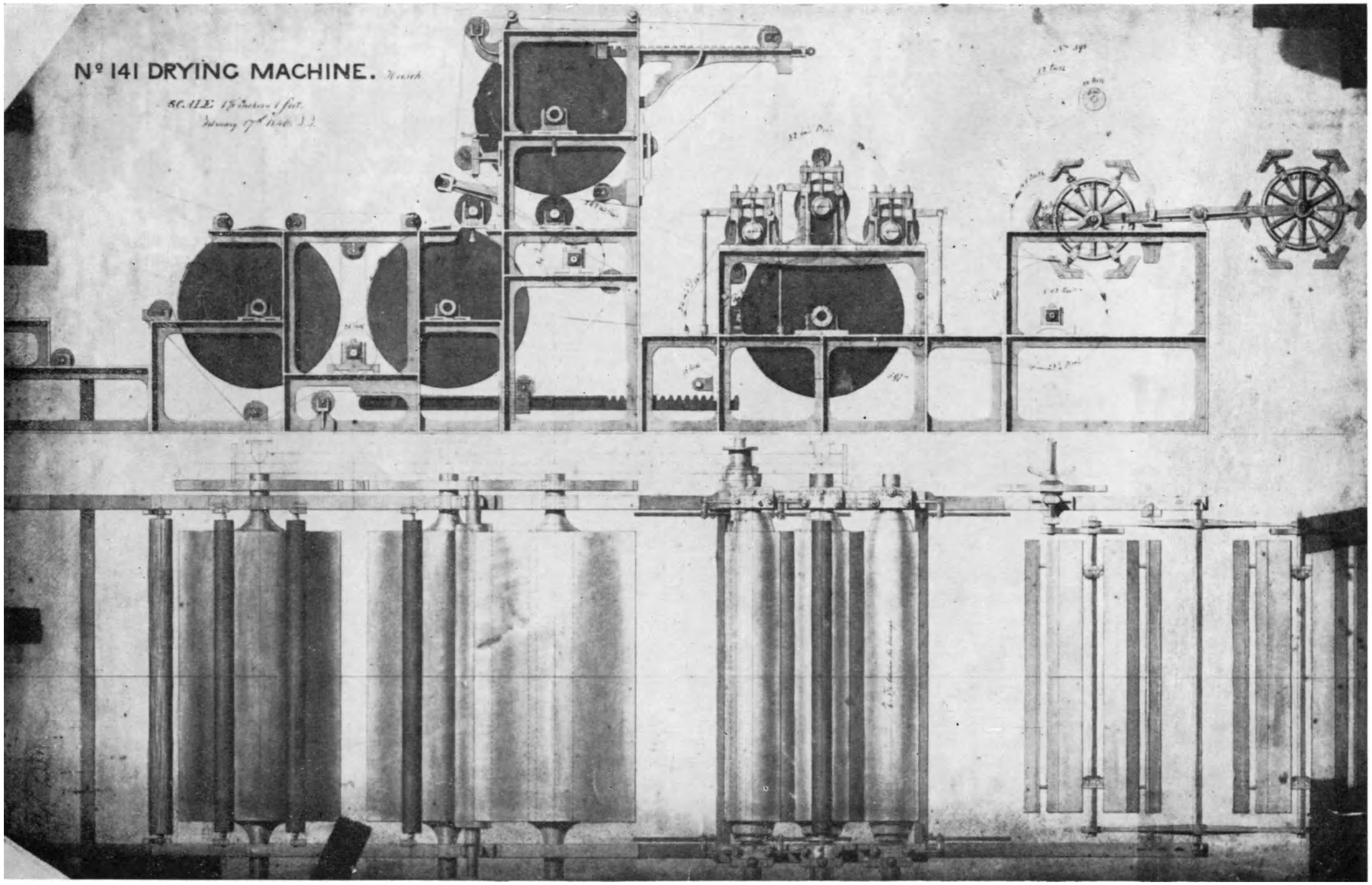
This is the first mention of a brass plate in a beater, and is evidently the forerunner of the phosphor bronze bars used for strong papers many years later.

The method of bleaching is closely akin to the three-stage bleaching now common to many mills.

A number of experiments were being carried out in various mills at this time to destroy the residues of bleach in the stuff without having to resort to long periods of washing in the engine.

At Ibotson's mill, No. 279, at Poyle, the Hoesch method was used, and was as follows:

> The material used is the bi-sulphite of soda. An earthenware retort may be used, which should be filled about half full with vitriol, and mixed with a quantity of chopped straw. Another vessel is to be filled with a saturated solution of soda in pure water. The gas must be allowed to come off and mix with the soda solution from 12 to 18 h, when the Baume



No. 96. Drying machine for Hoesch of Düren, Germany, in 1846. The presser rolls on two of the drying-cylinders of this machine are an interesting feature, as also are the combined drying-cylinder and press-rolls, to give "calendered" effect. The reel-up has expanding drums.

> tube should be 21°. The retort may be about 13 in. deep by 17 in. diameter, containing about 35 quarts of vitriol and about 2½ lb straw. This solution of bi-sulphite should neither have a preponderance of gas or of soda, but both should be rendered neutral, and this point may be ascertained by the test papers, litmus and turmeric, neither of which should change colour on being dipped into the solution. Should the acid predominate the blue litmus will be turned red, and if the alkali, the turmeric paper will be turned red; of the two it is better the acid predominate.

This appears to be the first method used to make an antichlor, and it also establishes the fact that litmus and turmeric papers were already in use as indicators.

A good deal of experimental work was being done in mills to try to ascertain the best methods of drying the paper after it had been tub-sized, and much of this work is described by Bryan Donkin:

> Experiments tried in the presence of Davidson, Brock and Farey: A sheet dried in the open air gave little or no better sizing result than one dried at 90°, but Brock says that the same paper sized in the same way but dried in the loft, five or six sheets together, and taking three or four days, will bear dipping well. Brock says his paper usually increases in weight 8 per cent by being tub-sized.
>
> When the drying chamber was heated to 168° two sheets of paper were dried for 1½ and 2 min respectively, bore well to the tongue and dipping for 6 h. Tried other experiments from 168° to 130° with nearly the same result.
>
> At Towgood's mill (No. 24) the air-drying machine consists of thirty-one drums about 3 ft 6 in. diameter. The heat is 92°; speed of paper 35 to 40 ft/min. Towgood says that at times difficulty occurs in drying so quickly from want of sufficient draught. The drums are placed alternately over each other about 7 ft between centres and 3 ft apart laterally; each drum has an expanding rigger pully.

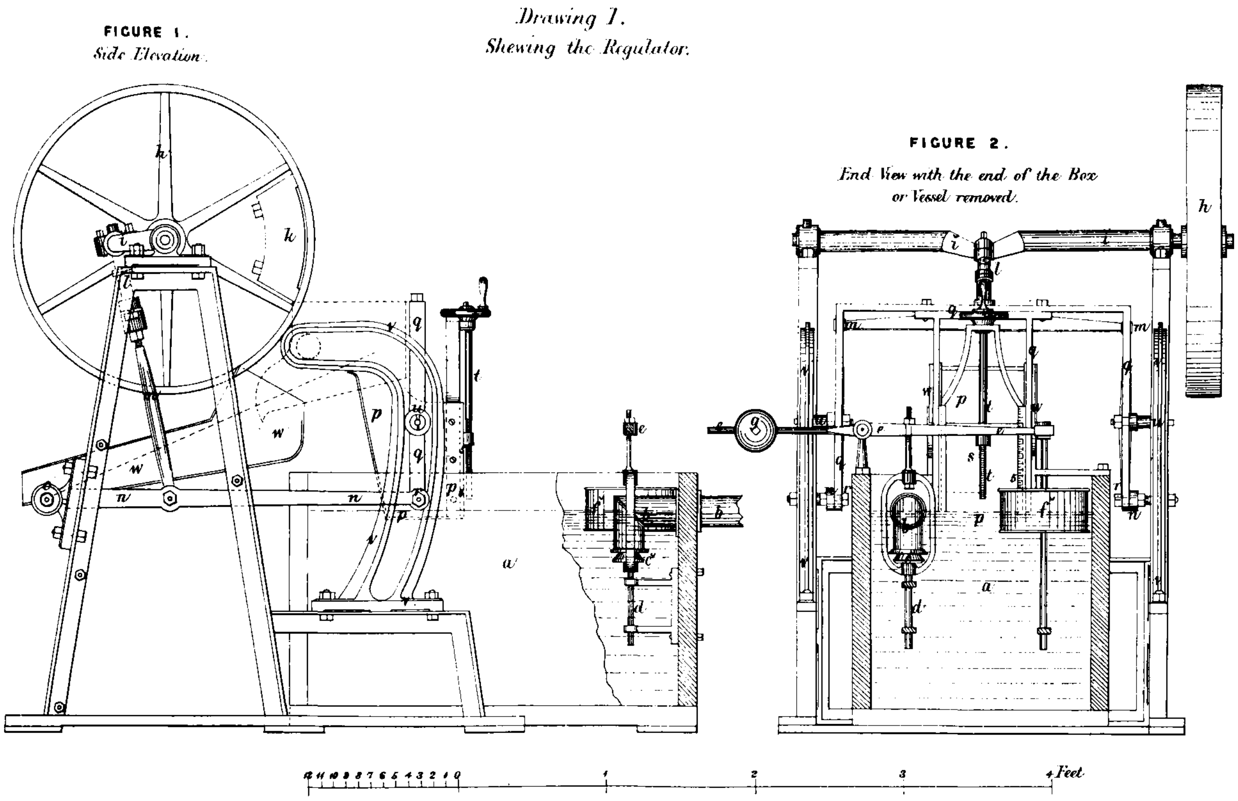
In 1846 the following prices were quoted to Harry Donkin, who was in Florence on a visit to the continental mills:

List of prices of machinery sent from Bermondsey to Harry Donkin at Florence, Italy, in 1846

	£	s.	d.
Paper machine 5 ft 2 in. wide wire extra long × 3 presses	650	0	0
Dryer machine 3–3 ft cyls. and driving app.	310	0	0
Finishing press 3 ft cyl. × 2–12 in. rolls	230	0	0
Pulp regulator and app.	50	0	0
Knot strainer	75	0	0
Sand strainer and hog	35	0	0
Vac box and pumps	110	0	0
Metal parts of engine 112 lb complete, except wood work and lining	105	0	0
Steel bars 10*d.* per lb			
Steel plates 11*d.* per lb fitted up			
Ream cutters (saw)	85	0	0
A patent (dandy) roll (covered)	15	0	0
A self actor for engines	21	0	0
Deckle straps (up to 17 ft long)	4	4	0
Deckle straps long 3*s.* per ft extra			

	£	s.	d.
Estimate for Mr. Archer, 1846			
Vacuum pump and box iron frame	135	0	0
Sand strainer and frames and 2 hogs	67	0	0
Box for strainer	7	0	0
Machine w. wheel 2 rings 9 ft 6 in. diam. wheel 11 ft 9 in. 3 ft 6 in. wide. 32 buckets bolts, etc., no shaft or starts	48	0	0
Various Prices			
A 3 press and app. 9½ in. rolls	120	0	0
A 3 roll press with repolishing rolls	175	0	0
A force pump with beam crank, etc., for a good cistern	19	0	0
T. cistern, elbows, etc.	14	0	0

In 1846 Charles Cowan, of Penicuik, "in that part of Great Britain and Ireland called Scotland", a paper manufacturer, invented a stuff-regulator, or consistency-regulator, in order to help in keeping the correct weight on the paper-making machine. This was quite a complicated stuff-regulator, and is described by reference to the two drawings, Figs. 1 and 2; one being an end view of the box, with regulator-tank removed, and the other a side elevation showing the operation. The cistern, or box, is marked (a), and the box was placed as near as convenient to the stuff-chest. The level of the stuff was kept a little higher than the bottom of the stuff-chest, in order that it could flow by gravity into the regulator-box, through the stuff-pipe (b). In the orifice of this pipe, which is shown in Fig. 1, there was a conical valve which, when closed, prevented any stuff from passing out of the chest into the regulator-box. The valve, which was attached to a spindle (d),



No. 97. Charles Cowan's stock consistency-regulator, showing all the details of operation.

and which moved in two guides, was connected as shown in Fig. 2 to a lever, the extremity of which was connected with a spindle of the float (f), and also moved in guides. The other end of the lever was loaded by a balance weight (g). In place of the conical valve, the usual ball-cock and float could be used if desired.

There was a driving pulley connected to a crank, and a bucket or cup (p) was attached to the framing connected with the other extremities of the lever by means of studs, so that the bucket could be moved up and down. One of the sides of the bucket consisted of a slide moving in grooves, and connected with an adjusting screw and handle, by which the slide was moved up and down in order that the capacity of the bucket might be increased or decreased. The idea was that this bucket dipped down into the float-chamber, and picked up stuff, and as it was lifted up it tipped over, as shown in Fig. 1, and delivered the stuff into the breast-box, or as near the breast-box as possible. It repeated this motion, so that the whole thing carried on according to the speed of the machine, delivering a predetermined number of bucketfuls of stuff per minute, from a constant height of stuff in the float-chamber. Hence the amount of stuff going to the machine was regulated to give a steady weight all the time the machine was running.

There was a scale on one of the grooves of the slide, which helped the machine-man to make note of the quantity of stuff required for different widths of deckle, weights of paper, and speeds of the paper-making machine. The consistency of the stuff emptied from the beating-engine into the machine-chest was also important, if this consistency-regulator was to function to the very best possible advantage.

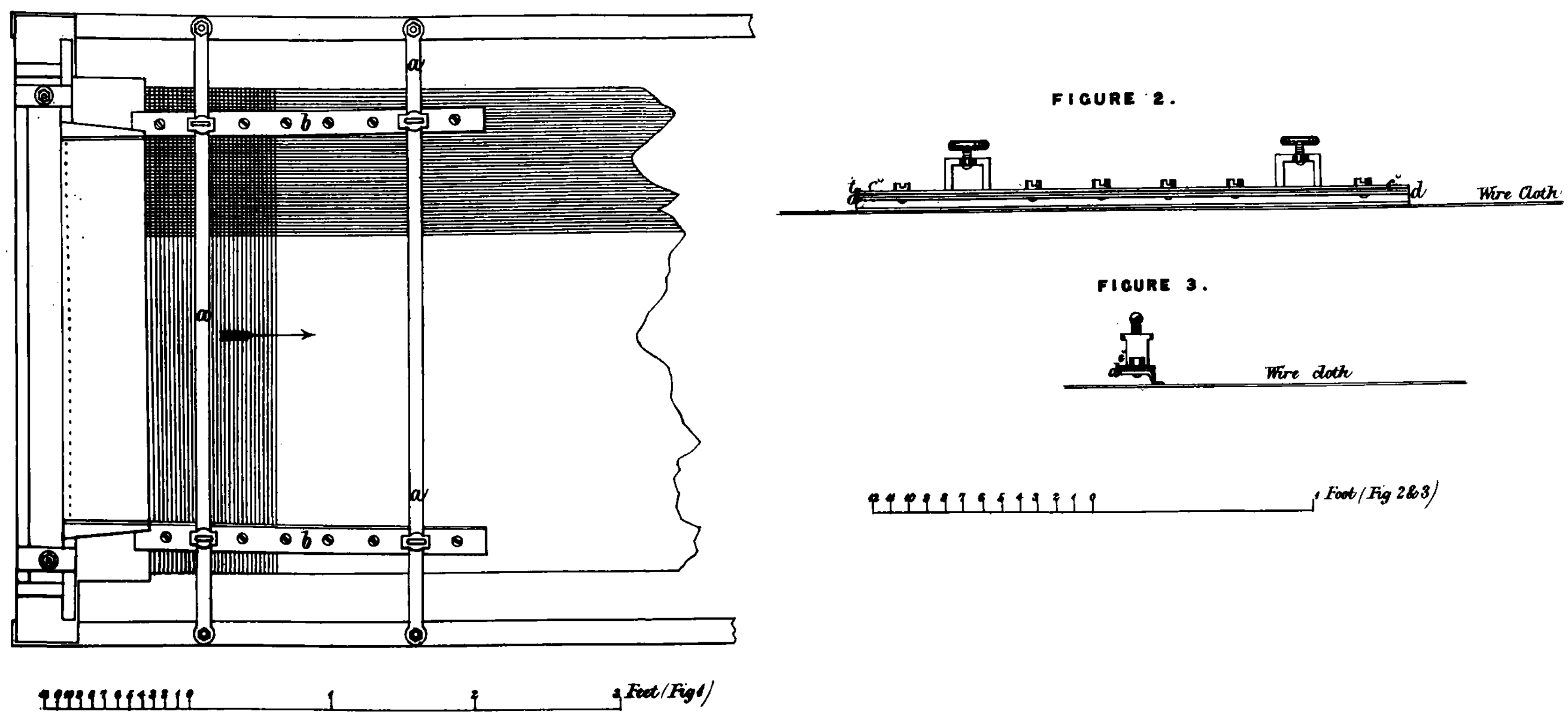
Charles Cowan also invented the fixed deckle, which was the first time that anyone tried to run a paper-making machine without moving deckle-straps. This deckle, as will be seen from a glance at the picture, was much the same as the present-day fixed deckles, or Wentz deckles, in use on most paper-making machines throughout the world. It seems a most extraordinary thing that, after Cowan had given paper-makers this excellent substitute for deckle-straps, the latter continued to be used for at least a hundred years afterwards, with their many troubles and faults. In fact there are many machines even today using deckle-straps, when these could easily be substituted by the fixed deckle, as invented by Cowan in 1846. The description of Cowan's deckle follows.

Two squared bars (a), shown in Fig. 1, No. 98, were secured to the side of the frame of the machine. These bars were made of brass, and fastened to them the deckles, which were made as follows: A thin plate of brass (c), Figs. 2 and 3, was bent in a rectangular shape so that its lower extremity reached to about $\frac{1}{4}$ in. from the wire-cloth. An iron plate (d) was secured by small screws to the brass plate (c), and between these two plates was interposed a strip, which he preferred to be of thin leather, or waterproof cloth, or other flexible substance. This strip was $\frac{1}{2}$ in. broad, or deeper than the bent side of the plate (c), and rested upon the wire, as can be seen in the drawing. The strip prevented the spreading of the stuff over the edge of the wire, and thus fixed the breadth of the sheet, or web.

He arranged that the deckles should be fitted so as to move easily, even when the machine was at work, along the brass bars. This enabled the width of the paper to be changed while the machine was running. He even had the brass bars (a) graduated in inches and eighths of an inch. He said that the square bars which supported the deckles should rest on a side framing in such a manner that they could be raised or depressed to the extent of $\frac{1}{4}$ in. in height, so that the lower edge of the bent part of the plate could be removed from, or towards, the wire, according to the nature of the stuff employed.

Cowan also invented a method of putting watermarks, or other marks, in paper without using a dandy, and he did this operation on the first or second drying-cylinders—a method which has frequently been tried since—but without much success. He stated that any of the drying cylinders would do, but that he preferred the first or second as being best fitted to impress the marks. He had

FIGURE 1



No. 98. Cowan's stationary deckle-straps, to replace moving deckle-straps. It will be seen that the brackets, adjusting screws and lips are the same as those recently adopted and in use on many paper-making machines at present.

an iron spindle with bearings carried by the levers. To this spindle he fixed any desired number of brass rollers, which were easily moved about to any part of the spindle, wherever it was desired to put the mark in the sheet. On the circular part of the surface of the rollers, the marks or devices to be put in the paper were made; the two levers, loaded with weights, pressed these rollers onto the paper, as it passed over the drying-cylinder.

In order to get over the formation and irregularity difficulties experienced on the horizontal Fourdrinier machine-wires in the early days, Samuel Millbourn, a paper-maker, of St. Mary Cray, Kent, produced a sort of vacuum-forming machine in place of the ordinary Fourdrinier wet-end. This was a very complicated affair, but can be quite easily understood by reference to the drawing No. 99. He used an endless-wire cloth, which passed up a vee-shaped breast-box, in which there was an agitator to keep the stuff from settling out. Just in front of the wire, and in order to prevent it being affected too much by the agitation of the propeller in the breast-box, he fixed a board, marked (c). The wire itself ran up at an angle of about 45°, and as it was passing over the three boxes (g, g1 and g2), stuff settled on it from the suspension of stuff and water in the breast-box. This was assisted by very gentle vacuum being maintained in the boxes already mentioned. This vacuum increased between the first, second and third boxes, from a very slight vacuum in box (g) to a much higher vacuum in box (g2). At the top of the box, and immersed in the water, was a board (e), which prevented froth and air bubbles being carried up from the surface of the stuff in the breast-box, as the stuff passed up along the wire. There were also deckle-straps running inside the box, marked (f2). These passed round on little rollers, to prevent the stuff running off the edge of the wire.

When the wire had passed the third vacuum-forming-box, it passed over two rollers, over the top of which a dandy, or press-roll, exerted slight pressure on the web of paper. The vacuum in this box (J) was about 6 in. The wire passed on round the second roll, and immediately after this the wet web was blown off by a jet of air onto the felt, which then took it through the first press. This stream of air came along a pipe (m) and was squirted through an orifice (k) to push or force the web of stuff off the wire onto the felt. The wire then passed on into a washing box to clean it, after which it passed round two further wire return rolls before going up to the suction-boxes and formation-box.

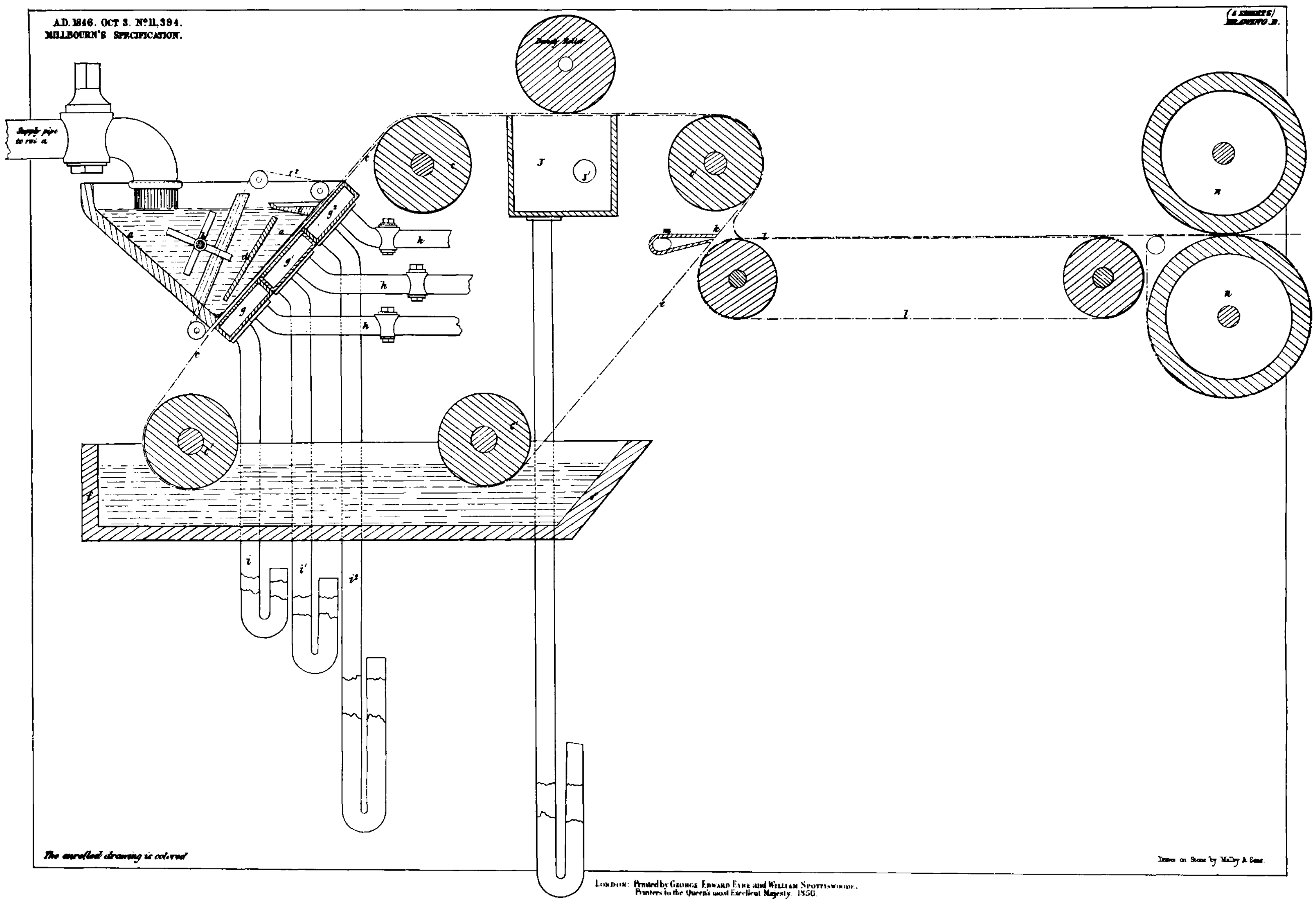
As will be seen in the drawing, these suction-boxes had barometric water legs to take away the excess water, and the air was drawn away along the pipes marked (h).

Millbourn maintained that by using this method he got far better formation and greater regularity, compared with the ordinary Fourdrinier wet-end, where the stuff ran down an inclined plane, past the slice, and over an apron onto the wire.

He also patented an improved type of tub-sizing machine, and a very elaborate enclosed air-dryer, rather like those used on some of the tub-sizing and air-drying plants in the United States of America at the present time. It consisted of a very large wooden chamber with numerous small rollers at top and bottom; the paper was led over these. Hot air was passed up through slits in the floor, and was drawn away through openings at the top. While it was in no sense a vacuum chamber, it certainly controlled the amount of warm air being passed in to carry off the moisture from the paper. It enabled a much greater degree of drying to be carried out, with a predetermined amount of hot air, than could be managed with an ordinary open air-drying plant fixed in a large machine-house or air-drying room.

J. and R. Shorrock were building paper-making machines at Darwen, Lancs., at this time.

In 1849, Amos and Clark made an important discovery with regard to the behaviour of paper after it had been sized and partly dried. They found that in the case of tub-sized paper, if they then passed it through a trough of cold water, and then through a pair of press-rolls, and dried it afterwards in the ordinary way on the drying-cylinders, the paper was very much better so far as bearing



No. 99. Samuel Millbourn's vacuum-forming machine of 1846. Elevation of this ingenious forming machine, showing in detail the complete cycle of operations, which are fully explained in the text.

ink was concerned. They also discovered that erasures might be made to the writing and then written over without the ink running in the way it does if sized and dried in the usual manner of the time. They also found that when paper was dried after sizing, by the sizing machine then in use, the paper was very harsh until it stood for some time "to get the weather", or to become matured.

Great difficulty was experienced in glazing this paper, but this could be overcome by passing the paper round a hollow cylinder through which a stream of cold water was continually running. By this means the heat in the paper was carried away, and it was rendered more tractable, and brought to a proper state for undergoing the glazing operation. This is extremely interesting, but the inventors do not mention another important fact in connection with damping the paper and drying it a second time, or passing it over a cylinder through which cold water is passing, that is the removal of static electricity, which has always been troublesome in the finishing departments of paper-mills. It may, of course, have been the case that the paper was not made at sufficiently high speeds in those days to make enough static electricity to cause trouble in the finishing.

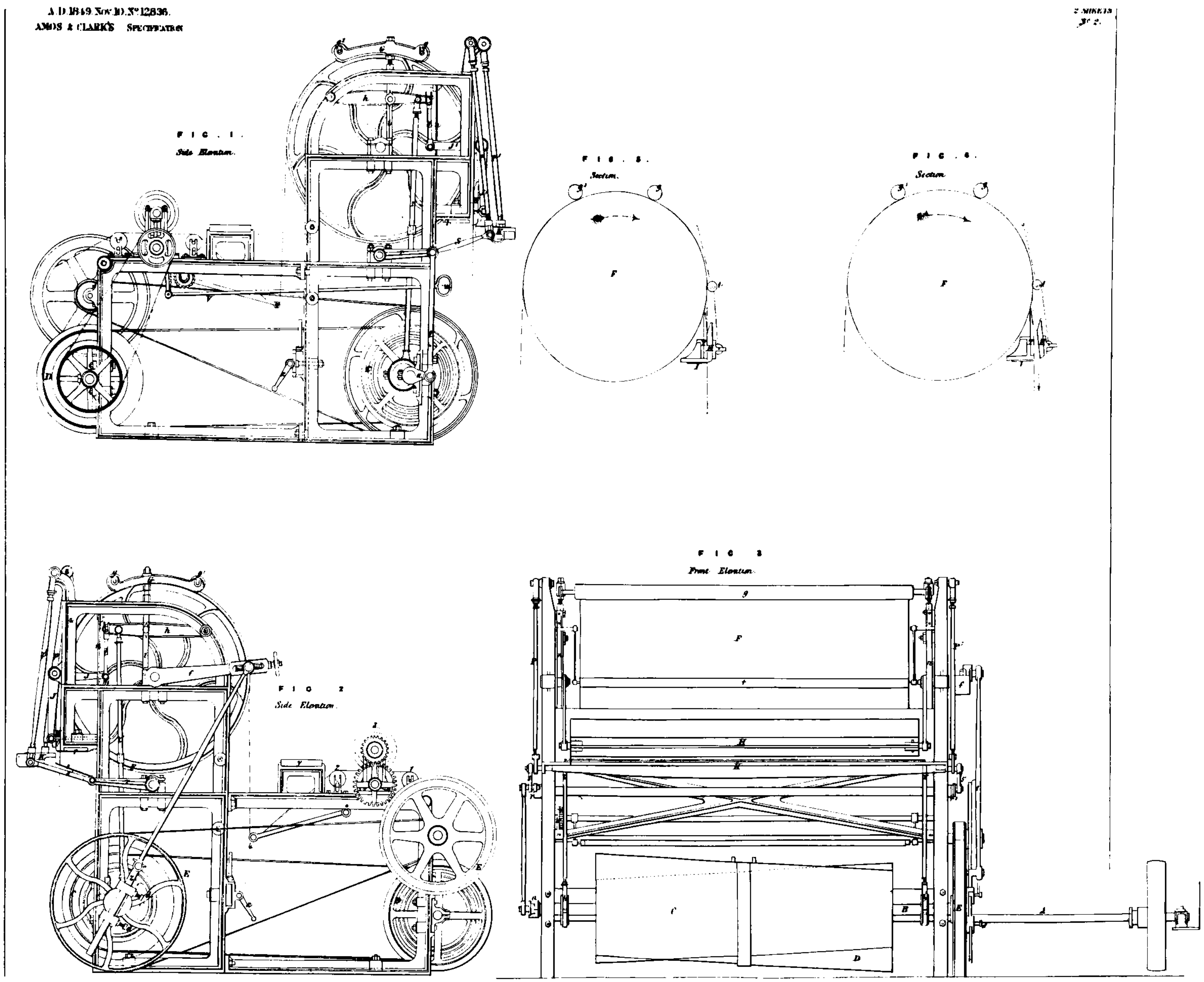
There is another feature of the cold water bath treatment to which they do not refer, although it may very well have applied, that is, the trouble which is often experienced with the paper cockling during drying. If it is passed through cold water when partly dried, and then the drying is completed, the cockling will disappear, and the paper will be perfectly flat.

Amos and Clark mentioned that great improvements had been made on paper-making machines during this period, about the middle of the nineteenth century, and they were running much faster. In consequence of this, trouble had been encountered in the cutting of sheets on the paper-making machines, as was common practice in those days. In order to get over this, they invented their new sheet-cutter for installation away from the paper-making machine itself, and, of course, this cutter became very well known throughout the world. It was in use until quite recent times, and may still be in use in certain mills even today, particularly on comparatively slow-running machines, where the paper has to be cut to register, on account of watermarking. Their new improved cutter is shown (No. 100) in elevation in Fig. 1, and Fig. 2 is an elevation of the opposite side. Figure 3 is an end view taken at the back part, where the paper is delivered, and Figs. 4 and 5 are diagrams showing the gathering-roll and the action of the parts in connection with it.

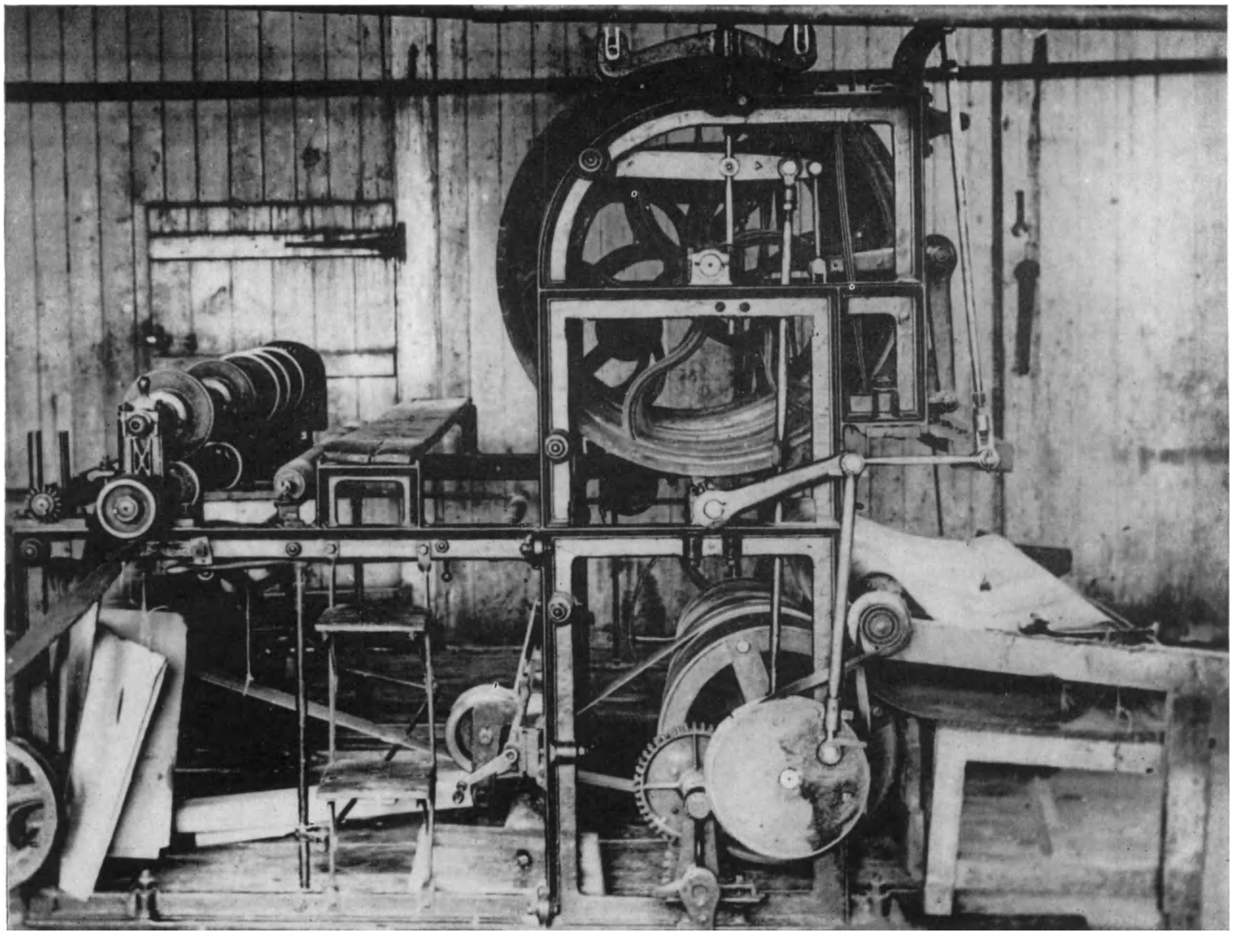
The machine was driven from a shaft (A) from any prime mover, and the shaft (B) was driven by a strap passing round the conical drums (C and D), mounted respectively on the shaft.

The principle of the cutter was that by a series of adjustable cranks, the paper was led round what was called the "gathering-drum" (F), which is the big wooden drum mounted at the top of the cutter. After the paper passed this, it went across the dead-knife and hung straight down, and when the length of the paper was sufficient to give the size of sheet required, the clamp came forward and held the paper firmly on the dead-knife plate. At the same time, the gathering-drum (F) came to a standstill, and the knife, which was swinging on the long arm, came across, cut off the sheet of paper, which dropped onto a slide. The machine then started to operate again automatically with the gathering-drum turning and bringing forward sufficient paper to give the next sheet. Very minute adjustments could be made to the cranks and on the cone pulleys on this machine, so that the machine-man could cut paper to register, which had very intricate designs and pin-marks in the corners of the sheets, such as postage-stamp and other papers. It was a most ingenious machine, and extremely accurate cutting was possible on it. It was also possible for the operator to watch the watermarks, and to fix a mark on the drum itself, so that he was quite certain that when his knife came across, the sheet would register perfectly.

As late as 1855, John Dickinson was still taking out patents concerned with paper-making machines. At this time he patented a machine for making a two-ply sheet of paper in which one of the plys was made on a Fourdrinier type of wet-end, or as he called it, the "shaking wet-end",



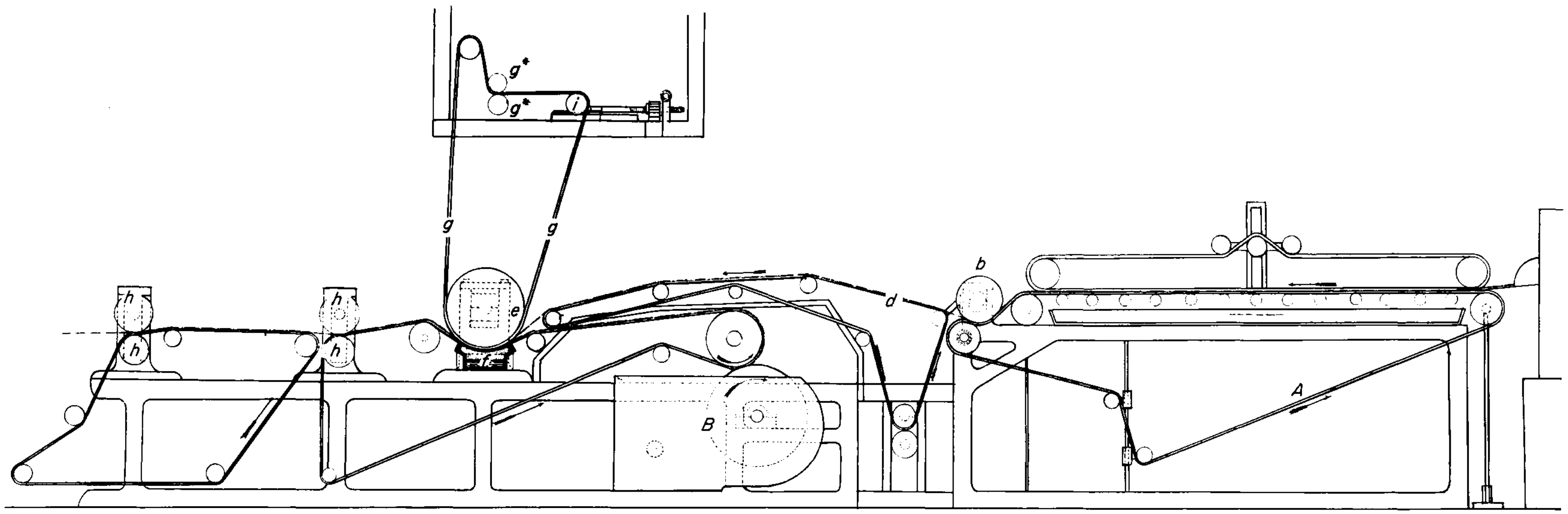
No. 100. Amos and Clarke single-sheet continuous-cutting machine for fitting at the end of the paper-making machine to cut the watermarked web to register as the machine was running. Some of these machines were cutting fine papers on the paper-making machine as recently as 1920.



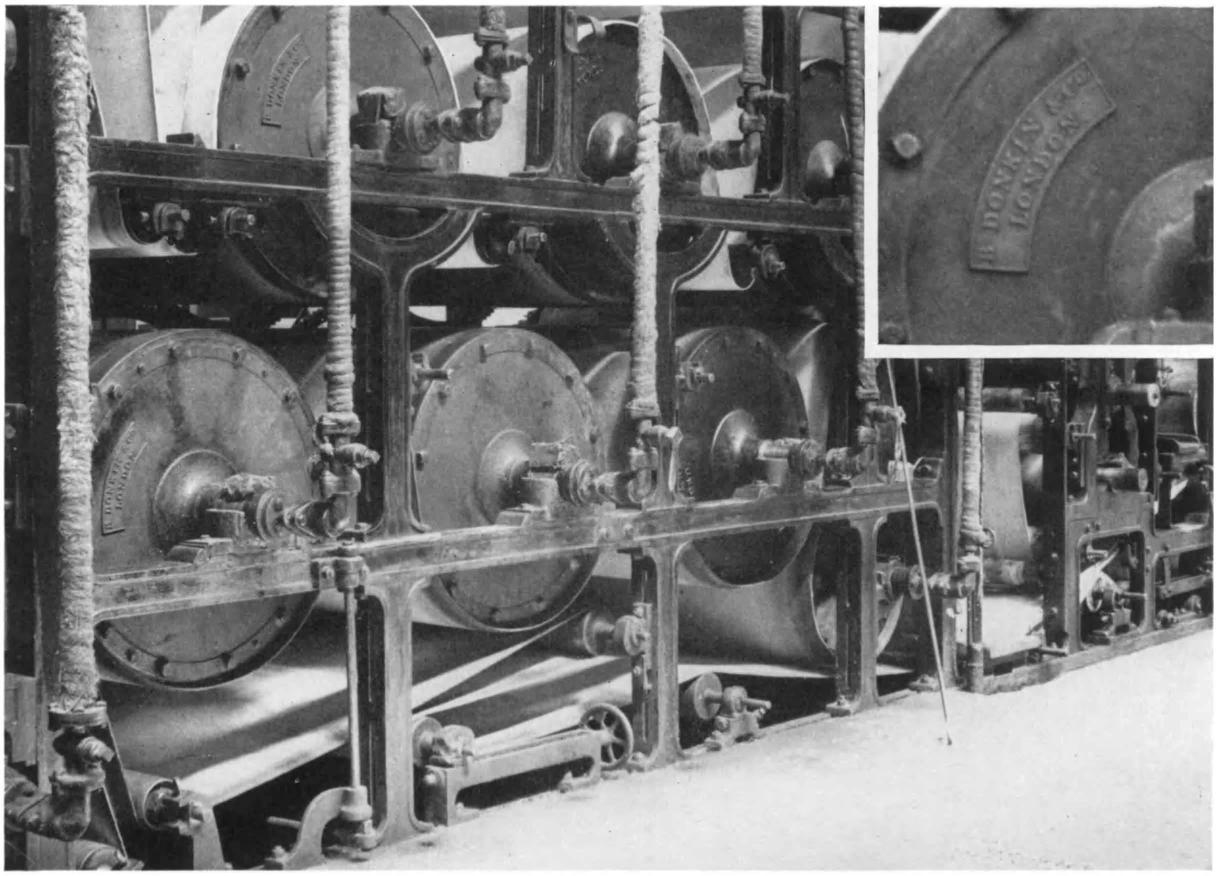
No. 101. Amos and Clarke's cutting machine formerly at the end of a paper-making machine at Frogmore Mills, Hemel Hempstead. (The British Paper Company Ltd.)

and the other, bottom ply, was made on Dickinson's original cylinder-mould machine. The drawing No. 102 shows how this two-ply sheet was made, and it was pointed out by Dickinson that the chief merit of this machine was that the two insides, or wire-sides, of the paper were combined together, leaving the two top-sides available for printing, and other work requiring a smooth surface. When the web of paper had been made on the Fourdrinier machine, it left the couch and travelled along the wet-felt to the wire-covered dandy-roll (e). At the same time another sheet of paper was being formed on the cylinder-mould, and was picked up by the felt passing round the couch-roll on the cylinder-mould. These two webs met at the dandy-roll (e), where they were combined into one homogeneous sheet. The dandy-roll was about 2 ft in diameter, and revolved immediately above a suction box. This roll was driven by a wet-felt (g) which itself was driven from above. The papers, while passing between the dandy-roll and the suction-box (f), passed between the two felts, one on the felt which had taken it round the cylinder-mould machine, and the other on the felt which came down and drove the dandy from above. The combined two-ply sheet then passed through two presses, and then along to the dryer.

Dickinson pointed out that it was very important to have absolute control over the draws on the various parts of the machine, by variable speed arrangements, because the rate at which the paper was made on the cylinder-mould had to be slightly faster than the rate of making on the



No. 102. Elevation of John Dickinson's combined cylinder mould and Fourdrinier duplex paper-making machine, showing the combining press. This machine, as can be seen, was designed for making two-ply papers.



No. 103 and inset. Drying cylinders working on a paper-making machine at Abelheira, Portugal, in 1953. Some of the cylinders are by B. Donkin and Company, London, and were supplied with the machine in 1853. Other cylinders were supplied by Tidcombe of Watford about the same time, and have worked for 100 years.

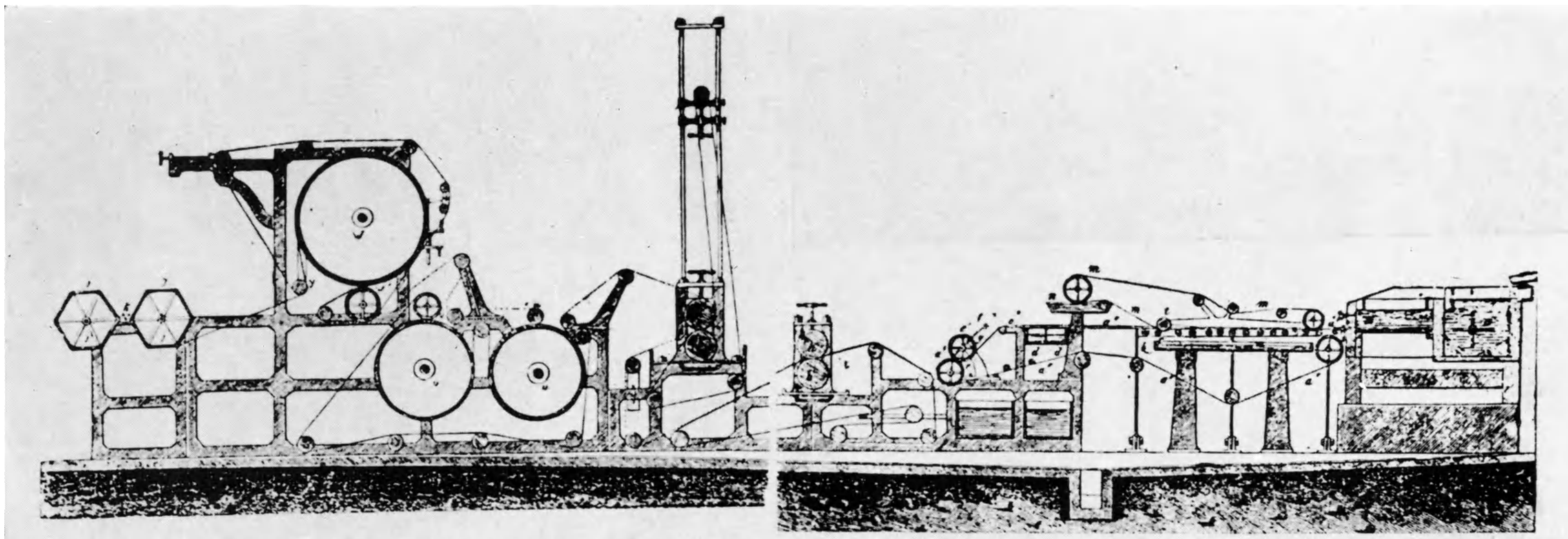
Fourdrinier machine, because of the stretch of the paper once it left the couch. This will be easily appreciated by paper-makers. The machine was very ingenious, and apparently worked very well, giving Dickinson the kind of paper he wanted for the various types of printing, which was important at that time. He said that the paper gave excellent results from copperplate and lithographic printing.

The real combining of the paper was done by the pressure of the dandy, and also the suction in the suction-box itself as the dandy passed over it. It was here that the two sheets were consolidated and stuck together so that they formed one homogeneous sheet on leaving this "suction-press".

In 1847, T. B. Parke put in a second paper-making machine at Chorley (Mill No. 166).

The following notes were made by Donkin about William Weatherley's mill about this time. This mill was at Chartham in Kent, and was numbered 30.

> When boiling rags Weatherley uses 3 lb of alkali to 10 cwt of fine rags, 4 lb for low rags, and for very low rags he also adds a little lime water.
>
> Preparation of animal size for the machine: William Weatherley has four wrot. iron boilers for boiling the size with an inner and outer case all round about 1½ in. space between for heating by steam (a jacketed pan). There are four of these, each holding 8 cwts of thick pieces of skins. The pieces are boiled, first drawing at 90°F, then second drawing at 140°, and then the last at 212°. The three drawings are mixed together to form the stock size, and while it is still hot, or if it has been allowed to cool, it is heated in the sizing room



No. 105. This German machine of about 1850 is a conventional Fourdrinier type of paper-making machine, the most notable feature being the very short making table of the wire part, and the steep fall to the couch. It has a reversing press.

> in an elevated cistern, and run in a pipe across the machine to a size box about 4 or 5 ft high, and it is then conducted by a wood trough to the sizing machine, by the time it reaches here it is about 90° (fit for use), and keeps hot enough without any heating pipe in the tube.
>
> Weatherley puts in 10 lb of alum to 5 cwts of pieces if ultramarine is used, otherwise considerably more alum is used.

This method was in use in many "fine" mills until quite recently.

Chartham Mill had been making paper since 1793, and Donkin put a machine in for William Weatherley in 1851. Donkin's erector, Savage, said the machine ran at 33 ft/min, making foolscap 17 × 13¼ in., 15 lb per ream, and made 182 reams in twelve hours. He found that the paper was 2 ft 3 in. longer when sized and dried, in 1 min, than on the wire. It gained this length in 33 ft, and was 2 in. narrower. Deckle was 66½ in. and the machine chest held nine engines.

> Weatherley's air-drying machine has thirty-nine drums 4 ft diameter, with fans. The driving tapes drive sections of seven or nine drums each, and the tapes bear but little on the drums—only on one rib at the time; they must not bear more down on the drums or they will not drive. Pullies with "ears" (or flanges) are used as guides, and adjust up and down; these must be set quite square and parallel with the direction of driving tapes.
>
> The fans are driven in five sets, each set can be thrown out of gear (a ⅝ in. gut is used). The first set of nine fans are driven at 50 r.p.m., the last at 189 revolutions.
>
> Weatherley thinks the first few drums should be close together, but the later ones could be further apart. The heat of the room should be and is kept at 80°. When I was there (on a hot day) it was 100°, the machine not going. Two tiers of 5 in. and 4 in. steam pipes about 3 ft below the floor. Schoeller and Hoesch drying machine has thirty drums 4 ft diameter, and takes out 310 ft of paper. Howard's drying machine has thirty-one drums, 21 in. diameter, 5 ft 6 in. centres, and takes out 191 ft of paper.
>
> On putting on a new wire if it is longer on one side than the other, which is often the case, you should not attempt to remedy it by the guide-roll or stretcher, as by using them the wire would be driven on one side or the other, or worked into a wrinkle. The best plan is to alter the pressure of the upper couch roll by pressing harder on the shorter side of the wire.

This was Harry Donkin's *verb. sap.*!

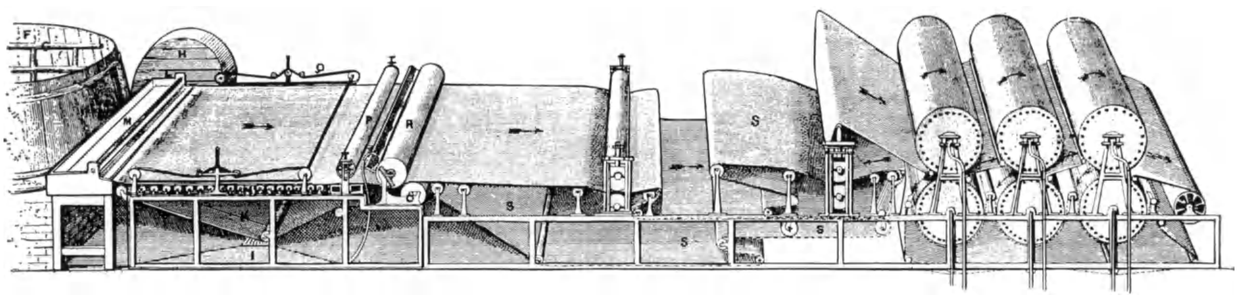
There are interesting notes in Donkin's diaries about the filtration of water. Some of the methods employed by him being very similar to the latest methods used by mills at the present time. Much more crude and ineffective methods have been employed in the intervening years.

One pond constructed at H. V. Bailey's mill at Woking (Mill No. 374) had its sedimentation pond 80 ft long by 90 in. wide. The filtering pond was 100 ft by 90 ft, both bottoms being puddled, and in the filtering pond there were four rows of slates with tiles on them 8 in. high, 6 in. wide and 9 in. long, of a horseshoe shape, the heels resting on the slates and placed about ½ in. from each other at the ends, to admit the water. The tiles also had several holes through them for the same purpose, and formed four channels for the filtered water, and these channels led to another channel along one side of the pond, and thence to a well, out of which the water was pumped to the engines.

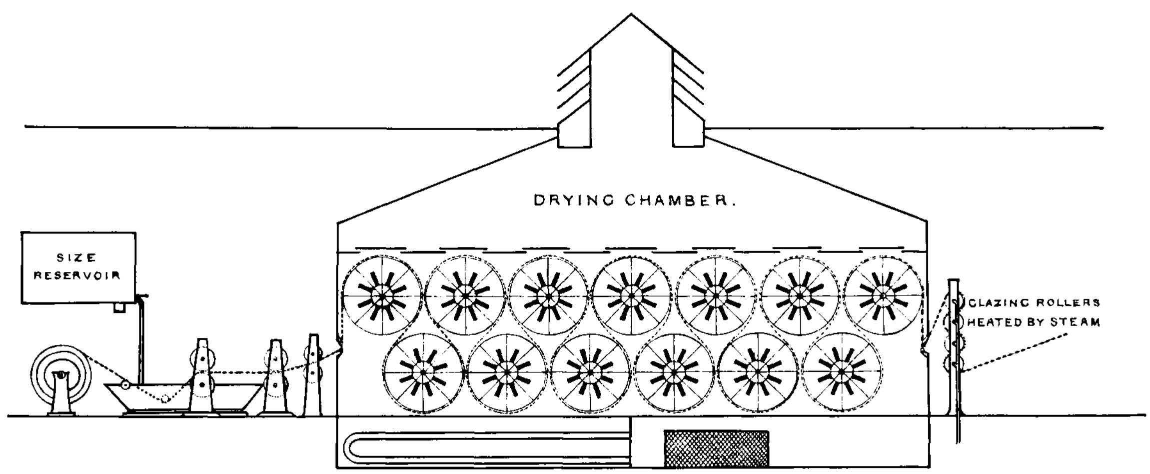
The bottom of the filtering pond was covered with large gravel stones to about 12 in. in depth, spread in an undulating fashion so as to cover the tiles to about the same depth as the bottom of the pond. The next course above was gravel varying in size from marbles to walnuts, and about 6 in. in depth. Above this was spread another course 5 in. in depth with gravel the size of peas and beans, and lastly 13 in. depth of fine sand on top, altogether 3 ft of filtering medium, the depth of water above the fine sand varied from 12 in. to 24 in., according to the height of water in the river.

Donkin said that this pond answered the purpose extremely well, and that a properly constructed filter should pass from ½ to 1 gal/min/sq yd of surface, and 3 ft is the best depth of water.

William Joynson, of St. Mary Cray, Kent (Mill No. 327), seems to have been very keen on heat conservation in his mill, and kept close records of coal consumption. He told Harry Donkin that he consumed 4 tons of coal for every ton of paper, including all steam power, boiling, drying, etc., and he only had 15 h.p. of water power. Joynson had eight steam engines made by Hall of Dartford, each averaging 20 h.p., and four small high pressure engines (two to each paper-making machine) whose exhaust steam was used for drying.



No. 106. A paper-making machine of 1856. This shows very little advance on previous machines, and it may have been built considerably earlier than the date of reproduction.



No. 107. The illustration of the tub-sizing and air-drying machine is the earliest known to show a complete separate unit for this operation and it does not differ in design from the present-day sizing and air-drying machines.

The heat of the drying room was 82°F, and he had one hundred and twenty-eight drying drums, with fans, and 1000 ft of paper out between the size-tub and the cutter at the end of the machine. The machine ran at 60 ft/min. He made and sold paper to the value of £120,000 in 1857, and the average price was 9½*d.* per pound.

This mill was very advanced in design and output for the period, and the dryer was one of the largest, if not the largest, ever to be built.

In contrast to the output of Joynson's mill, a vatman at Portals, at Laverstoke, made seven dips per minute of the small 18 in. mould on which the banknotes were made. This means that the output of the crew of the vat, vatman, coucher, layer, etc., was only seven sheets per minute.

The Times stated in their issue of 22nd June, 1858, that their previous week's consumption of paper was 1330 reams which, at 84 lb the ream, was 50 tons, and gave £732 duty to the Treasury, or upwards of £38,000 per year.

The Times also estimated the following output from a paper-making machine: "Foolscap $16\frac{1}{2} \times 13\frac{1}{4}$ in.—20 lb per ream—2.7 lb per 100 square feet; and if this paper is made 60 in. wide at 30 ft/min, then 150 square feet are made per minute, or 4 lb weight; then 4×60—240 lb/hr $\times$ 24—5760 lb per 24 hr or 2.1 tons per day."!

In a list of paper-mills in England, Scotland and Ireland, published by R. J. Bradshaw, Church Row, Aldgate, London, in 1853, there is a list of four hundred and thirt-five paper-mills in England, their excise numbers running from Mill No. 4, J. C. Goodall, of Great Cullis Street, Camden Town, London, to Mill No. 694, Richard Turner, Tuckenhay, Totnes, Devon. It is, however, unfortunate that no distinction is made in this list between purely hand-made paper-mills and those having paper-making machines.

At the present day, that is about one hundred years since this list of paper-mills was published, the number of mills in England and Wales has shrunk to one hundred and forty-two. A very large number of mills have disappeared altogether, and quite a large number of entirely new mills have come into existence.

Of the four hundred and thirty-five mills in existence in England and Wales a hundred years ago, only ninety-five are now in existence, and still working, and a large number of these have the same name as they had a hundred years ago. It is a strange fact that a number of these excise mill numbers have been taken over by new companies and applied to mills in entirely different parts of the country from those in which the mill number originally applied.

It is interesting to note that a hundred years ago many of the families, whose names are very well known in the paper-trade today, had several mills. For instance, John Dickinson had five mills, the Cromptons had five mills, the family of Venables had six mills, the Towgoods three mills, the Ibbotsons four mills, and Spicers three mills. The firm of T. H. Saunders had five mills, and Hollingworths had three. Messrs. Edward Lloyd's mill at Sittingbourne (No. 334), belonged to Edward Smith. Number 13 mill, Hollins, Darwen, now owned by the Wallpaper Manufacturers Ltd., belonged to Messrs. C. Potter and Company; and Mill No. 14, Chapps Mill, Slaughterford, now belonging to Messrs. W. J. Dowding and Sons Ltd., belonged to William Jones. Messrs. Brittains Ltd. now have the Ivy House Mills (No. 630), at Hanley, Staffordshire, which, in 1853, was owned by George Fourdrinier, the son of Henry Fourdrinier, who gave his name to the machine.

In the case of the Scottish mills it is very different. There were forty-eight mills in 1853, and forty-six in 1953, only two less than a hundred years ago; and no less than thirty of the forty-eight are still in operation in the same place, and most of them with the same name and under the same family management. William Innes owned No. 11 Mill, Messrs. Smith Anderson and Company Ltd. Messrs. J. and W. Dixon (No. 14 Mill) was owned by Janet Green, and John Galloway's mill (No. 15) belonged to John Hill; and the Carrongrove Mill (No. 41), was under the ownership of John McRobey. Nearly all the others operate under the same names as in 1853, although some are members of large groups, and include the Cowans, the Bruces, Robert Craig and Sons, and Alexander Pirie, Annandale and Sons, E. Collins and Sons, William Todd, and James Brown and Company; and the Tullis family owned Auchmuty Mill, at Markinch, and Rothes Mill, owned today by Messrs. Tullis, Russell and Company Ltd.

In London alone there were fifteen mills, in such places as Shoe Lane, Farringdon Street, Poppins Court, Fleet Street, Spitalfields, Upper Thames Street, etc. Leeds had nine mills.

Most of the mills in Scotland had paper-making machines and, as already mentioned, twenty-three of these mills had machines as early as 1832, that is twenty years before the directory was published.

Donkin mentioned that a machine wire running on a paper made from straw ran seven weeks.

T. B. Parke put in a third machine at Chorley in 1855, which is evidence that his mill must have been very successful from the beginning, as it was only eleven years since the first machine was installed. The second machine was installed in 1847.

It was now, in 1857, that Thomas Routledge patented his process for preparing bleached pulp from esparto grass. This was epoch-making for the paper-trade, and gave another very valuable fibre to the hard-pressed paper-makers, which has endured as a very important raw material to the present day, especially in Scotland and England.

Jean Antoine Farina had already patented a process for using esparto grass in 1852, but it was very costly to operate, and was not taken up by paper-makers.

Routledge used esparto grass for making paper at a mill at Eynsham, near Oxford, which had originally belonged to the Swanns, and where one of the first Fourdrinier machines was installed.

In October, 1854, Bertrams were building their No. 12 machine for Tempest and Son, Little Eaton. This mill also had a tub-sizing and air drying machine at the same time.

The wire was 72 in. wide, breast-roll 10 in. diameter, top coucher 18 in. diameter, bottom coucher 10 in.: two vacuum boxes, with three-barrel pumps, 4 in. diameter. Complete details of the machine, including all instructions for the works, of every roll, bracket and pulley, etc., are contained in a manuscript book, which is still in the possession of Bertrams, who were still doing a great deal of work at Little Eaton up to 1868, particulars of which are contained in the book. These books were evidently used in the works and the machines were entirely built from the instructions and sketches contained in them. There was also a works drawing, hung up in the shop and used by everyone concerned in building the machine.

In the *Staffordshire Sentinel* of 7th January, 1854, there is the announcement of the sale of the household furniture and effects of George H. Fourdrinier at The Cottage, Well Street, Hanley. The quantity of effects to be sold was considerable, as the sale was to last for four days, and included twenty dozen fine old port and sherry, horses and carriages and silver mounted harness.

Bertrams were building their No. 21 paper-making machine for Edward Lloyd at Lloyd's Paper Works, Bowbridge, London, E., in 1861. It was Lloyd's No. 2 machine, and was 90 in. wide. There is a foolscap book at Bertrams in manuscript, giving full details of the machine as it was to be built and numerous rough sketches. The book was kept as a record of the machine and contains entries up to 1865, in various handwritings, and alterations and additions to the machine and mill plant generally. The breast-roll of the machine was 93 in. wide and 10 in. in diameter. The tube-rolls were $2\frac{1}{4}$ in. diameter. The top couch was 21 in. Both top press rolls were 18 in. in diameter, and the bottom rolls 13 in. The felt-rolls were of wood. There were twelve drying-cylinders.

Messrs. Porritts and Spencer have a manufacturing book which dates back to 1856 and it is very interesting to note that in those days they were making felts for a very great number of the British paper mills, many of whom were trading under almost the same names as they are today. Among others are the following:

W. Tod and Son	Crompton and Co.	T. H. Saunders and Co.
Allnutt and Son	Bruce and Co.	Wm. Sommerville
C. Davidson	Brown Stewart	J. R. Crompton
A. Pirie and Son	E. Collins	Garnett and Son
R. Craig and Son	C. Potter and Co.	H. Wilkinson
Clyde	John Allen	Y. Trotter and Son
Wrigleys	R. Tullis and Co.	Townsend Hook
Annandale	J. W. Eright	A. Scott
James Cropper	Watsons (Bullionfield)	J. Roberts and Son
		T. B. Parke

Bryan Donkin also figures very frequently in the book and it is interesting to note that around that time the widths of the felts seemed to vary from about 64 to 84 in., one of the widest machines evidently being that of Clyde which took dry felts 84 in. wide and wet felts slightly wider.

The original Porritt firm was Chadwick and Porritt who were trading in 1808 in Bury and probably much earlier, but unfortunately records do not go any farther back than 1808.

Thomas Bonsor Crompton died in 1858, at the age of sixty-six. He left a very large fortune besides the mill at Farnworth (No. 211). He supplied the principal newspapers and merchants of London with paper. He was also a cotton manufacturer. For some time he was proprietor of the *Morning Post* and other newspapers. He took out many patents in connection with paper-making, including the continuous train of drying cylinders with dry felts. All these patents are fully described in their appropriate places earlier in this work. T. B. Crompton was a great sportsman, and was noted for his hospitality.

13

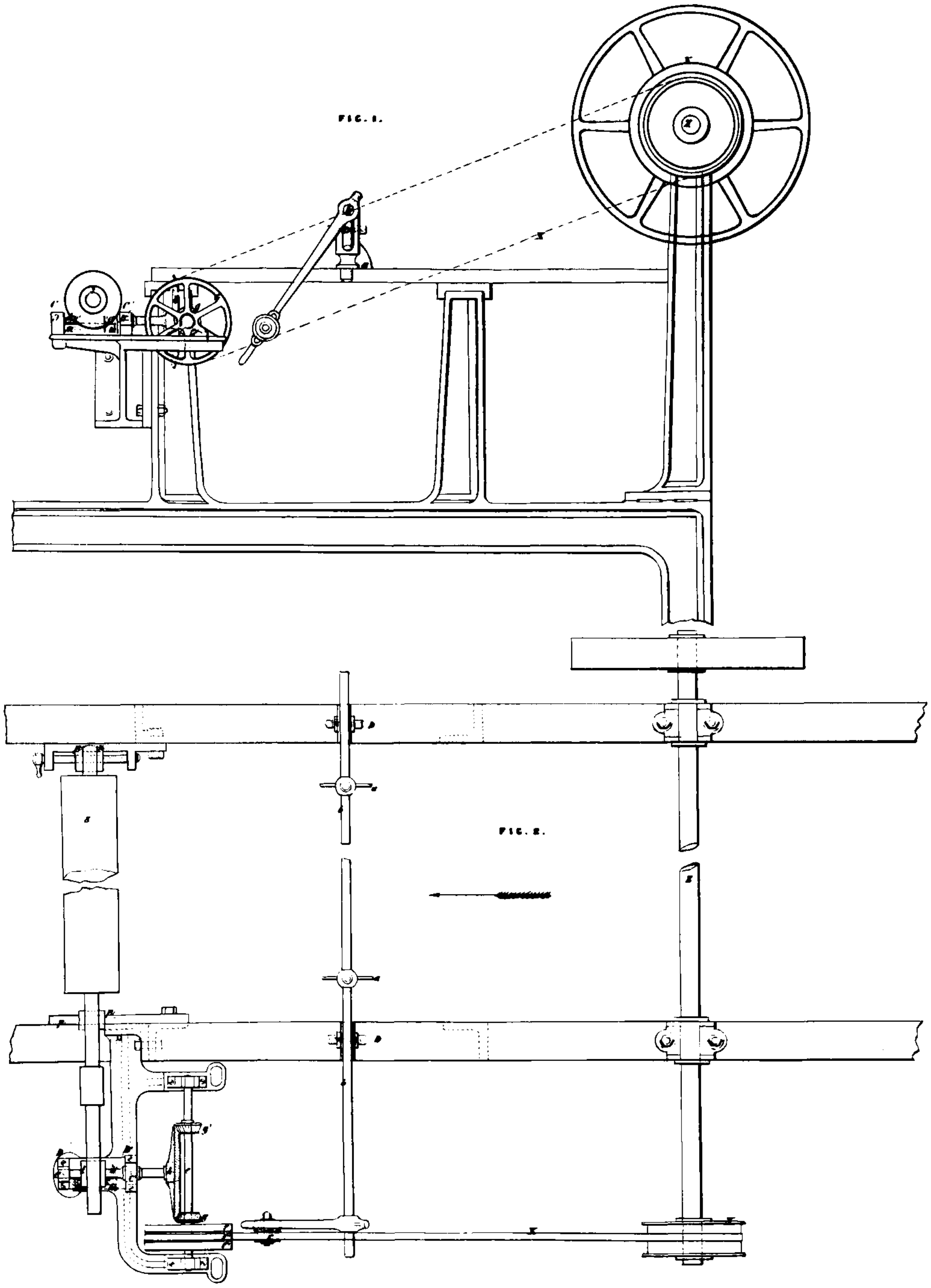
The Bryan Donkin Company

IN 1856, George Bertram, of Edinburgh, and William McNiven, manager of Polton Mill, Lasswade, made some important improvements to the strainer, or "knotting-machine" as they called it. Their alterations applied either to the flat jog-strainers, which were then in common use, or to the round or polygonal revolving strainers, which seemed to be coming more into use.

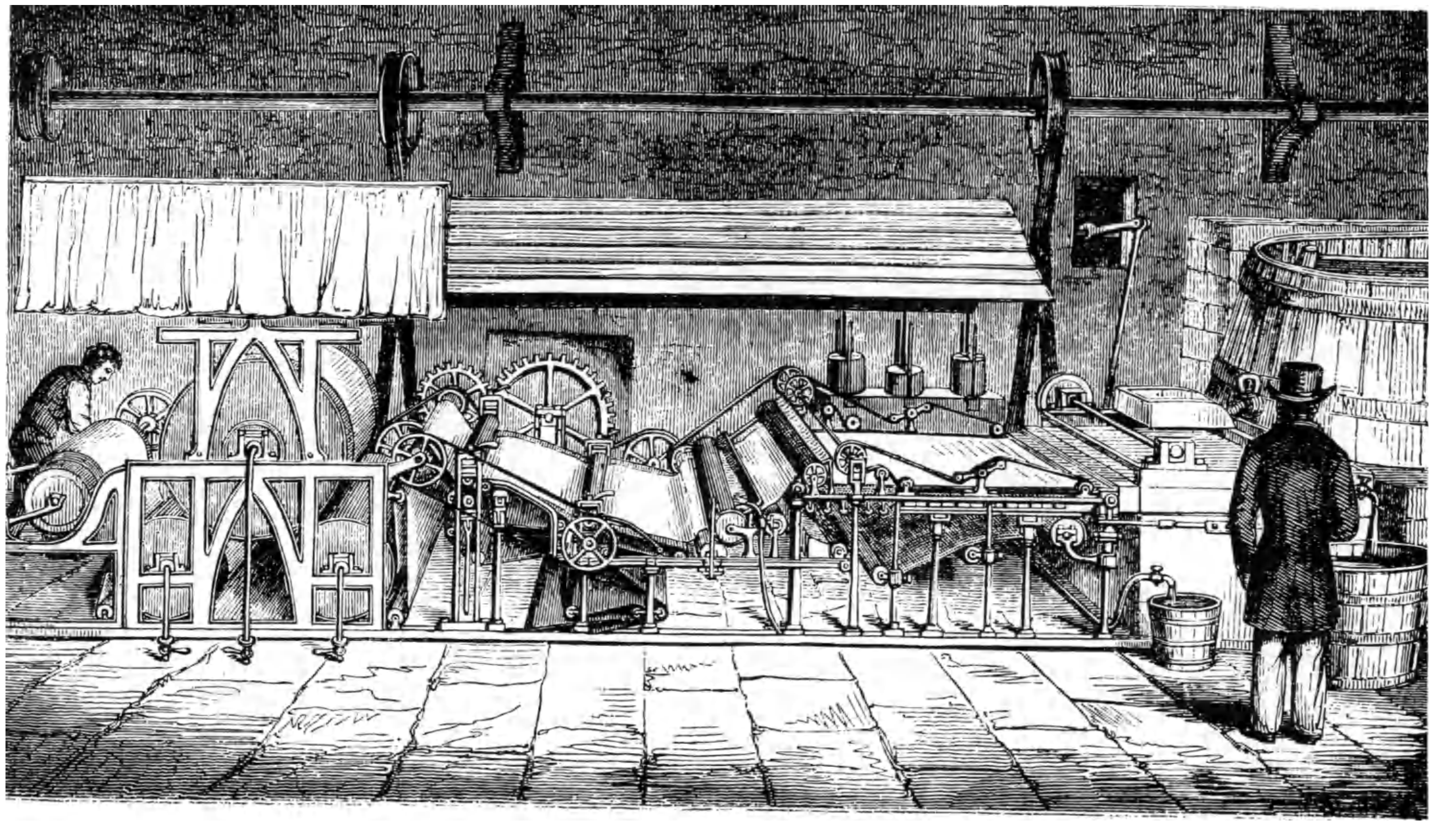
The important things concerned with their invention were those connected with the ebb and flow of stuff through strainer-plates. They realized that the strainer-plates would block up unless they were vibrated to give a sort of reflex action to clear the slits. They achieved this by making the strainer airtight by using vulcanized india-rubber to fix the strainer-plates to the vat. Jogging the plate up and down caused it, as it went down, to take the stuff through the slits, and when the jogger went up it forced air through and unblocked the slits which were choked up with fibres. This was applied in exactly the same way in the revolving strainer, except that in this case there was also added an air-pump to create a kind of vacuum inside what was actually an inward-flow revolving strainer. There were also flappers, or bellows, underneath to cause the reflex action on the strainer-plates. These improvements to the strainer had quite an important bearing on the subsequent "Leith Walk" full-drum strainer, which has since achieved world-wide fame, and is in use everywhere at the present time.

In 1858, an important advance was made on improving the Fourdrinier paper-making machine, when Thomas Donkin, one of the sons of Bryan Donkin, patented the wire-guide apparatus to control automatically the wire, or wet or dry-felts on the machine by altering the position of the guide-roller. The wire had been guided heretofore by a hand guiding mechanism, where the bearing carrying one end of the wire-guide roll was attached to a screw operated by a hand-wheel. Thomas Donkin, however, mechanized all this, putting the rod across the machine carrying the two forks, or spades, as they are now called. When the wire ran to one side it moved the rod across the machine, and this caused a belt to move from a loose pulley onto a fast pulley; the pulley operated the mechanism of the guide-roll, and caused this to be brought forward, or sent back, and in consequence the wire was made to run straight again. The apparatus is described by a drawing which shows how the arrangement worked. Actually the inventor of this wire-guide was Gabriel Planche, a Frenchman, who lived abroad. He allowed Donkin to have his patent, and it was Thomas Donkin who patented it in England. (No. 108.)

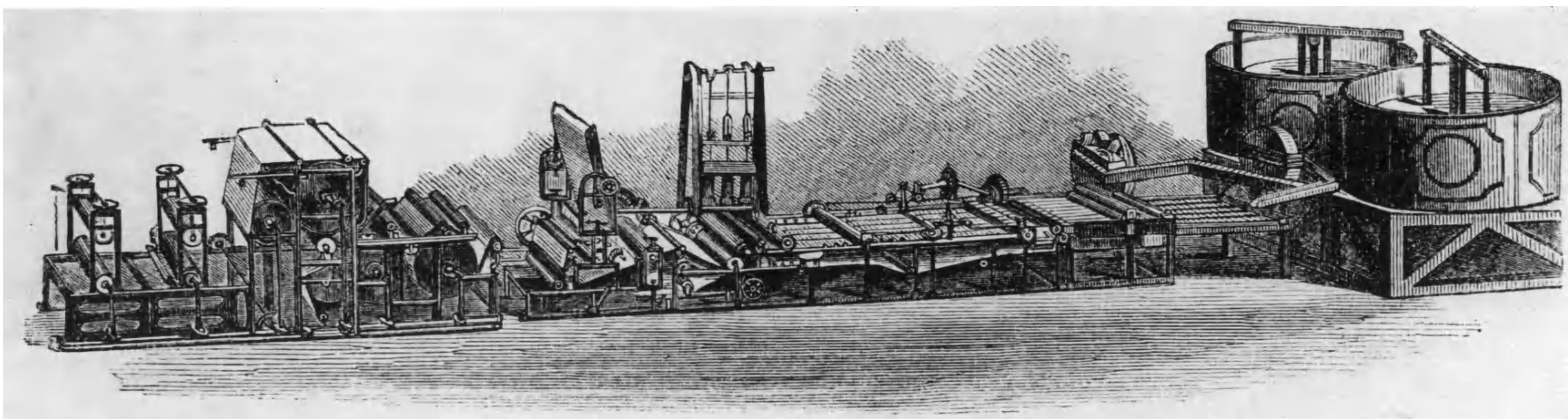
Although not strictly, in those days, a part of the paper-making machine, the refiner, invented by Joseph Jordan, junior, of Hartford, Connecticut, was patented in England in 1860. This type of machine has been in constant use ever since, and is frequently almost a part of the paper-making machine itself, being under the control of the machine-man, so that he can make the stuff suitable for the paper he is making, and make alteration to it at very short notice. It is considered worthwhile to illustrate this "Jordan" to show that there is very little difference between the one patented



No. 108. Gabriel Planche's wire guide patented and made in England by Thomas Donkin. This is an automatic guide operated by moving the guide roll (S) forward and back by means of gearing, controlled by "spades" at the wire edges and a fast and loose pulley.

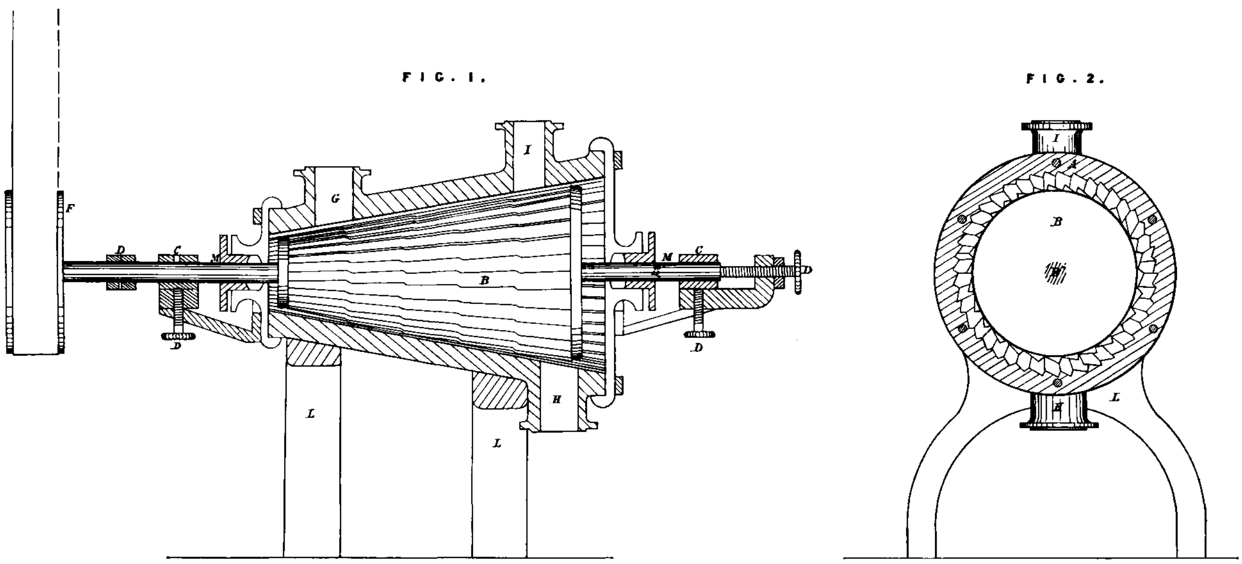


No. 109. Complete paper-making machine of 1859, which was probably built a good deal earlier. It has all the essentials, including a solid cover over the wire part to protect the wire cloth, and what is in effect the forerunner of the present-day hood over the dryers.



No. 110. Drawing of a paper-making machine of 1859, showing two chests, backwater lifting wheel, sand trap and strainer, long wire, three-throw suction pump for vacuum box, straight and reversing press, five drying cylinders and two calender stacks.

in 1860 and those in use at the present time. Jordan described his refiner as an improved pulp-making engine with pipes for the introduction of the rags and the size, so as to enable the grinder, or refiner, to act in reducing the rags to pulp, and mixing the sizing with it. Figure 1 shows the conical grinder (B) with the cone mounted on a shaft. The external surface of the plug or cone was provided with teeth or cutters which reduced the rags on their passage through the machine. The casing Fig. 2 (A) has two inlet pipes for the stuff, and one outlet pipe (H), as shown in the drawing. The stuff entered the refiner through the pipe (G), and the size was added at the pipe (I). The completed beaten mixture was discharged at (H). Jordan claimed that by adding the size to the stuff immediately before it went onto the paper-making machine, better sizing was obtained, because the stuff by that time had been reduced to the small fibre length required for the paper.



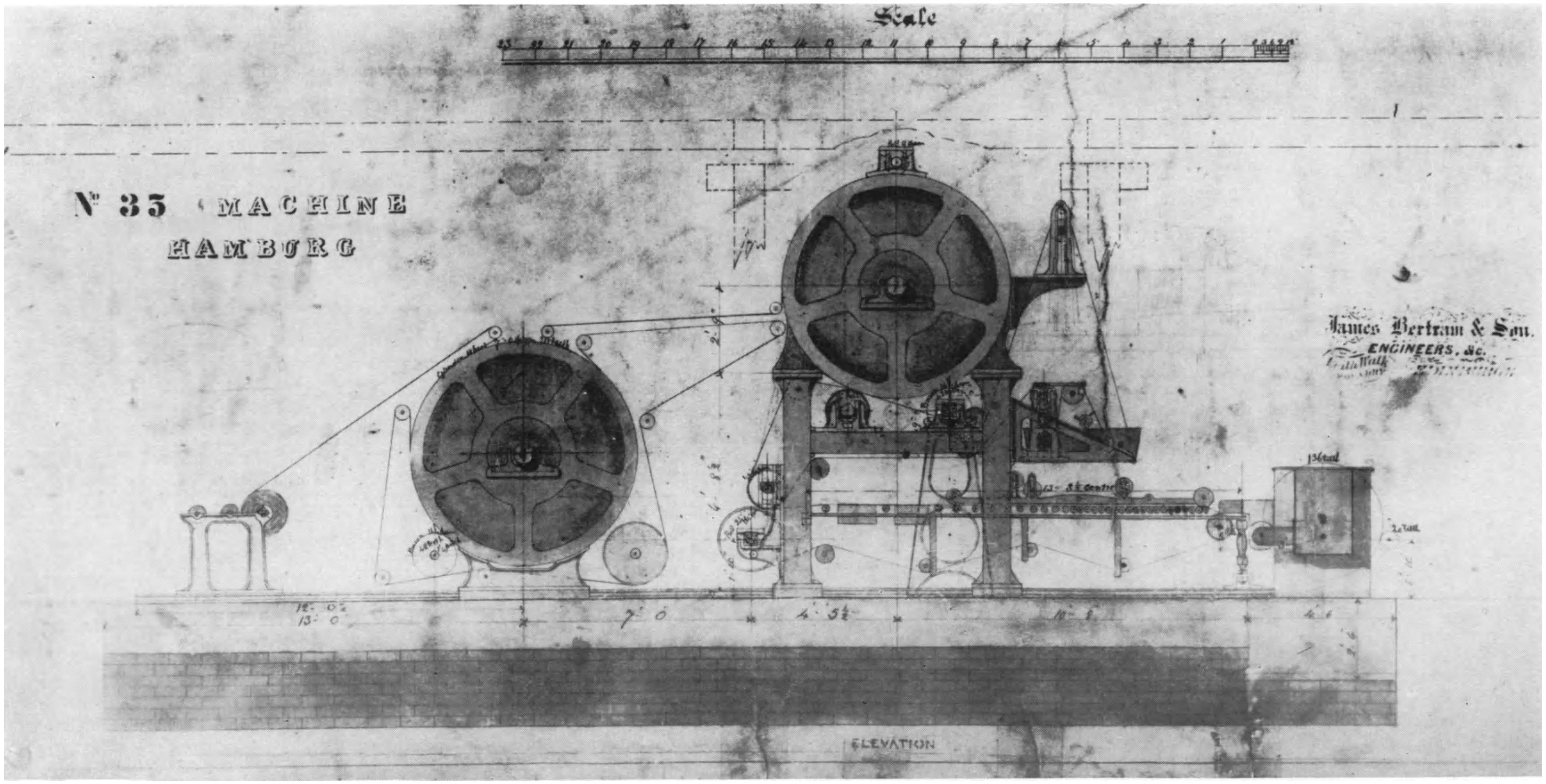
No. 111. Joseph Jordan's refining engine or "Jordan", 1860. This is probably the most notable advance in paper-making engineering since the invention of the hollander beater and the paper-making machine. Though strictly not a part of the actual paper-making, it has nevertheless become almost an accessory part of the paper-making machine one hundred years later, and is now usually under the control of the machine-man.

It will be generally agreed that the refiner of Jordan was a most important revolution in the preparation of paper-stock, and is one of the comparatively few things invented during the nineteenth century which continued in use throughout the intervening years, and did not go out of use, as so many other things did, to be subsequently patented again.

The Bryan Donkin Company were carrying out a very big export trade in paper-making machines to all parts of Europe in 1860, and were sending round their erector, R. Bowery, to all sorts of places following up machines which had been delivered and which required altering or extending or repairs. He visited such places in France as Hatterer, La Haye Descartes, and Dambricourt, near St. Omer, and took detailed particulars of the output of the various machines, and the speeds at which they were running.

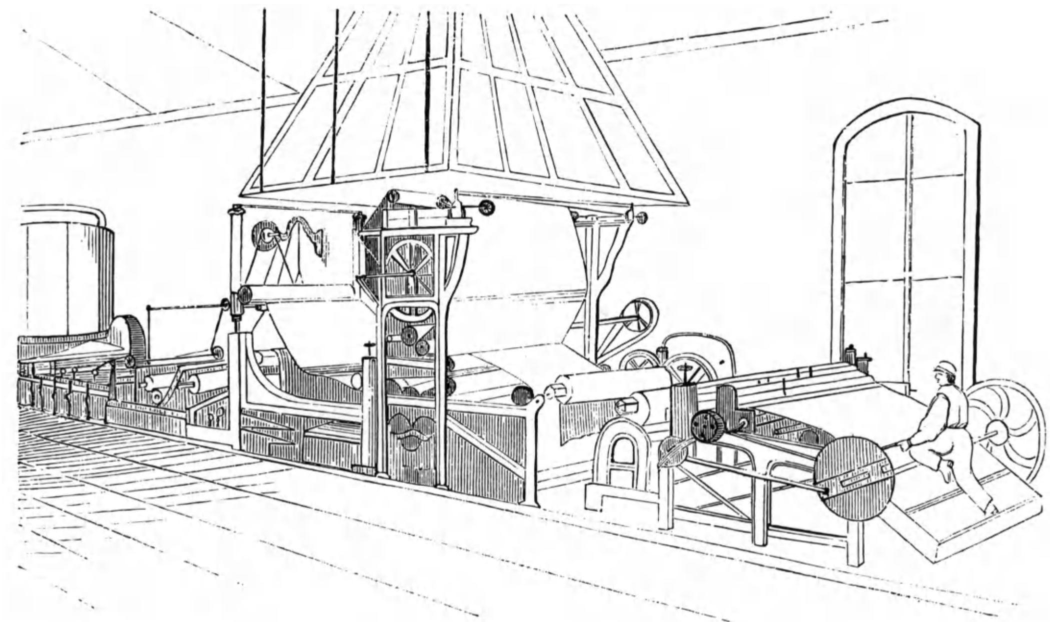
The machine at La Haye Descartes had a wire 7 ft 6 in. wide—presumably the widest machine in existence at that time. There was also an order from Frenchell for a new paper-making machine with a wire 62½ in. wide by 32½ ft long.

There was an order in 1859 from a Mr. Howard for a sizing and air-drying machine to suit a 70 in. wire machine, and this was supplied for a total of £851. P. Ibotson, of Poyle Mills, ordered a paper-making machine in 1860, and Thomas Donkin took particulars for the new machine on

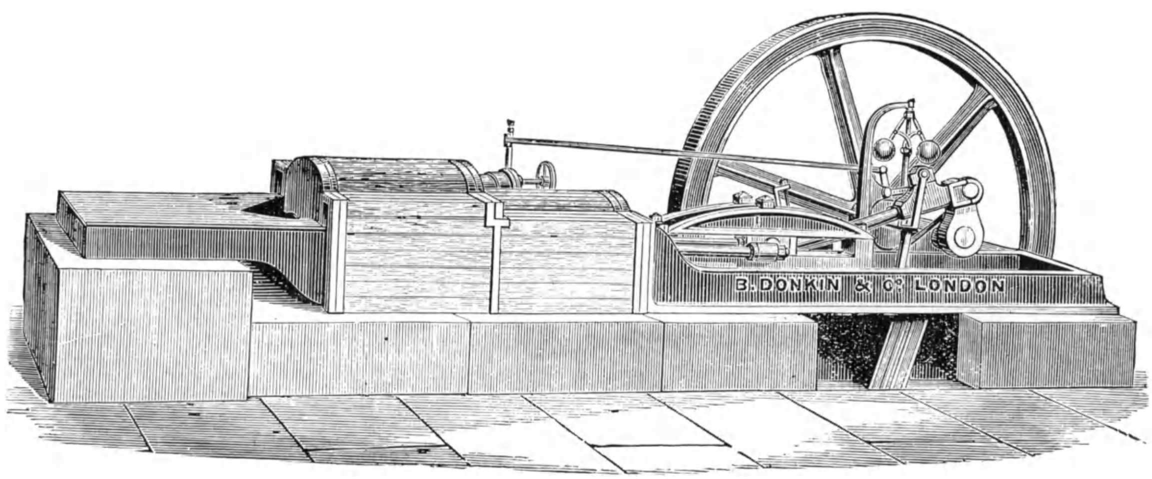


No. 112. Lick-up M.G. machine by James Bertram and Son for Hamburg in 1860. This is one of the earliest M.G. machines and the path taken by the paper is clearly shown. Almost the whole of the surface of the cylinder is made use of for drying the paper. There are two pressing rolls on the first or M.G. cylinder and one on the second dryer. In each case the underside of the sheet is against the surface of the cylinder.

Good Friday, April 6th, along with R. Bowery. Ibotson ordered the machinery to be proceeded with on the 21st April, 1860, and asked that the machine should be fixed on stone, and that it should be ready for delivery in the first week of July. He also wanted the guide roll to be placed under the wire. Messrs. Donkin were to supply the woodwork frame for the machine. The total estimate for the machine, including everything, was £759, and the actual cost worked out at £654 11*s.* 10*d.* There was an extra amount of £40 for erecting. This machine was certainly running in November, 1860, at a speed of 24 ft 3 in./min, and it was making paper 2 sheets 20¾ in. wide, weighing 52 lb per



No. 113. A French paper-making machine of about 1860. This is not a very detailed drawing, and the drying cylinders are not clearly shown. A hood, however, is shown above the dry part. The cutting machine for cutting the paper into sheets is shown very close to the paper-making machine, but it seems that the paper is first reeled up at the machine and then cut in a separate operation. This is the first known drawing of what appears to be a horizontal cylindrical fly knife being used to cut paper.



No. 114. Horizontal compound condensing steam engine by Donkin for driving a paper-making machine for Collins, at Hele Mill, Cullompton, Devon, in 1860. It is known that steam engines had been used before this time for augmenting the available power from water.

ream. It was found that the stuff- and water-pumps were throwing considerably more stuff than was required on the machine, at the speed of 24 ft/min.

A right-handed machine was also ordered in 1860 for the Papauer Paper Company. This was No. 215 paper-making machine supplied by Bryan Donkin, and the 190th drying-machine. It appears that at this time the machines were always quoted for in two parts; the paper-making machine up to the end of the presses being quite distinct from the dry part including the drying cylinders and any calenders. The machine ordered by the Papauer Paper Company had a wire 66 in. wide and 28½ ft long. The estimate for the machine, given on the 24th August, 1859, was £1515, and the terms of payment were one-third with the order, one-third two months after the order, and the remainder before the despatch of the machine, by good London bills; and on these conditions the price was subject to 3 per cent discount. Messrs. Bryan Donkin received the order on the 6th February, 1860, and the machine was to be ready for delivery at the end of May. It was to be fixed on stone. The cost of the machine eventually turned out to be £1232 9*s*. 1*d*., and the net weight of it was 22 ton 7 cwt.

Bryan Donkin machine, No. 216, was made for the Ligatschen Paper Company, of Riga, in 1860, who also had a drying machine, No. 191, supplied at the same time. It was a right-hand machine, and the wire was 72 in. wide and 32½ ft long. Together with the paper-making machine and dry part they supplied to the Ligatschen Paper Company they also supplied a 50 h.p. water turbine 5 ft 8½ in. diameter, working with an 18 ft fall, and the price of this was £261 5*s*. The casting of pipes, columns and top girders being extra. They also supplied a 40 h.p. twin-cylinder engine (by Wood) for £1324 17*s*. 9*d*., and a 40 h.p. Cornish boiler and fittings complete for £349 6*s*. 10*d*. They supplied all the fittings, steam- and feed-pipes required to fit this equipment up.

Another paper-making machine was also made in 1860, the order being received on the 18th October, from Kozloff. This paper-making machine was No. 218, and the drying machine No. 192. The correspondence in connection with this machine was all carried out in French, and the estimate was £2120, the machine being 72 in. wide with a wire 32½ ft long. The estimate for General Kozloff's mill—for it was really more the equipment of a paper-mill than merely a paper-making machine—was £5850, the wet-end of the paper-making machine being estimated at £665, and the total cost of the machine, up to the end of the presses, being £1822. There was an 8 h.p. steam engine, with steam boilers, etc., and all piping, for £630, and all the shafting, pulleys and belts for £296. Bryan Donkin also supplied all the metal parts for three beaters and three washers, with six extra steel bedplates, and a bar planing machine, for £554. Three washing drums for the beaters cost £90; and a lathe was also provided for £220. There was an 85 h.p. water-turbine supplied for £800, and the gearing for it cost £330. The terms of payment, agreed on the 17th July, 1860, were that there should be two-sixths of the payment with the order, one-sixth three months after the order was placed, two-sixths before shipment—of which Bryan Donkin and Company were to give proper notice—and one-sixth, or the balance, on the arrival of the paper-making machine at St. Petersburg against bills of lading; and on these conditions a discount of 3 per cent was allowed. The weight of all the machinery, turbines, boilers and everything else, was 99 tons net. It is interesting to note among the details of this order that a doctor was called a "paper plough", and cost £17 17*s*. 8d.; and the planing machine for the beater-roll bars cost £9.

The actual costs, as shown in the book of Messrs. Bryan Donkin and Company, seem to have come out well on the low side when compared with the estimates, and they seem to have made quite a good profit supplying these machines abroad.

In April, 1861, an order for a paper-making machine was received from Roberts, in Moscow, the machine being for Riazantzoff. The machine was numbered 219, and the drying machine 193. The wire was 66 in. wide and 32 ft 6 in. long. The total cost of this machine came to £1589 16*s*. 3*d*., and it was shipped in September, 1861, and weighed 31 ton 18 cwt. The actual charge made to

Riazantzoff for this machine was £2468 including Roberts' commission; and for this price it was delivered free at St. Petersburg. The whole of the cost of shipping it, including stamp, wharfage, shipping, bills, insurance, expenses, lighterage and agency amounted to £30 15*s*. 8*d*.

Number 220 paper-making machine, and No. 194 drying machine, were supplied to Hourko, of Vitebsk, on the 26th April, 1861, the quotation having been sent to Hourko on the 27th November, 1860. The total cost of the machine was estimated to be £2310 delivered at St. Petersburg. The charge for an erector was £5 per week plus expenses. The whole of the correspondence regarding this machine was carried on in French, and Donkin, Jr., was in Russia during the time of the placing of the order. He reported that Hourko had at present about ten or twelve rag engines and a hand mill near the town of Vatebeker, about midway between Ostroff and Kalouga, two days' journey from both of the latter towns, so it seems as if his mill was rather isolated. The particulars of the machine clothing for the Hourko machine are as follows:

	Longest length		Shortest length		Length ord.		Wide	
	ft	in.	ft	in.	ft	in.	ft	in.
Wire	32	11	32	7	32	9	6	11
Deckle straps	23	3	21	11	22	3		$1\frac{3}{8}$
1st Felt horizontal	20	7	16	9	17	6	6	2
2nd Felt vertical	20	11	17	2	17	6	6	0
10 in. and 12 in. jackets							6	0
1st or lower drying felt	43	3	39	11	40	4	6	4
2nd or upper drying felt	23	11	20	10	21	3	6	4

The Bryan Donkin machine No. 221 and drying machine No. 195 were built to be exhibited at an exhibition at Brompton in May, 1862. The machine, as exhibited, seemed to be complete, except that there was no driving equipment or tackle of any kind fitted to the machine. This machine was subsequently sold to a Mr. Henderson in 1864.

ORDER 3022/214. PAPER-MACHINE, 189 DRYING MACHINE 1860
PETERSBURG BANK PAPER-MILL.
(Wire 66 in. × $32\frac{1}{2}$ ft)

Specification

Article 35 Manufacture of Paper by Machine—two large stuff chests of galvanised cast iron with wooden agitators, driving apparatus, cast iron supports and pipes and cock for clearing out.
A Paper Making Machine with wire 66 in. English wide and 32 ft long with four presses, the lowe rrolls of these presses covered with copper—three felt presses.
A sand Strainer of cast iron galvanised. A Pulp Regulator.
Two Knotters of large dimensions. A perforated roll with wove wire cover, with bearings and carriages and apparatus for guiding the wire. Three throw Vacuum Pumps with two suction boxes.
A machine for drying the paper with five cylinders 4 ft each diameter, with cast iron and copper rolls, a set of felts and straps and the driving machinery.
Three smoothing presses, one of which is intended as a reserve, with apparatus for grinding them.
A machine for cutting the paper in sheets. Wheels for changing the speed of the machine.
A fan for carrying off the vapour arising from the paper in drying with pipes and casing in cast iron galvanized, the water pipes for the machine.
A small fire engine for washing the machine, and a machine for washing the felts; the steam pipes for preventing condensation in the room.
A machine for sizing the paper with animal size.
A machine for drying the paper thus sized by hot air with drums, fans, heating pipes and driving apparatus.
A three Roll Press. A machine for cutting the paper in sheets. A cistern for the size and a pump.

Notes

The driving riggers of presses (felt) to be large and no tightening pulleys; clutch levers to be strengthened; also felt stretching racks too coarse also, and adjustment wanted.
Good room to be left for dandy roll.

Shake apparatus cast iron caps of plummer blocks observed to be weak.
Hog box large with heating apparatus.

ORDER. 214 PAPER-MAKING MACHINE, 189 DRYING MACHINE. (1860) ESTIMATE BY B.D.

	£
Paper-making Machine with 3 felt presses, Wire Guide Sand Strainer, 2 Knotters, Vac. App., Dandy, Pulp-Regulator, Hog and Box and Heater	1431
Drying. 5–4 ft cyls.	765
Cast iron Galv. Stuff Chests, Agitators, driving, 2 wash pipes	400
Wheels for change of speed and extension of shafting	65
Cutting machine	230
Two sets of 3 roll Presses complete with frames, also a reserve Press and grinding app.	540
Water pipes for machine –a hand fire engine and a felt washer	77
A Fan for Machine Room; pipes and cover	65
Steam pipes to prevent condensation in Machine Room	57
An Air Dryer. Drums. Sizing Machine. Driving App. and steam pipes—a 3 roll Press	2000
A Cistern and size pump.	
A Cutting Machine	230
	£5860

NO. 214 PAPER-MAKING MACHINE. 189 DRYING MACHINE. ST. PS. BANK (1861)

	Longest length ft	in.	Shortest length ft	in.	Length ord. ft	in.	Wide ft	in.
Wire	33	0	32	8	32	10	5	1
Deckle Straps	23	4	22	11½	22	2		
1st Felt Press horizontal felt	20	1½	17	2½	17	9	5	8
2nd –do– vertical –do–	20	5	16	8	17	2	5	8
3rd –do– horizontal –do–	17	10	14	7	15	2	5	8
4th –do– vertical –do–	20	4	16	7	17	2	5	8
10 in. and 12 in. felt jacket							6	0
1st lower drying felt 3–4 ft cyl	43	1	39	10	40	4	5	10
upper –do– 1–4 ft cyl	26	3	21	11	22	5	5	10
lower drying felt 1–4 ft	21	1	17	8	18	2	5	10

No. 554 pat. Roll 6 ft 6 in. between shoulder bearings 5/8 in.

During the 1860's, besides the very large number of paper-making machines Messrs. Bryan Donkin were turning out for export, and also for sales at home, they managed to carry out a great deal of repair work and alterations and improvements to machines they had already made in previous years. It seemed to be the practice of this period for the dry part of the machine to consist of four, and sometimes six, 4 ft drying cylinders. The number did not increase to twelve or eighteen or more until very much later, probably due to the slower speeds which were considered sufficient in those days. In a wire of about 32 ft 6 in. in length, they usually had around 30 wire, or what we would call tube-rolls, of 1¾ in. in diameter, followed by about five slightly bigger tube-rolls 2¼ in. in diameter, and there was also a 3 in. guide roll.

The bottom couch-roll was usually 10 in. in diameter, and the top couch-roll about 16 in. in diameter, the cast iron press-rolls being 12 in. in diameter. The usual diameter of the breast-roll was 8 in. although there were some machines ordered with a 10 in. breast-roll. There were usually six 3 in. tube-rolls supporting the wire about the suction boxes and dandy, and on a number of machines the guide- and stretch-rolls were 5 in. The 5 in. rolls had six internal rings for stability, and the couch-rolls seven internal rings. The iron press-rolls were all arranged to be heated by steam, and the wet-felt rolls were all of wood, the dry-felt rolls being of iron, and 6 in. in diameter.

The usual thirty-one 2 in. tube-rolls, in brass, cost £34 for the set, and an 8 in. breast-roll for a wire width of 72 in. cost £9 4*s*. 6*d*. Twelve wooden wet-felt rolls cost £12 12*s*. 8*d*. for the dozen. A 40 ft wet felt 76 in. wide cost £17. A smoothing press or machine calender of six rolls 14 in. diameter, and made of cast iron, for a 90 in. machine, cost £121 16*s*.; and four 48 in. cast iron cylinders for a

72 in. machine cost £165. The whole of the frames and fittings for the wet-end, from the breast-roll to the end of the felt presses, including connecting shaft and pulleys, deckle, washing tubes for hoses, water scoop, patent rider (dandy roll) and a pair of cages for the roll, cost £304 9*s.* 9*d.* And the shake apparatus £18 7*s.* 9*d.* This was for a machine with a wire 72 in. wide and 32½ ft long. The reel-up, consisting of an expanding reel bar, frames and friction apparatus, cost £40 13*s.* 1*d.* All the air pumps, including two suction boxes under the wire, piping, etc., cost £64 7*s.* The circular cutting apparatus at the end of the machine, for slitting the paper into narrower widths before it was reeled up, including all the driving tackle and frame, was £37 10*s.* 8*d.* The plain wove dandy or riding roll cost £11 10*s.* for a 72 in. wide machine, but the diameter of the dandy is not stated.

The following alterations were carried out by Messrs. Bryan Donkin at Molineaux' mill in January, 1864. The old machine, which was driven by a water-wheel, was changed over to be driven by a steam engine, and the engine and boiler and necessary equipment were supplied, so that the heat from the steam engine could also be used for the drying cylinders. Two chests were to be provided in a different place, and then the wire could be lengthened so that the machine, which was then too short to make 60 ft of paper per minute, could be speeded up to run at this speed; also another knotter was provided, to make two working together, as on the other machine. There were to be three more drying cylinders provided, in addition to those already fixed on the machines; and also a cutting machine. Alterations were also to be made in order to enable a slightly wider sheet to be run on the machine.

About the same time a new wire-part was fitted to Bock's machine, the new wire being 61 in. wide and 28½ ft long. The alterations to this old machine necessitated supplying practically the whole of the rolls and equipment needed at the wet-end, and including the framework, breast-, couch-, wire-, guide-, and return-rolls, tube-rolls, etc., cost £159 1*s.* 1*d.*

Messrs. Bryan Donkin and Company quoted M. Drewsen and Son, of Silkeborg, for a paper-making machine, including the dry-end, on the 23rd November, 1864:

224 PAPER-MAKING MACHINE 198 DRYING MACHINE M. DREWSEN AND SON, SILKEBORG. 23 NOVEMBER, 1864

Paper-making Machine suitable for a Wire 6 ft 6 in. wide, 32½ ft long with couch rolls and two felt presses (12 in. rolls); lay and connecting shafts, shake, extra large water scoops and a patent dandy
A Drying Machine with five 4 ft Cylinders, roll under last cylinders, felt rolls, driving shaft and wheels: two 2 ft dia. felt Drying Cylinders with apparatus for 3 felts and a Doctor to each of the 5 cylinders
A double Sand Catcher, one placed above the other, with hog and box
Four Knotters 5 ft 6 in. × 2 in. with cam motion, all on the same level
Vacuum Pumps and two Suction Boxes
Two 3-roll Smoothing Presses (12 in. rolls)
Circular Cutters
A pair of Expanding Reels
Cast Iron Pipes to supply water to Wire, commencing at Stuff Chests
One Wire, set of Felts, deckle straps and driving straps for the above Machines, also screws for fixing on wood and spanners necessary:

	£
	2402
A large Laid Dandy Roll (12 in. dia.) to be sent only in case the one ordered for the narrow Machine is not made	14
Two Cast Iron Stuff Chests	{ 190
Driving apparatus for –do–	{ 55
A Rag Boiler	158
A Rag Cutter	85
	£2904

The prices of the girders and columns to carry the two Stuff Chests, the Pump to supply the Machine with water, the large reel at end of machine, and the extra pipes and cocks to supply and clean the Stuff Chest Agitators, we will send you as soon as possible, before putting them in hand.

A further machine, No. 225, and two drying machines, were supplied to R. Decker in 1865. The wire of the new machine was 78 in. wide and 33 ft long. The price quoted for the machine was £3228. The complete set of felts, wire, deckles and driving straps, or belts, cost £105, and an extra knotter plate for the strainer, in brass, cost £52. These were all included in the original quotation, and the actual cost of the machine was £2506. The reason for having a second drying machine was for the drying of the tub-sized paper after it had been made, a tub-sizing machine and subsequent drying machine being included in the total price. The dry-felt prices for the machine were obtained from Messrs. Porritt, four of them, of varying sizes, costing £67 17*s.* 10*d.*, with a discount of £3 7*s.* 6*d.* The jackets for the couch-roll cost two guineas each, and the press-felts £9 each. The price of the wire was £10.

In October, 1867, another order was received from Tervakoski Paper Mill for a paper-making machine, No. 228, and a drying-machine. The wire was to be 66 in. wide and 32½ ft long. The total cost of this machine was £2377, including £8 6*s.* 6*d.* for a 60-hole (mesh) wire. The dry-felt cost £27 14*s.* 1*d.*; two wet-felts £8 6*s.* 2*d.*; two couch-roll jackets £1 13*s.* 11*d.*; deckle straps £5 5*s.*; leather belting £18 2*s.* 4*d.*; and the dandy-roll £10 10*s.* 0*d.* (See facsimiles, pp. 205–8.)

When this new machine for Tervakoski was being costed out, a new system of estimating was instituted by Messrs. Bryan Donkin. A comparison between the old method and the new was given side by side for all the different items. The new system puts a small additional amount onto all the items, but it is not shown how this was arrived at; whether the overhead charges had anything to do with it or not is not clear. It does not actually amount to very much: for example, for the wet-end of the paper-making machine itself the extra amount is only about £48, although some of the items differ very considerably.

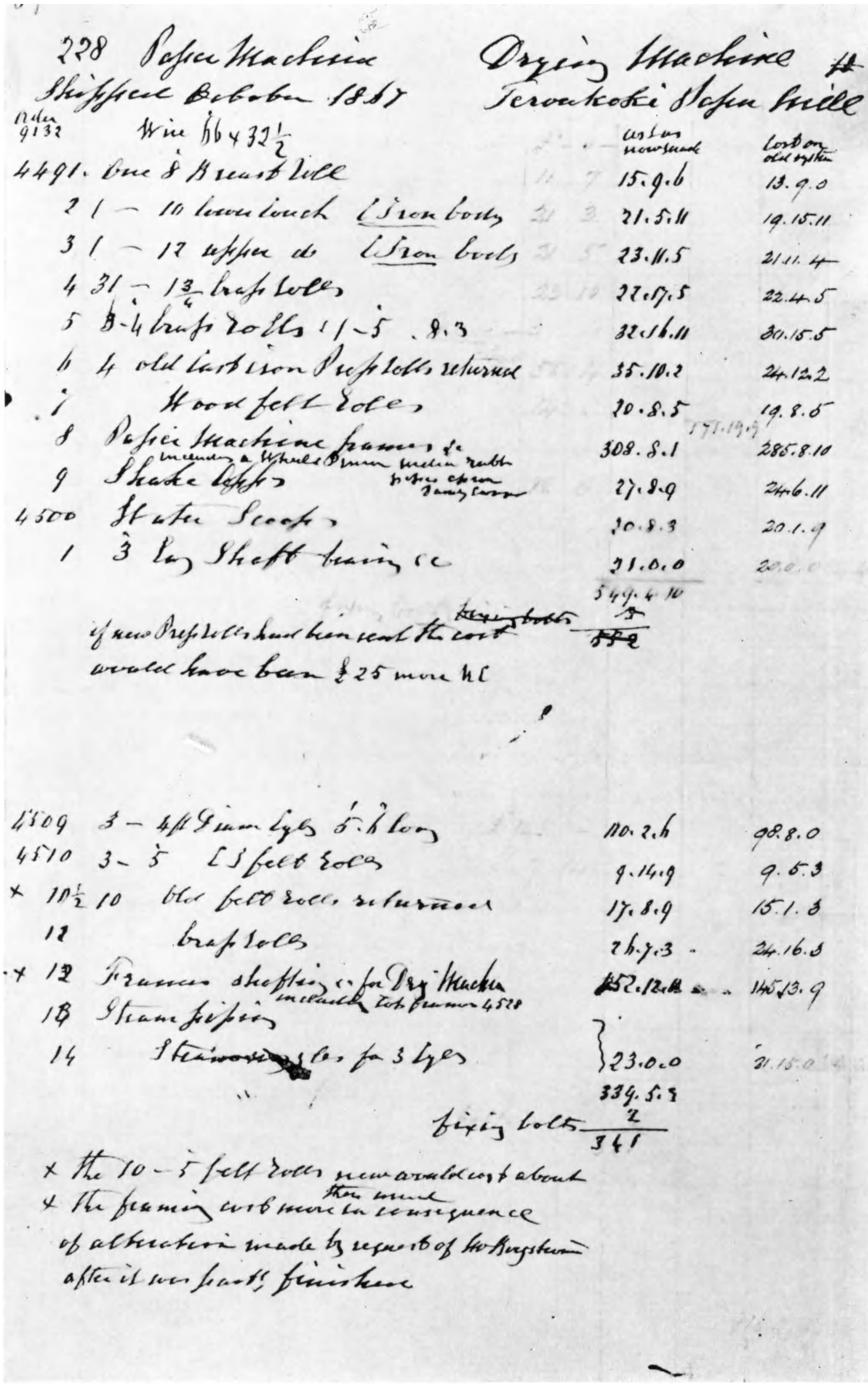
The price of the machine clothing seems to have been very cheap compared with modern standards, but then, of course, some of the wet-felts had to be changed every day. Nevertheless, a wet-felt at £4 3*s.* 7*d* for a 66 in. machine seems very cheap in any case, as also do two felt jackets for the couch-roll at £1 13*s.* 11*d.* the pair. The wire also seems extremely cheap at £8 6*s.* 6*d.* for 66 in. wide and 32½ ft long, 60-mesh.

The cutting-machine for this machine cost £230, and an extra set of three-roll presses £130, that is, a machine calender. An extra strainer, or knotter, was £90, and two extra knotter plates £56 the pair. The sand-catcher was also extended after the original estimate to 2 ft 2 in. and cost £12 extra. The strainer, or knotter, was also lengthened for an additional £10. Messrs. Bryan Donkin were also able to charge £25 extra because the machine was ready by 25th October, 1867. The total profit made on the machine was about £300.

In March, 1868, paper-making machine No. 229 was made for Messrs. Burt, of Witchampton. The wire was 36 ft 6 in. long and 82 in. wide. This was a longer and wider wire than those generally made about this time. There seems to have been more vacuum boxes on this machine, as the cost is £52; the actual number is not stated, but some of them were 8 in. wide and some 12 in. wide. The dandy-roll was also more expensive than usual, being £18 10s.

The next paper-making machine does not seem to have been made until 1872, when Bock, of Klippans, had another machine, No. 230, together with a dryer, No. 210. The wire of this machine was 70 in. wide and 36 ft 6 in. long. There is a note to the effect that the wire part of this machine was taken from stock. The machine had two wet presses and a fairly extensive dry-part requiring four dry-felts, the longest of which was 46 ft.

In 1872 another machine was made for the Siebersche Paper Company, Augsburg, in Germany. The estimate for this machine was £2560, and the number of the machine 231. The wire was 78 in. wide and 45 ft long—much the longest so far mentioned. There is a note to the effect that the two felt presses, or wet-presses, were taken from stock. It would appear from this that there was a shortage of orders at this time, and that Messrs. Bryan Donkin were making parts of



228 Paper Machine — Drying Machine #
Shipped October 1837 — Teroukoski Paper Mill

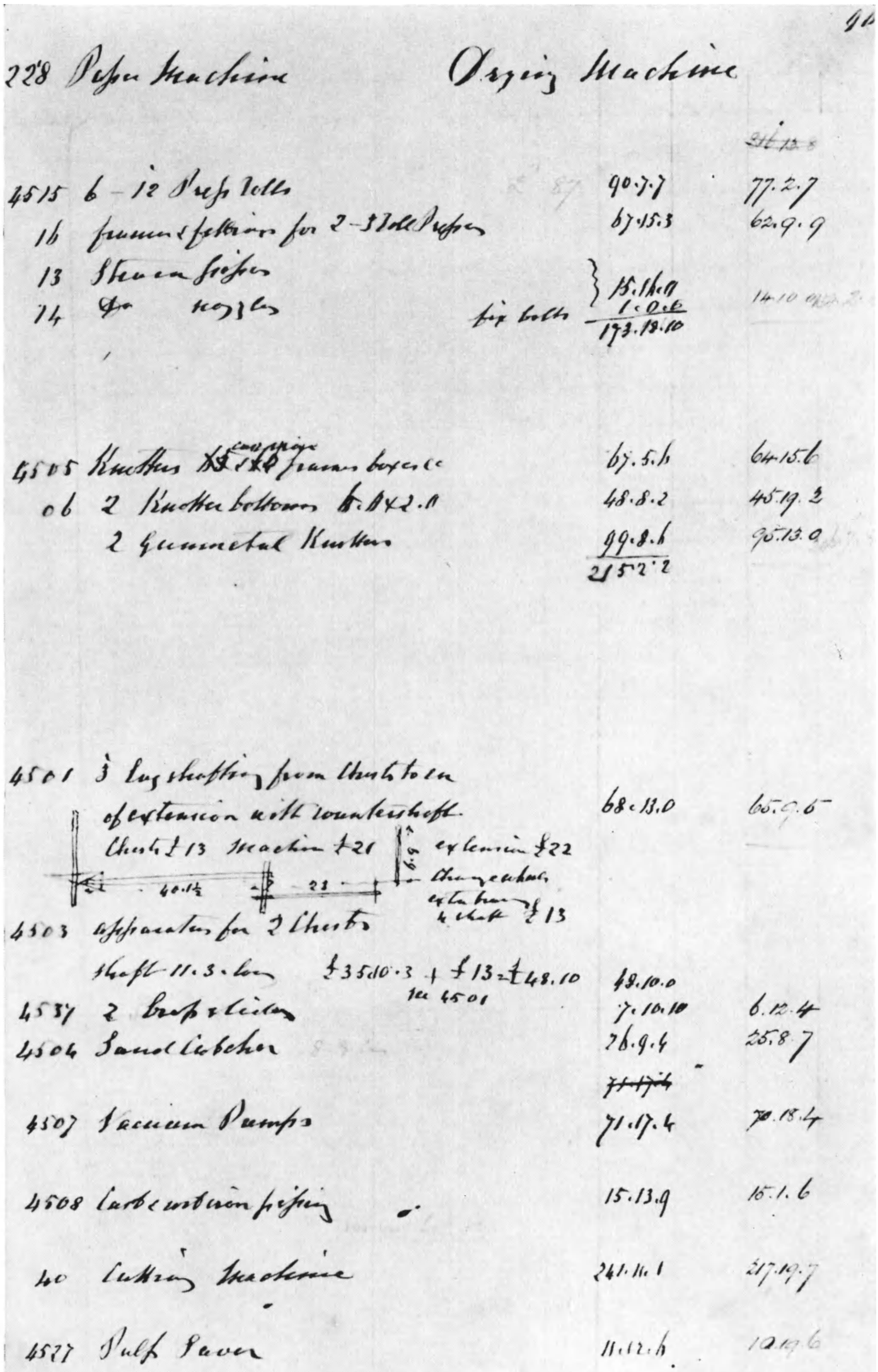
Order 9132 — Wire 66 × 32½

		cost on new plan	cost on old system
4491.	One 8 Breast Roll	15.9.6	13.9.0
2	1 – 10 lower couch (Iron body)	21.5.11	19.15.11
3	1 – 12 upper do (Iron body)	23.11.5	21.11.4
4	31 – 1¾ brass rolls	27.17.5	22.4.5
5	3-4 brass rolls 1/–5 . 8.3	32.16.11	30.15.5
6	4 old cast iron Press Rolls returned	35.10.2	24.12.2
7	Wood felt Rolls	20.8.5	19.8.5
8	Paper Machine frames &c including a Wheel & pinion [illegible]	308.8.1	285.8.10
9	Shake [illegible]	27.8.9	24.6.11
4500	Water Scoops	30.8.3	20.1.9
1	3 Lay Shaft [illegible] &c	21.0.0	20.0.0
		549.4.10	
	fixing bolts	3	
		552	

if new Press Rolls had been sent the cost would have been £25 more HC

4509	3 – 4ft Drum Cyls 5.6 long	110.2.6	98.8.0
4510	3 – 5 C I felt Rolls	9.14.9	9.5.3
× 10½ 10	old felt rolls returned	17.8.9	15.1.3
11	brass rolls	26.7.3	24.16.3
× 12	Frames shafting &c for Dry Machine including [illegible] 4528	152.12.11	145.13.9
13	Steam piping	} 23.0.0	
14	Steam [illegible] for 3 Cyls		21.15.0
		339.5.8	
	fixing bolts	2	
		341	

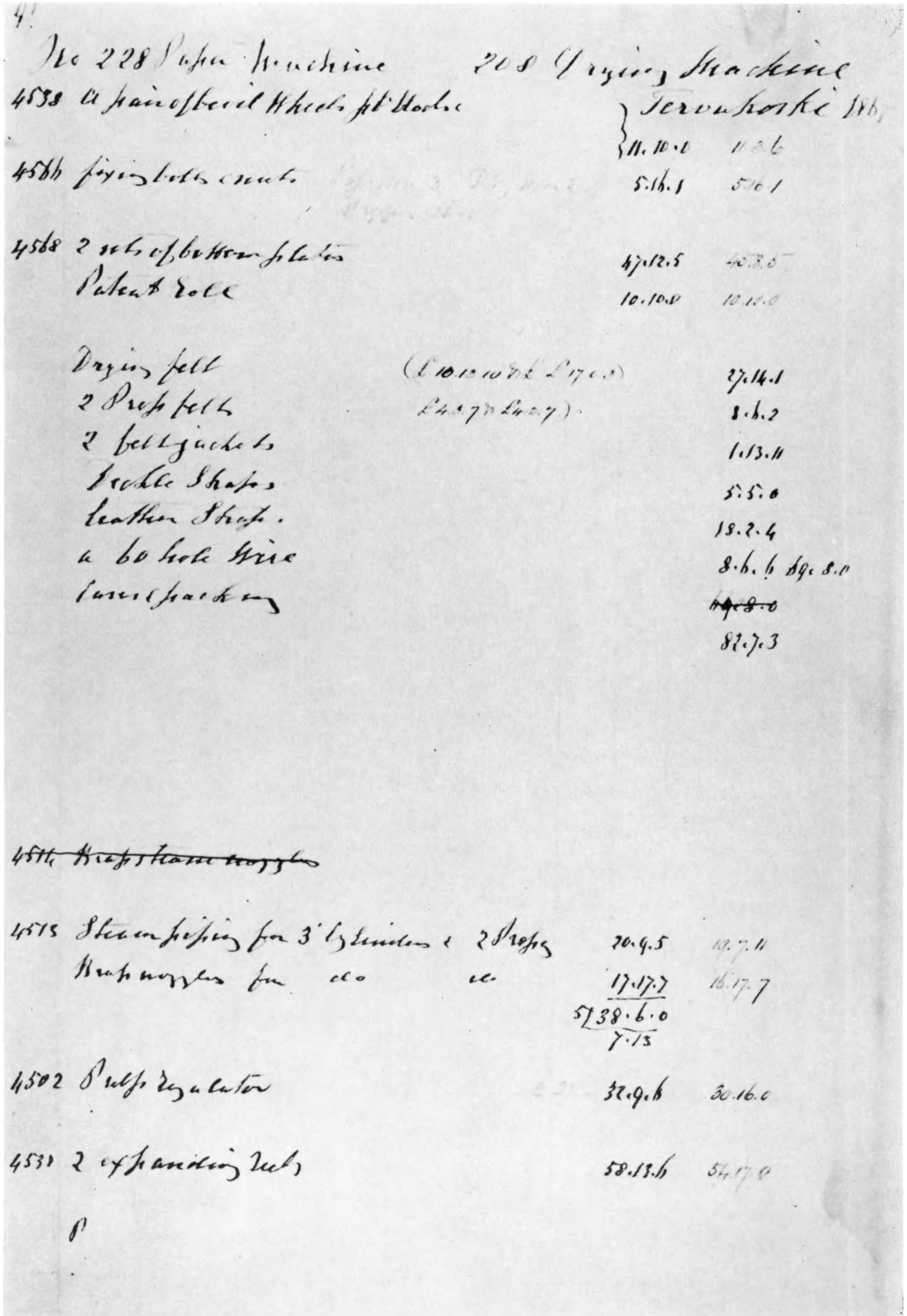
× the 10 – 5 felt rolls new would cost about
× The framing cost more in consequence of alterations made by request of Mr Kingston after it was partly finished



91

228 Paper Machine — Drying Machine

4515	6 – 12 Press rolls	90.7.7	77.2.7
16	frames & fittings for 2–3 roll presses	67.15.3	62.9.9
13	Steam pipes	15.16.0	14.10
14	do nozzles — fix bolts	1.0.0	
		173.18.10	
4505	Knotters coupling frames boxes &c	67.5.6	64.15.6
06	2 Knotter bottoms	48.8.2	45.19.2
	2 Gunmetal Knotters	99.8.6	95.13.0
		215.2.2	
4501	3 long shafting from Chests to en of extension with countershaft	68.13.0	65.9.6
	Chests £13 Machine £21 extension £22		
4503	apparatus for 2 Chests		
	shaft 11.3 long £35.10.3 + £13 = £48.10 see 4501	48.10.0	
4537	2 Brass & leather	7.10.10	6.12.4
4504	Sand catcher	76.9.4	25.8.7
4507	Vacuum Pumps	71.17.4	70.18.4
4508	Carbon iron piping	15.13.9	15.1.6
40	Cutting Machine	241.11.1	217.19.7
4527	Pulp Saver	11.12.6	10.19.6



No 228 Paper Machine — 208 Drying Machine — Tervakoski

4538	a pair of bevil wheels fit Works	11.10.0	11.8.6
4566	fixing bolts & nuts	5.16.1	5.16.1
4568	2 sets of bottom plates	47.12.5	40.8.5
	Patent roll	10.10.0	10.10.0
	Drying felt (£10.10.0 to £17.0.3)		27.14.1
	2 Press felts (£43.7 to £40.7)		8.6.2
	2 felt jackets		1.13.11
	Saddle straps		5.5.0
	leather straps		18.2.4
	a 60 hole wire		8.6.6 89.8.0
	Cases & packing		~~89.8.0~~
			82.7.3
~~4514~~	~~Press steam nozzles~~		
4515	Steam piping for 3 cylinders & 2 presses	20.9.5	19.7.11
	Brass nozzles for do do	17.17.7	16.17.7
		5738.6.0	
		7.13	
4502	Pulp regulator	32.9.6	30.16.0
4531	2 expanding reels	58.13.6	54.17.0

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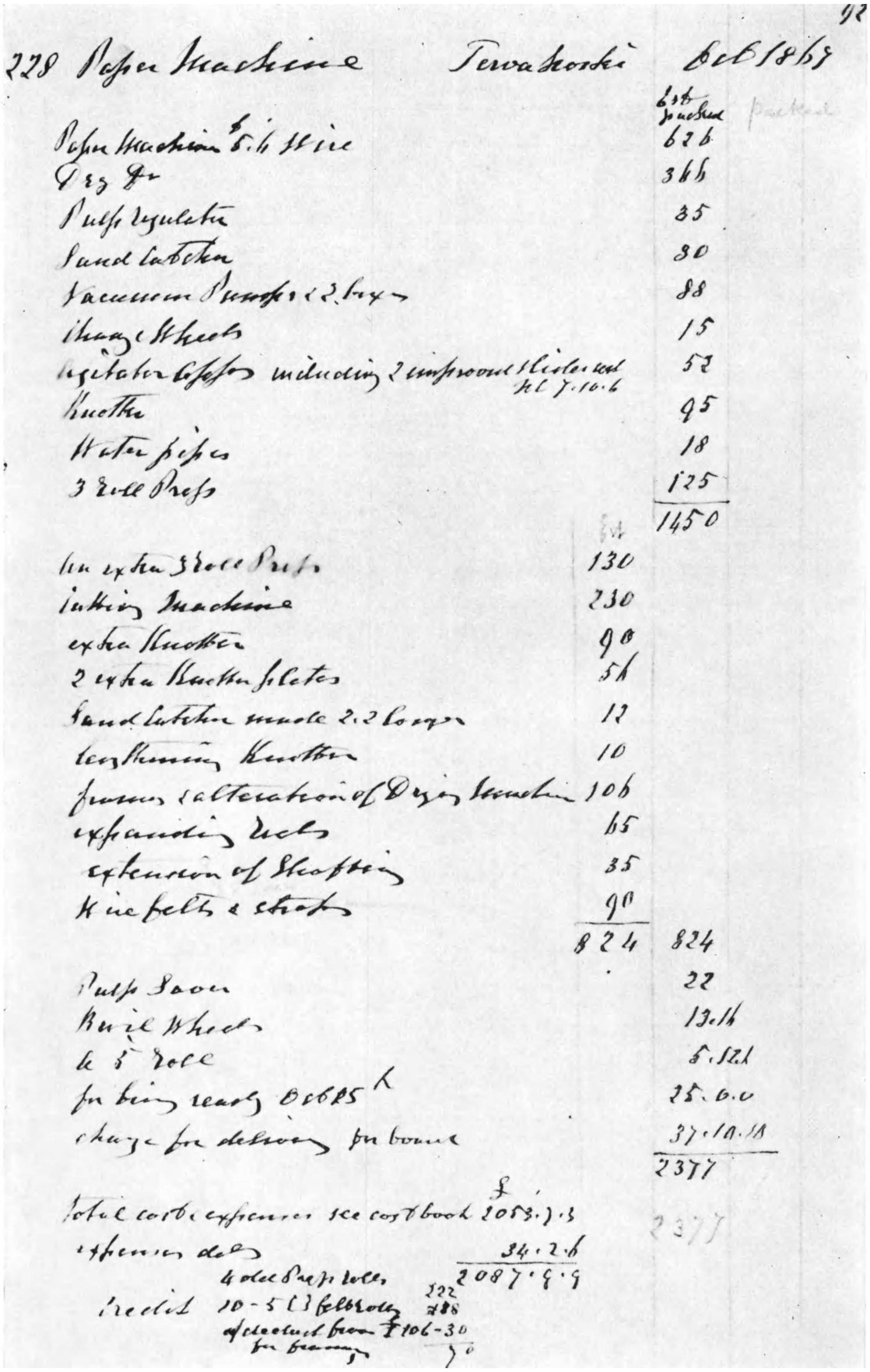

228 Paper Machine Tervakoski Oct 1867 92

		Cost packed
Paper Machine 5.6 Wire		626
Drying &c		366
Pulp regulator		35
Sand catcher		30
Vacuum Pumps & 2 boxes		88
Change Wheels		15
Agitator Copper including 2 improved Slides and £7.10.6		52
Knotter		95
Water pipes		18
3 Roll Press		125
		1450
Two extra 3 Roll Press	130	
Cutting Machine	230	
extra Knotter	90	
2 extra Knotter plates	56	
Sand catcher made 2.2 longer	12	
lengthening Knotter	10	
frames & alteration of Drying Machine	106	
expanding rolls	65	
extension of Shafting	35	
Wire felts & straps	90	
	824	824
Pulp Saver		22
Bevil Wheels		13.16
[illegible] 5 roll		5.12.1
for being ready Oct 65		25.0.0
charge for delivery [illegible]		37.10.10
		2377

Total cost & expenses see cost book £2053.7.3
expenses do 34.2.6
2087.9.9

Credit 4 old Press rolls 10-5 (3 felt rolls) 222 / 788
deducted from £106-30 for framing 70

2377

paper-making machines and putting them into stock against future orders which they expected to receive.

It must be remembered, of course, that there were many other people in the field now manufacturing paper-making machines, both in France, Germany, Sweden, and also such firms in Great Britain as George and William Bertram, James Bertram and Son Ltd., and also Tidcombe, of Watford, and Redfern Smith and Law, of Bury. Nevertheless, it is a wonderful achievement that from 1802 Bryan Donkin and his sons between them made at least 231 paper-making machines after a very slow start, and that these machines went all over Europe, including Norway, Sweden, Finland, Russia, Germany, Holland, Belgium, France, Austria, Italy, Spain, the United States of America, and, of course, mainly Great Britain. Some of these machines are still operating at present.

From 1854 until 1860 Messrs. Bryan Donkin and Company made twenty paper-making machines for various parts of the world, and in the preceding fifty years they had made one hundred and ninety-six machines, or very nearly four a year.

The Tervakoski mill in Finland, which had its first machine in 1851, ordered a further machine some years later. This machine was ordered on account of a fire at the mill which badly damaged the first machine. While the second machine was being shipped it was sunk off the coast of Sweden. Nevertheless, a third machine, to replace that one lost at sea, was delivered to Tervakoski in three months' time from the date of the emergency order; and at the present day parts of the two machines, that is, the machine supplied in 1851 and the other one supplied later, are still running, having been re-erected and put together to form one paper-making machine. This machine is actually running commercially, and the cylinders have never been touched since the time they left Donkin's works.

Donkin supplied the first machine in Sweden to Bock at Klippans on 20th June, 1832, and followed up with seven more machines to different mills in Sweden by 1862, before any other maker supplied a machine. After that date machines were supplied to Sweden by Swedish, German and also by makers whose names are not known. In 1873, however, Klippans ordered a second machine from Donkin, and both these machines were still running in 1956. The wire of the first Klippans machine was 135 cm wide and 12·5 m long. From 1873 Bertrams and Bentley and Jackson supplied most of the machines.

PAPER-MAKING MACHINES INSTALLED IN SWEDEN

Klippan	1832	Donkin
Lessebo	1836	Donkin
Grycksbo	1836	Donkin
Holmen	1836	Donkin
Nykvarn	1850	Donkin
Korndal	1850	Donkin
Fredriksstrom	1850	Swedish
Stensholm	1850	Unknown
Nykvarn	1852	Donkin
Korndal	1852	Donkin
Motala	1854	Unknown
Gransholm	1861/62	Swedish
Munksjo	1862/63	German
Munksjo	1862/63	German
Munksjo	1864	German
Skovde	1866	Unknown
Munksjo	1870	Bentley and Jackson

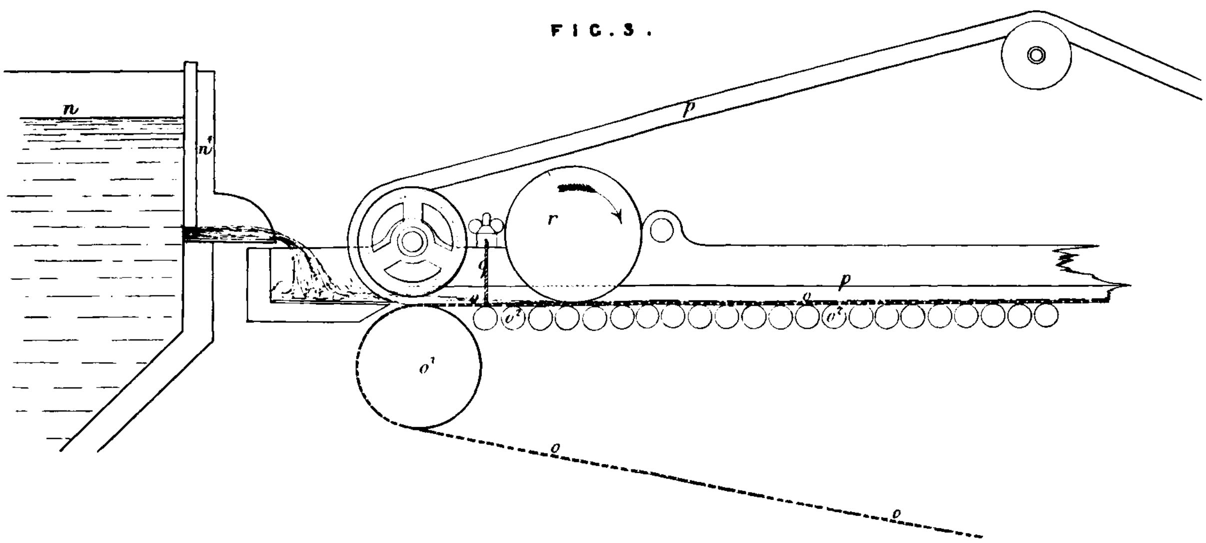
Katrinefors	1872	Wagner and Thiel
Katrinefors	1872	Wagner and Thiel
Katrinefors	1872	German
Fiskeby	1872	Unknown
Fiskeby	1872	Nagelschmidt
Fiskeby	1873	Nagelschmidt
Klippan	1873	Donkin
Munkedal	1873	Bertrams
Trollhattan	1873	Unknown
Munkedal	1873/74	Bertrams
Wargon	1873/74	Bentley and Jackson
Emsfors	1874/75	German
Munkedal	1875	Bertrams

14

Paper-making in the 1860's

IN 1861, Edmund H. Joynson, of St. Mary Cray, Kent, a paper-maker, patented an improvement to the wet-end of the machine, concerning the delivery of the stuff onto the wire, to make it even and regular across the width of the sheet. He maintained that the ordinary method of doing it, that is, allowing it to flow on over an apron at the breast-box, then levelling by vertical slices, was not very satisfactory. The paper was uneven and sometimes not very well put together, so he had the idea, which he carried into practice on his own machine, of putting a roller over the first few tube-rolls of the wire before the stuff had settled down. He made this revolve in the opposite

FIG. 3.

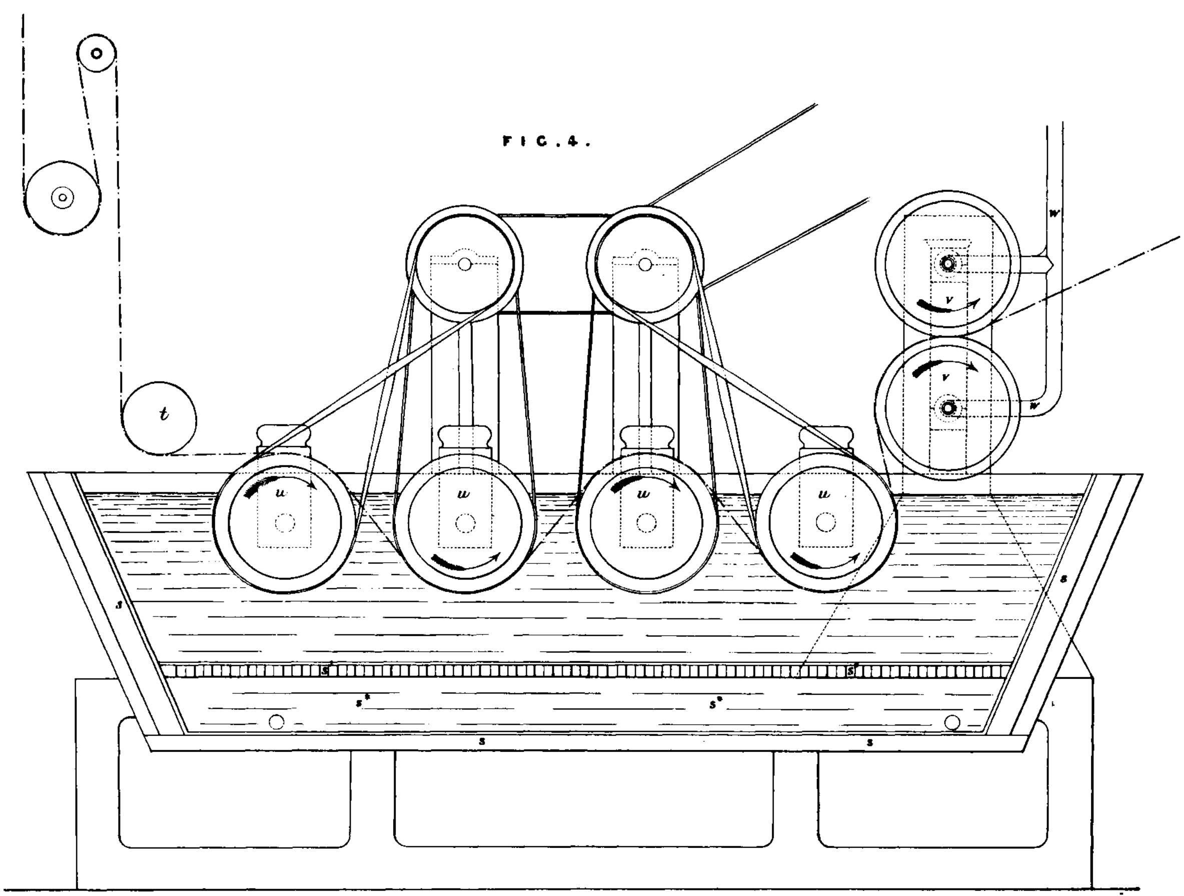


No. 115. E. H. Joynson's patented arrangement of dandy-roll at breast-roll end of wire. This roll was intended to take the place of the vertical slices, which by this time had been placed across the wire after the stuff had flowed onto it, in order to spread it equally. This drawing shows that the stuff was still being allowed to rush onto the wire from the shallow trough in front of the breast-box, and obviously something was needed to level it out.

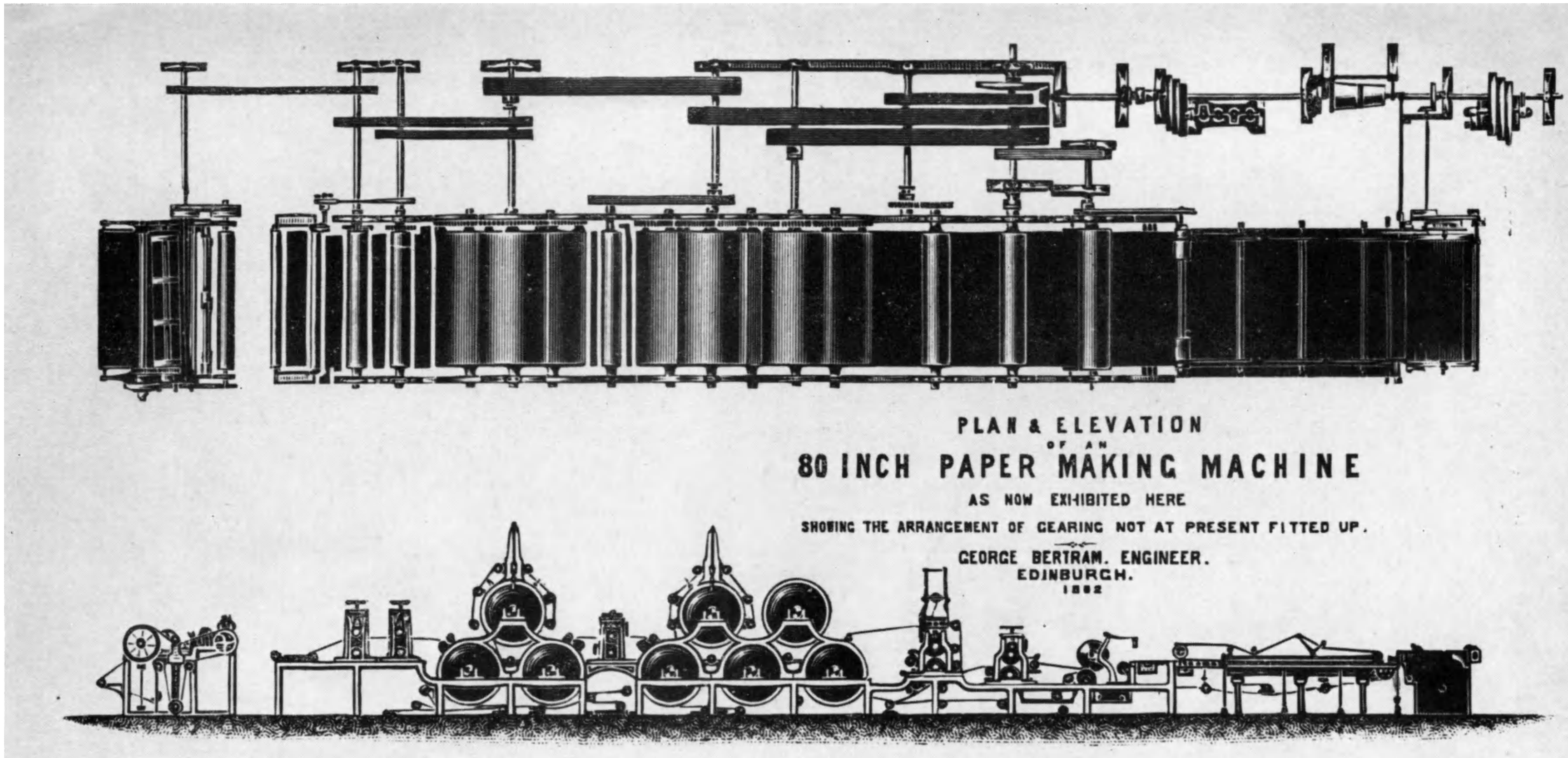
direction to that in which the stuff was travelling along the wire. This roller could be either plain, fluted, or corrugated. He maintained that he got better results, and a much closer sheet, with better regularity across the width of the paper, when this roll was in operation, than when he depended on the ordinary two or more slices—the vertical metal plates across the machine—which are, in fact, still in use on many machines at the present time.

Joynson was a very experienced paper-maker, and made excellent papers at this period, so it appears that there may have been something useful in this invention, although it seems to have passed completely out during the intervening years, and, so far as is known, it is not at present used on any paper-making machine. In some ways it had the same effect as the dandy-roll has further down the wire, but he maintained that the chief use of it was to stop the stuff rushing along the wire and almost forcing some of it back, in order that it might get more influence from the shake, and so the sheet would become better felted together than with the ordinary slices, which tended, and in fact still tend, to turn the fibres over, and discourage them from felting properly together. The whole arrangement is shown in the accompanying drawing, and it will be seen that he still used the moving rubber deckle-straps.

At the same time as he patented this alteration to the method of levelling the stuff on the wire, he also patented an improvement to the tub-sizing bath on the paper-making machine. This is shown in the drawing. The normal practice was to pass the sheet of paper under one or two rolls in the bath, and then bring it out and pass it through the squeeze-rolls. Joynson, however, considered he got much better results by having four rolls in the tub-sizing bath, and the paper was led over and under these alternately, so that each side of the paper came in contact with the size on the roll and with the size in the bath. When the paper was led through the squeeze-rolls to remove surplus size, he heated these rolls, and kept them at an even temperature, to avoid rapid cooling of the size as it left the bath. He maintained that in this way he got better sizing results. This method of sizing is still in use in some mills.

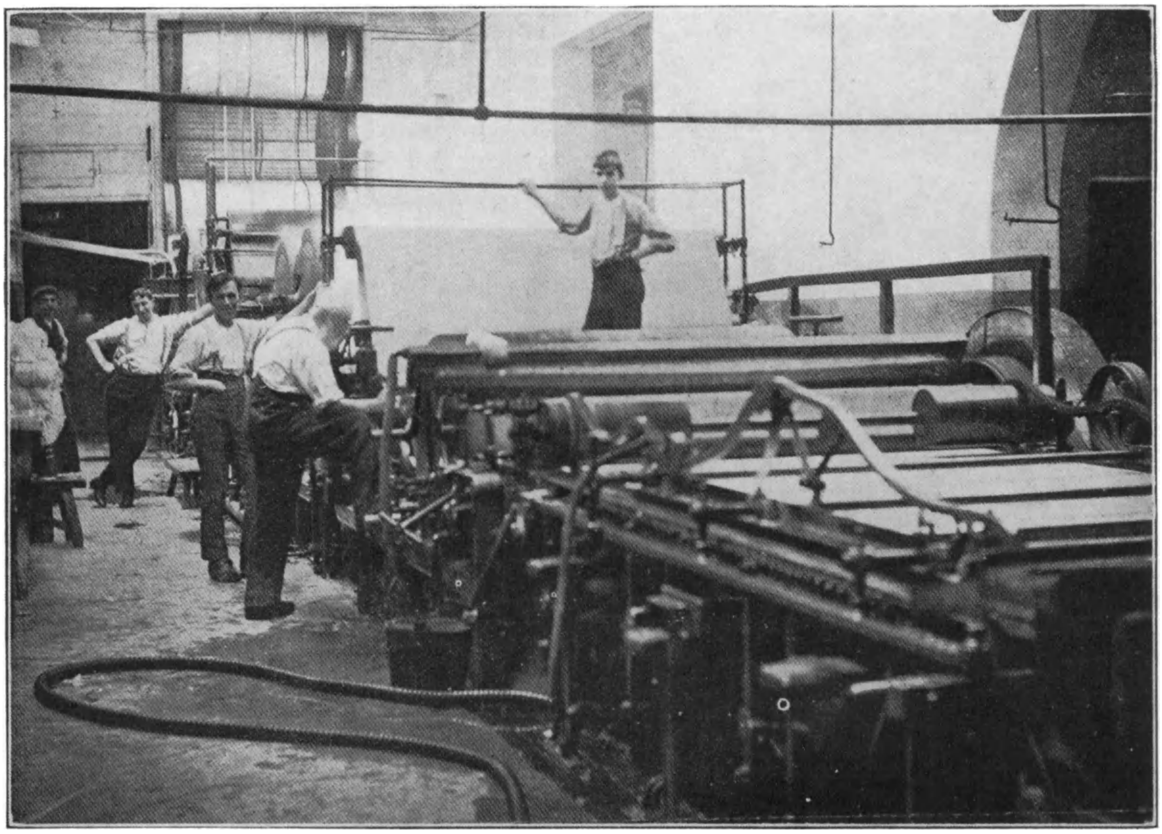


No. 116. Joynson's new design of tub-sizing vat, in which the web of paper passes over and under four rollers rather than under two. He maintains that he got more even sizing by this method.



No. 117. George Bertram's fine paper-making machine for making writing papers. This machine was made for the Exhibition of 1862 and was bought by John Allen, of Ivybridge, Devon, and installed in his mill there where it is still working over 100 years later. It shows for the first time intermediate calenders between two sections of drying cylinders. A cutting machine is also shown, although an Amos and Clarke cutter was subsequently fitted at the end of the paper-making machine and cut the paper as it was made.

In 1862, George Bertram, who was co-founder of Sciennes Works with his brother William, was awarded a gold medal for a paper-making machine at the Great Exhibition in London. This machine was bought by John Allen, of Stowford Mills, Ivybridge, Devon (Mill 191), after the exhibition and erected at Ivybridge. John Allen had recently purchased Stowford Mills from William Ackland. This machine, with little alteration to the wet-end, dryers or air dryer, is still running at Ivybridge at the present time.



No. 118. George Bertram's machine of 1862 running at Ivybridge in 1912. The wet-end is the same as that on the drawing at the Exhibition. The first part of the air dryer can be seen in the background. This dryer had a hundred and twenty sparred drums.

We have already referred many times, earlier in this book, to John Dickinson's patents connected with the cylinder-mould machine, from the single vat and the two-ply paper, and then the double-vat machine. Dickinson, in his patent, stated that any number of vats might be used to make a thicker board, but it is not clear whether he ever constructed a multiple-vat cylinder-mould machine. However, in 1863, John Franklin Jones, of Rochester, in the State of New York, in the United States, patented a multi-vat cylinder machine in England, and this had no fewer than seven vats, and could obviously make a very thick board. He claimed that by the method he employed to construct the vats, and mount them, he could put in a board-machine to make a very thick board in very little space, because he raised the vats off the ground in order to have plenty of room for the felts and felt-washing apparatus underneath, and this enabled him to bring the vats and presses very close together. The whole of this is shown in the accompanying illustration (No. 119).

The chief purpose of this was to make a thick board seven ply in a two-storey building so that he could have the dryer-part upstairs. The illustration shows the board getting thicker and thicker until it gets to the last cylinder-mould, when it is shown passing up through the floor into another press, and then onto the tiers of drying-cylinders, and from those through two-bowl stacks of calenders. It then passed to a guillotine type of cutter which cut it off into sheets, and the sheets were led on a layboy and piled up on a table which, by an arrangement of gearing, always remained at the same level. In other words, the table gradually descended as the pile of cut sheets mounted.

Jones claimed a slight alteration in the construction of the cylinder-moulds which he patented, and he had suction-pumps attached to them, drawing air out, so quickening up the deposition of the fibres on the outside of the mould. The rest of his patent seems to have consisted in getting the vats very close together, as already mentioned, and the disposal and washing of the wet-felts underneath. It was certainly a very advanced type of multi-cylinder mould-machine for 1863, and it does not appear that a machine of this description was erected in the United Kingdom until about 1900. It was the first time that an automatic layboy had been shown on a paper-making machine, although Amos and Clark achieved something very like this with their single-sheet cutter.

It will be noticed that instead of the usual single felt on the multi-vat board machine, passing between the cylinder-moulds and the couches on each vat in succession, Jones used a separate wet-felt for each vat. The reason for this was that he maintained he could make seven sheets of paper on this machine at the same time, without them sticking together to form a board. When he wanted to do this, he led the paper off each wet-felt onto a carrying roller suspended from the floor above, and as these separate sheets had not been pressed together successively after each layer had been taken up, as in making a board, he maintained that the laminations did not stick together, so that when the seven sheets got to the drying-cylinders, they were quite separate, or could be easily separated. It was when passing through the dryers that he dried the sheets separately by taking seven sheets through the first two drying-cylinders, and then leading the top sheet off direct to the calenders.

The remaining six sheets passed against the next two drying-cylinders, when the second sheet was led off, and so on successively, so that the seven sheets were dried in turn, each sheet being peeled off after it had passed with the others round two cylinders. All the sheets passed together through the calenders, and all were cut off at the same time. It is difficult to see what the object of this was. It would appear to have been a very difficult operation, but he maintained that it worked, although this type of machine does not appear to have been adopted for general use, the multiple-vat machine having been used entirely, right up to the present time, for making multiple-ply boards.

In 1863 the first number of the *Papermakers' Monthly Journal* was published. The *Journal* was to be devoted entirely to the interests of paper-makers.

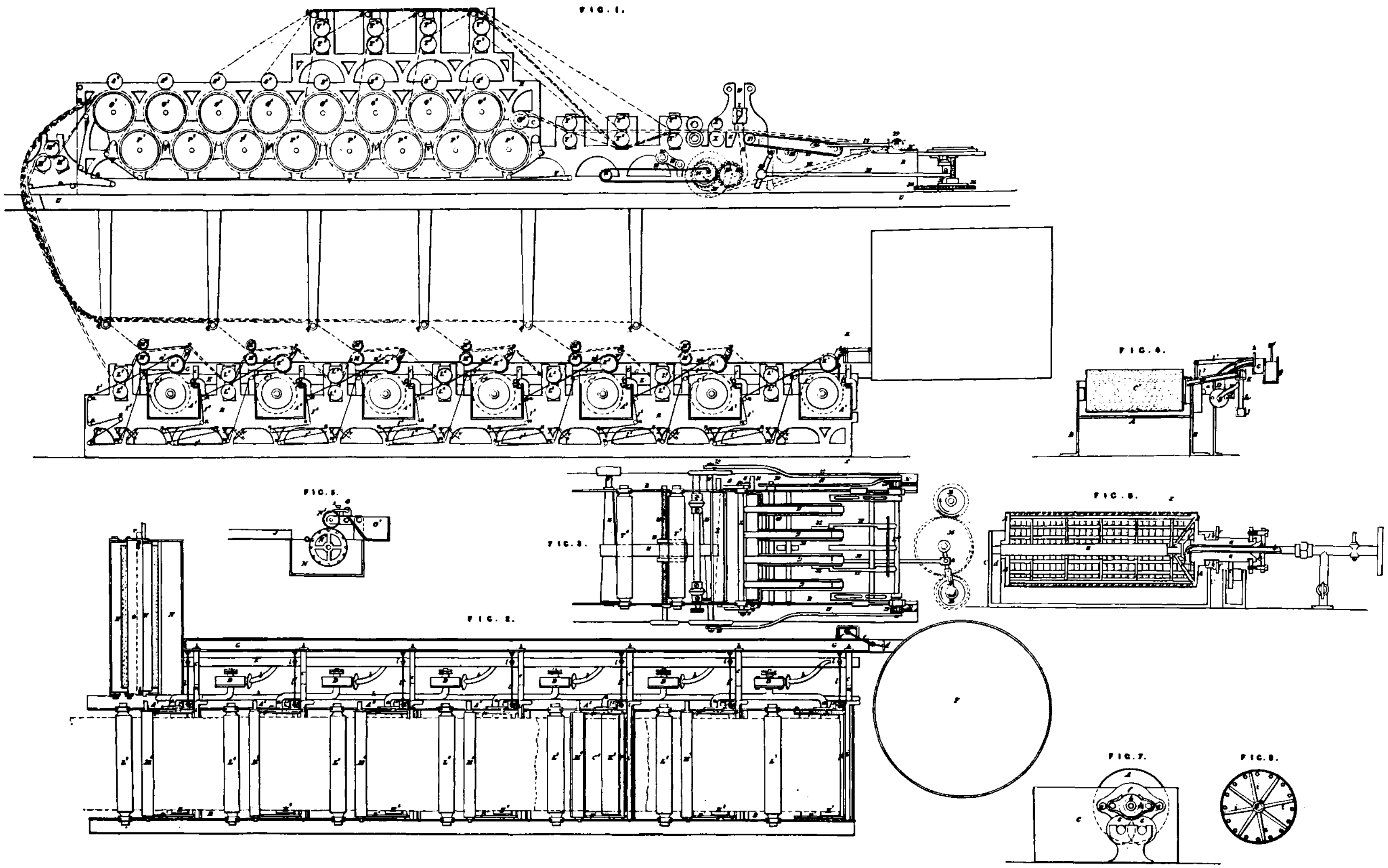
In it there is a notice of the monthly meeting of the Paper-makers' Club, at the Bridge House Hotel, London Bridge, and the Chairman was John Evans (Messrs. John Dickinsons).

The Paper-makers' Club had just appointed a Consulting Chemist, a Professor Redwood, of 19 Montague Street, Bloomsbury Square. Professor Redwood received a retaining fee from the Paper-makers' Club, and would conduct analyses for members at very moderate charges.

There is also an account of the annual meeting in Edinburgh at the Rainbow Hotel, of the Paper-makers' Association of Scotland presided over by John Cowan of Alexander Cowan and Sons, Valleyfield. At both the Meetings of the English Paper-makers' Club and the Paper-makers' Association of Scotland, it was decided to send a deputation to wait on Lord Palmerston to complain of the hardships inflicted on paper-makers by recent government legislation.

There were tables giving prices of raw materials, mostly rags, from all over Europe. Also the Board of Trade returns of imports and exports. There were some advertisements, including one of William Makin and Sons for beater bars and plates.

From time to time during the first fifty or sixty years of the evolution of the Fourdrinier paper-making machine, many attempts were made to shake the wet-end in different ways. We have



No. 119. John Franklin Jones' multi-vat cylinder-mould machine, the first very large cylinder-mould machine to be built. It could use up to seven vats if necessary, which is the maximum ever used today. Contrary to usual practice he did not include a press part to consolidate his seven-ply sheet, but passed it straight to the drying cylinders situated on the floor above. The board was cut by a vertical knife at the end of the machine.

already described some of these earlier. In 1864, James Easton of Southwark and Thomas Leigh of Cheshunt, who were engineers, patented a method of shaking the wet-end in an unconventional way. Instead of shaking the frame laterally from side-to-side, they shook it backwards and forwards in the direction in which the paper was running.

There have been similar methods of shaking applied before, but this one was very elaborate, and the whole design seems to have been extremely well thought out and carried into effect (No. 120). Instead of shaking the frame laterally, it was shaken forwards and backwards by an eccentric (H) which can be seen just at the back of the chest. The connecting rod (G) carried the eccentric motion to the shake table (A). This table was suspended immediately after the breast roll, and also at the couch, from two stands, and actually the frame rocked backwards and forwards for the distance allowed by the eccentric (H), so that the wire frame was going a short distance in the direction of travel of the wire, and then back again, rather in the same way as a vibrating Panda-type conveyor works. The wire frame (A) was adjustable also for slope, from the breast-roll to the couch, according to the speed, and the type of paper which was being made. In the drawing, the table (A) carried the endless wire web and the other operating parts of the machine. It also received a rocking or irregular compound vertical and longitudinal motion from the crank-shaft. The frame was supported in such a way that when imparting an oscillating endway motion, the opposite ends of the table were maintained throughout the operation at the same relative position in respect to a given horizontal line. To effect this they bolted to the opposite sides of the frame of the table (A) bracket arms (b), through the extremities of which there were bolts or studs (c). These bolts or studs were carried by links (D) that descended from and were free to rock on the studs (E), carried by the standards (F) at the opposite ends of the machine.

In order to obtain the greatest available speed of manufacture, that is the felting of the fibres of the pulp properly together, they made the forward end of the table adjustable in height. They used for this purpose pendant links which were adjustable in length, as shown at (D), and they could, therefore, regulate to the greatest nicety the degree of inclination required for the wire. It will thus be seen that the table, without the use of any balance weights, had the tendency like an ordinary pendulum to return to its normal position. They claimed that by their improved method of supporting the table they got a balanced action, which ensured a smooth and regular motion with an economical expenditure of power. The machine-man was able to adjust the length of the pendulum, or swinging links, and also the eccentric, to suit the paper he was making at the time.

There does not appear to be any evidence that this method of shake enjoyed any great vogue among paper-makers or manufacturers of paper-mill machinery, but it was certainly quite an ingenious and well-thought-out design.

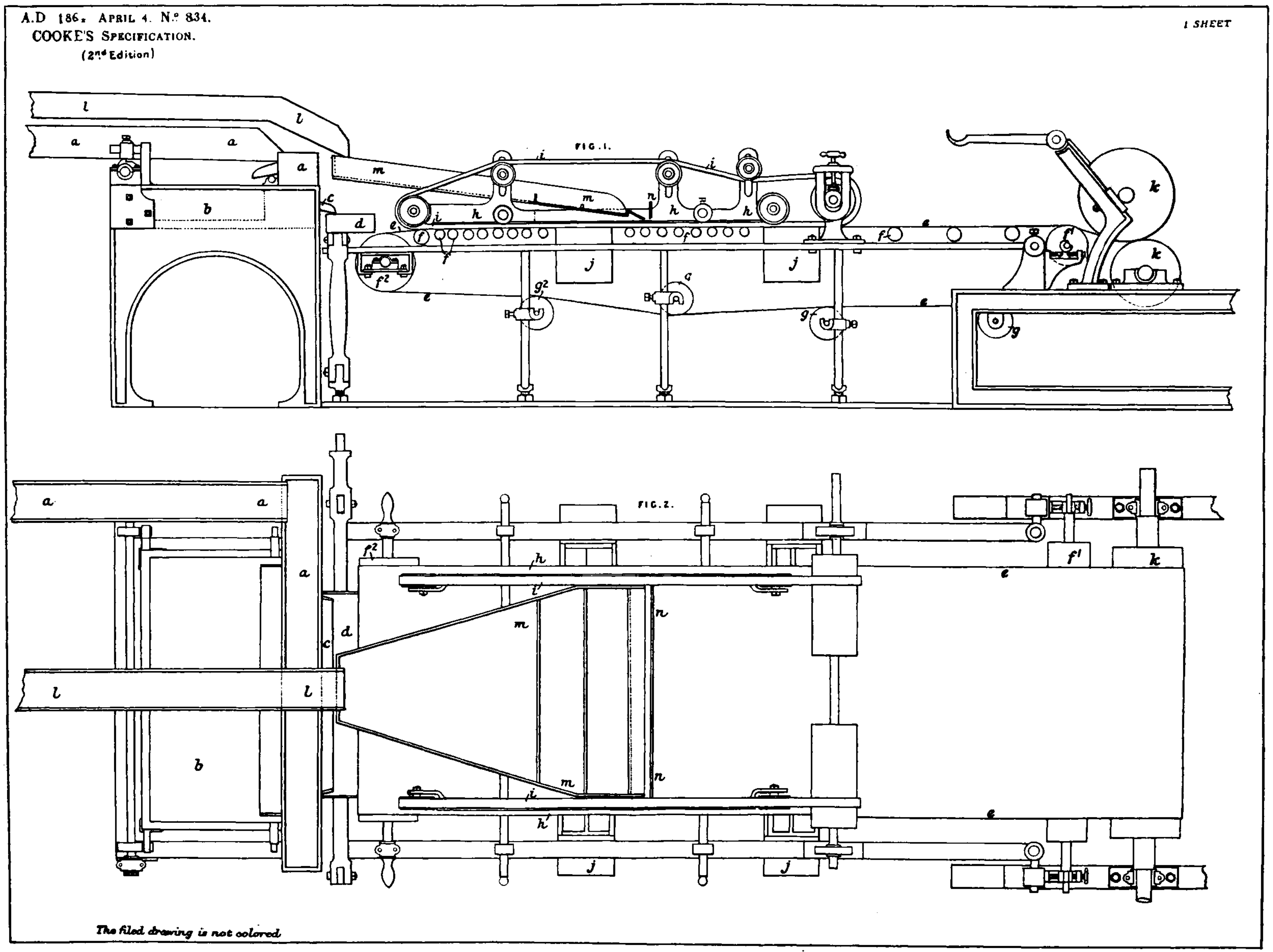
In 1864, William Ibotson, of Wraysbury, a paper-maker, to whom we have referred before as the inventor of the slotted strainer plate, patented an improvement on the flat strainer, which enabled it to be used continuously, or for very long periods, without shutting down to clean it. These flat strainers had always been troublesome because they got clogged up with stuff, and this had to be scraped off. During this operation more stuff was let through the strainer than was necessary for the weight of the paper being made, and a lot of dirt got through at the same time. Ibotson's idea was to pass more stuff onto the strainer at several points than was actually necessary for the substance of the paper being made, and to have an escape for the surplus stuff opposite that point of the strainer at which it flowed on. This meant there was a continuous stream of stuff passing across the strainer and escaping into a box, which led it to a back-knotter, which could be cleaned without interfering with the substance of the paper. In other words, he bled off from the strainer the surplus stuff which carried most of the knots and lumps and dirt which would not pass through. This is frequently done at the present time with revolving strainers, where a surplus is also bled off continuously, and passed to a back-knotter or through a refiner to clear it. His idea seems to have been quite a good one, and to have had the desired effect of giving much longer runs of clean paper, helping to keep the substance regular.

Quite a novel idea was put forward and patented in 1864 by Leonard Cooke, one of the founders of the firm of Cooke and Nuttall, of Horwich. His idea was to make a two- or multiple-ply sheet on a Fourdrinier machine wire. The method he adopted was as follows: The stuff was run on in the normal way from the breast-box onto the wire, and about a third of the way down the wire a further lot of stuff was laid on the layer of stock already on the wire, thus making two layers, or a two-ply sheet. He could use this for making a thick paper or for putting on colour, but it was important that the point at which the second lot of stock was put onto the wire should be at a place where a good deal of the water had already drained out through the wire, so that the second layer of stuff did not upset the make of the sheet already forming.

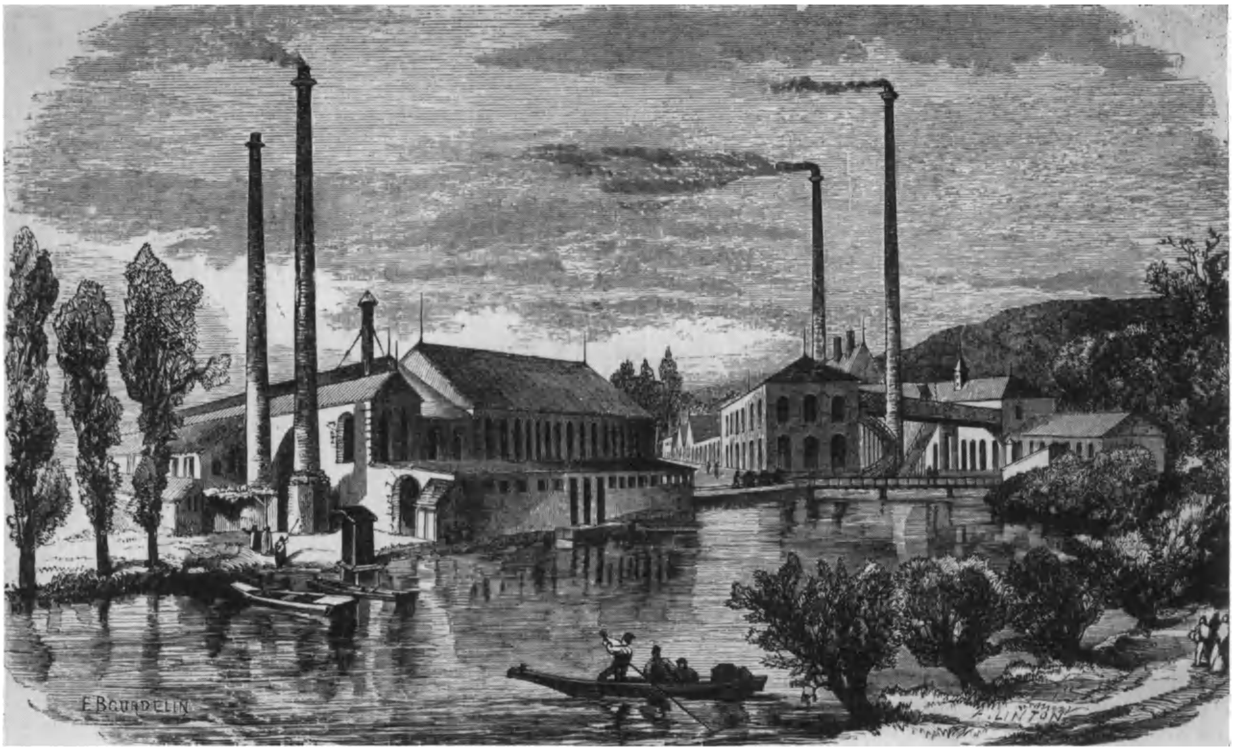
Cooke stressed that his invention was particularly applicable to the manufacture of paper for paper hangings, but that it could also be applied in the production of papers for many other purposes. He used this method for applying either a second layer of pulp, size, colouring matter, or other substances, either separately or combined. He could do this at two or more places provided he had the required number of chests to supply the stuff to the endless wire. Care had to be taken that a portion of the moisture in the pulp already deposited on the wire had been removed in the usual way, before the additional pulp or colour were added. No. 121, Fig. 1 is an elevation of the machine on which his improvement was applied, and in this case it is shown where only one additional lot of pulp was to be added. (a) is a spout for conveying the pulp from the chest to the strainer (b). (c) is a spout for conveying the pulp from the strainer to the delivery board and apron, by which the pulp was spread on the wire (e), passing over the tube-rolls (f). (j) are the vacuum boxes, and it will be seen that one of these was placed very much nearer to the breast-roll than usual. This was in order to take out as much water as possible before the second layer of pulp was spread on the wire.

The patent actually consisted in the application of one or more additional spouts, troughs, delivery trays, or other equivalents to the ordinary Fourdrinier paper-making machine, in any convenient manner. The second lot of stuff was passed to the machine through the spout (l), which took it from a second stuff chest, or strainer, to the trough (m), which could have cross ribs or other means for spreading the pulp evenly, and preventing too rapid a flow of the stuff onto the wire. The point of delivery of the trough (m) was above and beyond the first vacuum-box, and beyond this point of delivery there was a slice (n) to level the pulp, or a roller could be applied instead of or in addition to the slice (n), to act as a dandy-type roll.

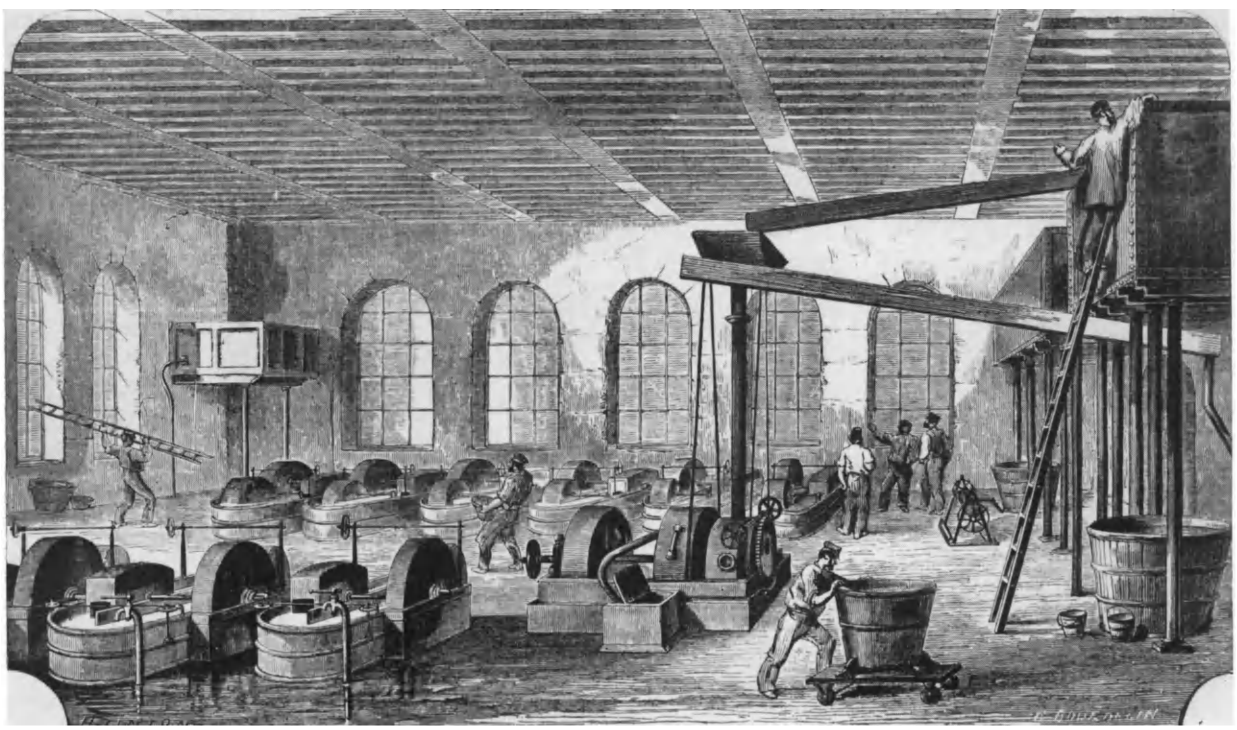
When a two-ply paper was being made, with a good top and an inferior lower surface, the coarser pulp had to be fed first onto the wire at the board and apron (d). As the wire passed over the first vacuum box (j) a portion of the moisture was removed from the coarser pulp before the finer pulp was deposited from the trough (m). The two thicknesses of pulp then continued to move on, and passed over the second vacuum box (j), by which more moisture was removed, and the compound paper, when arriving at the roller (f′), was sufficiently consolidated to be removed from the wire when carried between the couch-rolls (k) in the usual manner. When a compound paper was required with a fine surface on each side and an intermediate portion made of an inferior material two additional troughs and a corresponding number of vacuum boxes had to be applied. It might therefore be desirable to apply additional troughs, delivery trays, rollers, etc. By making troughs by which colour, for instance, had to be supplied, with slots in them, it was possible to make paper with coloured stripes, with one or more colours, at the same time. Also, wavy stripes could be produced by giving a lateral motion to the colour troughs by an eccentric or other means, and other designs could also be produced by means of rollers with patterns. The object of all this, of course, was to produce various kinds of wallpapers.



No. 121. Leonard Cooke's arrangement for making a two- or multiple-ply sheet on a Fourdrinier wet end, by causing further lots of stuff to be run down onto the stock already on the wire.



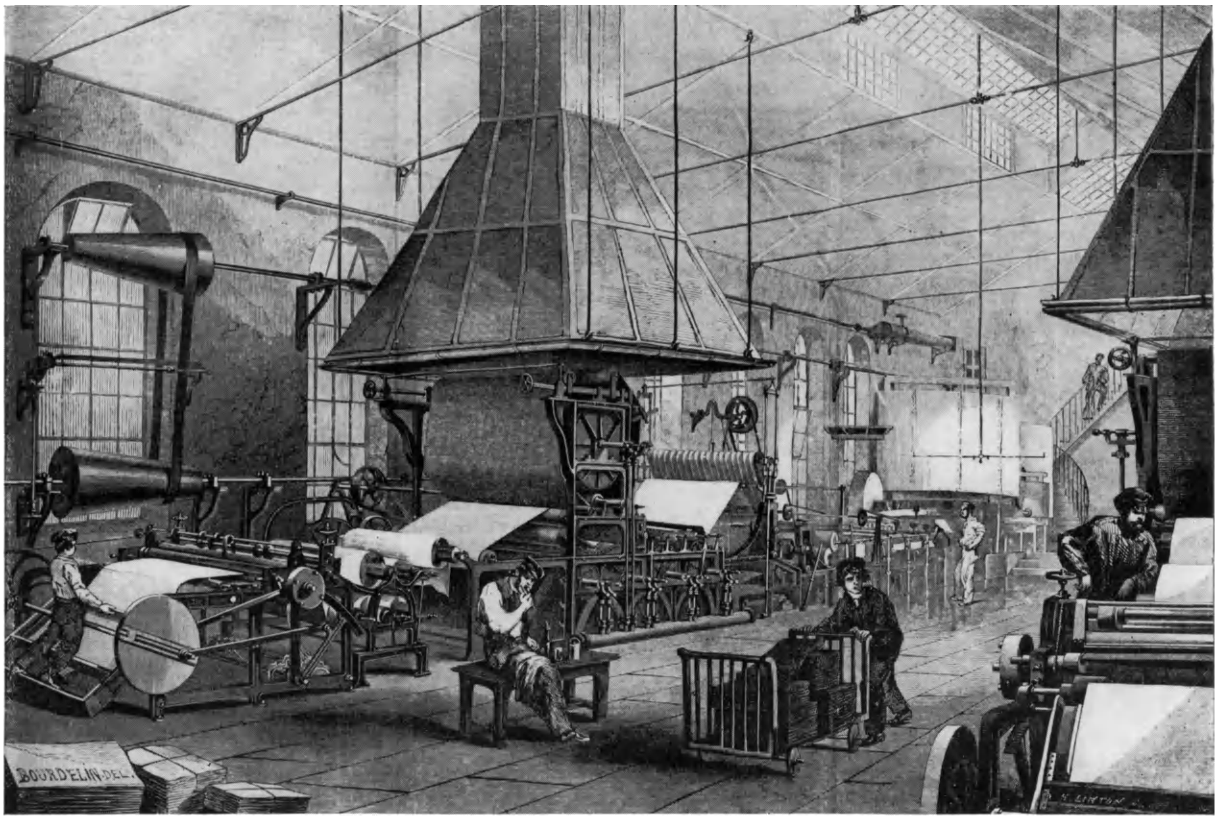
No. 122. The Didot paper mill at Essonnes, France, in 1864. This is an interesting picture of the famous mill at which Louis Robert was working when he patented the endless wire machine in 1798. It was here that Robert and Didot developed the machine before the prototype was taken to England for further development by Bryan Donkin for the Fourdriniers.



No. 123. The beater room of the Didot mill. Some of the beaters have cover washers while others have drum washers. A refiner is also shown in the foreground. This is not a jordan, but a disc refiner, of which there had been no mention in England up to this time.

Similar methods to this have been adopted in recent times for putting colour onto paper on the Fourdrinier wet-end.

In 1865 John Franklin Jones, of Rochester, in Monro County, in the State of New York, patented in England a very revolutionary paper making machine. This machine had original features both as regards the wet-end and the dry-end. Essentially it consisted of an ordinary Fourdrinier wet-end with table-rollers, suction-boxes and a couch, and it could be shaken laterally. Above the wire was suspended a second wire, rather like the upper wire which was on the original Fourdrinier machine,



No. 124. The large machine house of the Didot mill. There are at least two paper-making machines with dryers and cutters. The picture of the press part shows a scrolled felt roll at the reversing press. There is a paper cutter with slitting knives and apparently a cylinder knife for the chop. Cone pulleys for the alteration of draws are also shown.

but with many differences. This top wire was pressed down on the thick paper or board stock as it was being carried along the wire on the tube-rolls by a series of dandy-type press-rolls, and these rolls pressed the upper wire onto the stuff on the lower wire, causing water to be driven upwards through the wire, and to be picked up by the buckets inside the dandy-type rolls, marked (N) in the drawing No. 125. It was thus possible to make a very thick paper or board on the Fourdrinier wire and get enough water out of it to enable it to be couched. The wet-end is shown in the drawing, which illustrates the ordinary Fourdrinier-type table with the small tube-rolls and the wire. The other wire above, which was raised much higher at the breast-roll end, sloped gradually down towards the suction-box end, as the paper or board was consolidated by the pressure. The upper wire (M) ran round guide-rollers and was pressed down onto the stuff on the lower wire by the dandy-type rollers (N), inside which can be seen the hollow buckets, or tubes, for picking up the water and running it off at the back-side of the machine. When the stuff had passed between the nip of these two wires the lower wire carried it over two suction-boxes (S) and round the couch-roll (L). The top couch-roll had a felt running round it, and it was therefore a "lick-up" method of removing the web from the wire, and the wet-felt carried it from the upper couch-roll (T) round to the first press (U) which was a reversing press. It was picked up by the top roll of this press, and carried down to the second press (Z), which also had a felt round the lower press-roll, and thence the stuff passed to the drying-cylinders, which were four in number (B′). On top of the two top drying-cylinders were two press- or calender-rolls.

After the stuff had left the felt at the first press, the felt passed onto a washing tub with a batter in it, and then to a stretch-roll situated high above the press. The felt then returned round the upper couch-roll (T). When the wire had parted company with the web of pulp, and was on its way round the lower part of the lower couch-roll, it passed a revolving brushing roller which helped to remove any fibres or dirt adhering to the wire. The two presses, as will be seen, had compound levers for exerting a good deal of pressure on the web of paper or board as it passed through the presses.

Another entirely novel feature of this machine was in the dry-part, because after the board or thick paper had passed round the four drying-cylinders, it was led along a flat metal table which was heated internally by steam, and thus the drying of the board continued. As this drying was proceeding, calender-rolls, situated above the table and resting on the paper, were revolving and polishing the surface of the damp board. Halfway along this drying-table was a single calender-press, and there were three more calender-rolls revolving on the paper when it was nearly dry. Finally the paper passed through a single calender stack, which imparted the final glaze to it.

The whole object of this machine appears to have been to enable paper-makers to make a very thick paper or board on a Fourdrinier type machine, and to glaze it before it was thoroughly dry, as it passed over this drying-table. Little is known as to whether this machine ever became a successful proposition, and it is not heard of again. The principle was not apparently used in England until the Inverform Machine of St. Anne's Board Mill was patented almost a hundred years later.

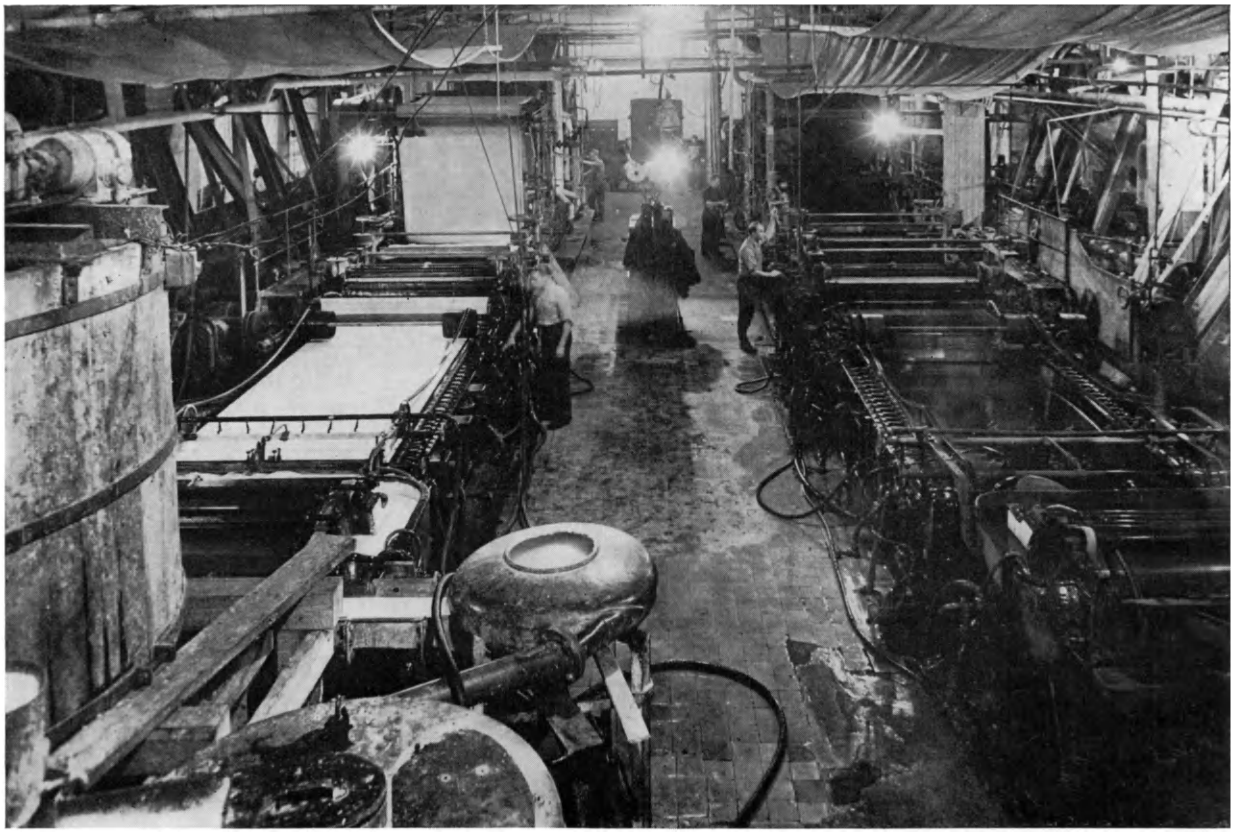
In 1865 Messrs. Pirie & Sons floated a new company, The Culter Mills Paper Company Limited, which they had acquired from Robert Arbuthnot, who had been co-partner in the mills with Thomas McCombie since 1837. The mill had two paper-making machines. The prospectus states, among other things: "It is now proposed that the Company should more particularly interest themselves in the manufacture of paper from Esparto or Spanish Grass—a fibre which for the last two years, has been largely, and very successfully imported for paper manufacturing purposes."

The board of directors of this new company consisted of Gordon Pirie, manufacturer; Alex George Pirie, manufacturer; Hugh Hogarth, merchant; Alex B. Whyte, merchant; John Gray Chalmers, printer; James Abernethy, engineer; John Johnson, manager.

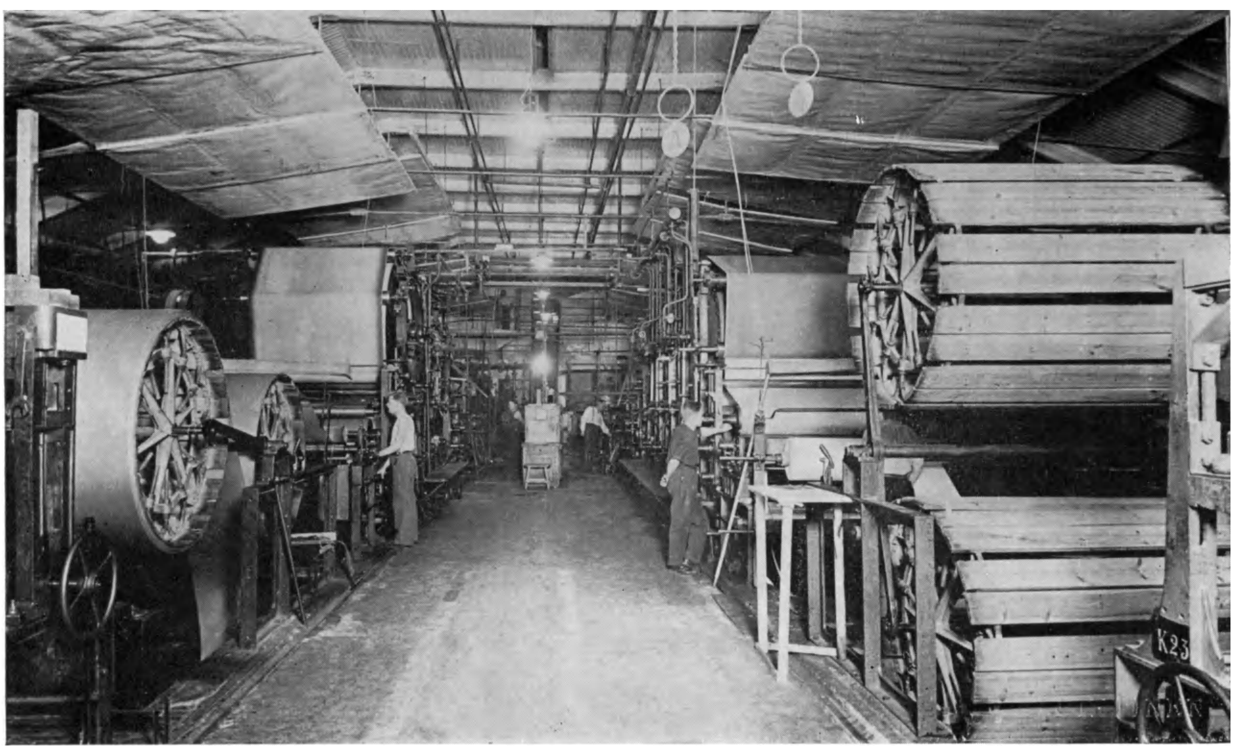
In 1866 Edward Lloyd was re-building Sittingbourne Mill (No. 334) which he had bought from Edward Smith who had owned it for many years. Lloyd was re-equipping it for the manufacture of newsprint. During this period Lloyd also owned Bowbridge Mill, Bow, Middlesex, where for a number of years he had been making newsprint. In 1861, he ordered a new machine for Bowbridge, 90 in. wide, from Bertrams, Sciennes, of which there is a detailed specification in a book owned by Bertrams.

During this period No. 621 Mill at Sandford-on-Thames was being operated by Granville Pixley and Company.

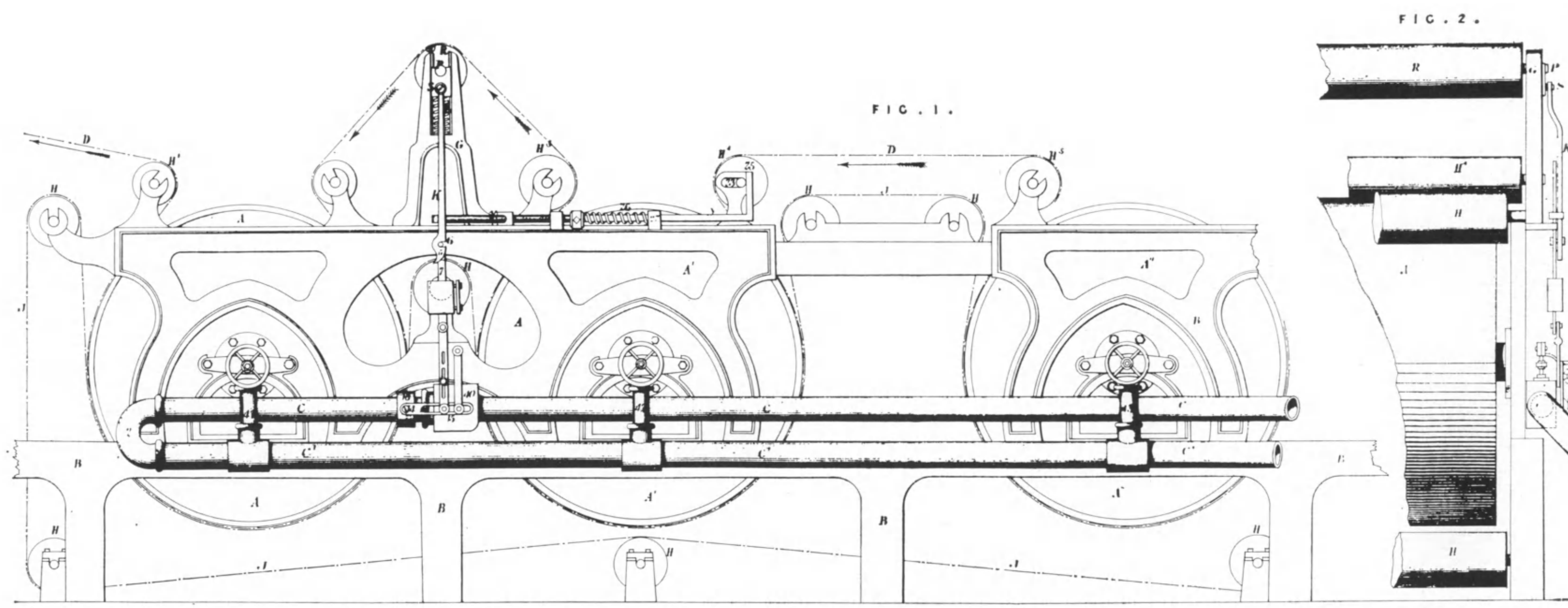
In 1866 Richard Smith and Oliver Ellsworth, both of the United States, patented in England a novel means of trying to control the drying of paper as it passed over the drying-cylinders. In order to effect this they used the expansion and contraction of paper, according to the amount of moisture it contained, to operate a valve. It seems very doubtful whether this would actually have worked in practice except on very thick paper; it certainly could not have operated on thin papers. The apparatus is shown in the drawing No. 128. When the paper was passing from one drying-



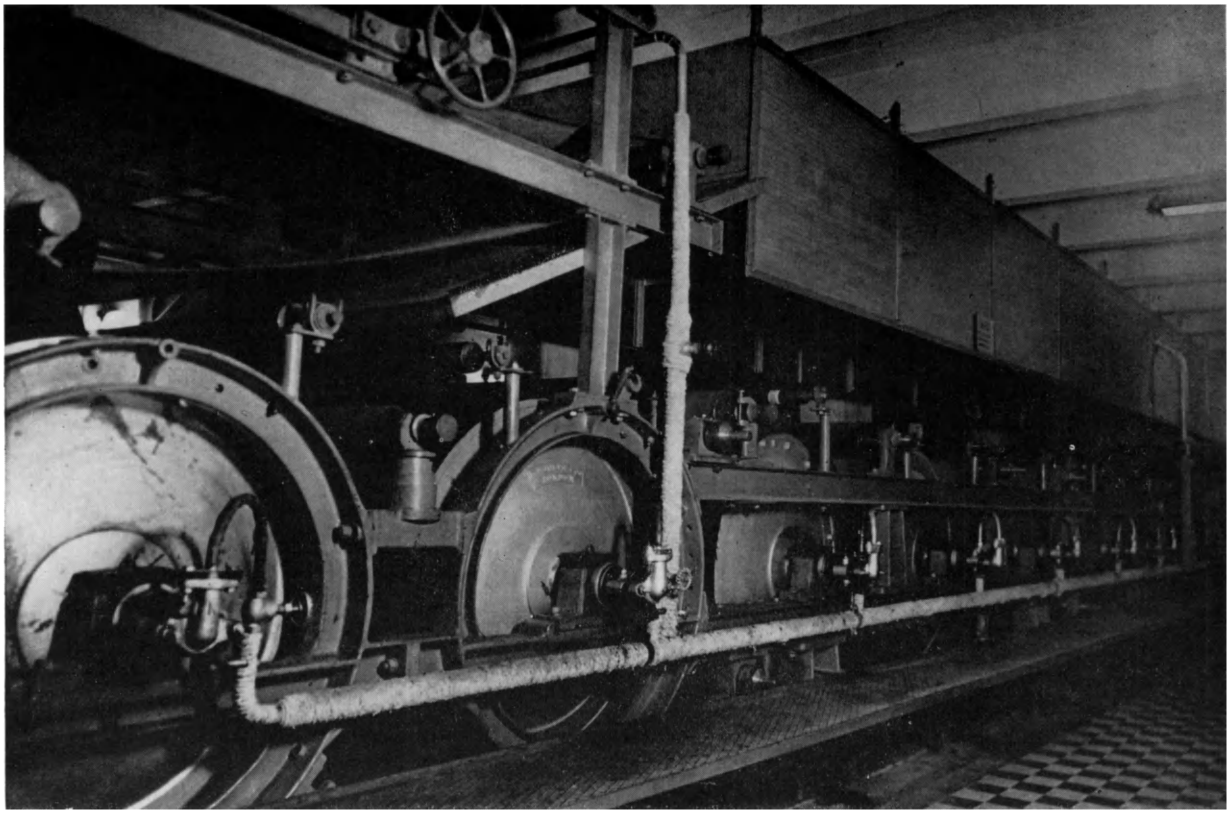
No. 126. The two wet ends of the Bryan Donkin machines at Tervakoski, Finland. These machines were supplied from London in 1864 and 1868, and were still running in 1950. The machines have since been combined to form one paper-making machine and are still running.



No. 127. The dry part and reel-up of the Donkin machines at Tervakoski. The machine on the left has the original reel-up drums in use. The drums on the right-hand machine are still available for use.



No. 128. Smith and Ellsworth automatic heat control for drying cylinders. The drawing shows the three rollers, the top centre one of which operates the valve on the steam line.



No. 129. Composite dryer part of the Tervakoski machine. Some of these drying cylinders were supplied with the original Donkin machine in 1852, the others are from the two later machines of 1864 and 1868. None of these cylinders has been renovated or ground since originally delivered.

cylinder to the next, it passed round two guide-rolls which were fixed, and then, after it passed the first of these guide-rolls, it was led up to a further guide-roll (R) which worked in a vertical slotted frame. The guide-roll bearing housing was fixed to a vertical rod, which was connected at its lower end to a throttle valve on the steam-pipe supplying steam to the cylinders. When the paper became too dry and contracted, the guide-roll (R) was pulled down against the pressure of the vertical spring (l), and took with it the vertical connecting rod (K). As this passed down, it closed or partly closed the throttle valve and shut the steam off from the cylinders, the paper soon became less hard-dried and expanded so that the guide-roll (R) could come up into its normal position again. It was maintained by the inventors that if the arrangement was properly set to begin with, at what was considered the correct amount of tension and dryness of the paper at that particular point, it operated satisfactorily in practice. It is certainly quite ingenious and very simple, provided that there is sufficient contraction and expansion in the paper over such a short distance as this to operate successfully a throttle valve on a steam-pipe.

Report of jurors of 1851 Exhibition on the progress of paper-making by machine

When the peace of Amiens restored intercourse between England and France, Leger Didot came over to England to join John Gamble and to seek what was lacking in France at the time, namely capital, engineers and enterprising paper-makers, in order to develop his paper-making machine.

In the first ten years thirteen machines were started. In the next ten years twenty-five machines, and by 1851 Donkin and Company made their 191st machine.

The destinations of these were as follows:

83	Great Britain
46	Germany
23	France
22	Scandinavia
14	Italy
2	America (in 1826)
1	India (in 1825)

For France the first machine was built for Canson in 1822; the second for Maupeau in 1823; the third in 1825 for F. Didot.

The first machine for Germany was built in 1818 for the Prussian Government and sent to Berlin; the second was for Mr. Rauch at Heilbronn in 1823. In 1837 the Bank of Poland had one sent to Warsaw. In 1826 Firmin Didot put onto his machine at his mill at Mesnil the Crompton drying arrangement, the first in France.

In 1830 Ibotson of Poyle patented his strainer plates and arranged for Donkin to manufacture them for him, with great precision.

John Wilks was a partner in the firm of Donkin and Company and did a great deal to improve the manufacturing and finishing of paper.

In 1851 the very fashionable Cream Laid writing papers were made by Hollingworth and Company at Turkey Mill, Maidstone. The thinnest writing papers were, however, made in France and other parts of the Continent, those from Angoulême in France and Heilbronn (Mr. Rauch) in Germany being the best. These papers are imported in quantity in spite of a duty of $4\frac{1}{2}$*d.* per pound.

About 1830 Phelps and Spafford of Connecticut, U.S.A., started what proved to be a very important paper-making machine manufacturing business. Soon after How and Goddard of Worcester, Massachusetts, began making large numbers of paper-making machines. About 1850 these two firms made nearly all the paper-making machines for United States of America. Most of the machines were modified types of the Fourdrinier, and also a "cheaper kind", known as the "cylinder" machine, which was used for cheaper and coarser kinds of paper.

Sweden had five mills and seven machines in 1851. Switzerland had twenty-six paper-making machines.

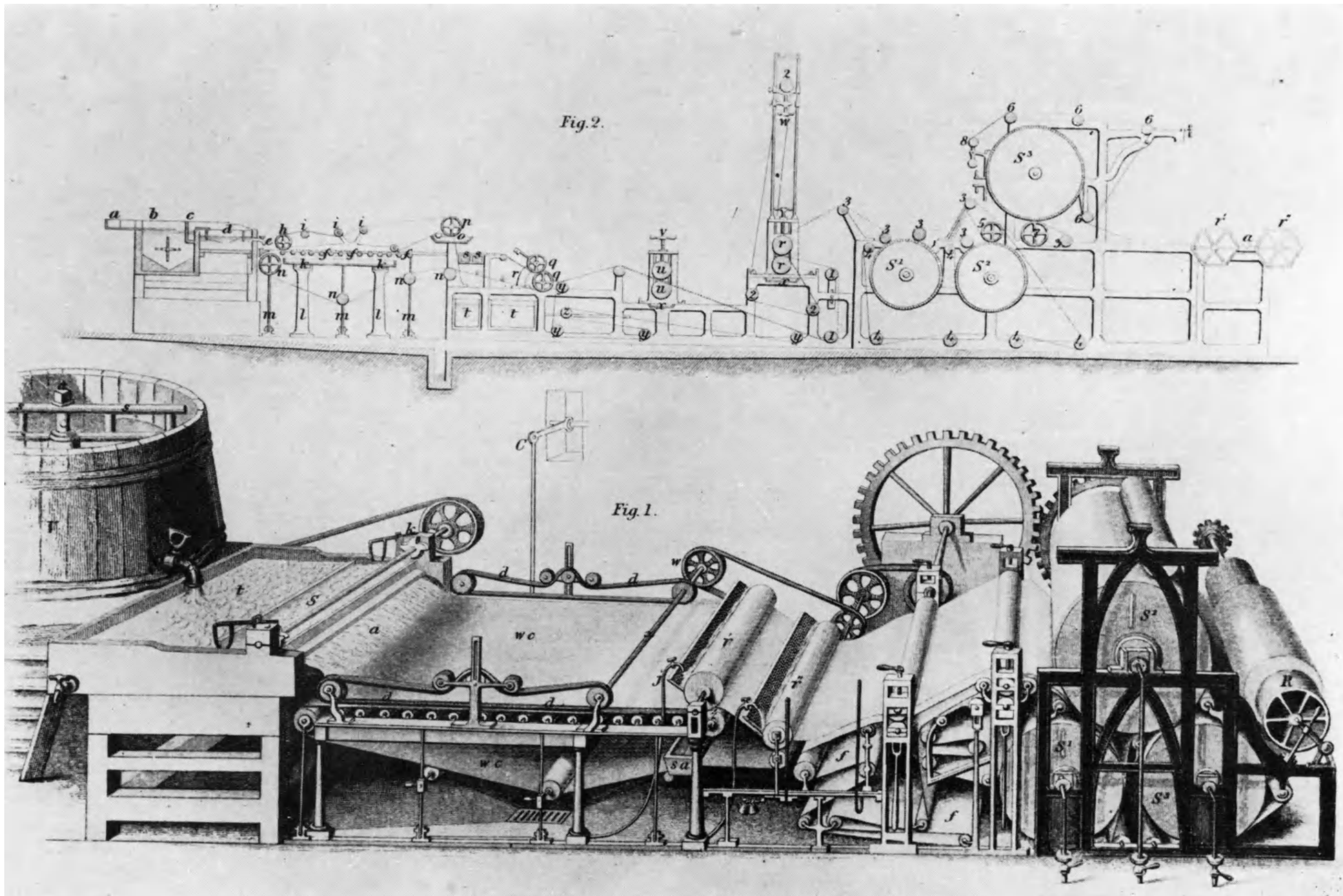
B. Donkin and Company were awarded a gold medal for paper-making machinery at the Exhibition.

Description of working of paper-making machine taken from the *Cyclopaedia of Useful Arts*, 1866 (Fig. 1, No. 130)

Stuff is kept stirred in a chest. The cock (c) is opened more or less according to the thickness of the paper, to let the stuff into the large trough, (t), where it meets a large supply of water, which has already been used and has passed through the wire of the machine and been pumped back.

The stuff then passes through the strainer, (s), for the purpose of separating from the pulp, knots, sand and hard particles. The strainer was invented by Ibotson. Prior to the invention of the strainer, the knots, etc., were scraped out of the paper in the salle, to the injury of the surface of the paper, and causing much retree (damaged paper).

The strained pulp flows upon a leather apron, (a), which conducts it to the endless wire cloth, (w.c.), over which the web of paper is formed.



No. 130. This picture shows two different designs of paper-making machines operating in 1866. The pictures appeared in the *Cyclopaedia of Useful Arts*. Obviously both machines must have been in use for many years as designs had been much improved by this time. Probably the machine, Fig. 1, had been working for at least thirty years.

The wire cloth was about 28 ft in length and varied from about 48 in. to 100 in. in width and had 60 holes to the linear inch.

The wire is kept in motion upon a number of small copper rollers, about $1\frac{1}{2}$ in. in diameter and the same distance apart. The rollers are supported by a frame, to which a slight but rapid lateral motion is given by means of a crank, C; the shaking motion facilitates the escape of the water and the felting together of the fibres of pulp. The water, holding a good deal of the flour of the pulp, is received in a large wooden save-all, placed beneath the wire cloth, and from this vessel it is raised by scoops and poured into the trough, (t), where it dilutes the supply of stuff from the vat, (v).

The edges of the paper on the wire are contained by belts or deckles of linen and caoutchouc, (d,d). They are $\frac{1}{2}$ in. thick and 16 ft long and are kept distended by the system of friction rollers shown in the drawing. Motion is given to them by the wheel, (w), acting on the axis, (x), and they press with moderate force, not sufficient to prevent the free motion of the wire cloth, but enough to prevent the pulp flowing off laterally before the fibres have set.

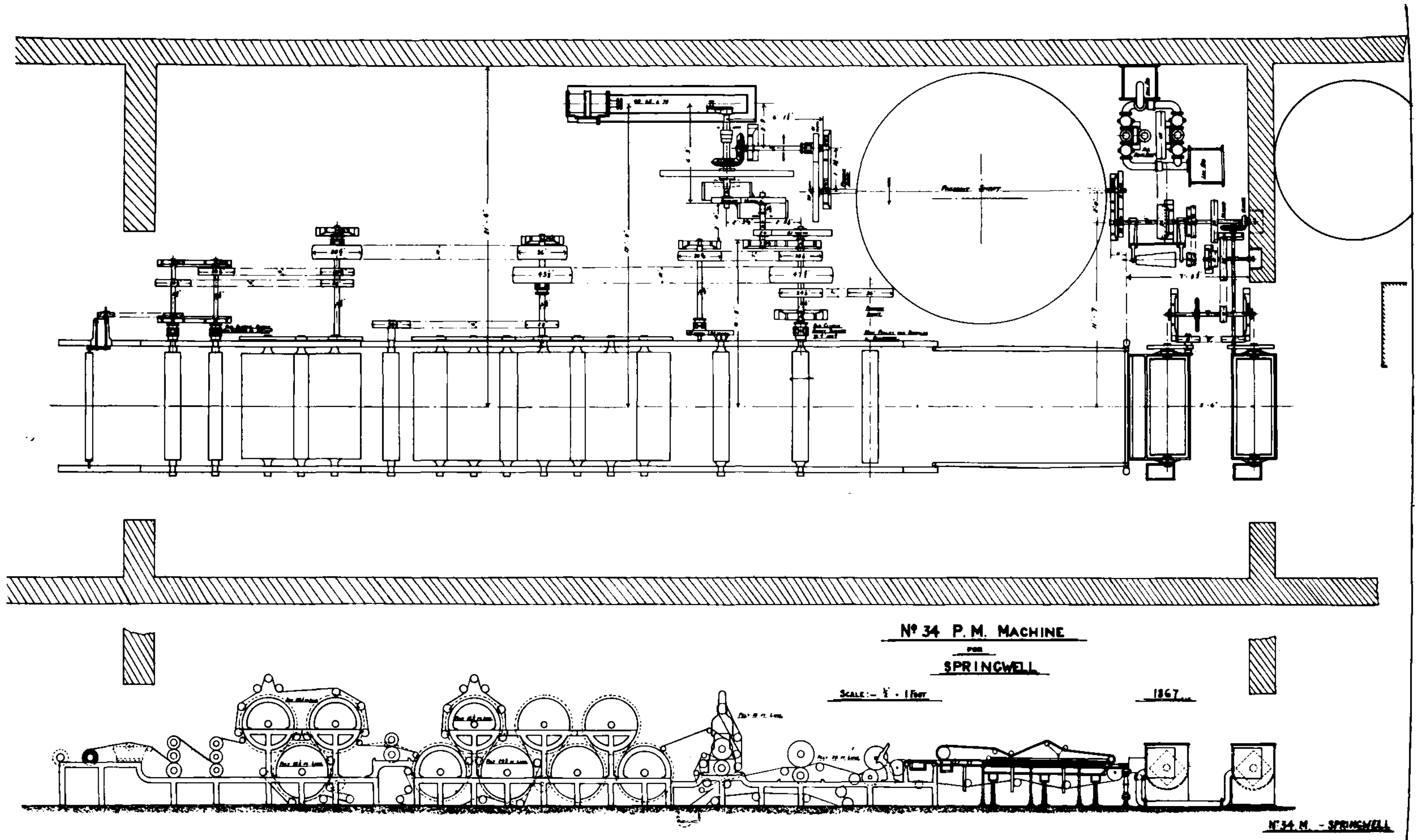
The wire-cloth, with the pulp upon it, passes on until it comes to a couple of wet-press cylinders, (r), the lower of which is of metal but covered with a jacket of felting or flannel; the upper one is of wood, made hollow, and covered first with mahogany and then with flannel. These cylinders give the gauze with the pulp upon it a slight pressure, which is repeated upon a second pair of wet press rolls, (r′′), similar to the first. The paper pulp is then led on upon an endless felt or blanket, (f), which travels at exactly the same rate as the wire cloth. The wire cloth turns round under the wet press cylinders to obtain a new supply of pulp and is kept stretched by copper friction rollers, which turn by the friction of the cloth. (This is a machine with a wire press, as well as a couch press.)

From the wet felt (f) the web of paper passes to the drying cylinders (s) and then to the reel up R.

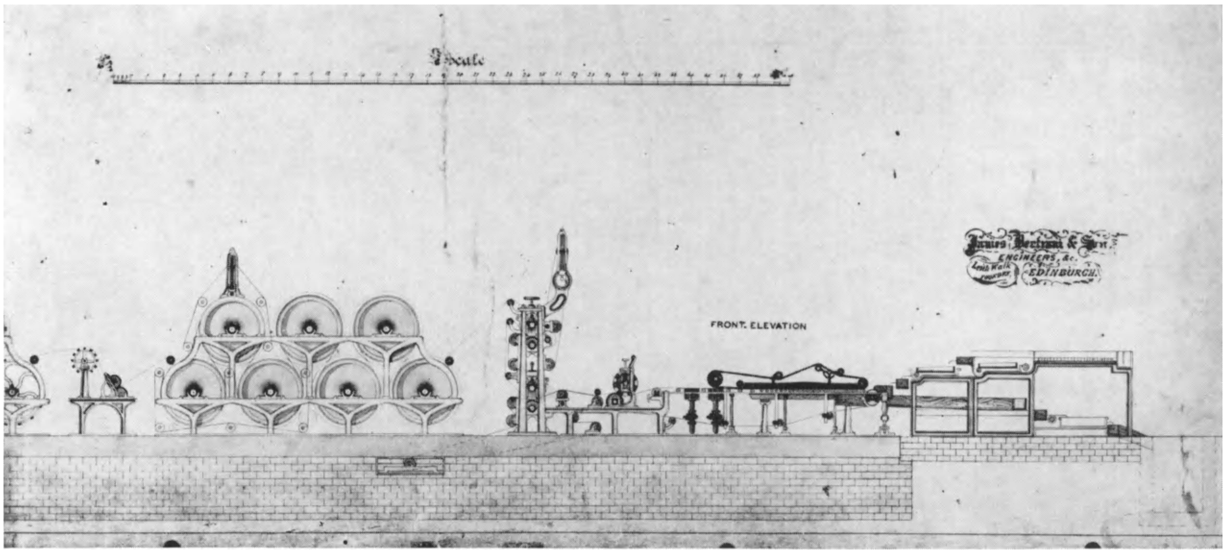
In 1869, William Frederick de la Rue, of Bunhill Row, London, invented a new way of making a dandy to give different types of watermark compared with those which had always been produced during the previous thirty years or so. Up to this time the mark had been obtained in the paper by fixing to the wove surface of the dandy-roll letters or figures in wire, which were sewn or soldered onto the surface of the dandy. When the dandy-roll revolved on the stuff the device pressed into the paper and made it slightly thinner at these places. Thus the mark was fixed in the web of pulp, and when the suction-boxes had drawn the water out, the design or lettering was permanently fixed in the paper. De la Rue, however, invented the countersunk watermark, which had hitherto only been used on hand-moulds. In other words, he used a die to press the wove wire cloth of the dandy inwards, so that when the dandy revolved on the stuff, the sheet was actually more bulky where the roll was countersunk, and of its normal thickness elsewhere across the sheet with intermediate shading. This method has been frequently used since, and wonderful light and shade in watermark designs can be made in this way.

He also mentioned in his patent specification that apart from this countersinking, the ordinary raised mark could also be used in addition on the same roll, so that very accentuated designs could be obtained by the raised lettering or wires shading away to nothing by the countersinking of the rest of the design.

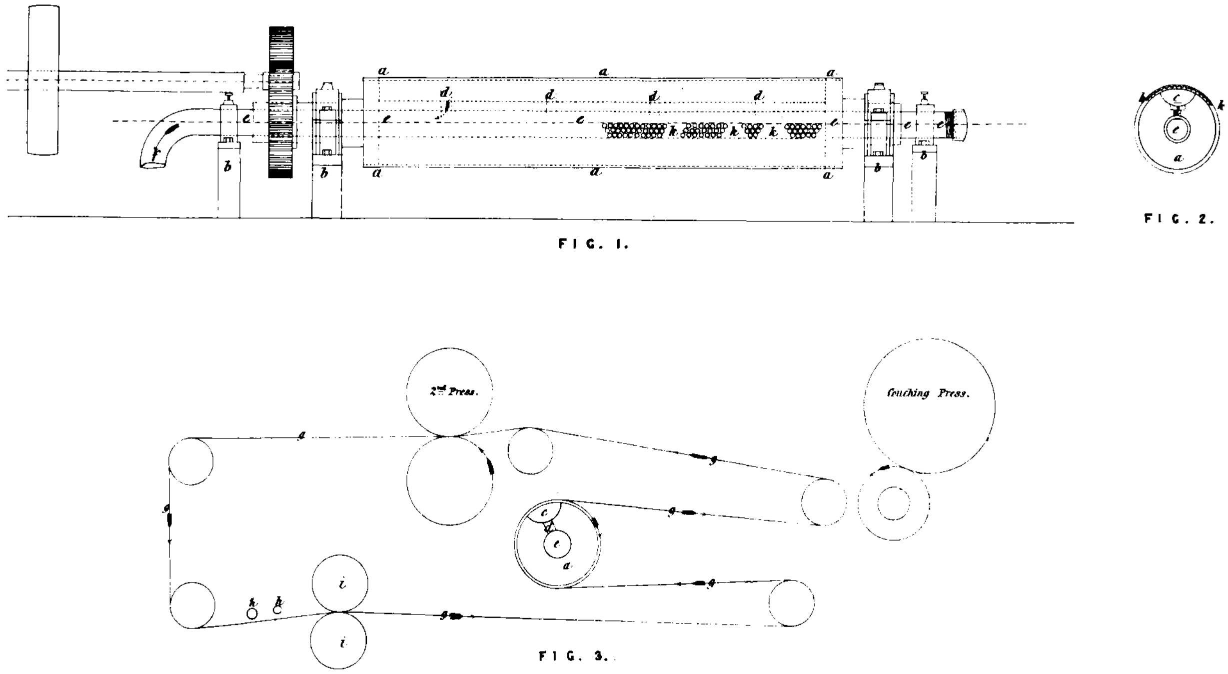
Two of the Marshalls, Thomas Allen Marshall and Charles Dudley Marshall, of Bishopsgate Street Without, in the City of London, who were the manufacturers of dandy-rolls and whose firm had been very well known in this connection for about seventy years, patented in 1870 the method of fixing the letters or devices to the dandy by soldering them on instead of sewing them, which had hitherto always been the practice, and this method has been used throughout the years since 1870 to the present time, as being far more satisfactory than sewing. When the devices or letters were sewn onto the wire of the dandy, the sewing wires always showed, and they were easily damaged and broken, causing the watermark letters and devices either to fall off altogether or to be out of



No. 131. George Bertram's No. 34 machine for Springwell. This machine was built in 1867 and is of advanced design, having a long wire, large diameter top couch-roll and large top press. It also had a reversing press, and the drying cylinders are in two sections with intermediate press-rolls, and two stacks of three-bowl calenders.



No. 132. James Bertram's No. 26 machine for Mendip Paper Mills, Somerset. This is a short machine and has a "stacked" press. It is the first example known of a stacked press and by an ingenious arrangement of felts the bottom half of the press is straight through and the top half reversing. There is only one section of drying cylinders and no intermediate press. It was built in 1868. In the previous thirteen years James Bertram had built twenty-one paper-making machines.



No. 133. T. J. Marshall's arrangement of suction roll for cleaning and drying the wet felt. This was a very early attempt at conditioning the wet felt and the method was not in general use until about seventy years later. This firm made chiefly wires and dandy-rolls, but they also built paper-making machines.

place and to slip about. With the soldering this was much less likely to happen and in fact the devices on dandy-rolls thus soldered seem to stay in place for many years.

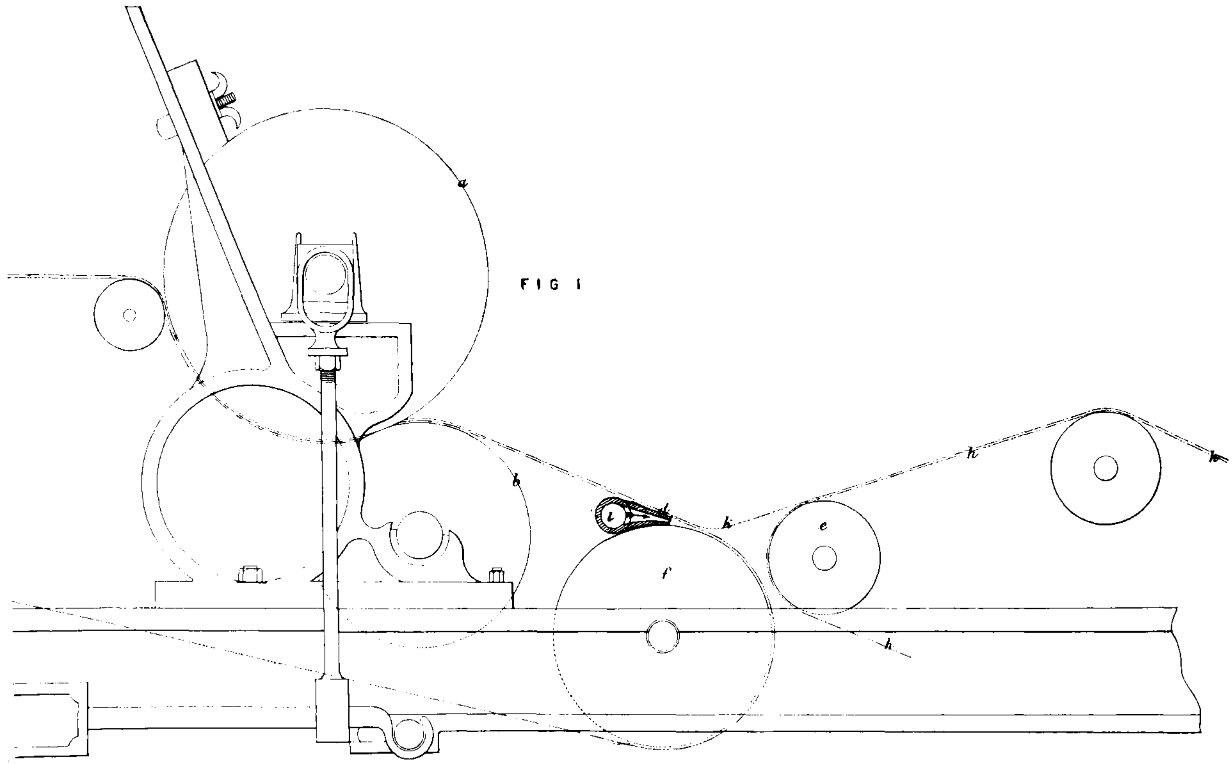
Although the Marshalls were best known as manufacturers of moulds and dandy-rolls, they had actually made paper-making machines, and they were very interested in paper-making and very knowledgeable about the problems of the paper-making machine itself. T. J. Marshall, about this time, patented a suction-roll for cleaning wet-felts, which is described and illustrated in the drawing. Marshall refers to his invention as effecting washing or cleaning of the felts, usually known as the wet-press felts, while the paper-making machine was working, describing it as being a perforated cylindrical roll, or vacuum cylinder, of gunmetal. The roll was mounted on hollow trunnion bearings fitted to the interior surface in such a manner as to be air-tight, and had within it a box or trough. This box might be of any convenient shape for the purpose, but he made his in the shape of a segment of a circle. The box was connected by means of two or more short pipes with another pipe passing through the centre of the perforated cylindrical roll or vacuum-cylinder. One end of this pipe was connected to another leading to a suction pump or pumps, preferably a set of three-barrel pumps. The perforated roll was driven by means of ordinary gears, which drove the rest of the machine, and was driven at the same speed as the felt. He could control the speed of the roll by means of an expanding pulley.

After the felt carrying the paper from the machine through the press-rolls had left the paper, it passed under two jets of water, or it could be passed through a trough of warm or cold water, or in fact through a trough with a batter. It then passed through a pair of squeeze-rolls, and finally it came to the perforated suction-roll, where the cleaning and drying of the felt was completed and the felt was made ready to receive the paper from the wire. Marshall also used brushes across the felt to assist in freeing the felt from any particles of pulp or stuff that might otherwise adhere to it.

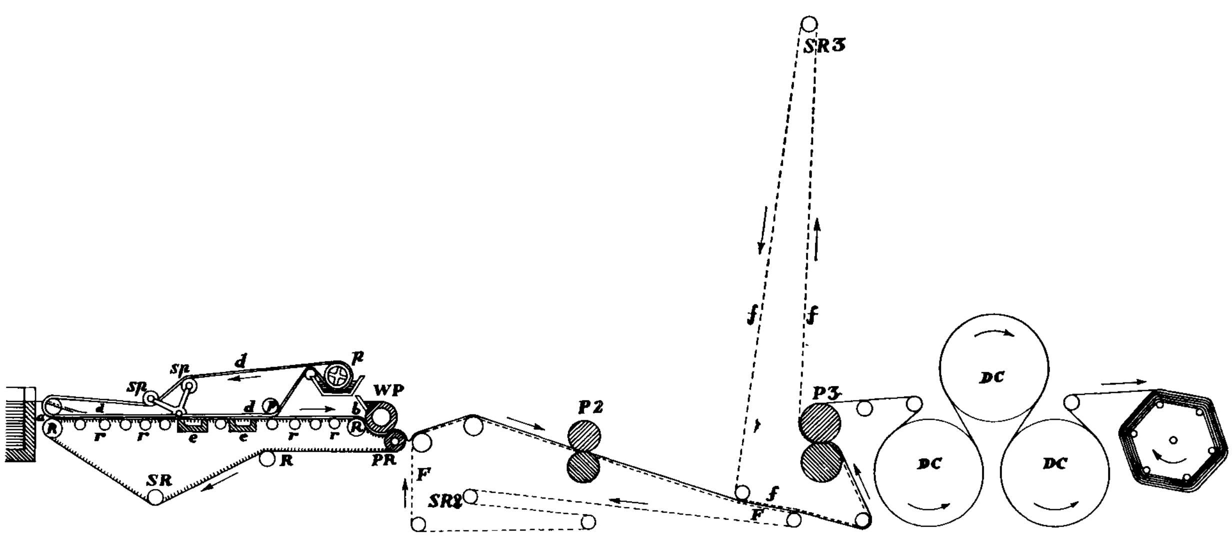
Earlier in this book we have described the suction press-roll invented and patented by George Dickinson, but this roll does not seem to have met with much general success; and also T. J. Marshall's felt-cleaning vacuum roll did not seem to succeed at the time, although at the present day these vacuum felt-cleaning rolls are being increasingly used throughout the world on first-press felts and other wet-felts on different types of paper-making machines. It seems probable that the reason that these suction-rolls did not succeed in those early days was the lack of suitable pumps, because up to this time the centrifugal pump had not been made available to the paper trade, or was not in general use.

In 1870, Yates Duxbury, of Hall i' th' Wood Paper Works, near Bolton, patented an alteration to the method of passing the wire round the bottom couch-roll and delivering the stuff from the wire onto the wet-felt. Previously the wire had returned round the bottom couch-roll, and in fact that is the method usually adopted at the present time. Yates Duxbury, however, discovered that when making thin papers it was difficult to get the paper which had been pressed into the meshes of the wire to leave the bottom couch-roll and the wire without breaking frequently, so he had the idea, which he patented, of taking the wire round a second roll, shown in the drawing, No. 134, Fig. 1 (f), after it had come off the bottom couch-roll, and before it returned to the breast-roll. He maintained that it was much easier to get the web of paper off the wire at this second roll because there was plenty of air behind the wire, or if need be it could be actually assisted off by blowing it. In a way, this method has been re-introduced in recent times with the vacuum pick-up. In other words, in present-day practice the wire is taken beyond the suction couch-roll round a further roll or forward drive roll, and meantime, as the wire is passing over these two rolls, a vacuum-roll lifts the stuff off the wire onto the wet-felt. Yates Duxbury maintained that by adopting his method, far fewer breaks occurred, especially on thin papers, and this can easily be understood by those conversant with the difficulty of trying to get thin paper from a bottom couch-roll after it has been pressed tightly in by the top coucher.

In 1875, Walter Ibbotson (who now spells his name with two b's), and who was resident at that time in Cartmel, in the county of Lancaster, patented the two-wire machine. He was of the same family of Ibbotsons to whom we have referred frequently during the development of the paper-making machine, who had mills at Glossop. Walter Ibbotson left Glossop and went to Cartmel.



No. 134. Yates Duxbury's method of removing the web of paper from the wire after it had passed the couch. Instead of returning round the bottom couch-roll, the wire came forward to return round a second roll (f). If any difficulty were experienced in removing the paper from the wire, this could be assisted by blowing air from a pipe underneath the wire at (d). The drawing is otherwise interesting in that it shows that the top couch-roll was well laid back into the wire, and in fact was in contact with the paper for about one-quarter of its circumference.



No. 135. This sectional drawing taken from *Objects in Art and Manufacture* about 1870 shows the moving parts of a paper-making machine which was probably built a good many years earlier. It shows the prevailing method of working the top couch-roll well staggered back into the wire, as in the previous illustration, and also a large wire-roll (R) very close to the couch-roll. The suction boxes also are shown approximately half-way along the wire.

No. 136. Couch and press part of a machine at the Melbourne Mills of Australian Paper Manufacturers Limited, made by Redfern, Smith and Law, of Bury, Lancs., in 1871, and still running. Apart from a few small modern additions this machine is much the same as when supplied nearly ninety years ago.

The illustration (No. 137) shows Walter Ibbotson's patent. He had two Fourdrinier wet-ends with couches and wet-felts, and he also had two large drying-cylinders which were on movable bearings and could be kept in contact, or removed from contact, with each other as desired, so that there were really two completely separate paper-making machines with single-cylinder drying. When it was desired to make a two-ply sheet, the machines were started up, and when the paper was passing round the cylinders, these were brought together so that the cylinder (F) took up the paper from the cylinder (F′), and the paper was reeled up a two-ply sheet at (G). It could also be arranged that a further web of damp paper (H) could be introduced between the wet web coming from the left-hand wet-end and the wet web coming from the right-hand wet-end, so that a three-ply sheet could be made. There was a further possible arrangement for making a three-ply sheet, shown in Fig. 2. Instead of a reel of paper having to be previously made, and then unwound from a roll, a cylinder-vat (K) could be provided under one of the drying-cylinders, and this licked up a second web of paper on the already existing web of paper which had been made on the Fourdrinier wire and was sticking to the drying-cylinder as it passed the making drum in the vat (K). This drying-cylinder then had two plies on it, and when it came to (x) it joined the web coming from a wet-felt

FIG. 1.

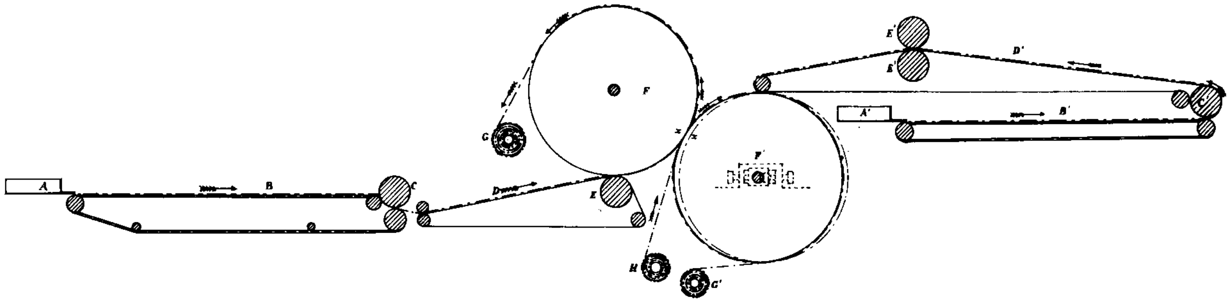
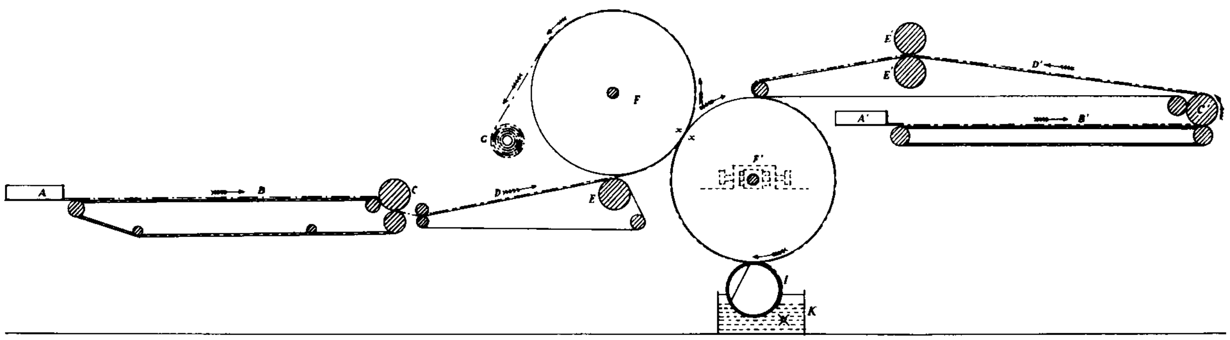


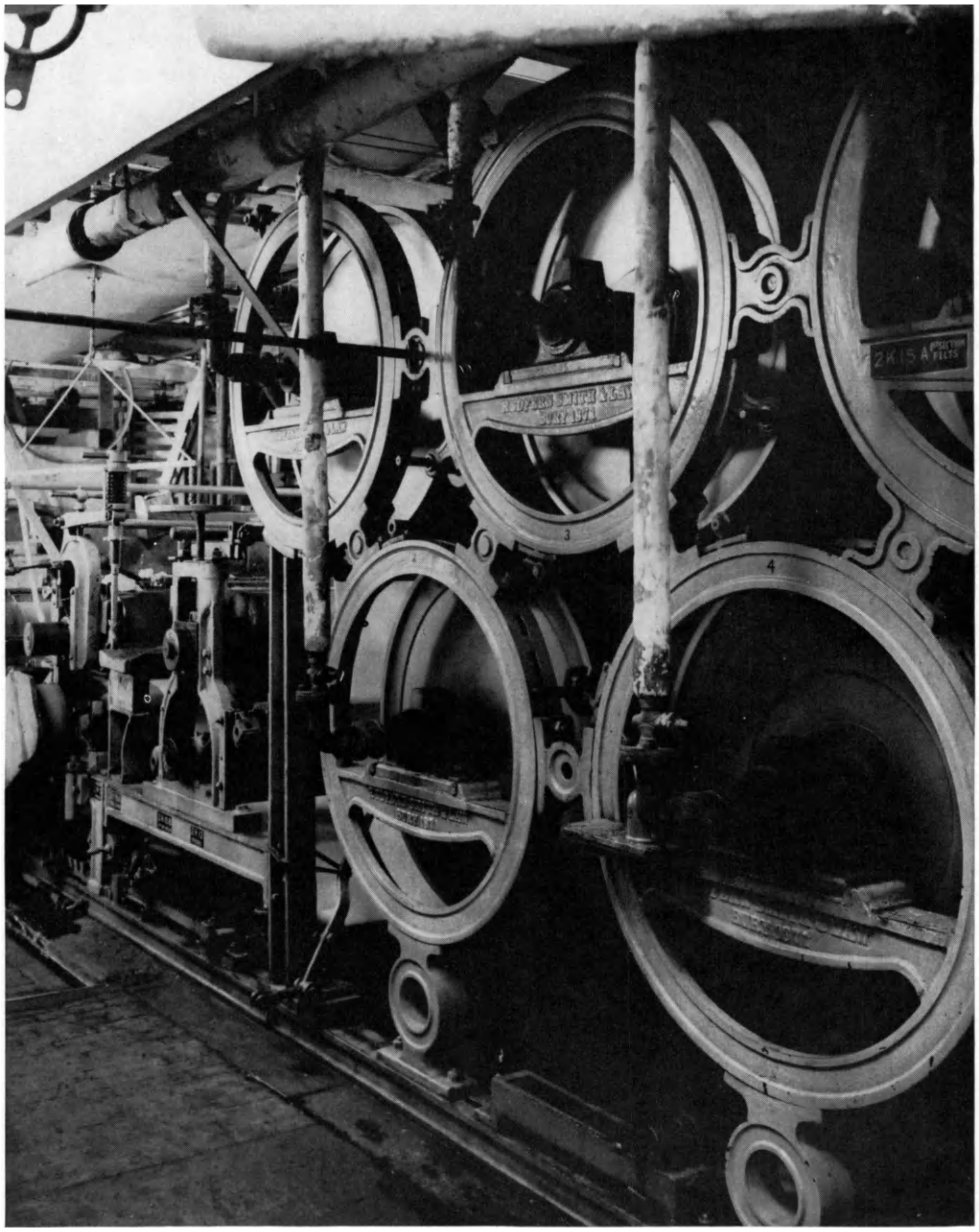
FIG. 2.



No. 137. Two arrangements of Ibbotson's twin wire machine. Fig. 1 shows the arrangement of the two wires, wet felts and the drying cylinders, also the method of adding a third ply or "middle", by running a web of wet paper, already made on another machine, from a reel-up between the two sheets at the drying cylinders. Fig. 2 shows the addition of a cylinder-mould and vat, by means of which the "middle" was added as it was couched onto the wet sheet just formed on the wire at (B).

(D) and went round the cylinder (F), and was reeled up a three-ply sheet at (G). This arrangement is the forerunner of the two-wire machines of the present day, except that it is usual to combine the sheets at the couch, or the press, and not by having the cylinders touching each other. In fact Ibbotson says that if preferred the webs of paper pulp may be brought into contact and joined together at the couch-rollers, or at any other part of the machine, instead of at the drying-cylinders.

It was a good many years after this that the same method of making a two-ply sheet on Fourdrinier machines came into prominence. In fact, it was almost a hundred years later. The idea of combining sheets, of course, was not new, and had been introduced by John Dickinson many years earlier, and was in general use on the vat or board-machine at this time.



No. 139. The drying cylinders of the Melbourne machine just as supplied by Redfern, Smith and Law in 1871. The name and date appear on the cast iron framing. This machine was running quite fast and with no trouble of any kind in 1953.

15

Standardization of the Paper-making Machine, 1870-90

BETWEEN the years 1870 and 1880 the paper-making machine had taken a definite pattern which was to last, with few changes, for many years. While machines made by different manufacturers differed in many details, the design was, for all practical purposes, the same, whether the machines were made in England, Scotland, or the United States of America, or on the Continent. Actually the principle on which the machine operated was much the same as on the machine patented in 1807, and made by Bryan Donkin for the Fourdriniers. The width and length of many machines had been much increased, the speeds at which some machines operated were very much faster, and there was a definite trend on the part of paper-makers to specialize in such papers as newsprint or writing papers or wrapping papers. Some companies had large mills with many paper-making machines.

There is an excellent book, published in America in 1873 and written by Carl Hoffman, which describes the paper-making machinery in use in America at that time. This seems to have been the only book, in any language, which described and illustrated all the machinery being made and used at this time. As Hoffman was a paper-maker and paper-mill manager, both in Germany and America, he is able to describe all the operations for making the different types of paper being made, also the preparation of the various raw materials.

By 1870 many materials were in general use which were unknown to the paper-makers of the early nineteenth century. The only raw material in use at the beginning of the nineteenth century was rags of cotton and linen. Although Matthias Koops had written his book on the use of straw, waste paper and wood, and had actually had his book printed on papers made from these raw materials, nevertheless they were not in general use for making into paper until about fifty years later, when the demands on paper-making to supply the ever growing printing industry had outstripped the supply of rags and rendered urgent and necessary the provision of other raw materials. Koops had made paper from mechanical or ground wood and sawdust in 1801, but it was not until 1840 that Keller and Voelter introduced it on a practical scale.

Chemical wood pulp by the soda process was produced by Burgess and Watt in 1853, and subsequently Tilghmann made sulphate pulp, and finally Mitscherlich in 1874 became famous for his process of making sulphite pulp from wood. Meanwhile straw had been used in increasing quantities for the low-grade straw papers and strawboards, and many mills made paper exclusively from straw.

However, wood pulp, prepared by the new processes, being a much cleaner and stronger raw material, partially ousted the use of straw; and esparto grass from Spain and North Africa also displaced straw, and became established as an important raw material for the making of high-class printing and writing papers. It was in 1856 that Thomas Routledge patented his process for making pulp from esparto grass, which started a most important branch of paper-making, particularly in Scotland. By 1870, 140,000 tons of esparto grass were being imported annually. Thus it will be seen that by 1870 paper-makers were in a much better position as far as raw materials were concerned, and it is this fact which undoubtedly led to the vast increase in paper-making during the latter part of the nineteenth century.

Although the Bryan Donkin Company had a virtual monopoly in the manufacture of paper-making machines until about 1850, other manufacturers gradually entered the field, first in England and Scotland, and later in France, Germany, and the United States of America.

In Scotland the Bertrams established engineering works of great importance to the paper trade and these have grown and prospered right up to the present.

In England, Tidcombe established the works which are now known as the Watford Engineering Works at Watford. Smith and Law made paper-making machinery at Bury, Lancashire. Bentley and Jackson were also established in the same town and became world famous as makers of paper-making machines. In Switzerland and Germany, Escher Wyss was amongst the earliest engineering firms to make paper-mill machinery and sometimes they co-operated with the Bryan Donkin Company. In Germany also König and Bauer were among the earliest, if not the first, to build paper-making machines.

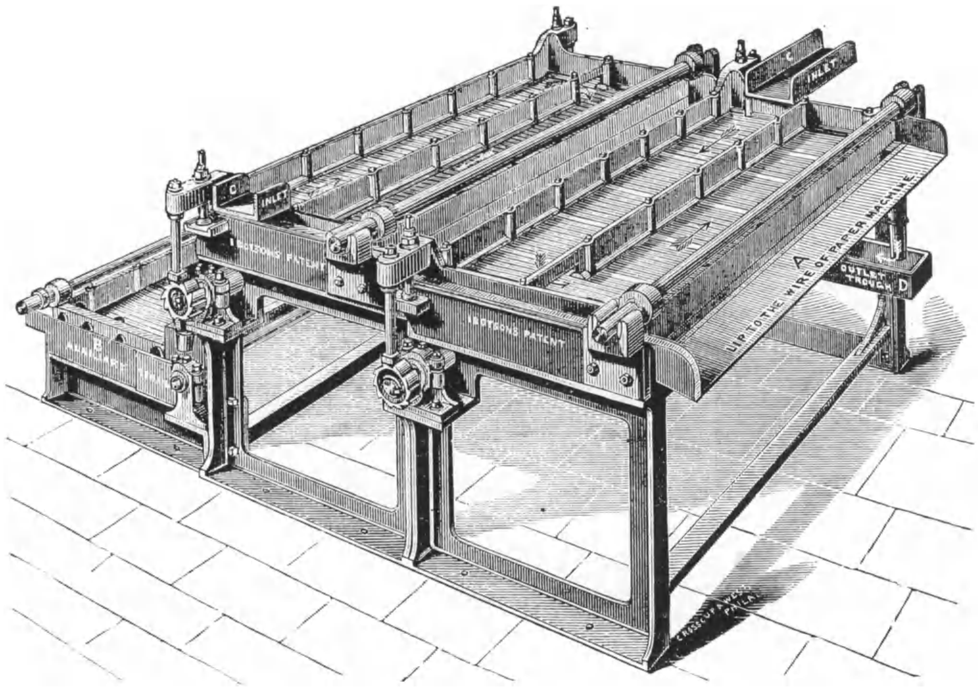
In the United States the Pusey and Jones Company of Wilmington, Delaware, were, by 1870, making paper-mill machinery of all kinds, including Fourdrinier and cylinder-mould machines. The Smith, Winchester Company were established as engineers at South Windham, Connecticut, as early as 1828, and besides building Fourdrinier and cylinder machines were the sole manufacturers of the Jordan refining engine in 1870. The Boston Machine Manufacturing Company of South Boston was making paper-mill machinery in 1870, including Fourdrinier, cylinder-mould and Harper machines. The Company was originally established in 1864.

The Rice, Barton and Fales Machine and Iron Company, another very well known firm of Worcester, Massachusetts, was also making all types of paper-making machines at this time, and of course these two last mentioned companies were in the centre of a very flourishing paper-making part of New England.

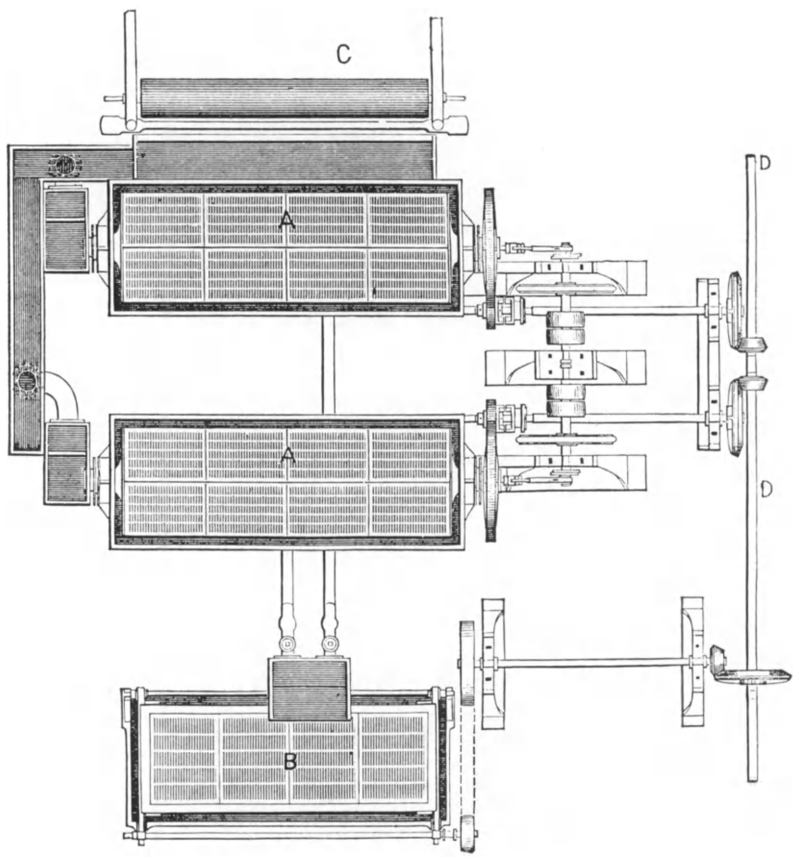
In Newark, New Jersey, Cyrus Currier and Sons were making paper-making machines and other machinery, and were the sole makers of the Kingsland refining engine which was in general use in America and also in France.

Besides the machinery makers mentioned above there were doubtless many other firms making paper-making machines in other parts of the United States, and we find that Bentley and Jackson, George and William Bertram, and James Bertram were also advertising paper-making machines in periodicals and journals in America. From Hoffman's book it is clear that paper-making machinery was being imported from England for use in America, and we find that Ibotson's Flat Strainer (see No. 140) was in use there. Hoffman has this to say of it:

The pulp enters the strainers through the two inlets (c) and flows over the plates in the direction indicated by the arrows, thus passing over every part of them. Both strainers were actuated by knockers, and the pulp which passed through the slits flowed over the lip (A) directly onto the wire. All the stuff which did not pass through the slits descended at the end of the strainer into a trough (D) which led it to an auxiliary strainer, or "back knotter". The stuff which passed through this auxiliary strainer was pumped back again into the supply to the upper screens, and the knots and impurities remaining on the auxiliary strainer were removed by hand. Hoffman says that many revolving screens have been made and then abandoned, but that those made by George Bertram in Edinburgh have found favour with paper-makers in England and Scotland.



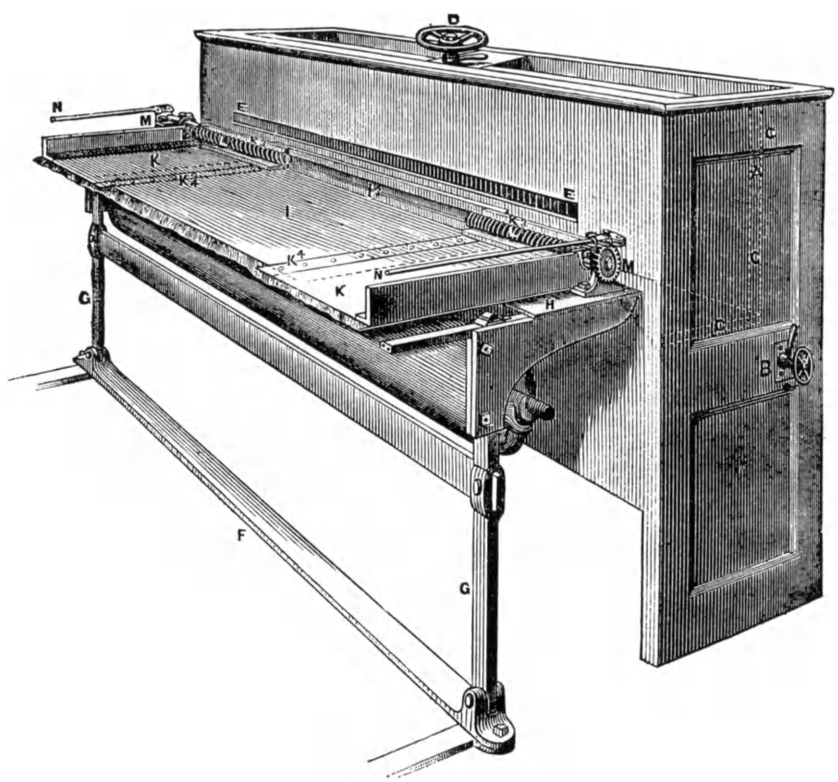
No. 140. Ibotson's double flat strainer, with auxiliary strainer for dealing with the rejected material from the main strainers; the delivery plate to pass the screened stuff onto the wire is also shown. This strainer was in general use in America in 1873.



No. 141. George Bertram's revolving inward flow drum strainer in use in America in 1873. The auxiliary strainer is also shown.

John Dickinson was the first to patent the inward-flow revolving strainer, as mentioned much earlier in this book, but for some reason it was not persevered with, and for many years the flat downward flow strainer was in general use.

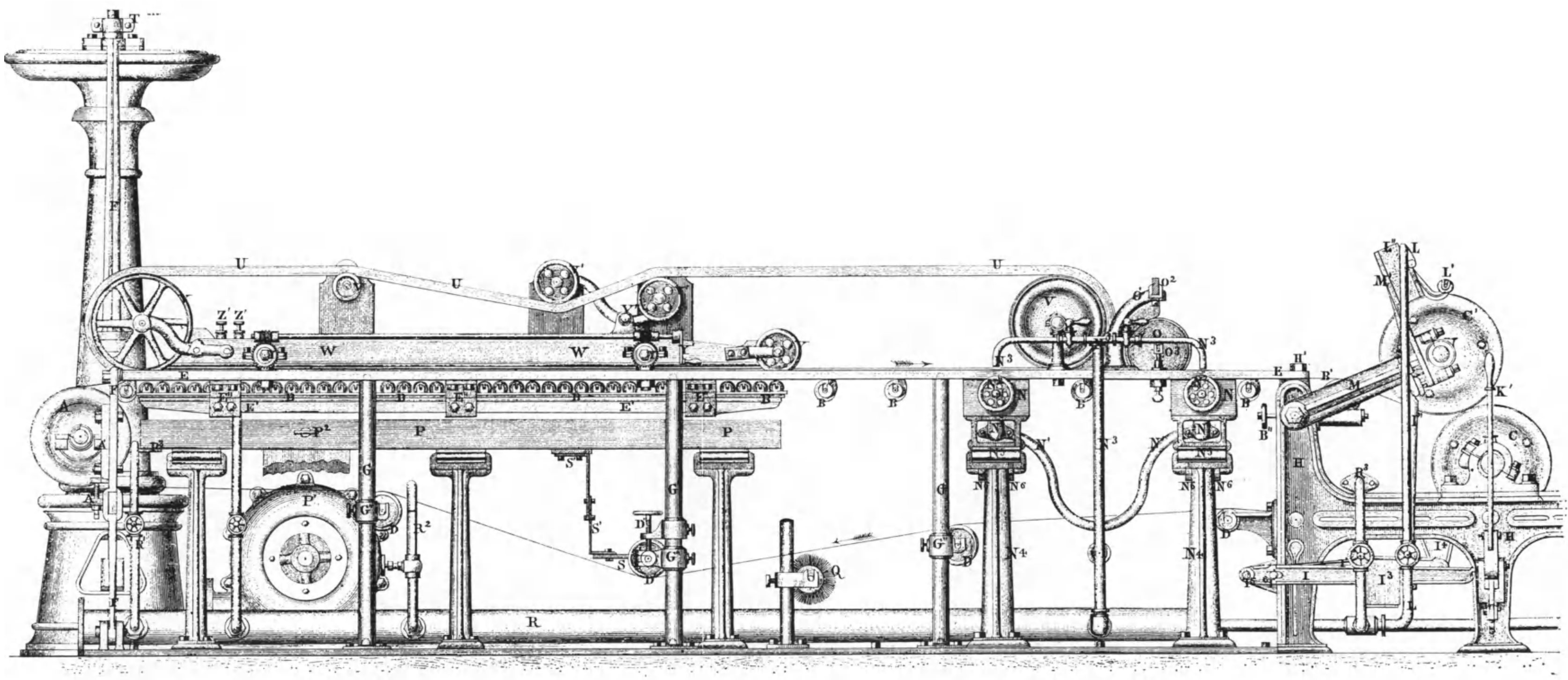
The Bertram Strainer was distinct from the "Leith Walk Strainer". The two strainers A/A revolved in vats filled with pulp. They were driven by the gearing shown in the drawing, and their four sides were covered with ordinary screen plates. Their interior was provided with a rubber suction arrangement or bellows, which moved from the centre, like the piston of a pump; the pulp was thus drawn in from the outside through the slits of the plates, and discharged into the troughs, which conducted it to the machine wire. The knots which were unable to pass through the slits in the plates passed out of the bottom of the vat through a pipe, controlled by a valve, and ran to an auxiliary flat strainer, as was the case with the Ibotson strainer.



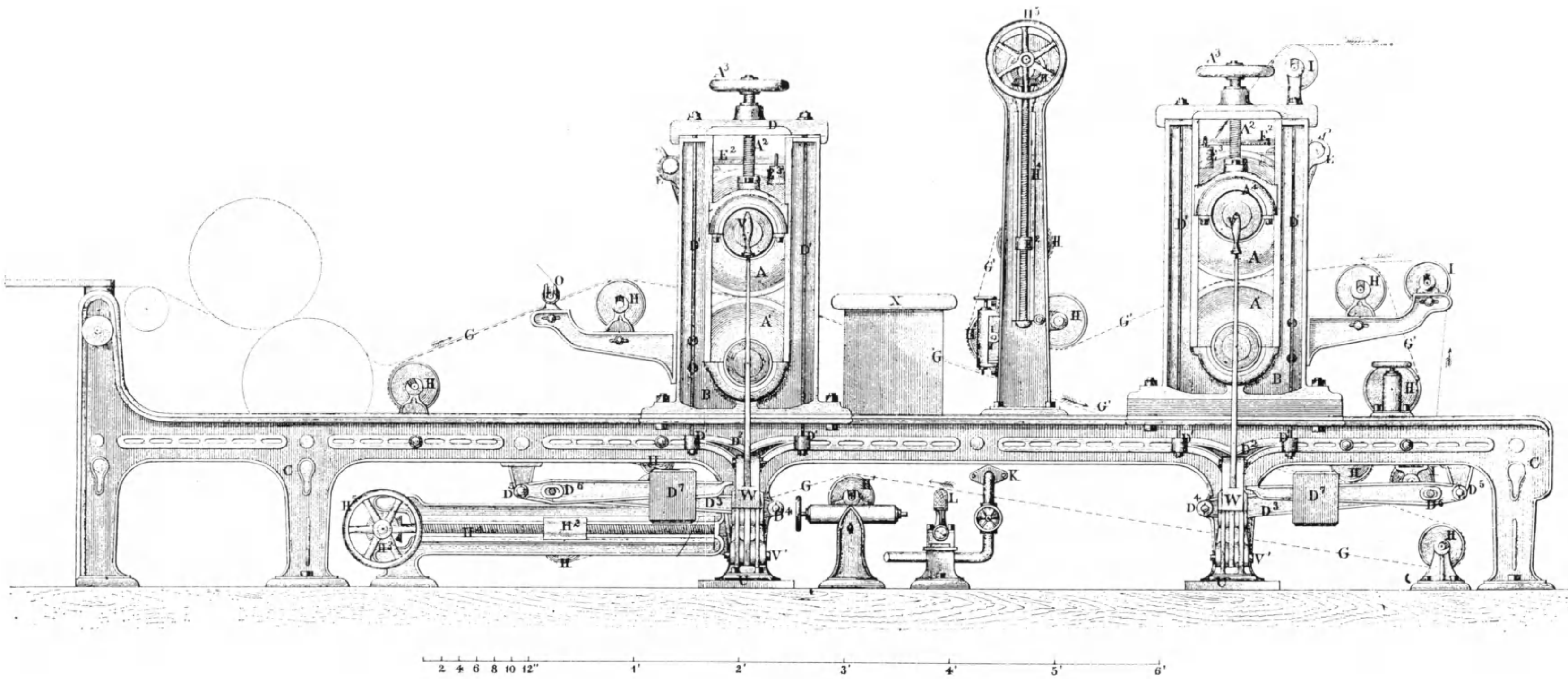
No. 142. Thomas Lindsay's breast-box and adjustable apron. This arrangement enabled the machine-man to alter the width of the stuff flowing onto the wire while the machine was running.

Thomas Lindsay patented a new and revolutionary type of breast-box and slice for the better regulation of the flow of stuff onto the wire. His main object was to dispense with the leather aprons in use hitherto, and, in fact, for many years subsequently, and to enable the machine-man to change deckle width by sliding in two brass plates, one from each side actuated by a screw, whilst the machine was running. Hoffman states that machine wires were made from brass wire, which was annealed to make the wires softer and more pliable. Number 60 mesh, plain weave, was in general use, although 70 mesh was used for some fine papers.

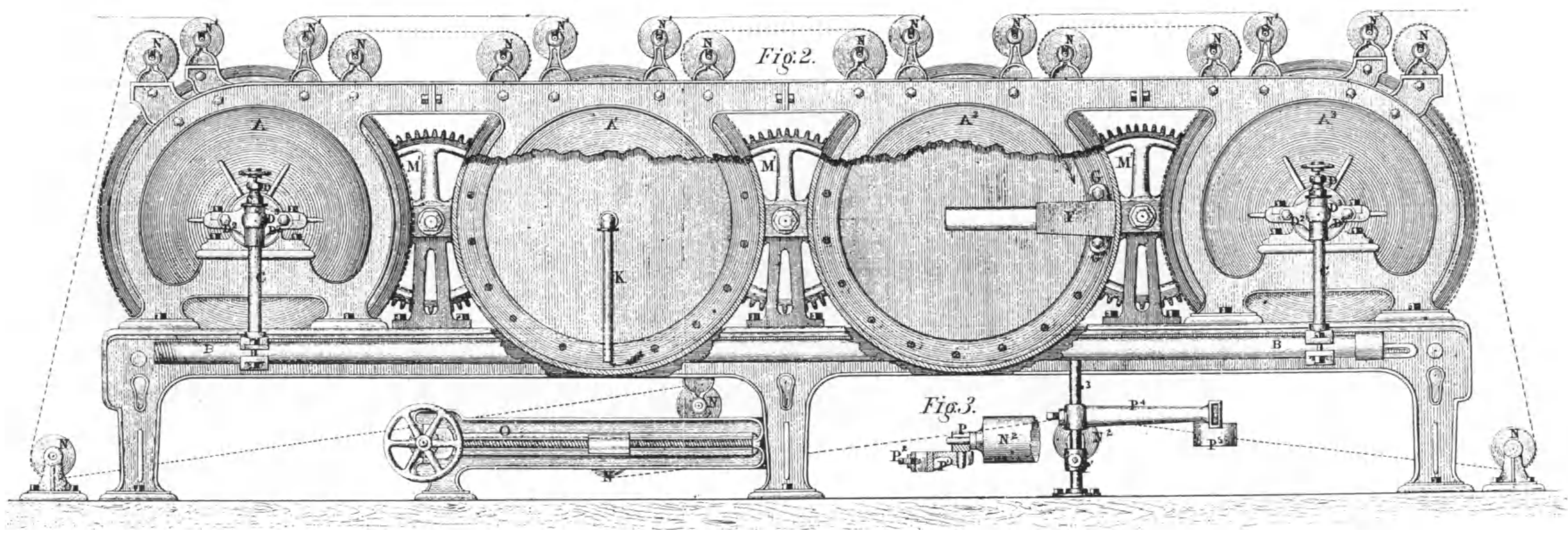
The Pusey and Jones machine as illustrated was made for Messrs. Jessup and Moore's Rockland mill. It is a well-designed, uncomplicated machine of which the only unusual part seems to be the heavy pillar used to house the shake mechanism. Otherwise it is in every way conventional. It has a "fan" or centrifugal pump for sending the back-water from the machine to the mixing box.



No. 143. The wire part of the wet end of a Pusey and Jones Fourdrinier machine of 1873. The suction boxes, which had perforated tops, are placed unusually far apart.



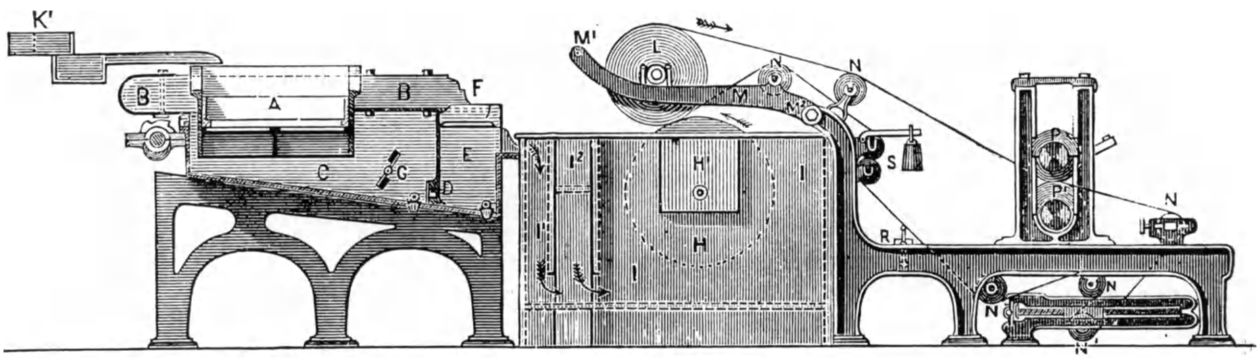
No. 144. Press-part of machine with straight through and reversing press. The second press top felt has a stretching arrangement between the two presses. There is a horizontal stretching arrangement for the first press felt and a guide-roll on the return. The pressure of the top roll in both first and second press is actuated by levers and weights. Screws are provided for raising the top rolls when changing felts.



No. 145. Part of the drying cylinders, with some of the front cut away, showing the steam inlets. The felt stretching arrangement is shown, also the felt and paper rollers above the cylinders.

This was one of the earliest examples of a centrifugal type pump being used on a paper-making machine. Later on, centrifugal pumps almost completely displaced ram pumps for all purposes on paper-making machines. The press part was very simple and substantially constructed, with one straight through and one reversing press. Number 145 shows a part of the drying cylinders with some of the framing cut away to show the details more clearly. Only four drying cylinders are shown in the drawings but actually the machine had seven dryers. This machine was designed for speeds up to 130 ft/min.

The cylinder paper-making machine which was in very general use in America in the latter half of the nineteenth century does not appear to have changed much, if at all, from the original design of John Dickinson, in 1812. It remained a simple machine, with a strainer, a wooden vat, in which the cylinder-mould revolved, and on which revolved the wooden couch-roll, which was 12–18 in. in diameter, and had several layers of felt wrapped round it to give it the necessary elasticity.



No. 146. The cylinder-mould machine, in elevation. The illustration shows the strainer, vat with making cylinder, wet felt, couch-roll and press. The stock inlet is shown by arrows.

The wet felt passed round the coucher and over the usual felt rollers, stretcher and guide-roll, and carried the wet web, which it picked up from the cylinder-mould, through the first press. The sheet could be taken off here wet, and carried away to be dried by air or, as on most machines, it was taken through to a second press, not shown in the drawing, and thence to drying cylinders. After the wet felt had delivered the sheet to the press, it passed back to the coucher, and on the way it was subjected to a thorough cleaning in order to remove loose fibres which always adhered to it. It was necessary that it should be as clean as possible when it passed over the cylinder-mould to pick up the sheet.

The paper was formed in the following manner: The pulp, diluted by the back-water, was spread across the whole width of the vat, and filled it to the height of the overflow gate, which guarded the entrance to the spout. The rim of one of the ends of the cylinder fitted into the side of the vat and ran on it, while the other end of the cylinder was closed by a solid plate; the pulp was prevented from entering the inside of the cylinder by the meshes of the wire cover. The water poured through these meshes, into the interior of the cylinder, and escaped through the ends to a fan pump which delivered it back to the mixing box. The fibres adhered to the wire cover and built up to form a web of paper. The couch-roll pressed water out of the paper, by its own and by additional weight which could be added to the arms carrying the bearings. As soon as the paper came into contact with the wet felt under the couch-roll it left the wire cover of the mould and was carried on the felt through the press-rolls, and usually through a second set of press-rolls, then to the dryers, as on a Fourdrinier machine.

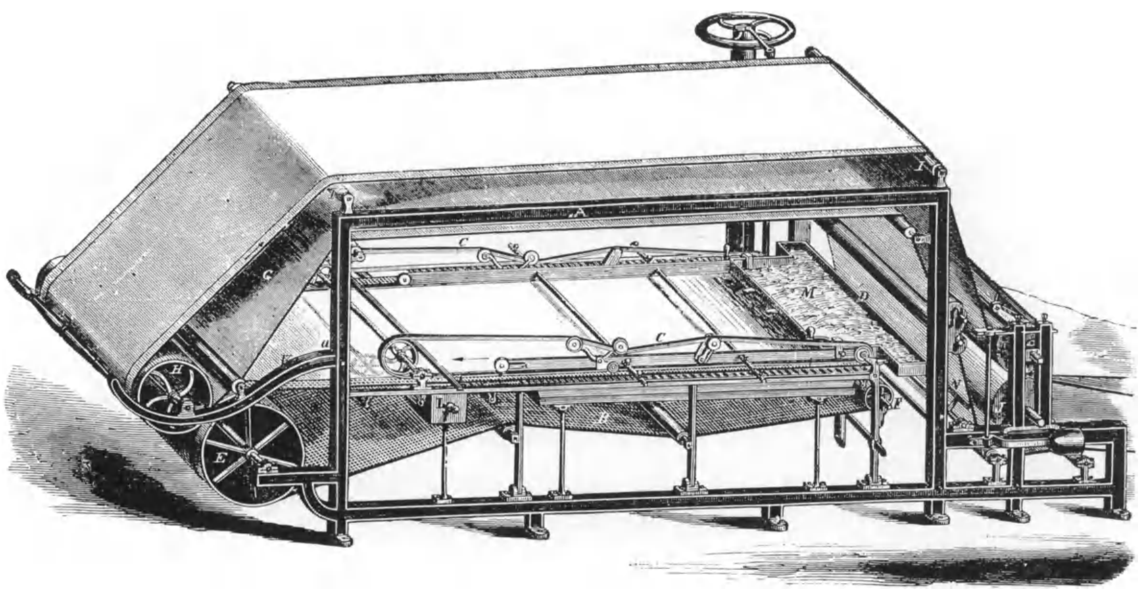
The diameter and consequently the wire surface of the making-cylinder was very limited and the pressure of the pulp in the vat was the only means by which the water could be forced from it. Very heavy sheets could not therefore be made on this machine, but if the paper from two or more making-cylinders was united on one wet felt, it would, after having passed through the presses and dryers together, form a solid web. Paper, the two sides of which were of different colours or qualities, could be made by giving a separate vat to each cylinder, and supplying them with different pulps. Three or more, up to six, cylinders have been combined in one machine for the manufacture of heavy boards. The number of drying cylinders must be increased in the same proportion, and as many as sixteen or even twenty dryers have been used on some of these machines.

The two earliest multi-cylinder board machines erected in England at the end of the nineteenth century were both imported from America and were made by the Black–Clawson Company.

The first was installed at Cannon's Mill at Sandford-on-Thames, near Oxford, and the second one at Hedley's mill at Loudwater.

James Harper, paper-maker, of New Haven, Connecticut, patented and constructed a machine which was a combination of the Fourdrinier and the cylinder-mould machine. Paper was made in the ordinary way on the Fourdrinier wire, which carried it to the couch-rolls. The wet felt was passed round the top couch-roll and in passing it picked up the sheet from the wire as it passed round the bottom couch-roll. This latter roll was constructed in the same way as the making-cylinder of a cylinder-mould machine.

Harper's machine was in effect the first "lick-up" machine to be used in America. It is reported that about ten of these machines were built, but they ceased to be used on account of the high cost of the wet felts. Nevertheless, the idea of the "lick-up" persisted and many machines making thin papers at the present time use a felt which passes round the top couch-roll and removes the web from the wire in the process. The advantages which Harper claimed for his machine were that the paper passed from the wire to the wet felt without assistance, and that the losses of pulp, which on a Fourdrinier machine occur at this point, were avoided; that thick paper cannot be crushed by

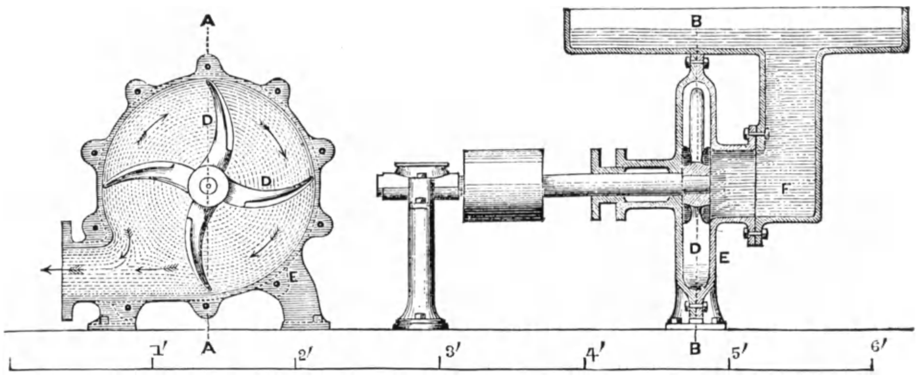


No. 147. Harper's improved paper-making machine. This is a combination of a Fourdrinier wire and a cylinder machine. The breast-roll, wire, deckles and suction box are the same as on a Fourdrinier machine, but the lower coucher is an open forming cylinder, on which the Fourdrinier wire is substituted for the fixed wire cloth. The wet felt passes round the upper coucher and back above the wire onto the press, which is placed behind the breast box.

the couchers; and that the thinnest paper, which cannot be taken from the coucher of a Fourdrinier wire to the wet felt, can be made on this machine.

At about this time the "fan" or centrifugal pump seems to have been established as an important part of the paper-making machine in place of the plunger pumps in general use hitherto. Apparently, however, its use was confined chiefly to the pumping of back-water on the machine, and also as a mixer of stuff and back-water, between the machine chests and the strainers.

The fan pump illustrated receives the back-water from the save-all trays under the wire, and throws it back into the mixing box, thus saving not only fresh water, but also colouring and sizing matter and fibres. The stuff enters through the centre of the casing opposite to that pierced by the shaft, is pushed forward by the wings into an outlet at the periphery, and thence through a pipe to the height required. Instead of using a separate mixing box, the box (F) above the fan-pump is frequently made large enough to serve. In that case the stuff flows from the regulating box directly into the fan-pump receiver (F), where it is diluted with the water from the save-all. By this arrangement a separate mixing box is not only saved, but the stuff and water in passing through the fan-pump together are more thoroughly mixed.



No. 148. The "fan" or centrifugal pump which was beginning to be used on paper-making machines, chiefly for pumping back-water. The stuff enters through the centre of the casing and is pushed forward by the "wings" or vanes into the outlet at the periphery.

The suction boxes in use at this time relied on syphons or double-acting piston pumps to obtain the vacuum. The syphons could not, of course, be used unless it were possible to have a long straight pipe descending vertically from the box for from 10 to 18 ft.

Steam was also used by employing an injector, but this was costly in live steam. Injectors have been in use on vacuum boxes in England in some mills until quite recent times. The tops of the vacuum boxes were either perforated metal plates or hard rubber, and the latter was preferred. They were perforated by as many holes as possible. Glass plates were also used for this purpose.

The wires on most machines were only 33 ft long, although it was felt that with the tendency to increase speeds above 100 ft/min longer wires would prove necessary. Much progress had been made by this time in the making and cambering of press-rolls. In place of the iron rolls which had been used since the earliest machines, rolls were being covered with brass shells. This did away with trouble from rusting and consequent roughening of the surface. Rolls were also being covered with hard rubber, which was a great improvement, and this is still the practice at the present time. The iron roll was first given a coating of vulcanized rubber, hardened so that it would stick to the iron, and then a second outer cover, not so highly cured, and therefore softer and more elastic. These rolls present a very smooth surface and are largely used on lower press-rolls, where they are protected by the wet-felt and are not exposed to the action of the doctor. The upper press-roll, often covered with a brass shell, was always fitted with a doctor, which prevented parts of the paper, or the whole sheet, when broken, from going around and thickening on the roll. In other words it kept the roll permanently clean.

The doctor consisted of a cast-iron body, fitted with blades or plates of iron, steel, brass or hard rubber. It was also the practice to make the doctors oscillate, in order to prevent the rolls from being worn unevenly.

Various attempts had been made to clean the felts continuously while running, in order to prevent frequent stoppages of the machine for the removal of felts for washing. None of the methods used had proved entirely satisfactory, although one method seems to have been reasonably successful. It consisted in having two shower pipes, one above and one below the wet-felt, on its return run, followed by a pair of squeeze-rolls. This method, in spite of the modern "felt conditioners", is still in use, and found to be very satisfactory at the present time. In spite of these methods of cleaning the felt while running, however, it was the practice in many mills to change the felts frequently, even daily, and wash them independently before putting them back on the machine.

It was calculated that from $\frac{1}{2}$ to 1 lb of coal was required to produce the heat necessary to dry 1 lb of paper, depending upon the quality of the coal and the efficiency of the drying arrangements on the machine. The best dryer felts were undoubtedly those made from wool, but they were so expensive that felts made from cotton duck were frequently used, and these were cut from long lengths of material and the ends sewn together when the felt was on the machine. Automatic felt guiding rolls were fitted to the dry part of the machine. These operated in much the same way as the wire guide rolls.

Chilled iron rolls were now in use on machine calenders, and these were a great improvement on the earlier types of soft iron rolls and lasted much longer, before they had to be ground. On super calenders also, chilled iron rolls were used in conjunction with paper-rolls, which were built up from discs of paper in the same way as they are at present. Messrs. Rice, Barton and Fales made a super calender with automatic guide bands and fingers to take the paper through the calenders without the help of human hands.

Various types of paper cutters were in use for cutting the paper into sheets after it had left the paper-making machine. Some of these cutters were continuous and cut the paper by means of a revolving knife as it passed over a stationary or "dead" knife. On other cutters the paper stopped during the actual cutting operation. The continuous feed cutter was much the same in principle as those in use at present.

By this time, however, much paper was for many purposes required on rolls instead of in sheets. For instance, for hanging, roofing, manilla bag paper and for some printing presses, the paper was slit into webs either on a slitting machine or on a cutter, in which part of the cutting mechanism, the "chop", was at rest.

Much of the motive power in paper-mills both for driving the beaters and also the paper-making machines, was water, although many mills also had steam engines, especially for driving the paper-making machines. The following remarks are quoted from *The Manufacture of Paper* by Hoffman, and give the views of an experienced paper-maker about 1873:

> If every part of the paper-making machine is constructed with the utmost care, substantially and true, with a wire 33 ft in length, and seven drying cylinders of 3 ft diameter, it can make newsprint at a speed of from 110 to 130 ft/min.
>
> If the length of the wire and the number of presses and drying cylinders are increased, the machine may be made to run faster, and there is no doubt that improved machinery will, in the future, admit of much higher speeds than those at present used.
>
> The paper-mills depend in this matter almost entirely upon the perfection of the tools and the skill of the operatives and engineers in the machine shops.

> The width of the machines has also been increased, until wires 86 in. wide are quite numerous, and some of 90 and even 100 in. are in use.
>
> A positive limit is set to the width of the machine of the present construction by the proportions and capabilities of the human body. The machine-tender must be able to reach the middle of the sheet with one hand, so that every part of it may be taken hold of by the men on both sides.
>
> Wider machines than those mentioned would certainly offer difficulties in this respect.
>
> A larger machine, on the other hand, allows of a larger variety of sizes to be made; it takes less room and costs less than two machines of half its width. The same quantity of paper, which loses only two trimmings or edges on a wide machine, would give twice as much waste from this source if made on two narrow machines. Taking everything into consideration, it is our opinion that paper can be made as cheaply on 62 to 72 in. machines, as on wider ones, though the latter may be preferred for some reasons.

Although these views were expressed about eighty years ago, the author has often heard similar views expressed by paper-makers in quite recent times.

According to the *Paper Mill Directory of the World*, 1884 Edition, published by Clark W. Bryan and Company, the number of paper and pulp mills in the United States of America was one thousand and eighty-five; England had two hundred and ninety-three and Scotland sixty-eight. In the United States most of the mills were paper and board mills, and a very large number made straw-board and straw-paper.

There is a marked difference in the type of machines principally used in the United States as compared with those used in England and Scotland. Out of a total of one thousand one hundred and sixty-eight paper-making machines in America, no fewer than seven hundred and eighteen were of the cylinder-mould type, chiefly with one vat, and a very large number had a cylinder of only 36 in. in width, while many were only 48 in. wide.

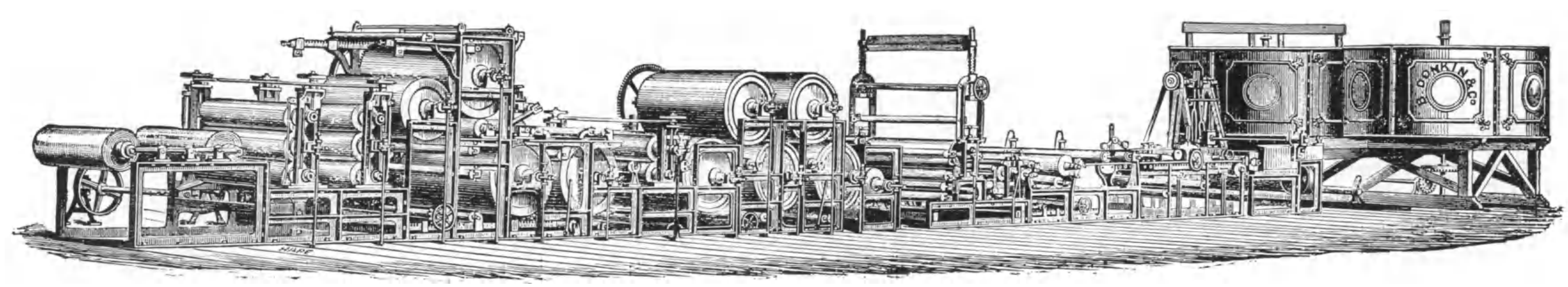
There were four hundred and fifty Fourdrinier type machines in America, three of these being 100 in. wide. There was a cylinder-mould machine of 100 in. and one of 120 in. In England the majority of the machines were of the Fourdrinier type, the mills were much bigger, and there were twenty-eight Fourdrinier machines of 100 in. in width, or more.

In.	*Machines*
100	12
102	5
104	1
105	1
106	1
112	4
120	3
125	1

The 125 in. machine was at Edward Lloyd's mill at Sittingbourne. In the United States there were two hundred and thirty-five mills with twenty or fewer employees, and a hundred and eleven mills with ten or fewer, eight of the mills employing only two people.

From these figures it would appear that the practice in America was to have many small mills with only one narrow cylinder-mould machine, even for making newsprint, while in England the Fourdrinier machine was in use almost exclusively, and greater width and speed had been achieved, especially in those mills making newsprint.

The chief paper-making centre in America was around Holyoke, Massachusetts, where there



No. 149. Complete paper-making machine by B. Donkin and Company, 1874. The illustration shows the chests in cast iron, the wire frame and shake motion, straight and reversing presses, two sections of drying cylinders with intermediate calenders between the sections. There are also two stacks of machine calenders before the reel-up.

were forty-one paper-making machines, in nineteen mills. The S. D. Warren Company of Maine had ten paper-making machines.

However, by the end of the century the Americans had begun to make much more use of Fourdrinier machines and in the twenty years from about 1885, the number had increased to six hundred and sixty-three Fourdriniers, while there were only five hundred and sixty-nine cylinder machines. This shows an increase of about two hundred Fourdriniers and a decrease of about a hundred and fifty cylinder machines.

We have mentioned the firm of Escher Wyss of Zürich earlier in connection with Bryan Donkin's journeys abroad, and they did work for Donkin and acted sometimes as his agent. From 1841 to 1890, Escher Wyss built a hundred and seventy paper-making machines, but we have few records of these. About 1880 Sembritzki invented and patented a machine for mechanizing the making of "hand-made" paper, and eventually this very elaborate machine was built and supplied by Escher Wyss. Sembritzki said that the growing demand for first class hand-made paper for documents, note-paper, etc., had necessitated the construction of a machine to produce the same quality of paper as that made by hand, especially as first class hand-made paper-makers were getting very rare and this work was very expensive.

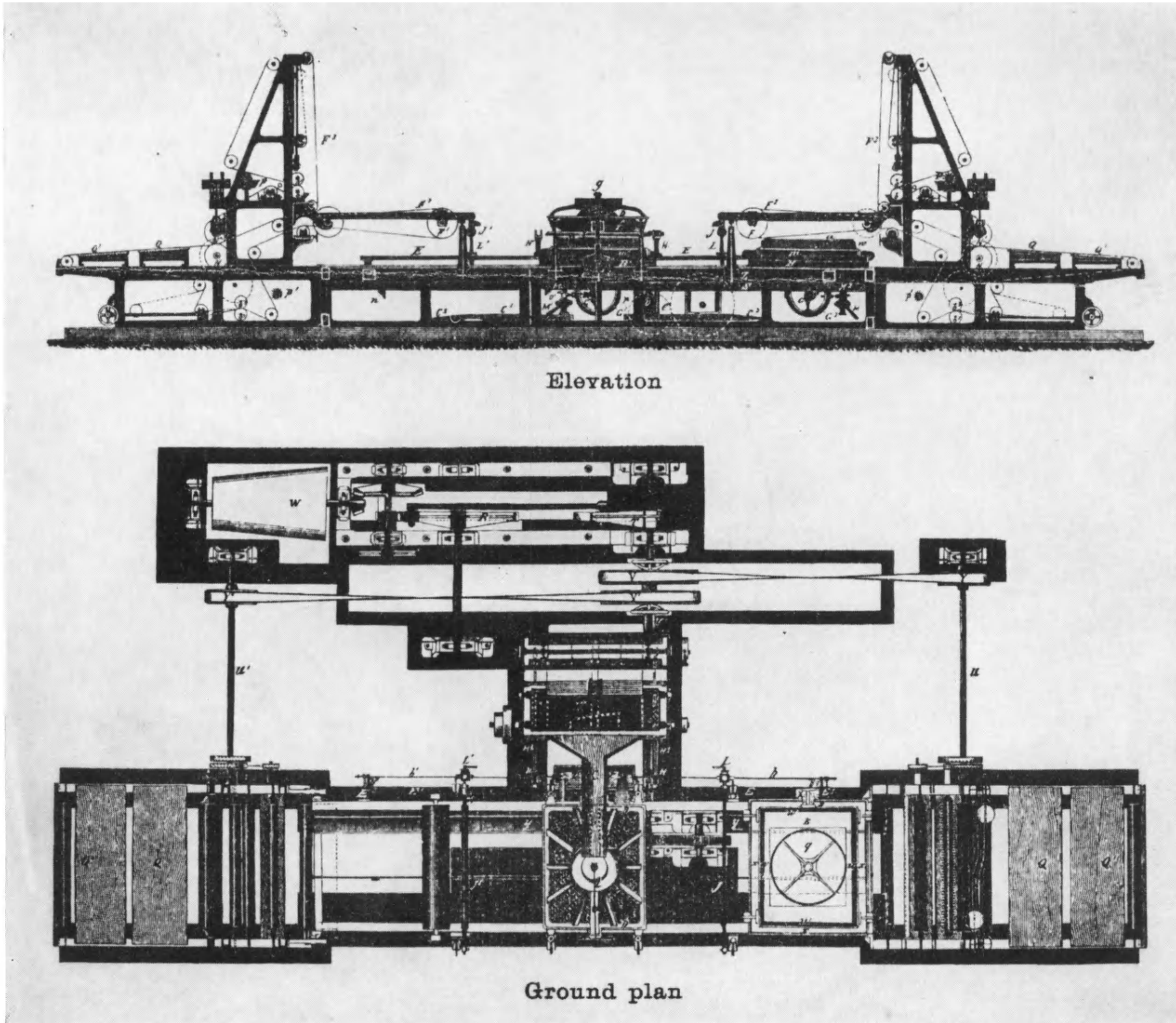
He invented the machine for producing this paper at considerably less expense than that made by hand, and Escher Wyss and Company undertook the working out and construction of the machine, which he says produced paper in sheets of any size required, which perfectly resembled the hand-made produce, including the "deckle edges". The machine worked with one or two movable moulds, in the same way as the vatmen have done for centuries. Each mould alternately took its material, threw over the edges of the deckle all that was not required for making the sheet and felted the remainder by constant shaking to-and-fro. It strained the water from the sheet and couched it onto a felt and still further drained it in a press. After the machine had performed these operations, the still damp sheet of paper was taken from the felt, and afterwards treated as hand-made paper. The machine thus gave a product not merely resembling hand-made paper, but really like it, with similar formation of sheets and edges, and of like strength and durability.

Further said Sembritzki, the regularity of these mechanical movements gave a greater equality of product than could be expected from a vatman!

A further advantage claimed for the machine was that the size of the mould was not limited by the length of the arm and the bodily strength of the vatman. It was stated that the paper on which the prospectus of the machine was printed could be made at a speed of up to 450 sheets per hour. Several of these machines were made by Escher Wyss and Company, and one at least was sent to Turner Symon and Company, Totnes, Devon.

Other machines besides the one working at Sembritzki's mill were supplied to mills in France, Germany and Russia. The machine is shown in elevation and plan in the illustration No. 151, but it is not very clear from the drawing just how the machine worked, and it has not been possible to obtain a detailed description. It seems, however, to have differed considerably from those of Didot and Cobb, whose machines of some sixty years earlier, with the same objective, namely the mechanization of the making of sheets of paper on a mould to eliminate the vatman, never succeeded in ousting him and never came into commercial use. While the Sembritzki machine seems to have had some commercial use in various countries, it never became established as a serious rival to the hand-made craft, which is still quite flourishing.

Escher Wyss and Company made an interesting twin-wire machine about 1884. This machine was like an ordinary Fourdrinier machine, and could be used as such, but it had a second wire part, situated above the couch press of the lower wire. This upper wire supplied a second web of paper, which was led down onto the lower wire where it combined with the wet-web at a small press roll situated on top of the lower wire. The two webs, now combined, passed between several "baby



No. 151. Elevation and plan of the Sembritzki patent paper-making machine as made by Escher Wyss about 1880.

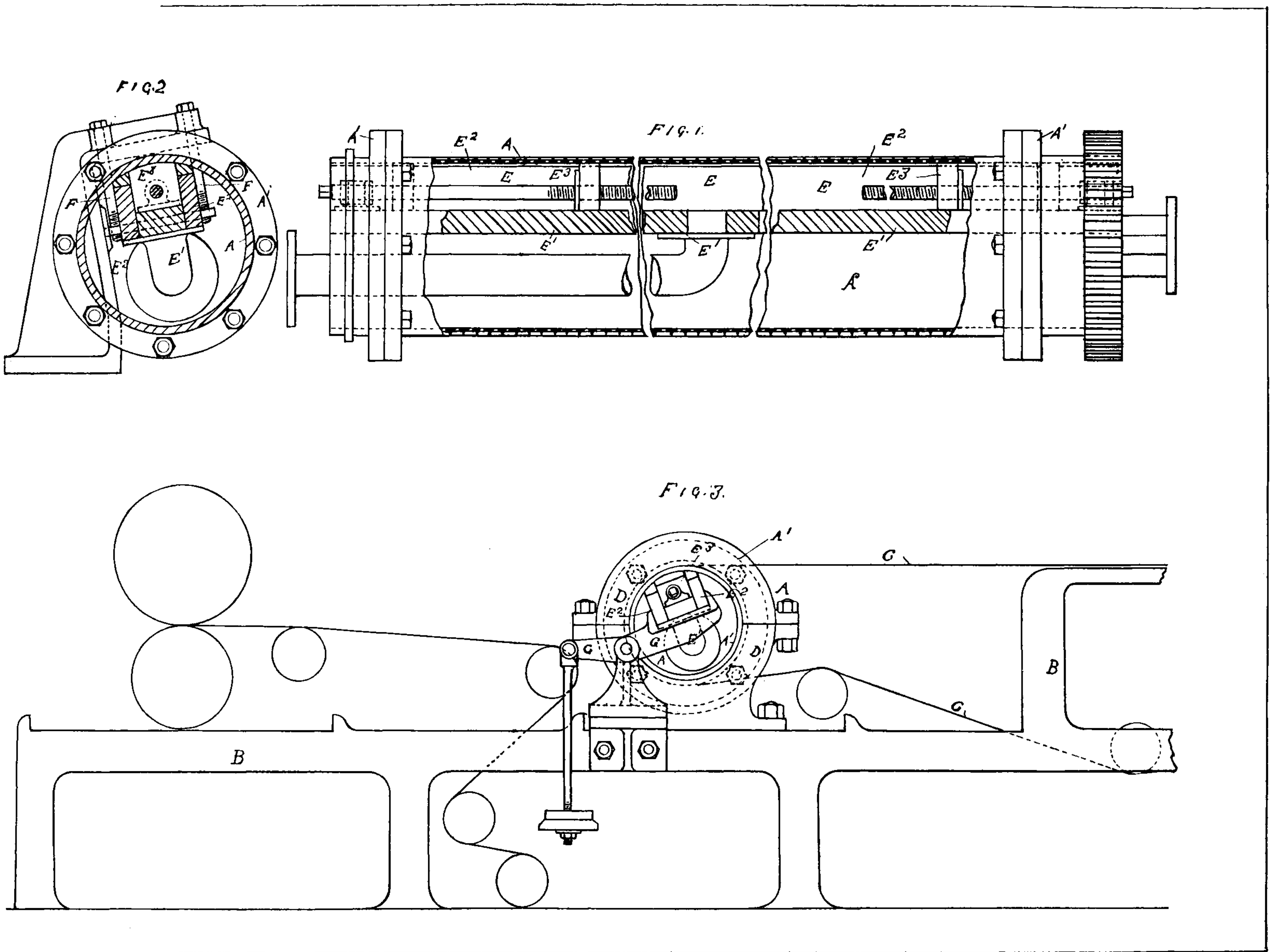
presses" before arriving at the couch press, and after couching in the usual way, the web passed through two straight presses and a reversing press and then to the drying cylinders and calenders.

The drawing shows an elevation and plan of this interesting machine, one of the earliest twin-wire Fourdrinier machines to be built. This machine was supplied to the German paper-mill Limmritz-Steina (No. 152).

At this time another attempt was made to introduce the suction couch-roll and in 1897 Alexander Black, a paper-maker of Invergowrie, took out a patent for a suction couch-roll, the objects of which were as follows:

> (1) To dispense with the usual top and bottom couch-rolls, with their jackets, doctor and water spray arrangement. (2) To relieve the wire of the larger amount of friction resulting from being drawn across the surfaces of the ordinary stationary vacuum boxes, thereby increasing the life of the wires, and decreasing the amount of power required to drive the paper-making machine. (3) To relieve the paper of the crushing and thinning effect of the usual top couching-roll, thereby increasing the "bucking" of the paper, and

(1 SHEET)



[This Drawing is a reproduction of the Original on a reduced scale]

No. 153. Three drawings of the suction couch-roll patented by Alexander Black, 1897. Fig. 1 shows the perforated shell and the internal arrangements for controlling the deckle, suction box, etc. Fig. 2 is an end view showing the position of the suction box relative to the shell. Fig. 3 shows the position of the suction roll on the machine.

greatly decreasing the marking on the under side of the paper, caused by the usual top couch-roll crushing and pressing the moist pulp into the meshes of the wire. (4) To relieve the wire of the crushing and bending action due to the top couch-roll.

To effect this Black introduced a hollow perforated roll in place of the bottom couch-roll, to drive the wire, and this roll was placed at the same level as the breast- and table-rolls, so that the wire was in a straight line, more or less except that if necessary it might slope up or down if the breast-roll were raised or lowered. Inside the perforated roll was an oblong vacuum box arranged to suit the internal diameter of the roll, and the top of the vacuum chamber was held against the interior surface of the perforated roll.

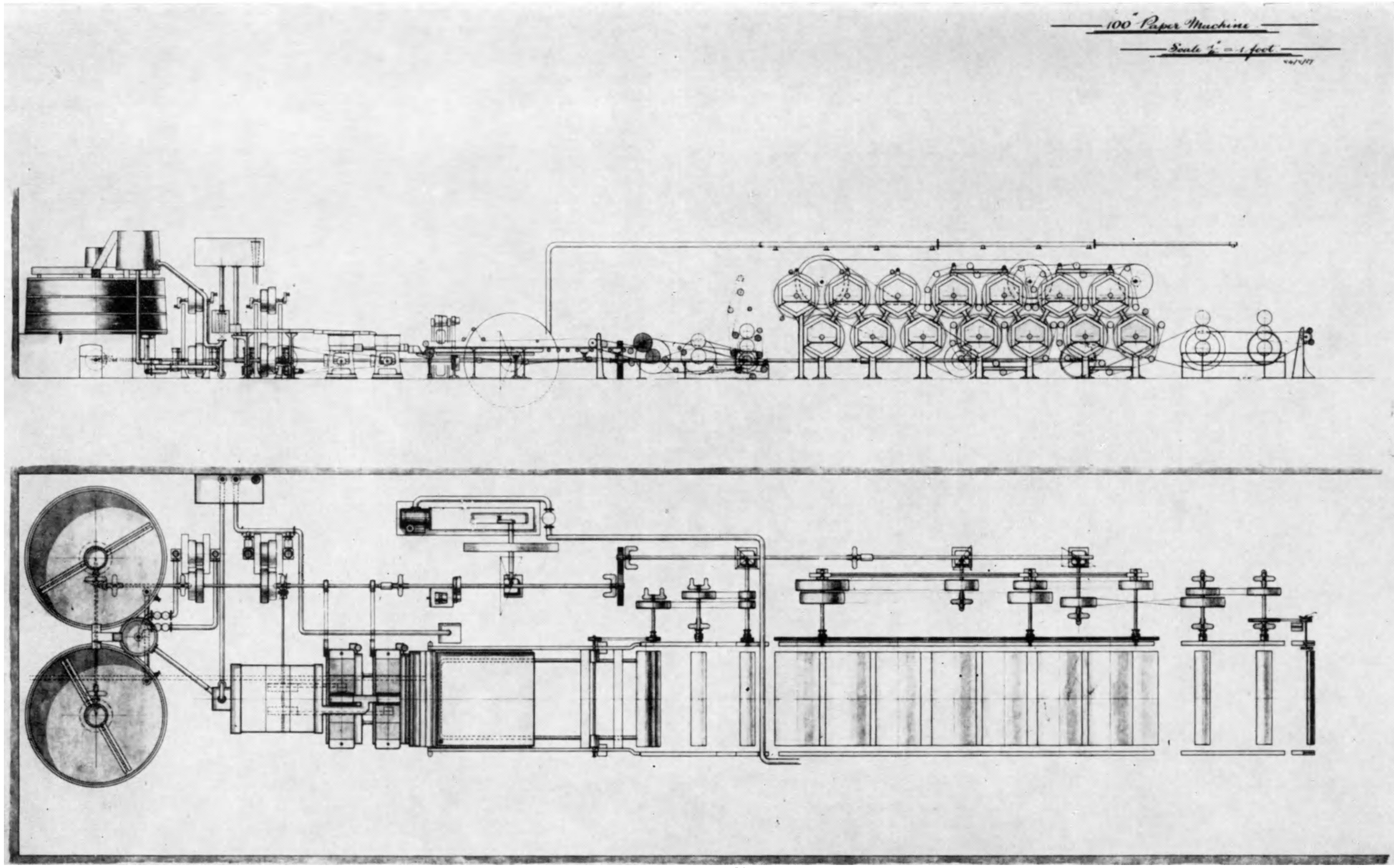
The vacuum box was connected to a vacuum pump or other exhauster. Unfortunately Black's suction-roll, although obviously well conceived and designed, does not seem to have met with success at the time and this was apparently due to the lack of capacity of the vacuum system, as seems to have been the case with George Dickinson's suction-roll seventy-five years earlier.

The roll was made by James Bertram and Son, of Leith Walk, Edinburgh, and installed in Inveresk Paper Mills by Happer, and is illustrated in No. 153.

The Bryan Donkin Company was building machines about this time, which were fairly well standardized and were about 100 inches wide and designed for speeds of about 200 ft/min, for making fine printing and writing paper. There was a choice of dryer framing, either circular or hexagonal, the second press was reversing and there was a set of smoothing rolls before the last section of dryers, and at least two stacks of calenders. Among the last of the machines designed by this company are illustrated in the pictures Nos. 154 and 155, and are described in the relevant captions.

Towards the end of the century the Fourdrinier machine and the cylinder-mould machine had become firmly established in design in most countries, and in fact many of the machines made about this time are still working, over seventy years later, although most have been improved, and modernised, not so much in design, as by the much improved engineering skill available to paper-makers through the services of paper-maker's engineers. Machines have been made to run very much faster, and are in many instances very much wider than the 100 in. or thereabouts, which was a usual width at the end of the nineteenth century; also the tendency now is for machines to be designed and made for specific purposes and papers rather than for general use, as was the practice during the period which we have described.

Particulars and descriptions of modern paper-making machines are to be found in the many excellent books on paper-making which are now available.



No. 155. 100 in. wide paper-making machine. Scale: ¼ in. to 1 ft. 24th February, 1887. This machine is designed on the standard lines of the later Bryan Donkin machines, and the present-day Fourdrinier machines vary very little from these machines of seventy years ago. There are two stuff chests with vertical gate agitators driven from underneath through a hollow column; backwater head tank, high-level stuff box fed by double-acting plunger pumps; mixing box discharging direct onto sand tables; two jog knotters through which the stuff passes after leaving the sand tables. There is a breast-box with baffles to even out the flow of the stuff and pass it onto the wire above the breast-roll which, in this case, is level with the tube-rolls so that the wire is horizontal all the way from the breast-roll to the wire-guide roll. The breast-roll stand and the rods supporting the shake rail are pivoted on the sole plate, and the deckle straps run almost the full length of the wire. There are two vacuum boxes, one before the end of the deckle straps, followed by two tube-rolls and then a dandy-roll, another tube-roll, a second vacuum box, another tube-roll and then the wire-guide roll. The wire travels almost straight back, with only one return roll inside the wire. The top couch is again laid well back beyond top dead centre of the bottom couch-roll, and there is a straight wet press followed by a reversing press, followed by fourteen drying cylinders, the first six of which are not provided with a dry felt, the dry felt starting at the seventh drying cylinder, after which all cylinders have dry felts. There are two three-roll presses and a friction reel-up. This machine is driven by a steam engine, the pass-out steam from which is used for drying the paper. The constant speed shaft, driven direct from the engine, drives the usual auxiliaries, and then, through change wheels, this shaft drives the main driven shaft of the machine. This shaft drives the second press direct, the first press, couch, and deckle straps through pulleys and belts, and the drying cylinders, calenders and reel-up through belts. There are two-throw stuff pumps and two-throw backwater pumps to raise the stuff and backwater to the head-boxes.

Appendix 1

PROSPECTUS OF THE PATENT MACHINE FOR MAKING OF WOVE PAPER, 1813

IN August, 1806, the Machine for making wove paper was first announced to you.

In 1807, after a very strict investigation of both Houses of Parliament, the Legislature was pleased to grant an extension of the Patents. Prior, as well as subsequent to this period, manufacturers in different counties in England, Scotland and Ireland, adopted, and have since continued in the constant use of this Machine, and have found that all the advantages ascribed to it in the Prospectus of 1806, were stated with the utmost accuracy.

Notwithstanding, however, the enormously expensive experiments of several years, yet so long as any improvement appeared practicable, the Patentees spared neither exertions nor expense (however great) for its accomplishment. It is with the most perfect confidence their entire success is now announced; and it is here proposed to state the nature of the improvements, and the superior advantages to be derived from the Machine in its present state.

In this as in all other manufactures are economy, expedition, and the perfection of the article produced. The nature and importance of the improvements, since the first announcement of the Machine, will be obvious from the following statement.

The improved Machine, from its greater simplicity, may be erected at a considerably less expense than the former. Mr. Donkin, the Engineer, will engage to furnish Machines of the dimensions specified below, with all the present improvements, at the prices annexed to each.

IF DRIVEN BY STRAPS

	Inches			
3 or 4 Vats	30	between the deckles		£715
6 do.	40	do.	do.	£845
8 do.	44	do.	do.	£940
12 do.	54	do.	do.	£995

IF DRIVEN BY WHEELS

3 or 4 Vats	30	between the deckles		£750
6 do.	40	do.	do.	£880
8 do.	44	do.	do.	£980
12 do.	54	do.	do.	£1040

The reference to vats means the output of the machine was equal to the output of the number of vats of hand-made paper stated in 12 hrs.

These prices are for the Machines respectively when taken from the premises of the Engineer, and do not include the water-wheel, or its shaft, nor the expense of erection, or any work upon the premises of the manufacturer; but the wire, felt and leather edges (deckle strips), are included.

The time required for making and erecting a Machine is from four to five months, according to local circumstances.

Besides the saving in the first cost of the Machine, the simplicity of the new construction is productive of much more important advantages, in point of economy, by the great reduction of the current expenses.

For instead of five men, formerly employed, three are fully sufficient for the management of the present Machine, without requiring that degree of attention or skill which before were indispensable; but that the extent of this advantage may be properly understood, it will be necessary to enter into some detail.

It is well known that paper is made by the Machine of great width, and of unlimited length, at the pleasure of the manufacturer, and that it requires to be afterwards divided into sheets. This division, in the unimproved state of the Machine, was performed sheet by sheet, and four expert workmen employed in this operation alone, were found insufficient either to keep pace with the Machine, or to cut the paper square, or to preserve a tolerable uniformity in its dimensions.

But in the improved Machine, this operation is not only very much facilitated, but the paper also cut perfectly square, and of uniform dimensions, by two ordinary workmen, with a common knife, in less than a third part of the time formerly required by the four.

The paper being collected upon the reels, in any convenient quantity, the whole is reduced into sheets, by simply cutting off the edges; and with equal facility, when further subdivision is required, by cutting it transversely.

But it is under-rating the value of this expedient only to say that the labour of two men out of five is saved; for, in fact, the two men who are employed in cutting the paper, not only do that with ease, which formerly was done with difficulty by four; but also in the intervals between the successive operation of cutting the paper, as each reel is fitted, they place the whole of the paper in packs, put it into the press, and convey it to the lofts.

The current expenses are also very considerably lessened, not only by a great reduction of the quantity of wire employed, but also from its greater durability in consequence of a variety of improvements, the enumeration of which would now be superfluous. Only one piece of wire, 25 ft long, is now used, instead of two, which altogether were 44 ft 6 in.; the latter were generally worn out in two or three months; whereas the wire in the new Machine lasts from four to six months, according to its quality.

Instead, however, of attempting to describe the particular means by which all the various other improvements have been accomplished, for indeed it cannot be adequately done by words only, it will be sufficient to state, in general terms, what the improvements are, and the advantages which result from them, as being of much more importance for the manufacturers to know.

FIRST. A better mode of agitating the stuff in the vat by a vertical instead of a horizontal agitator, and the delivery of the stuff from the vat by one aperture only, instead of several, which prevent the formation of lumps and rolls.

SECOND. The method of delivering the stuff upon the wire, by which not only a greater uniformity in the distribution is obtained, but it is so contrived that the stuff flows with much less velocity than it did in the old Machine, which prevents any cloudy appearance, and gives that beauty and clearness peculiar to Machine Paper.

THIRD. The construction of the deckles, and the method of supporting the wire, are much simplified and improved, so that the apparatus of the former Machine is rendered less complicated.

The advantages resulting from these improvements are a considerable reduction in the nett cost, and in the current expenses of the Machine, and also an increase in the quantity of paper which may be made in a given time.

Enough has been said to show to what perfection the Machine has at length been brought; and as to its general merits, it certainly possesses, in a pre-eminent degree, all those properties which can render any machine desirable.

For the truth of this assertion, appeal is made first to the unrivalled excellence of the article manufactured by the Machine, in the decided preference given to Machine Paper in the Market; and secondly, to the Machine itself, for the correctness of the report as to the ease and facility with which it is managed, the number of men employed, the quantity of paper made in a given time, and the ultimate saving produced.

It only remains that there should be brought together, into one comprehensive view, all the advantages to be derived from the use of this Machine, together with such other facts and observations as may enable you to draw your own conclusion on comparing them with the old mode of manufacturing paper by hand.

In 1806 the Machine was capable of doing the work of six vats in twelve hours; it is, however, now capable of doing double that quantity at one-fourth of the expense. For by the various improvements enumerated above, the consumption of wire is reduced nearly one-half, and lasts above double the time; the quantity of paper produced is doubled; and, taking into consideration the work which is now performed by the men over and above their immediate attendance upon the Machine, it may be fairly stated, that the number of men is reduced to one-half; consequently the expense of wire and labour is reduced to one-fourth of what it was.

The other advantages incidental to the nature of the process of making paper by this Machine, may be classed in the following order.

FIRST. That the paper is much superior in strength, firmness, and appearance, to any which can be made by hand of the same material.

SECOND. It requires less drying, less pressing, and parting, and consequently comes sooner to market; for it receives a much harder pressure from the Machine than can possibly be given by any vat press, and is therefore not only drier, but on account of the closeness and firmness of texture, even the moisture which remains is far sooner evaporated on exposure to the air, than it would be from the more spungy or bibulous paper made by hand.

This superior pressure, and the circumstance of one side of the paper passing under the polished surface of one of the pressing rollers, contribute to that smoothness which in hand-made papers can only be obtained by repeated parting and pressing; consequently a great part of the time necessarily spent in these operations is saved, and the paper sooner finished and ready for market.

THIRD. The quantity of broken paper and retree is almost nothing compared with what is made at the vats.

FOURTH. The Machine makes paper with cold water.

(Note: In making paper by hand the stuff in the vat is heated to make it drain more rapidly and for the comfort of the vatman.)

FIFTH. It is durable, and little subject to be out of repair. The Machine at Two Waters, in Hertfordshire, for the last three years, has not cost £10 a year in repairs.

SIXTH. As paper-mills are almost universally wrought by streams, which vary considerably in their power from time to time, there will result from this circumstance a very important advantage in the adoption of the Machine. The common paper-mill being limited by its number of vats, no advantage can be taken of the frequent accessions of power which generally happen in the course of the year; but, on the contrary, as scarcely any mills are capable of preparing stuff for twelve vats, every accession of power to the mill, where a Machine is employed, will increase its produce without any additional expense.

SEVENTH. The manufacturer can suspend or resume his work at pleasure; and he is besides effectually relieved from the perplexing difficulties and loss consequent upon the perpetual combinations for the increase of wages. (Strikes of Workmen.)

From what has now been said, it will be easy for anyone who is conversant with the manufacture of paper to form a statement illustrative of the aggregate result; but it may be necessary to observe, that in making the comparison between the expense of the manufacture by the hand and by the

Machine, advantages have been enumerated in favour of the latter upon which no certain value has been fixed. The following remarks may enable the manufacturer to appreciate these, and to form a more correct judgment upon the whole.

FIRST. In many situations the annual dues upon the Machines would be in a great degree met by the saving of coals.

SECOND. That the expense of wire and felts will be little, if anything, more than for moulds and felts.

THIRD. That the workmen's wages will be more than paid by the difference in favouring the Machine in the quantity of broken paper, the capability of advantageously employing the temporary increase to the power of his mill, and by the superiority of the paper.

The annual rents for the Licence to use the Machine are as follows:

For the use of a Machine making only 3 vats work	£200 p.a.
For the use of a Machine making only 4 vats work	£300 p.a.
For the use of a Machine making only 5 vats work	£380 p.a.
For every additional vat's work	£80 p.a.

And so on in proportion for any quantity less than a vat.

The average work of one vat is established at 1000 lb weight per week for paper subject to the First Class Duty by George III; and 2000 lb weight per week for paper subject to the Second Class Duty by the same Act.

Should any further information be required, in addition to what is above stated, Messrs. Fourdrinier's and Company, Sherbourne Lane, London; or Mr. Donkin, of Fort Place, Bermondsey, the Engineer, will be happy to give it.

The great object of this Address is to lay before you a correct account of the Machine in its present improved state, by which alone you can be enabled to estimate the value of the invention.

That no notions may be entertained by any that the Machine is yet imperfect, or that it is susceptible of improvement, the Manufacturers are earnestly requested to inspect the Machines already erected, when they will find the most satisfactory corroboration of every assertion made in its favour.

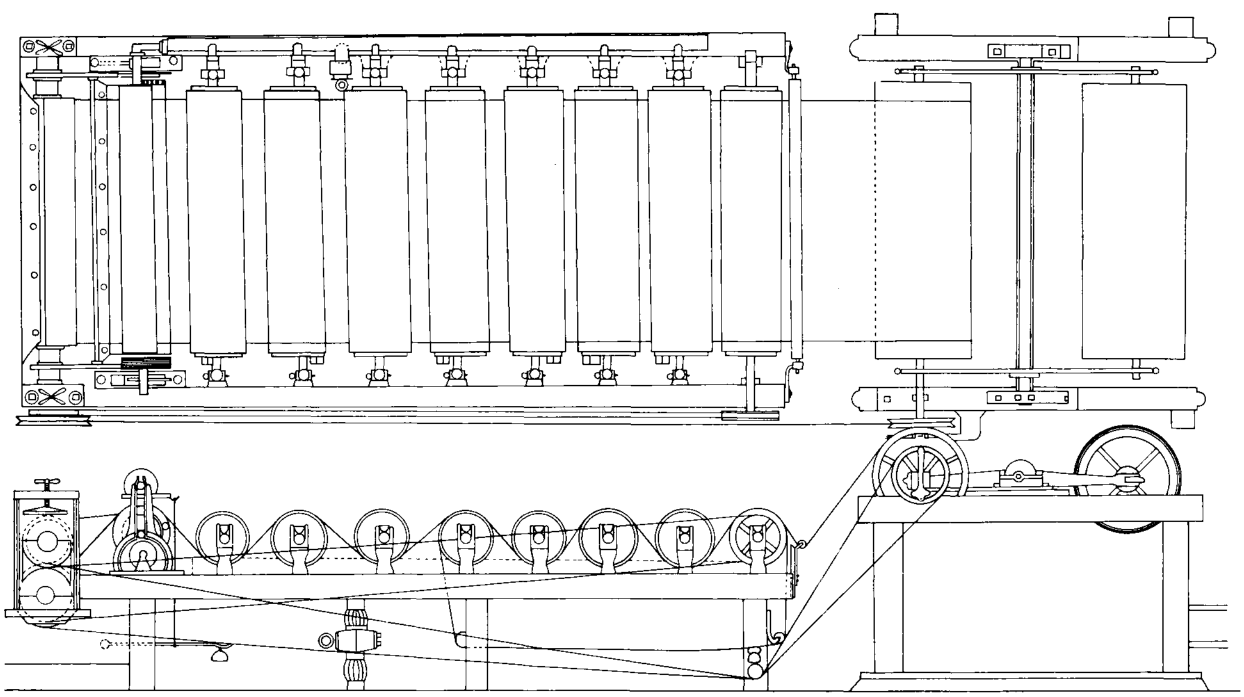
The House of Longman and Dickinson is using one of these Machines at Apsley Mill near Two Waters, having relinquished all right of selling the Machine for which they obtained a patent.

This Prospectus is printed upon extra large thick Post, manufactured by a Machine erected at Mr. Buttanshaw's Mill, West Peckham, Kent.

Appendix 2

DESCRIPTION OF A PAPER-DRYING APPARATUS EMPLOYED AT THE IMPERIAL PAPER-MILL OF PETERHOFF, IN RUSSIA, INVENTED BY MR. WILLIAM REED*

DEAR SIR, I send you an account of a paper-drying apparatus, with a plan to scale, which has been in work here night and day for upwards of four years, and with the help of a boiler of little more than two-horse power, dries the paper well, and as fast as two machines can make it at the rate of 25 to 30 feet per minute. As I never saw or read of a description of a drying-machine, and seldom two people contrive a thing the same way, I am induced to present this account to the mechanics of England; hoping there may be something new about it. My director having heard of a machine being made in England for this purpose, asked me to make one: I accordingly set to work, and, with the assistance of a machine paper-maker, produced the apparatus of which the following is a description. The large perspective view I leave to speak for itself; the particulars which follow are to be considered as referring more particularly to the other drawing.



Drawing by William Reed of a section of drying cylinders which he made in Russia and added to one of the Czar's machines in 1825.

The lower half exhibits the elevation, consisting of 8 steam-rollers of 13 inches diameter; at the left are the paper-machine dry-press cylinders (so called in the trade to distinguish them from

* *Mechanics Magazine,* No. 331, 12th December, 1829.

the other cylinders). The paper on leaving the machine in the wet state is put through the first pair of steam-rollers, which have a lever-weight on each end. This pair of stout copper cylinders requires to be turned very true; the upper one is 7 inches diameter, and covered with a felt drawn on very tight. We found that the lower roller, though ever so smooth, soon acquired a crust of fur, but I applied a steel blade fixed in a cast-iron frame for the purpose of scraping it, called by machine-makers the *doctor*. It requires, however, a little cleaning once a fortnight with pumice-stone and water, which is soon done without removing the roller out of its place. The under roller having not only its own weight, but that of the upper roller loaded with lever-weights, I found that turning on friction-wheels was far before any other mode of bearing. I had a small frame with two small friction-wheels on the top roller with its lever-weights attached. The friction-frames are of iron, and set on a double-bridge piece. The steam-press rollers are of iron, as before. When on the wooden frame the wet and steam caused a twisting, and there was no keeping the steel knife, or doctor, close to the cylinder. The weight on the upper felt-roller may be about 3 cwt. or more; the use of it is to take out the machine felt-mark. The remaining rollers are just wide enough for a man's hand to get between them for passing the paper under and over the rollers till it arrives at the fifth roller, where the endless felt begins. It is then led on to the reel, which, as well as the drum-roller for driving the rollers and felt with the strap, has a good stress on the paper when dry, and can turn the whole of the rollers except the first pair, which are driven by a strap at each end and riggers fixed on each end of the machine-cylinders; these are seen better in the plan.

The method of admitting steam from the boiler is by two-inch iron pipes under the machine, from which rises a leaden pipe with a two-inch cock, for stopping or starting. On one side of the machine there runs a stout leaden pipe, wherein the stuffing-boxes (containing the copper elbow pipes) are soldered. On the end of the cylinder at which the steam enters I have a steel end turned to a hollow sphere, and a corresponding brass end on the copper pipe to fit, which is kept up with a bridle and wedge at starting, as when cold the valve is nearly one-eighth of an inch apart. The cast-iron bearings for the light or thin copper rollers are merely screwed to the machine-frame, having a pin for tipping up the end of the clarionet-valve (so called from being formed like the best metal keys of that sort, a likeness, however, which I did not find out till after I had them at work) but having the valve fixed on the edge of the cylinder. We thus get rid of all the condensed water, having a trough to take it back to the feed-head of the boiler, under the machine-room.

The thin copper rollers are only hammered by a good coppersmith. Brass ends, turned and soldered in the four rollers carrying the endless felt, have edges cast on a little lower to allow the double edge of felt to rest on, as it requires guide wheels—three pair on each side—to keep it stretched. The reels are round or square, as required (flat reels we have thrown away).

When the dry paper is wound about 500 times, we cut it off from the reel with knives made of handsaws, backed with a piece of sheet-iron to keep them stiff. Four at a time in use will last a year, if good.

It may be as well to notice, that in making the first pair of copper rollers, the copper must be full a quarter and sixteenth brazed and hammered true; otherwise, in turning, the slide-tool will find its way through it before it is round. The brass-tube gudgeons are let in about two inches into the end; drove very tight, and well soldered; because, on account of the great distance from the bearing required by the driving riggers and valve for escape of condensed water, they would be apt to get slack. I likewise screwed copper $\frac{3}{8}$ screws through the tube and brass end, and they are now as firm as the first day. At the delivery from the clarionet-valve there is a small tube with a hole in its side to guide or prevent the water splashing or wetting the paper as it falls into the trough. The steam-rollers, felt-drum, reels, &c., are all driven by straps from the machine-cylinders.

The cost of a set of such steam-rollers is about £250, without the boiler; copper in sheets being 11*d.* per lb. and cast-brass 16*d.* to 1*s.* 8*d.* per lb.

I should have mentioned that the cast-iron forked bearings have on the top a piece of iron with a stout wire pin to keep the roller in its place, and likewise a small funnel for holding suet—it not being so soon melted. If the rollers get dry they soon cut.

I am, Sir,

Your obedient servant,

'William Reed'.

Note. These two paper machines of which Reed has described the new dry part are the two machines bought by the Czar of Russia in 1814.

Appendix 3

THE following is a report by Donkin on boiling and bleaching rags in 1835 at Tapsfield Blue Anchor Mill:

"*Boiling Rags.* To 6 cwt of rags take half bushel of chalk lime, put into a coarse bag, the bag put into the tub before the rags, on the false bottom; for the coarse rags put in 5 lb of potash melted in warm water, and strained through a sieve. The liquor may be used several times, for the same sort of rags. The rags to be boiled about 6 hr, coarser rags a little longer. Tubs to hold 5 cwt are the most convenient size. A cock or plug must be put into the bottom of the tub to run the liquor off, and have a pump to return it. About four boilers or tubs to one large machine. After boiling let the rags drain on a false bottom, in other chests. The rags should be about 3 hr in the breaker, according to the quality, till the water is clear. The roll should be brought down gradually to draw the stuff out properly.

"*Bleaching.* 16 cwt of half-stuff middling rags (sheevy rags), 12 quarts of vitriol, 40 lb of manganese, 50 lb of common salt: Pound the manganese and salt well together and put them into the retort; take half vitriol and half water, about three or four quarts of each, put it into the retort and let stand ½ hr before turning the steam on the jacket; put the rest of the vitriol and water, in equal quantities, into the retort as it will take it, if it gets thick add a little water. Coarse rags require 12 hr bleaching; half hour in washing engine. Put a clay plug in the bottom of each bleaching chest, and an inch pipe to allow the gas to pass off, when the rags are bleached; the gas will pass off in about an hour, then open the chest and take out the rags, when they will be ready for the washing engine. The dryer the half-stuff, and the smaller separated, the better; it must either be pressed or racked, the latter is preferable. If a whiter colour is required the half-stuff must be washed and re-bleached in the same way."

For making tub size 4 cwt of scrolls (parchment) will make 300 gall of size with 70 lb alum.

Harry Donkin obtained the following particulars from Thomas Sweetapple at his Cotteshall mills at Godalming, Surrey, in 1839.

"The average quantity of paper made was fifty reams in 12 hr on 20 lb demi. When the paper was 56 in. wide on the wire the shrinkage in width varies from ¾ to 1¼ in. Double Medium, 45 lb per ream, used nearly one engine of stuff per hour, making two sheets at a time."

Engine Sizing at Cotteshall Mills

"*Printing Papers.* To 12½ pails of water add 28 lb of Am. Pearl ash and 28 lb of soda, and boil till they are dissolved, then add 112 lb of resin and boil for 7 or 8 hr. Care must be taken or this will boil over and waste. To prevent this drop in a small piece of fat or grease, or, if boiling by means of steam, turn the cock. Use this size in the following manner: Put a middle-sized hand bowl of it into half a pail of water and stir it, then pour it through a fine strainer into your beater. About ¼ hr after this, dissolve 5 lb of alum in a pail of hot water, and pour it through a strainer into the beater. Always put the size into the engine and let it get well mixed before you add the alum. They boil this size by steam at Cotteshall, and the condensed water is equal to putting ten or eleven more pails, and that quantity of water must be added if the boiling is carried on by fire instead of steam.

"At Cotteshall the rags are washed off and broken in, in about 2½ hr; they are then, in a state of half-stuff, let down to the draining chest below, and carried to the bleach house; 12 hr steeping is the usual time, unless for very coarse rags; they are carried back to the engine room, where they lay for a day or two more if convenient, as they continue to whiten a little by laying without the bleaching liquor being washed out of them. They are then rinsed for an hour to get the bleach out of them; if coarse rags they are emptied down a second time and bleached again, then rinsed again, and let into the beater, where they are beaten 2½ or 3 hr according to how wet or fast you want your stuff."

Steep Bleaching at Cotteshall Mills

"Three bleach chests 12 ft long by 5 ft 6 in. wide × 3 ft 8 in. deep, 3-in. yellow deal, each chest holds five engines of 1 cwt each, along with the necessary liquor. To eleven of water by measure add one of chloride of lime liquor. The chloride and water is here mixed in tubs. To 63 lb of lime 36 pails of water are added, stirred up for ¼ hr, and the lime allowed to settle 10 or 12 hr, but the liquor is better for use if left 2 or 3 days. When this is drawn off, eighteen pails of water are added to the residue, stirred and allowed to settle, and a third mixing is made with ten pails of water. When about to bleach in a chest, pump the necessary quantity of water into it, or if there is any spent liquor left in the chest, it will be better to use that than fresh water. Then add the proper quantity of bleaching liquor, pouring it through a sieve. Add your half-stuff, breaking up any large lumps, and stir for ½ hr. 12 or 14 hr will be sufficient time to bleach."

Appendix 4

MUCH interesting information about the introduction of the paper-making machine into Germany is contained in a most comprehensive book entitled *Geschichte der Papierindustrie im Düren-Julicher Wirtschaftsraum*, by Joseph Grevenich.

History of the Paper Industry in the Düren-Julich Area of Germany

As is well known, the first paper-making machine was invented in 1799 by the Frenchman Nicolas Louis Robert, who was employed in Didot's paper-mill at Essonnes. He was not able, however, to exploit the invention and his idea was developed in England. It is to the English machinery maker Bryan Donkin, among others, that the credit for bringing a commercial paper-making machine onto the market belongs.

Up till 1823 Donkin had already built thirty-eight paper-making machines. He also supplied the first paper-making machine in Prussia, which was installed in the Berlin Patent Paper-mill in 1819. On this occasion, the Englishman Corty acquired a Prussian patent for the supply of machine-made papers for fifteen years, that is till 1834. For the time being, this stifled the building of paper-making machines in Prussia. Shortly before the expiry of the prohibition period in 1828, however, paper-making machines were already being assembled in Prussia. The south German states in which paper was made had taken a lead over Prussia.

When on 7th February, 1837, the firm of Piette Bros. at Dillingen, Saarlouis, applied for permission to import "paper-making machines for making continuous paper" and "cylinder-machines" duty-free (these were probably machines made by Bryan Donkin in London) the provincial Customs authorities in Cologne rejected the application on the grounds that such machines were already being made by Jos. Reuleaux and Company at Eschweiler. The Customs authorities also stated that paper-making machines were also being made in factories at other places within the Zollverein (Customs Union), for example at Heilbronn. Thus, there was no reason for importing such machines from abroad.

The Reuleaux firm itself reported that it had supplied a paper-making machine to the firm of J. C. Schwartz and Sons at Göttingen and that this firm, as well as Gustav Schäauffelen at Heilbronn, was prepared to attest to the quality of their paper-making machines. In accordance with the Berlin Government's decree of 28th September, 1830, requiring periodic reports on machinery works, on 7th December, 1838, the Aachen authorities reported that "Reuleaux are making paper-making machines based on Doncien's [Donkin's] system, and hydraulic presses for paper." A rather unfavourable and gloomy opinion was expressed by Keferstein and Germar of Cröllwitz in 1839 when they applied to import a Donkin machine under a reduced Customs duty and were recommended to Reuleaux amongst others. Keferstein replied, "The Eschweilers are no good", and stated as a reason for this request that the London machines were being used abroad, in Brandenburg, in Silesia and in Westphalia.

It is not known how long the Reuleaux firm was in business. It is established that there was another machinery works making paper-making machines in Aachen in 1841. It was certainly for this purpose that on 27th March, 1841, the firm of Emunds and Herrenkohl of Aachen "in order to complete the equipment of our machinery works" requested duty-free importation of a newly invented lathe from Whitworth and Company of Manchester, because this machinery was not made in Prussia nor in the states of the German Customs Union.

In 1842 in Aachen there were seven machinery works, employing 250–260 workers. In spite of the high quality of their work, the prejudice that foreign products were better prevailed. The Aachen and Burtscheid Chamber of Commerce and Industry found this highly regrettable and in a report of 12th December, 1842, stated:

> In this respect the local manufacturers desire that the prejudice should not be supported by allowing duty-free or reduced duty imports as in the case of the two paper-making machines for Düren, one for Brachelen, one for Grellwitz (Cröllwitz) and one for Tilsit, whilst the Aachen manufacturers are forced to look for markets in distant countries—the Emunds and Herrenkohl workshop has sold two paper-making machines to Hungary, one to Russia and one to Brunswick.

The two Düren paper-making machines mentioned here were supplied by Donkin of London, and one was for August Schoeller at the Schoellershammer mill and one for Hoesch and Schüll in Friedenau. At that time, these Donkin machines were regarded as the best on the market. Since the Düren paper industry was important and the mill owners had the necessary capital, Donkin was interested in soliciting their business and in edging the local Aachen paper-machinery works out of this market. Donkin himself visited the Düren mill owners in order to learn how his machines had been performing and to give advice on the purchase of other equipment necessary for paper-making. In the diary of his journeys Donkin himself reports on his visits to the above firms in Düren in 1842 and 1843. These visits are reported elsewhere in this book.

Donkin also mentions that he spoke to a Herr Godin, the founder of Papeteries S.A. in Andenne and Fleury in Belgium, who had three Chapelle machines which were supplied by the Chapelle firm of Paris. In the same connection he speaks of a machine made in Aachen by Emunds and Herrenkohl.

Further evidence of the existence of the Aachen paper-making machinery firm of Emunds and Herrenkohl is given by an exchange of letters between the Arnsberg and Aachen authorities on the 15th January, 1845.

It is undecided whether it really was a question of unsubstantiated prejudice or whether the Aachen paper-making machines really did not come up to requirements and were unable to compete

Year	Number of machines	Firm	Place	Supplier
1837	1	Friedr. Wilh. van Auw	Lamersdorf	Joh. Widmann, Heilbronn
1840	3	Carl. Heinrich Engels	Inden	Joh. Widmann, Heilbronn
		M. Hoesch & Lud. Schüll	Friedenau	Bryan Donkin, London
1843	7	Schmitz Bros.	Merken	Joh. Oechelhäuser, Siegen
		Heinr. Aug. Schoeller	Krauthausen	Bryan Donkin, London
		H. Steinbach	Malmedy	Bryan Donkin, London
		Jos. Andreas Berens	Brachelen	Andre Köchlin, Mühlhausen
1846	8	Hoesch & Sons	Friedenau	Bryan Donkin, London
1849	9	Hoesch & Sons	Krauthausen	Bryan Donkin, London
1852	10	Heinr. A. Schoeller & Sons	Krauthausen	Bryan Donkin, London
1855	—	—	—	—
		Eb. Matth. Lud. Hoesch		
1858	12	Ludolf and Emil Hoesch	Krauthausen	Bryan Donkin, London
		Felix Heinrich Schoeller	Düren	Bryan Donkin, London

with other machines. At any rate none of these machines were installed in the Düren area, or even in the Aachen administrative district, between 1837 and 1845, during which period it is known that the Aachen machinery works were operating, and this continued until 1858. The evidence for this is the reliable official industrial statistics which give the number of paper-making machines on a basis of three-year periods (see table on p. 265).

In particular detailed information on the first paper-making machines obtained from Donkin, London, by the local paper-makers can be obtained from a hitherto inaccessible source. Import from abroad and reduction of duties had to be approved by the Finance Ministry in Berlin. For this, a case of necessity had to be shown and it had also to be proved that no equivalently good machines were available in the German Customs Union states. On approval of an application a licence was issued by the Finance Minister and sent to the provincial Controller of Customs in Cologne for transmission to the applicant. Thus, in response to their application of 10th April, 1840, Matthias Hoesch and Ludolph Schüll received the following licence on 26th April:

> Licence for an English machine for making continuous paper for the paper-makers, Matthias Hoesch and Ludolph Schüll of Düren.
>
> Berlin, 26th April, 1840
> Finance Minister
> Signed Gr. v. Alvensleben.

On the 31st May, 1841, Heinrich August Schoeller of the Hammer mill submitted a request to import a Donkin machine, written in his own hand. He based this on a detailed report, which presented a clear picture of the Düren paper industry at that time.

The Ministry's decision was as follows:

> Licence for a paper-making machine for Heinrich August Schoeller of Düren, given at Berlin, 27th July, 1841. This licence is valid to the end of the year and is for the duty-free import and delivery to Heinrich August Schoeller of Düren, of an English paper-making machine made of approximately 5–6000 lb of brass and copper and 30,000 lb of iron.
>
> Seal Minister of Finance
> signed Gr. v. Alvensleben.

In 1850 "The paper-maker Heinrich August Schoeller of Düren wishes to import a paper-making machine from the firm of B. Donkin and Company, London, and a small rotary engine machine and has applied to the provincial Customs authorities in Cologne for a reduction in import duty. In the case of the former piece of equipment the request has been approved, but has been rejected for the latter. The Imperial Ministry of Finance has thus asked the Imperial Ministry for Commerce, Trade and Public Works for information on whether the provincial Customs authorities proposal to reduce the duty on the paper-making machine to 15 Sgr per cent and to refuse any reduction in the import duty on the rotary engine may be complied with. Invited to give an opinion, under the relevant decree, we humbly submit the following:

> Paper-making machines like those built by B. Donkin and Company, London, and as shown in the diagram submitted by Schoeller have been made in the Zollverein (Customs Union) states. Paper-making machines have been made by Gustav Schäuffelen in Heilbronn, by B. Wietherich and Company in Bergisch Gladbach, by Jon. Oechelhäuser in Siegen, by C. F. Baller and Company in Wilhelmshütte bei Sprottau and by Herrenkohl in Aachen. However, Baller's and Herrenkohl's works are now closed and, as far as we know, the others have withdrawn from this field as they found it unprofitable. Under these circumstances we must support the applicant's request to import this paper-making

> machine, as was done on 29th July, with reference to a similar request from Lehmann of Halle an der Saale for a paper-making machine from Escher, Wyss and Company, Zürich. With reference to the reduction of duty on a rotary steam engine from Donkin, we cannot support this application as the Zollverein states make steam engines as good as the English ones and the special construction of the Donkin machine is explained by diagrams in Vol. 53 of the *Mechanics Magazine*."

On the basis of this opinion, it was expected that approval would be granted. Difficulties, however, arose through a report sent by the technical deputation to the Ministry of Commerce on 29th November, 1850. In this it was stated that "contrary to our earlier assumption, it is now known that paper-making machines of the Donkin type are being made by Sigl in Berlin and these satisfy the specifications. The paper-making firm of Jachmann at Trutenau bei Königsberg has obtained a machine built in the Sigl works and, used alongside the new 60 in. Donkin machine in the local paper-mill, the Sigl machine with the latest improvements showed itself to be reliable and efficient. We cannot therefore recommend that any further import duty concessions be made on paper-making machines imported from abroad."

In 1851, Hoesch and Sons of Düren applied for duty-free import of the latest type of paper-making machine, which they had already imported in 1849. They based their request on the fact that domestic machines were unsuitable for making fine grades of paper. They listed the advantages of the new type as follows:

1. The screen is double the normal length, which results in an increased flow of cleaner stock to the machine.
2. The metal wire is longer than that on the largest of the old machines: thus the machine capacity is considerably greater.
3. The deckle is so constructed that the width of the sheet can be changed while the machine is running.
4. The machine speed can be altered without changing the speed of the drive unit.
5. The dryer cylinders are fitted with a device that enables the condensate to be removed through the same tubes as are used for the steam supply.
6. The circular knives for slitting the paper can be adjusted while the machine is running.
7. A new type of cutter accurately cuts single sheets of the smallest desired size even at the highest machine speed.

Permission was granted only because the paper-making machine was of the latest type and "under the conditions that the applicants undertake to provide an accurate and detailed description and diagram of the new machine that can be reproduced so as to enable the domestic machinery makers to build copies and finally, if the authorities so decide, to allow those designated to examine and photograph the machine for the purpose of publication".

On the 9th August, 1853, the firm of Heinrich August Schoeller was refused an import licence for a newly-invented paper and air-drying machine. This machine was built by Bryan Donkin and Company of London. The firm intended to install this type of machine in their mill and wanted to negotiate with Donkin for the import rights to the Prussian states. According to the technical deputation the machine for sizing and drying the paper consisted of "two rows of iron and wood drums, one above the other, over which the paper treated with animal size is led by means of felts. In order to accelerate drying, thirty such drums are used each with a vane-type device inside it and there is a steam heating system under the machine."

On 1st August, 1858, the firm of Hoesch and Sons was dissolved by the treaty of partition of 29th January, 1857. Eberhard Matthias Ludolf Hoesch and his brother Emil Hoesch received the Hoesch mill at Krauthausen. Some time before the treaty came into effect he had ordered a new paper-making machine from Donkin in London and applied for a tax concession. He wrote, "With the intention of founding a new paper-mill, after having proceeded with the necessary buildings, I ordered the paper-making machines for these from Bryan Donkin and Company of London. . . ." After a long exchange of letters between the Ministry of Commerce and the Ministry of Finance his request for a reduction in import duty was refused on 7th May, 1858. The paper-makers Schmitz Bros. of Düren were refused a similar request at the same time.

The single paper-makers, naturally, did not have the necessary capital for building a modern, metal paper-making machine. Schulte mentions that there was a number of wooden paper-making machines at that time. This is suggested since the whole mill was built of wood. According to tradition, Wilhelm Anton Kayser of the Niederdrove paper-mill also worked with a home-made wooden paper-making machine. This was appropriate as his father Joham Wilhelm Kayser was a very well known and active builder of mills in Düren.

In 1809 Peter Joseph Erkens came to Stockhein bei Düren and founded his mill in 1836 at Krauthausen in the midst of the numerous paper-mills on the Ruhr. His son Johann Wilhelm Erkens was called from a simple repair shop to build the first paper-making machinery works in 1836. His sons Joseph, Jacob, Ignaz, and Peter helped him in his work. The works grew with the sons. In 1856 the Erkens installed a steam engine in their works, followed by a second in 1868. This was an 11 h.p. steam generator made by the Düren firm of Petty-Dereux. Now the mechanics and turners shop had become a machinery works.

In 1872 the works was extended by building an iron foundry. Soon the first paper-making machine made in Düren was being built. In 1874 this was supplied to Leo Schleipen of Koslar bei Jülich, who on the 1st May, 1873, had acquired the Küppers mill and turned it into a groundwood mill. In order to be able to make paper from the groundwood, he obtained a paper-making machine from J. W. Erkens. Perhaps it was financial requirements that caused the Erkens to merge with Leo Schleipen. The firm of "Schleipen and Erkens" was formed on the 15th August, 1874. J. W. Erkens became a co-founder of the firm and his sons were directors or partners. On 1st March, 1853, Schmitz Bros. sent Adolf Oechelhäuser of Siegen a testimonial to the effect that he had altered the machine supplied by his father in 1840 to their complete satisfaction. A new machine was supplied by Escher Wyss in 1857.

Thus the firm of "Schüll and Hoesch" existed from 1st January, 1840, till 30th June, 1846. It comprised three paper-mills, namely Kreuzau under Ludolf Schüll, Friedenau, and the "Hoesch mill" at Krauthausen, the property of Ludolf Matthias Hoesch. There was one paper-making machine at Friedenau. The partially treated material from Kreuzau and Krauthausen was brought to Friedenau for further processes. However, the business relationships during the period of association are not quite clear. Ludolf Schüll alone always signed for all Kreuzau mill deliveries. From 1842 to 1845 Ludolf Schüll had bitter battles with the Aachen authorities over the regulations concerning the stream in Kreuzau village. He was the most important paper-maker on the Kreuzau stream and became the spokesman for all the other paper-makers when they were accused of causing flooding in the village.

In 1845 there was an auction of paper-mill equipment:

> The machines in question together with the following accessories shall be delivered to the auctioneer on the appointed day, namely:
>
> I the complete machine made by Bryan Donkin and Company, London, that is at present in the Friedenau bei Kreuzau mill together with all its accessories, namely a new metal wire, new large and small hose pipes and a complete set of felts.
>
> II the two stock chests complete agitation equipment and machinery.
>
> III a regulator with machinery, pulleys and base.
>
> IV all copper and wooden flow equipment for passing the stock to the machine house.
>
> V all the drive machinery for the machine that is in the machine house, including the

wheel of the trunnion, the water wheel itself and its trunnion on the pond side, and other accessories.

VI all zinc covers in the machine house.

VII steam boiler, pumps in the machine house, felt stretchers, cutting table with a new knife and weight, air pumps and the drive machinery.

VIII all lead pipes in the machine house from the water tank on, but excluding the tanks for the warm water outside the machine house.

IX the barometer, the cylinders and the dandy-roll clamp.

X two dandy-rolls with new covers and the block and tackle.

XI all patterns made here.

XII stock pumps with pipes, drive machinery and chests.

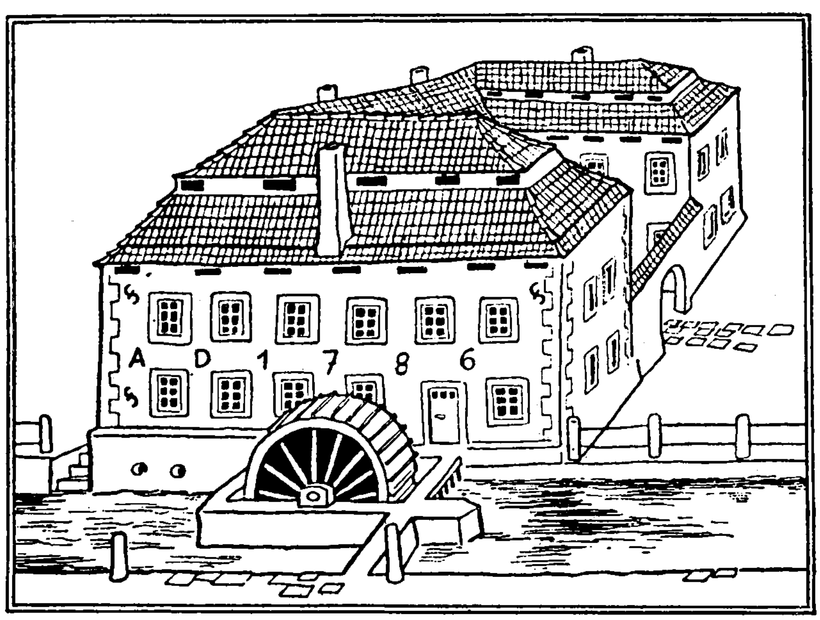
XIII all monkey wrenches belonging to the machine, an assortment of those for the board machine and the spare brackets for the screen.

XIV wooden steam funnel.

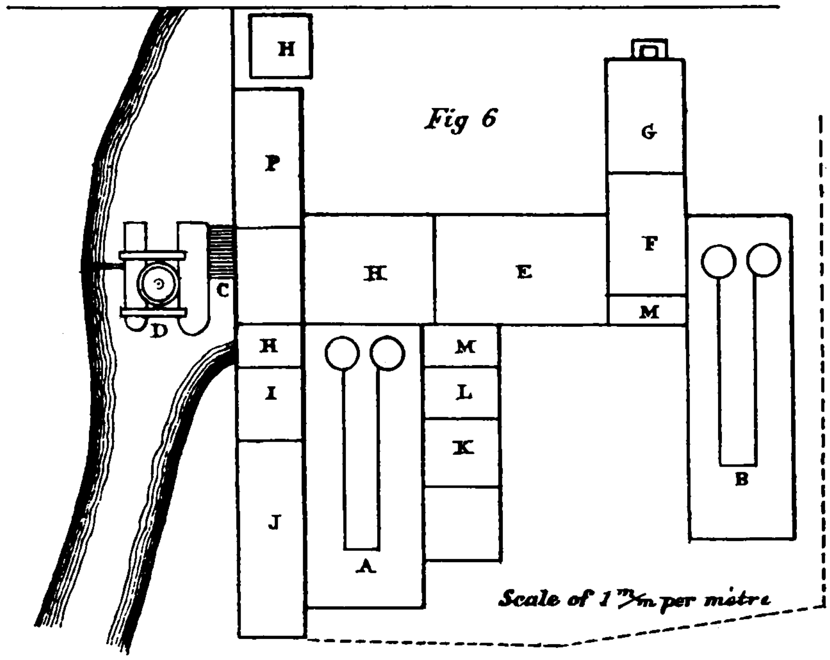
XV all "Poulis" [pulleys?] and the old manometer.

In 1857, Eberhard Matthias Ludolf Hoesch had installed a new paper-making machine built by Bryan Donkin and Company, London. In 1859 "a new fourth steam boiler to ensure a good and regular supply of steam with the three already operating and licensed (1851)" was installed at Friedenau. On 15th July, 1861, Hoesch Bros. applied for permission to do away with their vertical water-wheel and install two turbines instead.

In October, 1857, the old water-wheel came to the end of its life and was replaced by a turbine, which presumably was the first in a Düren paper-mill. On 25th October, 1858, there was an application for a third steam boiler, which was licensed on the 13th December, 1858, and on 27th December there was an application for a fourth boiler to be used to operate a high-pressure steam machine. All these applications prove that when the mill was rebuilt the second paper-making machine was installed—which is shown in the Trade Tables for 1858. This was a 70 in. (177·8 cm) wide machine made by Donkin. There were thus four paper-making machines when Birgel was Burgomaster (two at Schoellershammer, two at Hoeschmühle). The four Hoesch brothers also had four paper-making machines, Edmund and Edward owning the machines at Kreuzau and Friedenau, Ludolf and Emil the two at Kreuthausen.



The Hoeschmüle of 1786 of Eberlard Hoesch. This is a large hand-made-paper mill.



The Hoeschmüle by 1857 in the same position beside the river, but now equipped with two paper-making machines and other equipment as listed.

A	1st paper-making machine	H	bleaching vat and storage area for the (paper) pulp
B	2nd paper-making machine	I	glazing machine
C	water wheel	J	packaging and storing area
D	turbine wheel	K	office
E	machines (drivers)	L	main office
F	steam generators (boilers)	M	stairway
G	large boiler	N	store

In 1837 a paper-making machine made by Johann Widmann of Heilbronn was installed in Lamersdorf by Friedrich Wilhelm Van Auw, and another was installed in 1839 in Inden by Karl Heinrich Engels. They were financed by borrowed money, which made the owners' position weak and prepared the way for bankruptcy.

In 1840 a third paper-making machine followed and this was the first Donkin machine in Friedenau. At the same time another, made by Oechelhäuser of Siegen, was supplied to Schmitz Bros. in Merken. Heinrich August Schoeller was cautious although his good financial position made him secure. England had become the land of paper-making machines. The firm of Bryan Donkin, London, had gained a market in the Düren area for their products and personal visits were made to the leading paper-makers. Heinrich August Schoeller decided on a Donkin paper-making machine.

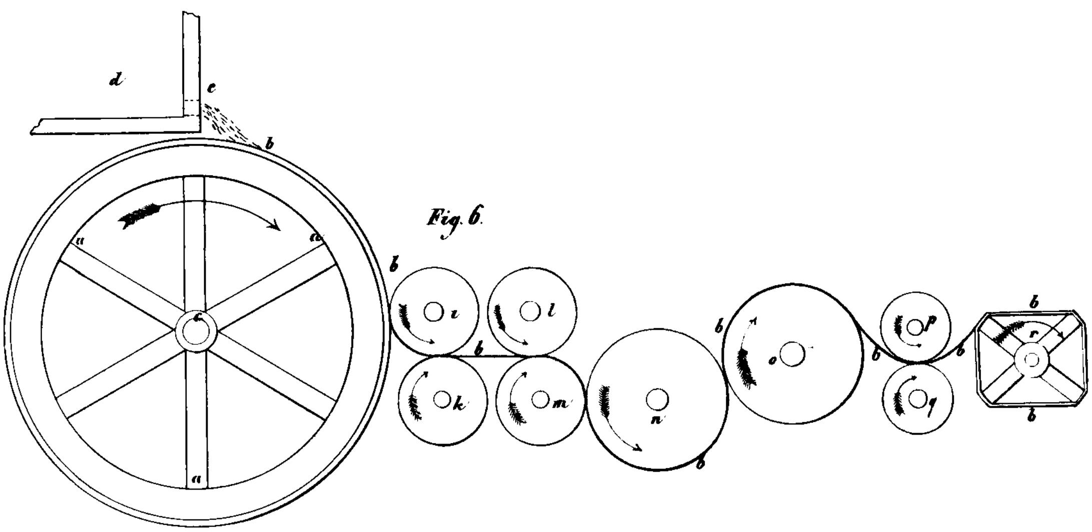
The Prussian government, too, was interested in the design of this machine. They allowed it to be imported at half duty and for this concession required that it be made available for inspection by engineers appointed by them. Felix Heinreich Schoeller was the first paper-maker in the Düren area to replace his water wheels by two turbines and these were supplied by Escher Wyss and Company of Ravensburg and used 3100 litres of water per second.

Appendix 5

THERE is a description in German, in a book by W. A. Rüst, of the German idea of what was intended by Joseph Bramah in his patent of April 25th, 1805.

Bramah describes his patent as being sundry improvements in the art of making paper, and goes on to give details of what we now know as a type of cylinder-mould machine, which can make paper in sheets of much larger dimensions than can be done by hand in the usual way.

Bramah, as we have said elsewhere, did not give drawings of his proposed machine and it was not apparently developed in England. It is interesting therefore to find a complete description of Bramah's patent, with a drawing, in Rüst's book on *The Technology of Paper*. The drawing with detailed description is given herewith.



In reading this, however, it should be borne in mind that Rüst's description was written a good many years after Bramah's patent and after the satisfactory performance of John Dickinson's cylinder-mould machine.

"The Englishman Bramah tried stretching the wire mould on to a large cylinder, the face of which was as wide as the paper to be made and the sides of which had a raised edge to prevent the pulp from flowing off. Let us consider, in Fig. 6 [above], that *a* is the large cylinder the exterior of which is covered with a wire mesh, which can move about its axis *c*, above which there is a chest *d* filled with pulp and that this chest is as wide as the cylinder and has an aperture *e* through which the pulp can flow onto the wire mesh covering of the cylinder *a*. Two rolls *i* and *k* are covered with felt or cloth and can be pressed close to one another by means of springs as also the upper roll *i* can simultaneously be pressed against the cylinder wire *a* by a spring. Two similar rolls, *l* and *m* can be forced together more strongly and thus exert a high pressure on the wet, soft paper web as it passes between them. In addition, *n* and *o* are two metal drums which are heated by steam and which serve to dry the paper passing between them. Finally, *p* and *q* are metal rolls to smooth the paper and from which the finished paper is reeled up on a core *r*.

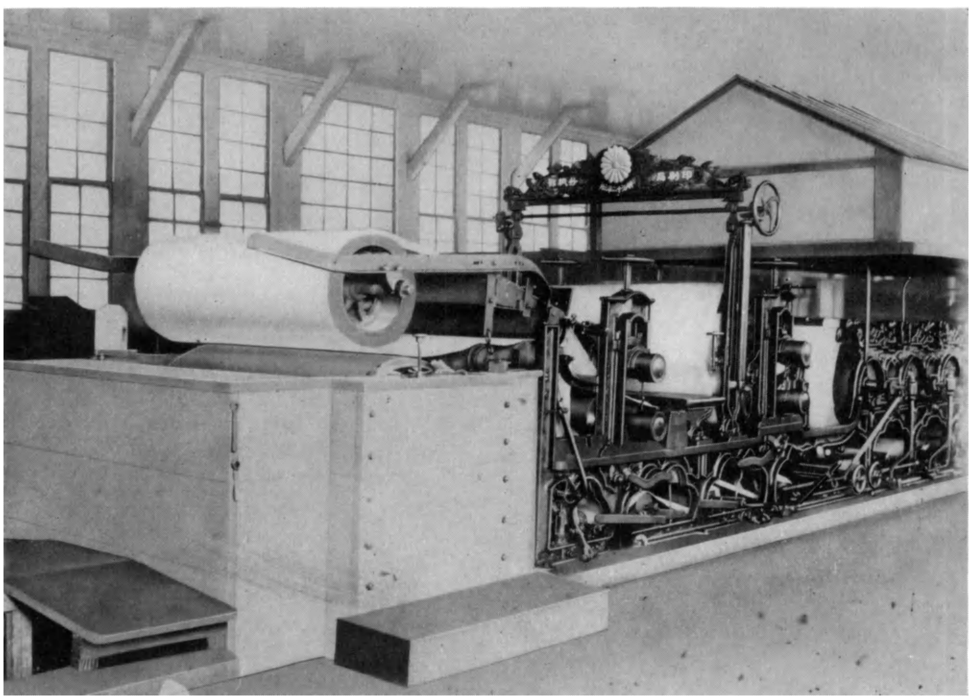
"When the chest *d* is filled with pulp and this flows through the aperture *e* onto the wire of the cylinder *a*, then the pulp spreads out and, as the water flows through the wire into the interior of the cylinder, the paper is deposited or formed on the surface of the wire. Since the large cylinder *a* is constantly rotating then the paper formed on the wire moves forward with the cylinder until it arrives at the felt-covered roll *i*. The paper adheres more firmly to the woolly surface of this roll than to the metal wire and so follows the rotating felt-covered roll, which first leads it between the felt rolls *i* and *k* where most of the water is removed and the paper becomes stronger. The paper follows the course *b*, *b*, *b*, *b* and passes between rolls *l* and *m* which are also felt-covered but which exert a greater pressure. The sheet then passes to the metal drums *n* and *o*, which are heated internally by steam. Here it is dried and is then pressed and smoothed by the metal rolls *p* and *q* and finally is reeled up as finished paper on the cross-reel *r*. Since the large rotating cylinder *a* and its wire mould cover have always an empty space for the pulp flowing onto them (as the formed sheet passes to roll *i* and finally to the reel *r*) then the formation of paper is continuous as long as pulp is flowing out of the chest *d*.

"The particular difficulties connected with this arrangement are to achieve a uniform flow of pulp onto the slowly rotating cylinder so that distribution is even, and to control drainage so that the pulp does not spread immediately over the cylinder. This latter condition is encountered when the cylinder is so large that its surface is almost level; as stated before, raised edges prevent sideways flow. It is more difficult, however, to arrange that, in addition to rotation, the cylinder has a simultaneous sideways shake in the direction of its axis. The purpose of this shaking motion is to imitate the vatman's action—to achieve uniform distribution of the pulp over the mould and assist the drainage of water. A method has also been used involving the creation of a low pressure space (if not a complete vacuum) inside the large cylinder and beneath the pulp flow so that the water drains out of the pulp more quickly than is possible on the conventional wire mould; it is easy to understand how difficult it is to arrange such a suction space on this machine.

"In addition to the obstacles and difficulties discussed, this equipment for making a continuous sheet has too many incipient defects and the making of paper by machine is of too great importance for men not to devise other devices for its achievement."

Appendix 6

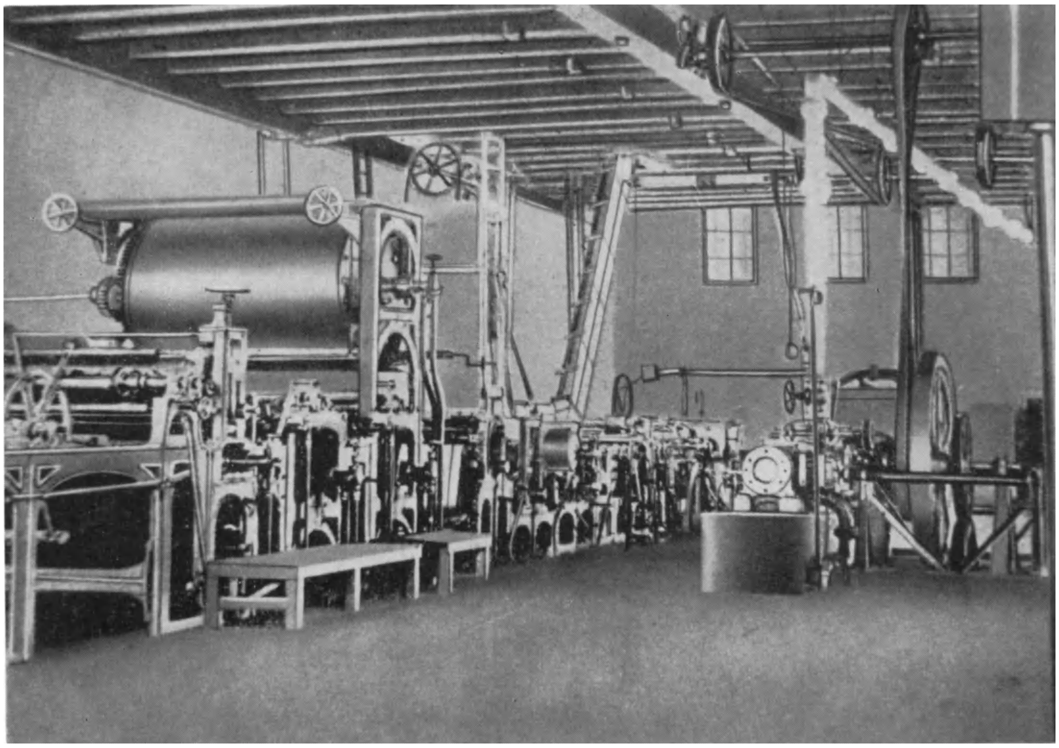
FOR thirteen hundred years the Japanese have been very highly skilled papermakers. They learned the art from the Chinese in the seventh century and developed and improved it to such an extent that today they are by far the best makers of hand-made paper, especially in the very great variety of paper for many purposes which they make with such skill. In the West a very few makers of paper by hand are still in existence and the excellent papers which they make are almost entirely confined to the purpose of writing and printing. In Japan, however, a very great variety of paper is made and used for many purposes for which they are indispensable, particularly paper fabrics, paper for windows and screens in Japanese houses, for underclothing in winter, also for paper patterns for needlework, and for handkerchiefs, in addition to the numerous papers made for writing, painting and printing, paper flowers, umbrellas, overcoats and tarpaulins.



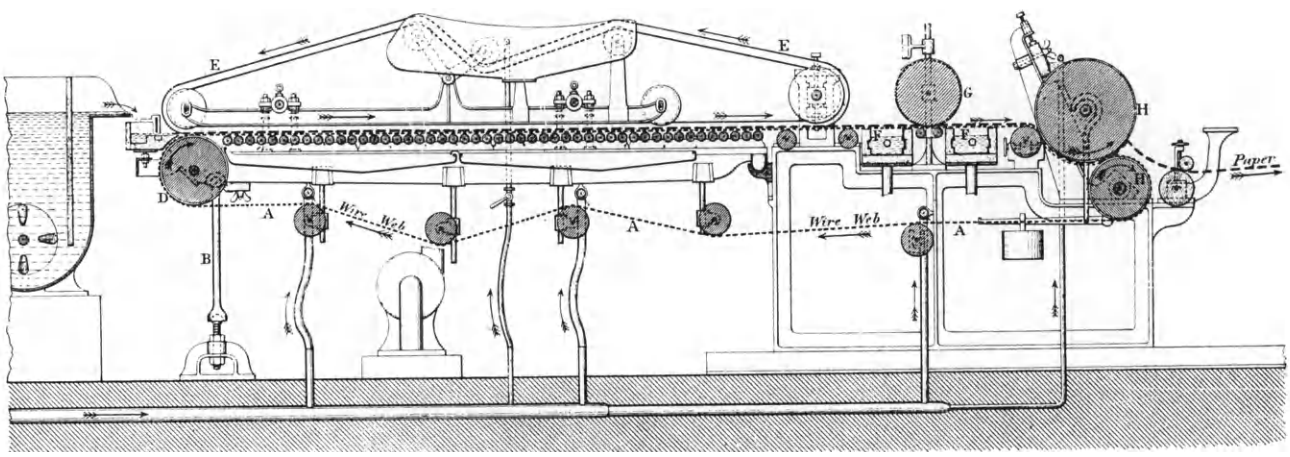
The first paper-making machine imported into and installed in Japan about 1870.

As a rule machine-made papers are not suitable for most of these purposes, being not nearly strong or tough enough and not so easily made waterproof.

In consequence of the excellence of their hand-made papers and their general suitability for Japanese requirements, many hundreds of Japanese hand-made mills still exist and prosper. At the same time also there are many large and very modern paper and board mills in Japan as up-to-date as any elsewhere in the world. The fact that the Japanese probably made far more use of paper than Western countries, chiefly because they had far better raw materials available, and that they made it by hand, was probably the reason why they were somewhat late in adopting machinery,



The first paper-making machine built and erected in Japan at the Oji Paper Mill in 1879.



Longitudinal section of the wire part of a machine of 1874 supplied to Yukosha Paper Mill. The stuff is carried onto the wire from a distributing box over a rubber apron above the breast-roll, which is 12 in. diameter. The making part of the wire is 8 ft long, carried over 48 tube-rolls each $1\frac{1}{2}$ in. diameter. There are rubber deckle straps stretched over flanged pulleys. Two suction boxes with a dandy-roll between carry the wire onto the guide-roll, after which the wire carrying the stuff comes at once into contact with the top couch-roll, 18 in. diameter, and staggered deeply into the wire above the botton couch-roll, 12 in. diameter. After passing between the couch-rolls the paper web leaves the wire and is carried forward to the first press. The wire returns round the bottom couch-roll to the breast-roll via the wire return rolls, which have water sprays above them to keep the wire clean.

added to the fact that the early paper-making machines, as developed in Europe and America were quite unable to make the wide variety of papers which the Japanese needed, and still need It was after the beginning of the Meiji period, about 1867, that the Japanese began to lay the foundations of a new Japan and to realize the principles of industrial development which was to bring the status of the country up to that of the countries of the West. And thus the first paper-making machine was imported in the 1870's.

Between 1870 and 1877 six paper mills were established in Japan to make machine-made papers, of which only one exists today. The first Japanese built paper-making machine was installed in 1879 at the Oji paper mill in Tokyo.

The wire part shown in the illustration is part of a machine supplied by Umpherston Iron Works of Edinburgh and started up at Yukosha paper mill, Tokyo, in June, 1874. It had a wire 60 in. wide and 31 ft long, five 3 ft diameter dryers and a 6-bowl calender. Another machine of similar dimensions, also supplied by Umpherston Iron Works, was put into operation at Horaisha paper mill, Osaka, in February, 1875.

Messrs. Bertrams Limited of Edinburgh supplied a machine to Yokohama in 1888 with a wire 84 in. wide and 40 ft long, and with eighteen drying cylinders 48 in. diameter. They also supplied one to Kintoro Kurobe in 1896. This machine was 100 in. wide, and the wire was 42 ft long. There were twenty drying cylinders 4 ft in diameter. From this it is evident that the Japanese were keeping abreast with the Western countries so far as their paper-making machines were concerned by the end of the nineteenth century.

I

Nicolas Louis Robert

NICOLAS LOUIS ROBERT was born on the 2nd December in the year 1761, at Paris in the rue Neuve Saint Eustache. His parents were well-to-do business people who gave him a fair education. He was very fond of study. Owing to his serious disposition his schoolfellows called him "The Philosopher". When he had attained the age of fifteen years he left home secretly and went to Nevers, where he tried to enlist as a volunteer in the army. Having neither the stature, nor the age prescribed by the military regulations, he was sent back to his parents at Paris, who were very much upset by his disappearance, and from whom he received a severe reprimand.

Nicolas Louis Robert.

After finishing his studies he was placed as a clerk in the offices of a lawyer in the rue Saint Marais. His parents, whom reverses of fortune had reduced to very modest circumstances, consented at last that he should take service in the army. Robert found himself enrolled on the 23rd April, 1780, in the regiment of Grenoble Artillery, whose first battalion was in garrison at Calais. Fifteen months after his entrance into military service he asked to be sent to America with a regiment of artillery. His request was granted and he was accordingly sent to the regiment of Metz Artillery stationed at Brest, and embarked almost immediately for San Domingo. Soon appointed a gun-layer, he took part in several battles against the English, in which he distinguished himself by his coolness and courage. The rough experience he gained at that time in his military career, and the lack of any future for the private soldier, caused Robert to reflect, and administered a salutary check to his dreams of glory. After he had obtained his leave, with most honourable mention of his good conduct and his courage, he went back to Paris in the second year of the Republic, holding the position of proof-reader in the establishment of M. Pierre François Didot the younger, the printer, and youngest brother of M. François Ambroise Didot, both celebrated for the editions that they had published. M. Pierre François Didot, who appreciated the ability of his proof-reader, advised his son, Didot Saint Leger, to whom he had turned over his paper-mill at Essonnes, to put Robert in charge of the accounting department of the mill. The young proof-reader was at that time in the happiest period of his life; he had just been married, and his wife had presented him with a daughter, whose god-parents at her baptism were Madame Didot Saint Leger and M. Firmin Didot, her brother-in-law.

Gifted to a high degree with the genius of a mechanic, which his natural taste and studies had happily developed, giving him both theoretical and indispensable practical knowledge, Robert, installed at Essonnes in his new position of clerk inspector of workmen, soon felt the desire awaken in him to profit by his special aptitudes. He was keenly aware of the difficulties presented by the direction of three hundred workmen, whose minds, naturally excitable, were still more inflamed by the ideas and events of the times. At that time the Essonnes Paper Mill manufactured the paper used for *assignats*, or bank-notes, and often the lack of discipline amongst the workmen had been the cause of serious disorders.

Robert conceived the idea of making paper by a machine which could function with the aid of very few workmen. He communicated his idea to Didot Saint Leger, who authorized him to take from the workshops the material necessary for the execution of his plans. The first model was made by Robert, but it did not reach perfection at the first attempt. However, the results obtained were satisfactory enough to encourage him and give him hope of success.

For some time Robert was not concerned about perfecting his machine, his leisure being taken up with other work. When the machine did not turn out satisfactorily at the beginning, Didot became rather sarcastic about it, and told Robert he was wasting his time. Later on, however, Didot, who must have been thinking hard about the matter, changed his mind again, and asked Robert what had become of the machine for making paper. He told him that he should not be discouraged, but should go on and make it a success, saying that the discovery would make his fortune, and also promising that he, Didot, would make him an advantageous offer when he made the machine work. Encouraged with this hope, Robert put himself to work again with renewed ardour, and after many calculations, researches, and trials, which cost him nearly five years of thought and study, he ended by constructing a machine—a new model in which his dreams were realized. The continuous paper-making machine was created. Didot wanted Robert to allow him to make use of his invention, but Robert refused, and wanted to take his machine away from Essonnes because Didot had not paid him the money he had promised, but Didot would not allow this because he had supplied the material and labour used in the making of it. Hence, there was a lawsuit, in which the court ruled that the machine should be given back to Robert on condition that he would reimburse Didot for his share of the expenses. Robert had, however, by this time gone to Darnetal, near Rouen, where he tried to build a paper-mill, but his resources were inadequate so he returned to Paris. There he met Didot and came to terms with him, ceding, on the 28th March, 1800, his rights to the patent to Didot for the sum of 27,400 fr., of which 2400 were to be paid down in cash; the balance was to be paid from the results of the manufacture of paper in the factory at Essonnes. Robert consented to superintend the making and sizing of the paper for three months.

A full description of the patenting of Robert's machine, and his correspondence with the authorities about it, has already been given in the description of the invention and evolution of the machine earlier in this work.

When Didot went to England, he left Robert in charge of his mill, and sent the drawings and model of the continuous machine to London with Gamble, feeling certain that the English manufacturers would be interested in profiting by this valuable discovery. For the first five years that Didot remained in England, Robert continued to superintend the mill at Essonnes, but, unfortunately, Didot was too far away to keep closely enough in touch with his work, and financial embarrassments arose, which paralysed his business. There were serious strikes amongst the workmen, which hastened the débâcle, and in the end the mill had to be sold. Robert found himself in a difficult situation; he had only received the interest on the price of his patent, and was obliged to give up all hope of receiving the capital sum. However, on account of Didot's failure to live up to the contract, Robert recovered the rights to his patent in 1810. He then constructed another machine, intending to sell it to M. Guillot, then proprietor of a mill at Mesnil-sur-l'Estres (which eventually was bought in 1826, by Firmin Didot Brothers). Robert's resources, however, were not sufficient, and his health was failing.

In 1814, the term of his patent came to an end. He could not find sufficient funds to renew it, and he later learned that Messrs. Berthe and Grevenich had just made one of his machines from drawings which Didot had sent them, and established it at Saint Roche. In order to get back the interest in Robert's machine which he lost in France by his default, Leger Didot, in 1811, had sent from London to M. Berthe in Paris a copy of the periodical *The Repertory of the Arts and Manufactures* for the month of September, 1808, which contained a description and the plan of the machine as it had been improved by Donkin in England, and he ordered Berthe to take out a new patent which they would exploit in common. Berthe took out this patent in his own name, and put in a condition that Leger Didot would return to France to have the machine constructed within two years, which was the length of time the law allowed for the putting into action of a patent. It will thus be seen that Robert was side-tracked by Didot's trick. M. Berthe, in fact, had two machines made, and the engineer who built them was Calla, an engineer of Paris. These were built in 1814 and 1815. From that time they commenced to manufacture in France paper of continuous lengths for printing and also for wallpaper. The machines, however, were very imperfect compared with those which were later imported from England.

In 1833, a tribunal in Paris had the following to say about the French paper-making machines:

> The construction of these machines rests until this day almost exclusively in the hands of the English, excepting the two machines which were mentioned, namely, those made by Calla for Berthe. All establishments of this nature in France, such as those of Canson, Montgolfier, Thomas Varennes, Firmin Didot, Delcambre, and others are equipped with machines coming from England.

In 1814, as explained, the term of Robert's patent came to an end, and he could not find sufficient funds to renew it. Robert therefore saw the fruits of his labours escape him. He was without work and without position, and there were no resources left to him for the support of his family and he established a small primary school at Dreux. It was here that he died on the 8th August, 1828, at the age of sixty-six years, leaving a wife and children, to whom he had always shown great tenderness and devotion. Robert was a man of education, agreeable, and of good character, and in his leisure hours he was not ashamed to write poetry. Many graceful compositions which came from his pen are known to only a few of his most intimate friends.

Like many of the others who were associated with the early history of the paper-making machine, and who gave both time and money to its development, Robert got nothing but poverty and unhappiness, almost amounting to destitution in his latter days, while he saw other people profiting from the fruits of his early labours by the erection of paper-making machines in many parts of France.

Some years after Robert's death a subscription list was opened among paper-makers in France, Germany, Belgium, Holland, Italy, Denmark, Spain, and England, to provide some funds for

Robert's sole surviving daughter. This subscription raised the miserable sum of about £377, and an amount to the value of about £300 was employed in making an annual provision of about £30 to Robert's daughter. This poor effort is rather reminiscent of the subscription made among paper-makers towards Henry Fourdrinier's survivors in England after his death.

Inscription on Louis-Nicolas Robert's grave

(*Front side:*)

LOUIS-NICOLAS ROBERT
Who invented the Paper-making Machine
at
M. Didot's Paper Mill at Essones
In The
Sixth Year of the Republic (1798)
He was a Teacher in the Faubourg St. Thibault,
at Vernouillet, from 1814 to 1828
Born at Paris, December 2nd, 1761
DIED
at Vernouillet, August 8th, 1828

(*Right side:*)

This monument has been erected to his memory
by a public subscription initiated by the
Municipality of Vernouillet in 1912

(*Left side:*)

The Paper Makers Salute the Illustrious
Inventor

II

The Didot Family

THE Didot family may be said to have been responsible for the invention of the paper-making machine by Robert, as they were the mill-owners and Robert worked for them. He thus had the opportunity of seeing how paper was made by hand and then getting the idea of making it by machine, on account of the difficulties and troubles they had with workmen going on strike and wanting more money, etc., at that time.

Actually the Didot family were very famous printers, and they excelled for a very long time in the art. The history of the family recounts that they were "Paris printers, publishers, and booksellers," and that eventually they also owned their own paper-mill at Essonnes. As printers they were well known throughout the world.

The first Didot of this family of whom there is any record was named Denis, and he was a butcher, but it was his first son, François, born in the year 1689, in Paris, who became the printer. Most of the Didots were born in Paris, close to the Seine, in the rue Seguier No. 2. In 1713, François Didot started in the book-trade as a bookseller, and in those days booksellers were usually also publishers. Eventually, in 1754, François started to print his books himself, in his own printing office, where the Gold Bible was hung out; but in 1757 he retired from business, and two years later he died. He had, however, laid the foundations of a firm that was to attain world-wide repute for its very fine editions.

François had two sons; the elder of whom, François-Ambroise, was born in 1730 and, in 1753, this man worked at his father's book-shop. A few years later, in 1757, he succeeded his father in the printing office, running it for thirty-two years, until 1789, and became even more famous as a printer than his father. He was chosen by Louis XVI to print the books from which the Dauphin had to learn. In 1777, he invented a new hand-press, and a method for glazing paper after it was printed; and in 1780 he printed the first French sheet of *satin* paper, which was made for him by the paper-mill of Johannot at Annonav.

It is recorded that in 1790, Benjamin Franklin, of the United States of America, who was himself a famous printer, paper expert, and publisher, came to Didot's printing office in Paris; and the grandson of Franklin eventually came to Didot to learn to engrave and to found types. In 1786, François-Ambroise printed the famous *Épître sur le Progrès de l'Imprimerie.* His elder son, Pierre, was the author of this work. Three years later he gave the management of the firm to his son, and he died in 1804.

François Didot had a younger son, Pierre François, who was born in 1732, and he also became a famous printer and publisher. He soon enlarged the interests of the family by buying the paper-mill at Essonnes in 1789. He was the first paper-maker among the Didots, and it was he who engaged Louis Robert for the printing office in Paris. Pierre François Didot died in 1795, and was succeeded at the mill at Essonnes by his son-in-law, Bernardin de Saint-Pierre, a famous French author.

The elder son of François-Ambroise Didot, named Pierre, was born in 1760, and he has probably contributed most to the fame of the Didot family as printers and publishers. He succeeded his father in 1789 in the printing office, and became so famous as a printer that he had permission to erect his printing office inside the Louvre, which was a very great honour, and the "Éditions du Louvre" are his memorial. It was in the Louvre edition that he published the famous Racine books, which were hailed in 1801 as the most perfectly printed books that had ever been produced. One of his better known books is perhaps the *Contes de la Fontaine*, for which Fragonard made fifty-seven sepia drawings, of which twenty-two were engraved. The original drawings have been, since 1934, the property of the Petit Palais in Paris. Pierre was nearly one hundred years old when he died in 1853, but in 1819 he handed over the management of the firm to his son, Jules, who lived from 1797 to 1871.

Firmin Didot, whom we have already mentioned as being the person who designed the Didot type and trained the grandson of Benjamin Franklin, was also the inventor of stereotype printing. The first book to be printed by the stereotype process was the *Tables of Logarithms*. This new process, which was invented by Firmin Didot in co-operation with Herhan in 1796, caused quite a sensation, as it was subsequently possible to have a series of good books at what were, for that time, low prices.

After this the Didot family obtained the right to join the name of *Firmin* as part of their surname to that of Didot.

Henri Didot, the son of Pierre, also became famous as a type-founder, and when he was quite old he cut and founded the "Microscopique," a small letter of $2\frac{1}{2}$ points which was easily readable.

Pierre-François Didot-Saint-Leger, who was born in 1767, and was the second son of the original Pierre-François, came into possession of the paper-mill at Essonnes, and it was he who was instrumental, along with Robert, in assisting in the invention, or rather in the turning of Robert's invention into a practical working paper-making machine with an endless wire. He called himself Didot-Saint-Leger; dropped his first two names and also the name of Firmin, which the family had been allowed to adopt; and he is generally known nowadays as Leger Didot.

From the foregoing it will be seen that the Didot family were very famous as printers and publishers, and eventually as paper-makers, but it is Didot-Saint-Leger or, as he is generally referred to, Leger Didot, with whom we are chiefly concerned in connection with the paper-making machine.

At first he did not encourage Robert at all with his idea of carrying on with an endless-wire machine, as he thought it was of little use. Eventually, however, when Robert had shown that he could make long sheets of paper continuously, he changed his mind and supported the idea. After Robert had patented it he bought the patent from him for 25,000 fr., but then he only paid a very small initial instalment, and Robert regained his patent by an action which he brought against Leger Didot. Leger Didot, as we have already seen in an earlier part of the book, then got a friend to take the patent to England and patent it there, and as soon as possible he went to England during a short peace in the war between England and France, being very glad to escape from France for political reasons; in fact, he never returned until 1819. While he was in England he was dependent for his support upon the Fourdriniers, which was a very great drain on their resources, since he used all his influence to persuade them that the continuous-chain-mould machine was likely to be of greater success than the endless-wire machine. He continued to patent this machine, with various improvements, up to 1817. He quarrelled regularly with Donkin, and generally seems to have been rather troublesome. When he saw that the continuous-wire machine was obviously a success in England, he had it patented in his absence in France, but the patent was not confirmed because he did not go over to France to support it in person. It is a fact that the first successful Fourdrinier-type endless-wire machine to be used in France was imported from England, and made by Donkin.

During Leger Didot's absence in England, he handed over the management of his mill at Essonnes to Louis Robert, but the mill eventually failed, due to labour troubles and lack of financial support from Leger Didot, and was sold. The Firmin-Didot family, however, continued to make paper for many years, and at one time, towards the end of the nineteenth century, they had three machines making printing papers and newsprint at Croth-Sorel, and three machines making printings at Sorel-Moussel.

After Leger Didot came back to France in 1818, apparently in order to earn some money, he surrendered some of his interest in his patents which he had taken out in France for the Fourdrinier machine to Baron Canson, for his paper-mill at Vidalon-les-Annonay. He also installed some machinery at a paper-mill at Jean d'Heures. This paper-mill carried on after Didot's death, and it was here that Didot died at the age of sixty-two. He thus followed Louis Robert to the grave one year after Robert's death.

DIDOT

Three generations of the family

- François 1689-1759
  - François-Ambroise 1730–1804
    - Pierre 1760–1853
    - Firmin 1764–1836 (paper-maker)
  - Pierre-François 1732–1795
    - Henri 1765–1852
    - Pierre-François Saint-Leger (Leger Didot) 1767–1829 (paper-maker)
    - Didot Jeune

III

John Gamble

JOHN GAMBLE, who played a very important part in the introduction of Louis Robert's continuous paper-making machine into England, was a brother-in-law of Leger Didot at whose mill at Essonnes the machine was invented, built and used.

We have given a detailed account, written by Gamble himself, of the early efforts of Louis Robert, and of the circumstances under which Gamble was able to bring the drawings to England and get the machine patented in 1801. It appears that Gamble did not return to his duties in Paris, but gave up his post under Captain James Coates, in connection with the exchange of prisoners of war, in order to work for Henry Fourdrinier on the perfecting of the paper-making machine.

Gamble worked with Donkin at Dartford and Bermondsey, and then went to live at Two Waters to supervise the erection and working of the paper-making machines at Two Waters and Frogmore Mills. The Fourdriniers also lived in great state near Two Waters.

Gamble subsequently left Two Waters and went to St. Neots to look after the interests of the Fourdriniers who had bought St. Neots Mill and installed a machine there.

Gamble managed St. Neots for some years, and the Fourdriniers intended to give him the mill, with two paper-making machines, to recompense him for all the work he had done for them since he first introduced them to the paper-making machine in 1801.

Unfortunately the Fourdriniers were so much indebted to Matthew Towgood, that although Towgood continued to employ Gamble when he obtained St. Neots Mill, he refused to put in the second machine unless Gamble contributed towards it financially. Towgood knew well that Gamble was in no position to do this, and made this an excuse to swindle Gamble out of his share of the mill. Towgood in fact instructed Gamble to offer the mill for sale. It was not sold and Towgood, having got rid of Gamble, eventually put in a second machine and continued to run the mill for many years. Gamble, having been thus deprived of the assets given to him by Henry Fourdrinier, went back to Donkin, who took him on, and put him in charge of his canned meat business. Donkin and Hall had formed a company to run the canned meat business, and they took Gamble into partnership.

Nothing further is known of Gamble, except that it is certain that he was working for Donkin for many years.

IV

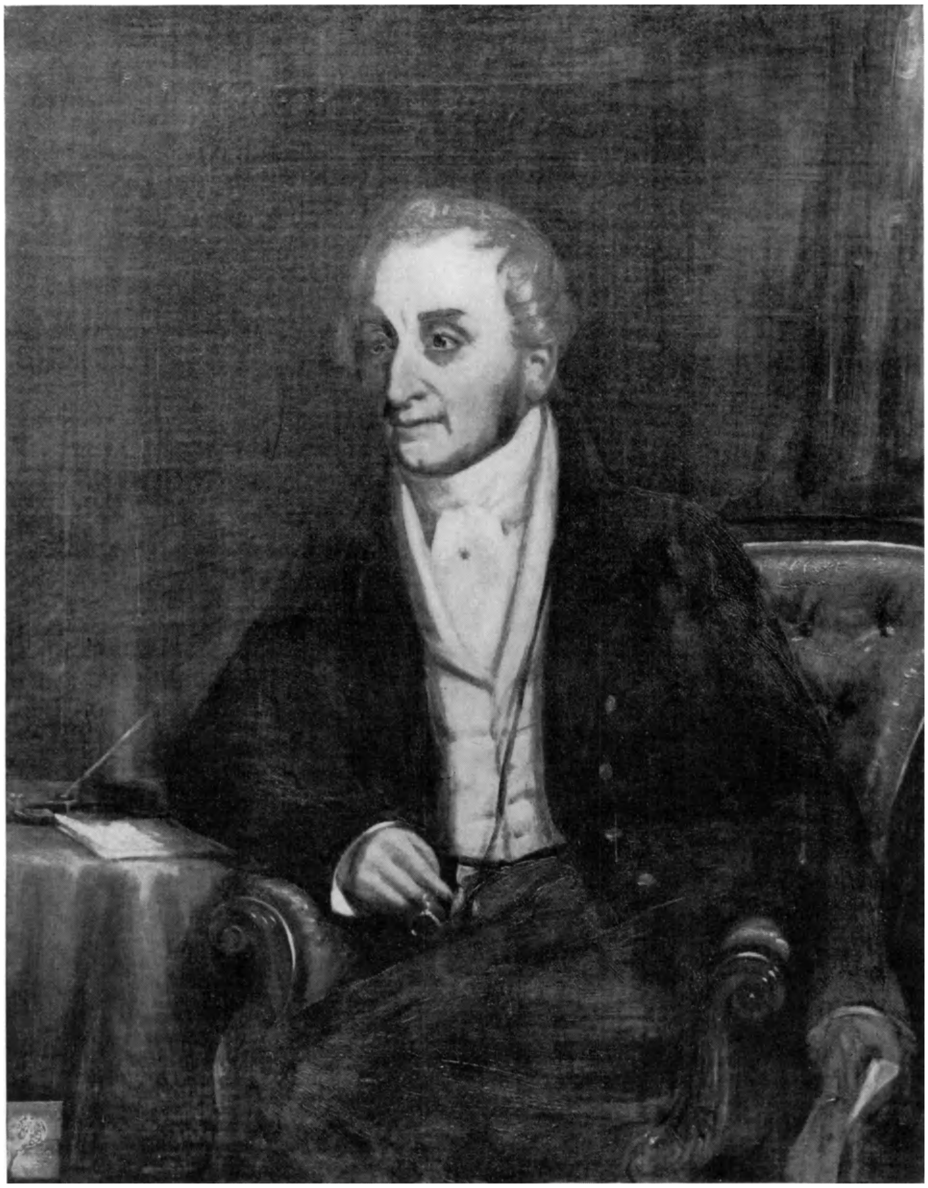
Henry Fourdrinier

THE Fourdrinier family were Huguenots who left France after the revocation of the Edict of Nantes, and went to Holland. Subsequently Pierre Fourdrinier, grandfather of Henry, came to England in 1719, and set up as a stationer and engraver in London, and the firm was later established as Bloxham and Fourdrinier in the year 1759. There is in existence a price-list giving the sizes and prices of their hand-made papers in that year. They also had paper-mills in which hand-made paper was made for a great many years before they became interested in Louis Robert's continuous paper-making machine, including one at Rickmansworth. The Fourdriniers' stationery business was a very substantial one, showing profits of £14,000 a year, which in those days was a great deal of money.

Henry Fourdrinier was associated with his brother Sealy, as well as with Bloxham, in the stationery business, which was in Sherbourne Lane in the City of London. Henry seems, however, to have been the one who was really interested in the paper-making machine, and who was responsible for spending so much money on its development, on account of the faith he had in it. Being an experienced paper-maker and stationer, he at once saw the possibilities of this machine, and eventually got Gamble to sell him a share in it. From this time forward he forced the pace of the Fourdrinier firm, and withdrew very large sums of money from the stationery business, which he seems to have rather neglected in order to develop the paper-making machine. It was Henry Fourdrinier who first of all took the French patent to John Hall, of Dartford, because Hall was the engineer who did the engineering work which the Fourdriniers required in their various hand-made mills.

As is well known, the Fourdriniers lost about £60,000 in the first few years of the development of the Fourdrinier machine, and became bankrupt in the process. There are many authentic particulars of how they suffered in their ordinary business in the evidence given to the Select Committee of the House of Commons in 1837, when this committee was considering whether the Fourdriniers should be recommended to the House of Commons as entitled to a reward for the money they had expanded on developing the paper-making machine for the benefit of the public, and the country as a whole.

When the Fourdriniers brought the Robert paper-making machine to Hall and asked him to develop it, Hall got in touch with Donkin and asked him to take on the work in Hall's works at Dartford. The work was carried on there until June, 1802, when the Fourdrinier brothers decided to take premises of their own, to be devoted entirely to perfecting the invention. A site in Bermondsey was selected and the factory erected, the undertaking being carried out on behalf of the Fourdriniers by Donkin, who had had charge of all the work at Dartford. In April, 1803, the factory at Bermondsey was started up at an address at Fort Place, and in the following year a working model was erected at the small mill at Frogmore, in Hertfordshire, which the Fourdriniers had taken for



Henry Fourdrinier. From an oil painting. Science Museum.

the purpose. Eventually they rented the factory at Bermondsey to Donkin. Here Donkin manufactured and sold the machines, and the Fourdriniers received an annual royalty from the users, paying from £80 to £200, according to the size of the machine. At least, that was the arrangement, but very few of these users ever paid the Fourdriniers any of the royalty due to them.

Owing to the want of enterprise among the paper-makers, and the opposition of the trade to the introduction of machinery, the business did not at first progress rapidly. During the first ten years only nineteen machines were made, and twenty-five during the second ten years. In 1811 the lease of the factory at Bermondsey was assigned to Donkin, he having until then rented it, with the plant and tools, from the Fourdriniers.

The following are some particulars taken from the hearing of the Select Committee into the affairs of the Fourdriniers, which show to what extent the country eventually benefited, the paper trade in particular, from the Fourdriniers' faith in the ultimate success of the machine.

The Select Committee met on the 9th May, 1837, and continued their sittings for several days. W. M. McKinnon was in the chair, and other members were Sir Oswald Mosley, Alderman Copeland, Mr. E. Bullough, Mark Phillip, Wilson Patten and Mr. Prime. The first witness was T. J. Bloxham, a son of the Bloxham who had been in partnership with the Fourdriniers. He proved that the Fourdrinier patent was good, and that the Fourdriniers were making an average profit of £14,000 a year in their stationery business, until they started to withdraw from the business to finance the paper-making machine. He proved also, to the satisfaction of the committee, that a sum of £60,000 had been withdrawn from the stationery business to further the development of the paper-making machine. Balance sheets were produced to prove all these matters. It was also proved that the Fourdriniers having taken all the money they could out of their business had to raise money by annuity; they were occasioned more loss. It was further proved that this caused their bankruptcy on the 8th November, 1810, under which Charles A. Bloxham, son of their former partner, and a person called Abbot, were appointed assignees on behalf of the unfortunate bankrupts. From being very flourishing stationers before they became concerned with the paper-making machine, and having a business making very big profits every year, by 1809 they had begun to make losses, and in that year the loss was £5635.

It was stated in evidence that no patent dues were received from the paper-makers from 1810 to 1816, because they took advantage of the fact that the Fourdriniers were bankrupt. It was also proved that the paper-makers employed the engineers of the Fourdriniers, namely the Bryan Donkin Company, to construct paper-making machines, and afterwards refused to pay patent dues for the working of them, taking advantage of their misfortune. This led to the Fourdriniers instituting suits in chancery, of which there were no less than twelve. Naturally this cost them a lot of money. There were also three or four actions of law, when witnesses had to be called from as far away as Dublin and Edinburgh; but the insistence on calling witnesses from these long distances was done in order to embarrass the Fourdriniers still further on account of the expense involved. This litigation cost the Fourdriniers over £5000, of which £2900 was still owing under the commission of bankruptcy.

The Fourdriniers were successful in most of their actions at law, but afterwards Lord Tenterden damaged them seriously by stating that in his opinion there was a technical objection to the validity of the cases because instead of being called paper-making machines, they were called *a paper-making machine*. This action of Lord Tenterden caused him to direct a new trial, but by this time the Fourdriniers' funds were entirely exhausted; they were not able to obtain any more money to go on with the case, so they let it drop. It appears that the Fourdriniers were actually owed very many thousands of pounds, but the paper-makers seem mostly to have behaved in a very bad way, and to have done everything they possibly could to avoid paying any of the dues under the patent which they were operating. The actual debit account of the Fourdriniers for the paper-making machine itself amounted to £51,865 12*s.* 10*d.* This was less any interest whatever, between 1823 and 1837, and was over and above the loss they had sustained in not carrying on their business as wholesale stationers, which had previously been so successful, and also very profitable.

The chief object of the enquiry by the Select Committee of the House of Commons was to establish that the Fourdriniers had expended a large sum of money in bringing to perfection an invention which not only benefited the public at large, but also the government itself, very substantially financially. The ultimate object being that the government should vote money to the Fourdriniers to finance them in their latter days, and to relieve them of the state of debt into which they had been reduced by the excellent work they had done in perfecting the paper-making machine. Overwhelming evidence was given before the committee in support of the claims of the Fourdriniers, and the committee were left in no doubt at all as to the great value to the country generally which had accrued from the establishment of the paper-making machine. One of the most damaging things, so far as the Fourdriniers were concerned, was the refusal of the House of Lords to extend their patent, this refusal being really the result of a ruse by Lord Lauderdale. The Commons passed a bill extending the Fourdrinier patent for fourteen years. The House of Lords extended the patent for seven years, and gave an undertaking that the Fourdriniers might apply for a further seven years if it could be proved by that time that they had not derived benefit from their patent. It was stated before the committee that in consequence of a regulation in the standing order introduced by Lord Lauderdale, none but the original inventor should be allowed to have an extension. Nevertheless, this ought not to have prejudiced the rights of Henry Fourdrinier, because it was considered that he was substantially the inventor of the machine.

It was contended before the Select Committee that Lord Lauderdale's action in putting this standing order upon the books of the House of Lords prevented Messrs. Fourdrinier from having any benefit from their invention. Further enquiry into the reasons which could have caused Lord Lauderdale to take this action were made by the committee, but they were not able to arrive at any conclusion as to the reason why he should have taken this course.

M. I. Brunel, the famous engineer, gave evidence before the committee on the great value of the Fourdriniers' patent and of their machine. Brunel said that in his opinion the specification of the paper-making machine was as perfect as a specification could be; and he further stated that he did not agree that Lord Tenterden's action in refusing to allow the patent was a valid one. Brunel also said that the Fourdrinier machine was one of the most splendid inventions of the age, considering what it did and what it was capable of doing. He went on to say that all the machines could make 1600 miles of paper in one day, and that one of the most beneficial results that had arisen from the invention was printing on rotary presses.

Another witness was George Turner, paper-maker, who said that although it was claimed that the Fourdrinier machine would do the work of five hand-made vats, it was capable of doing seven vats' work, and he frequently did this amount in his own mill. Among the enormous number of witnesses examined by the committee, paper-makers, printers, pottery manufacturers, and others, was John Joseph Lawson, a printer of *The Times* newspaper, who said that "great benefit had resulted from the manufacture of continuous paper, and that he couldn't conceive how they could get on without it, and they couldn't print a double sheet of *The Times*". He also considered that there was a great increase in consumption in consequence, because they printed now, in large sheets, as great a number as was originally printed in small sheets. One of the main advantages, as far as they were concerned, was that they could find room for a very large number of advertisements, and could also give the public very much more news. He strongly recommended that the Fourdriniers should be compensated financially for the money they had spent in perfecting the machine.

Another witness was Luke G. Hansard, who was the printer to the House of Commons, along with his brother. He thought that the invention of the Fourdrinier machine had been of enormous benefit to the printing trade, and had reduced the price of paper very considerably and, in particular, had reduced the time which it took to get an order for paper delivered. Many of the witnesses stressed this point, and insisted that when they were using hand-made paper they had to wait at least a month from the time they gave the order before they could get the paper; the time was often much longer than this. It was pointed out by very many witnesses that the hand-made mills were virtually controlled by the workers, and that strikes were very frequent, often the whole of the mill being at a standstill. Evidence was given that all the paper-mills making paper by hand had been shut down for eleven months, and no paper was available at all until the strike was settled. Moreover, it took very many years of apprenticeship to train a man to make a sheet of paper by hand, and in consequence the supply of men was limited, whereas it took only a very few weeks to train a man to run a paper-making machine, and no very high degree of manual skill was needed for this, as the machine did all the work. The committee themselves seemed to be much impressed by the fact that the machine was one way of getting over the combinations of workmen and strikes which were so frequent about this time, and caused great embarrassment to the country and the government. It was, of course, well known that the union or brotherhood of hand-made paper-makers was very strong, and that nobody could be engaged in a hand-made paper-mill who had not done seven years' apprenticeship.

The well known printer, George Clowes, also gave evidence, and said that "the Fourdrinier machine had been very beneficial to the printing trade, materially reducing the price of paper and enabling them to produce books at a much cheaper price". He believed that the paper-making machine had effected a complete revolution in the printing business, and where they used to go to press with an edition of 500 copies, they now printed 5000.

Many of the witnesses were asked by the committee whether they were in favour of Messrs. Fourdriniers having their patent returned to them. But all the witnesses were definitely against this, owing to the fact that the patent was common property, and that there could be a tremendous upheaval in the trade if the Fourdriniers had the right returned to them to demand compensation from all those people who were infringing their patent. All of them requested that the government should reimburse the Fourdriniers financially by a government grant!

All the printers who gave evidence said that the quality of the paper made on the paper-making machine was far better than that made by hand, that it was freer from knots, had very much better printing surface, and was generally much cleaner, more even and better made.

One piece of evidence placed before the committee was in the form of a letter from paper-makers in the neighbourhood of Exeter. It was dated at Exeter, the 22nd April, 1837, and read as follows:

> Gentlemen, We, the undersigned, paper-makers by machinery in the neighbourhood of Exeter, conceive it better to reply to you in a body than individually in answer to the letter received by Messrs. John and Henry Matthews. In December last we experienced a turn-out of our men, who were all practical paper-makers and members of their union, and which act suspended our work. The demands of the men were so improper and exorbitant that we were compelled to seek hands from other channels, and our mills are now in full work, having recruited our hands from agricultural labourers, carpenters and other artisans, which we are free to acknowledge we could not have done had we been working by manual labour as formerly. However willing we may be to render you every assistance in our power, and all the merits you deserve for perfecting the paper-making machine, yet we regret to find that your application to the House of Commons aims at a renewal of your patent, the restrictions of which we conceive would greatly shackle trade without rendering you the advantage you deserve, and should you persevere in that determination we shall consider ourselves bound, in justice to our own interests, to oppose you upon that point. As you already have a petition signed by us, as well as many other makers, to give you compensation, we sincerely hope that the House of Commons may be induced to remunerate you in that manner, than compel us to adopt steps that would be most unpleasant to our feelings.

The paper-makers signing the petition were John D—— (working two machines), Charles Matthews (two machines), Richard Matthews (one machine), R. and W. D—— (two machines), Matthews and S—— (one machine), Tremlett and Harris (one), and Harris and Tremlett (two), fourteen machines altogether.

Henry Fourdrinier was asked by the committee to put in evidence the number of paper-making machines at work, and what he estimated ought to have been paid to him in royalties on those machines supposing his patent had still been in existence. The list handed in to the committee by Henry Fourdrinier is given below:

	Vats,
There are 120 mills at work, with 1 machine, doing 5 vats' work -	- 600
There are 36 mills, 2 machines; 5 each machine, 10 vats' work -	- 360
There are 5 mills, 3 machines each, 5 vats, 15 ditto - - -	- 75
There are 4 mills, 4 machines each, 5 vats, 20 ditto - - -	- 80
There is 1 mill, 6 machines each, $4\frac{1}{4}$ vats, 25 ditto - - -	- 25
There are 2 mills, 7 machines each, $4\frac{1}{4}$ vats, 30 ditto - - -	- 60
TOTAL - 168 mills - - - - - -	1,200 vats.

	£.	s.	d.	
Each mill, with 1 machine, does 5 vats' work, when worked by hand; cost, 6 *l.* each vat per week, say 30*l.*; that in 52 weeks gives - - - - -	1,560	–	–	Our dues would be £.370.
5 vats, worked by a machine, cost 18 *s.* per week, is 4 *l.* 10*s.*; that in 52 weeks gives - - - -	234	–	–	
£.	1,326	–	–	
Each mill, with 2 machines does 10 vats' work when worked by hand, 6*l.* per vat, 60*l.*, 52 weeks -	3,120	–	–	Our dues will be £. 700.
10 vats, at 18*s.* is 9*l.*; 52 weeks - - - -	468	–	–	
£.	2,652	–	–	
Each mill, with 3 machines, does 15 vats' work when worked by hand, 6 *l.* per vat, 90*l.* - - - -	4,680	–	–	Our dues will be £.1,050.
10 vats, by machine, at 18*s.*, 13*l.* 10*s.* - - -	702	–	–	
£.	3,878	–	–	
Each mill, with 4 machines, does 20 vats' work when worked by hand, at 6*l.*, 120 *l.* - - - - -	6,240	–	–	Our dues will be £. 1,400.
20 vats by machine, at 18 *s.*, 18*l.* - - - -	936	–	–	
£.	5,304	–	–	
Each mill, with 6 machines, does 25 vats' work when worked by hand, at 6 *l.*, 150*l.* - - - - -	7,800	–	–	Our dues will be £. 1,750.
25 vats, by machine, at 18*s.*, 22*l.* 10*s.* - - -	1,170	–	–	
£.	6,630	–	–	
Each mill, with 7 machines, does 30 vats' work, when worked by hand, at 6*l.*, 180*l.* - - -	9,360	–	–	Our dues will be £. 2,100.
30 vats, by machine, at 18*s.*, 27 *l.* - - - -	1,404	–	–	
£.	7,956	–	–	

Henry Fourdrinier was then asked how many machines were at work at the time that the patent expired. He stated there were forty-two machines paying the dues of one hundred and thirty-two vats. The list of the paper-makers and their mills, and the equivalent number of vats, follows:

DATE of LICENSE.	TO WHOM GRANTED.	WHERE ERECTED.	No. Vats.
20 May 1807 -	Eliz. and James Swan - - - -	Evesham, Oxon -	10
4 Nov. „ -	Barn. Sullivan - - - - -	Cork - - -	3
1 July „ -	Lewis Smith - - - - -	Aberdeen - -	10
1 July „ -	J. B. Sullivan - - - - -	Cork - - -	10
1 July „ -	- - - - - - - - -	Blarney - - -	3
1 July „ -	John Phipps - - - - -	Dover - - -	10
1 July „ -	E. Martindale - - - - -	Cambridge - -	3
1 July „ -	Bacon Novino - - - - -	Norwich - -	4
1 July „ -	Rd. Elliott - - - - - -	Chesham - -	2
1 July „ -	Wrightons & Co. - - - -	Warwick - -	3
1 July „ -	Wright & Pepper - - - -	Marlow - - -	3
1 July „ -	Ibbotson & East - - - - -	Colnbrook - -	3
1 July „ -	John Buttenshaw - - - - -	- - - - -	2
			66
14 July 1816 -	James & John Livesey - - -	Prestolee, near Bolton	3
20 July „ -	John Livesey - - - - -	- - - - -	3
25 Jan. 1817 -	Binning Arnold - - - - -	Kingsland-road -	2
28 Aug. „ -	James & Francis Wrigley - -	Bridge Hall, Bury -	2
1 Nov. „ -	Smith & Rhedde - - - - -	Newcastle-under-Lyne	2
29 Dec. „ -	James Martin - - - - -	Wood Mills, Leeds -	2
3 Jan. 1818 -	Nelsons - - - - - -	Retford, Notts - -	2
20 Feb. „ -	J. & T. Crompton - - - -	Farnworth, near Bolton.	3
14 March „ -	- - - - - - - - -	- - - - -	2
25 Feb. 1821 -	- - - - - - - - -	- - - - -	2
25 July 1818 -	Smith & Ingle - - - - -	Thoostleness - -	3
14 Aug. „ -	N. Grace & Co. - - - - -	Llotwove Mill, Newcastle.	3
14 Aug. „ -	Abr. Smith - - - - - -	Langley, near Durham	2
16 Nov. „ -	John Ibbotson - - - - -	White Hall, near Manchester.	3
3 Nov. 1819 -	Charles Venables - - - - -	Hampton Guy, near Woodstock.	2
11 Nov. „ -	James Pegg - - - - - -	Wooburn, Bucks -	3
5 Nov. „ -	Joseph Wright - - - - -	Marlow - - -	2
5 Nov. „ -	- ditto - - - - - -	- ditto - - -	2
30 Nov. „ -	P. J. Fromow - - - - -	Clapton, near Wooburn, Bucks.	2
30 Nov. „ -	J. Allnutt - - - - - -	Chesham, Bucks -	2
5 June 1820 -	E. Wright - - - - - -	Thorney, Bucks -	2
5 June „ -	Flint & Tregent - - - - -	Littleton, Evesham -	2
15 July „ -	J. C. Radway - - - - -	Quimmington, Fairford	2
22 Feb. 1821 -	William Hill - - - - -	Greenfield, Holywell	3
28 June „ -	Grafton & Co. - - - - -	Birmingham - -	2
25 July „ -	T. Tempest - - - - - -	Little Eaton, Derby -	2
3 Nov. „ -	William Truer - - - - -	Coosbean, Cornwall -	2
16 Feb. 1822 -	John Pyne - - - - - -	Tovil - - -	2
2 May „ -	George Payne - - - - -	Choriton, Dover -	2
			66

Henry Fourdrinier was then asked how many machines were now at work in 1837, and he stated that the number was two hundred and seventy-nine, each machine doing the work of five vats, so that the total number of machines was equal on the whole to 1395 vats.

When Henry Fourdrinier was asked if he could give any proof of the great increase accruing to the revenue from the duty on paper from his machine, he produced letters from paper-makers. One was dated the 19th February, 1834, and it stated:

> In reply to your communication of the 17th inst., now before us, we beg to inform you that the amount of duty which we paid for a six-weeks period in the year 1828, when our concern was working upon hand-moulds, was under £100, and that it is now upwards of £3000, and though we cannot in justice attribute the extension on our part by any means solely, or even principally, but to the improvement in the paper-making machine, we have no hesitation in saying that without such a machine the extension could not have been so rapid, or perhaps at all practicable; and that by its means there is unquestionably a great saving effected, a better paper produced, and one more applicable to the general interests of the printers, than ever could have been done by hand.
>
> Signed C. H. and E. Hilton,
>
> Darwen Mills, near Blackburn, Lancs.

Another letter was put in by Henry Fourdrinier from John Livesey, of Springfield Mills, near Bolton. This letter is dated the 19th February, 1834, and is as follows:

> My dear Sir, I take the first opportunity of replying to your favour of the 17th inst., and shall be most happy to afford you all the information that lays in my power, in order that you may obtain that remuneration for which you are so justly entitled to. I believe that it was solely through your *perseverence* that the paper-making machine was brought to perfection, and I am positive that had there been no intention of making paper by machinery, then at this period there would not have been two-thirds of the duty paid that is at present paid. As regards my own concern, we paid only about £3000 per annum before we introduced your *machinery*; since then, we have paid upwards of £12,000 per annum in *duties*, and that for a many years back. Another great advantage derived is, that we can now make paper of any size for the purpose of packing goods with, whereas formerly they had to substitute *calicoes* and *wrappering*; and the duties paid upon these *extra-sized papers* must be productive of an immense revenue to the Government. If you will inform me when your petition is ready to be presented to the House of Commons, I will then write to both our borough Members to give it their best support.
>
> I remain, dear Sir, yours most truly, John Livesey.

Another letter was put in, among many others, from the Potteries, in this case from Messrs. Davenport, of Longport. The potters seemed to be very grateful that very large reductions had been possible in the price of paper, and they go on to state a list of the prices of pottery tissue from the year 1814 to 1833.

	1814	1822	1833
Demy. pottery tissue	11*s*. 6*d*.	9*s*. 0*d*.	7*s*. 0*d*.
Large Plate:	19*s*. 0*d*.	15*s*. 0*d*.	10*s*. 3*d*.
Royal:	16*s*. 3*d*.	12*s*. 0*d*.	8*s*. 9*d*.
Large Royal:	19*s*. 0*d*.	15*s*. 0*d*.	10*s*. 3*d*.

The potters stated that they considered the immense reduction in the prices of tissue paper was attributable to the introduction of the paper-making machine. They had no hesitation in stating that much of the improvement that had taken place in the manufacture of printed earthenware could not have been accomplished had not the quality of the paper kept pace with the improvements in the engraving department. With the aid of Fourdriniers' superior quality of pottery tissue adapted to the present style of engraving now in general use, there had been proved to be a great improvement, which was everywhere visible in the quality of printed earthenware and china.

The Clarendon Press also sent in a return of prices charged to the Clarendon Press for the University of Oxford. Their letter is dated Oxford, the 19th February, 1834:

> Sir, I am desired to say, in reply to yours of the 12th instant, that as there will be no meeting of the delegates for a considerable time to come, your questions concerning papers cannot at present as it regards our press, be answered. I have, however, inquired of Mr. Swan of Wolvercote the prices of paper at the different periods you mention, and he has favoured me with the following particulars:

The year	1814,	17*d.* per lb.	fine quality
	1820,	16*d.*	-do-
	1827,	14½*d.*	-do-
	1834,	12*d.*	-do-
	1814,	15*d.* per lb.	second quality
	1820,	14½*d.* and 14*d.*	-do-
	1827,	13½*d.*	-do-
	1834,	11*d.*	-do-

The letter is signed by John Arnett.

The committee finally set themselves two questions. The first leading question was: "What pecuniary advantage have the government already received in revenue from this invention?"

1800	No Machines duty	£195,641	14*s.*	6*d.*
1807	Machines partially established	£424,668	8*s.*	9*d.*
1814	Patent litigated	£484,930	2*s.*	6*d.*
1821	Machines progressing	£579,867	11*s.*	10*d.*
1828	-do-	£766,954	13*s.*	10*d.*
1835	-do-	£833,822	0*s.*	0*d.*

Ample proof of the great and gradual increase of revenue.

The second question was: "What saving have the public already received from the machines?" (see table on p. 297).

After the report of the Select Committee was ready there were several delays before it could be laid before the House, and the Fourdriniers addressed a letter to members, in the hope that they would see that the committee's report was attended to.

When the report was presented to the House, in which a recommendation of £20,000 had been made, the Speaker took exception to it because the word *compensation* occurred in it, for which he said there was no precedent, although it was afterwards pointed out that this opinion was erroneous. Then the matter slumbered for a couple of years, although one of the Chancellors of the Exchequer of that day seems to have thought that £15,000 might reasonably be granted to the Fourdriniers. As the government appeared to be reluctant to do anything themselves, Mr. McKinnon, the chairman of the Select Committee, in the spring of 1839, moved in the House that some definite action

ACCOUNT *of the Number of Machines and when Established*

Year Erected	Number of Machines		Number of Years at Work	Saving each Year	Saving from time Erected
				£ s. d.	£ s. d.
1807	13		31	31,754 13 4	984,394 13 4
1816	2		22	4,885 6 8	107,488 6 8
1817	4	Annual Saving	21	9,770 13 4	205,184 0 0
1818	7	of each Machine,	20	17,098 13 4	341,973 6 8
1819	6	as proved in	19	14,656 0 0	278,464 0 0
1820	3	evidence before	18	7,328 0 0	131,894 0 0
1821	5	Committee:	17	12,213 6 8	222,282 13 4
1822	2		16	4,885 6 8	78,165 6 8
1824	34	£2,442 13*s.* 4*d.*	14	83,050 13 4	1162,709 6 8
1826	30		12	73,280 0 0	879,360 0 0
1830	43		8	105,034 13 4	840,277 6 8
1832	45		6	109,920 0 0	659,920 0 0
1834	46		4	112,362 13 4	449,450 13 4
1836	40		2	97,706 13 4	195,413 6 8
				Total Saving	6536,577 0 0

Total: 280 Machines; saving annually for ever, £683,846 13*s.* 4*d.*

be taken upon the report of 1837. Some debate ensued, and Sir Robert Peel said that if the government's hands were not forced they would do full justice to the case.

One speaker referred to the fact that although the Fourdriniers were not the original inventors of the machine, it had been brought by them to such a degree of perfection as to enable the public to benefit by the discovery. The motion, however, was withdrawn in deference to the express wishes of the government. Another year passed by, and then a grant of £7000 appeared in the supply estimates for the current financial year. The vote was discussed in the House of Commons on the 8th May, 1840. The Chancellor of the Exchequer, in proposing it, said that he had great hesitation in proposing anything; that such a course might tend to encourage disappointed inventors to look to the government to recoup their expenses rather than to their own efforts. When the vote of £7000 was eventually passed, it was said that one of Henry Fourdrinier's sons alone had spent no less than £3000 in the efforts to get it.

As is well known, it was recommended that the Fourdriniers should receive £20,000 compensation, but this was finally whittled down in the House of Commons to £7000. This was surely a very mean act, having regard to all the circumstances and advantages which had been finally proved before the committee. It is a fact that Henry Fourdrinier lived to see that his own persistence had produced a very flourishing paper-trade, using machinery, throughout the length and breadth of the British Isles, and also all over Europe, including Scandinavia, Russia, France, Germany, and almost every other country. At the same time he saw also the enormous development of the printing trade, with cheap books and encyclopaedias and newspapers available to everybody. Yet in spite of the enormous success of the paper-trade and the printing trade during all the years of his life, he himself got absolutely no reward, and died practically in poverty.

During the time that the Fourdriniers were in such difficulties in financing the paper-making machine, their firm changed its identity on many occasions. The original firm of Bloxham Fourdrinier changed to that of Henry and Sealy Fourdrinier, as Bloxham became frightened of the financial position being created by the expenditure on the machine. The firm then became

Fourdriniers (Henry and Sealy), Towgoods (Matthew, Senr. and Junr.), and Fourdrinier (Charles), early in 1809. By the 31st October, 1809, the name was changed to Fourdriniers (Henry and Sealy), Towgood (Matthew, Junr.), Fourdrinier (Charles), and Hunt (Joseph Brooks). Towgood's London address was moved to Sherbourne Lane, and he evidently took over the Fourdriniers' stationers business there before moving to Upper Thames Street.

Some years after the small amount of £7000 was voted to the Fourdriniers by Parliament, *The Times*, which had supported this appeal, again called for justice in the following words:

> The important disclosures that have been made in the course of recent discussions upon the rise and progress to paper-making have awakened a desire on the part of some persons directly interested in the subject to show their appreciation of the merits of the man by whose untiring efforts and great pecuniary sacrifices the paper-making machine was perfected. Results, however, that have accrued from that admirable invention have proved so universally beneficial that to justify an appeal to society at large to co-operate in bestowing a reward to the inventor. It was the original intention of the promoters of the testimonial to purchase an annuity on the lives of Mr. Fourdrinier and his two unmarried daughters. A portion of this design has become impossible through the death of the father, but his claims upon the public gratitude have not died with him, and the reward that would have given to the inventor may with equal justice be bestowed upon the daughters, whom he has left with slender provision. Subjoined is a list of the committee who have undertaken the management of the fund, and also of the subscription already received. Further subscriptions will be received by the secretary, the treasurer, and by Captain Barford, the collector appointed by the committee. The committee follows:
>
> Charles Cowan, Esq., M.P.,
> Thomas Spalding, Esq.,
> William Joynson, Esq.,
> Francis Pirie, Esq.,
> George Chater, Esq.,
> George Staff, Esq.,
> Herbert Ingram, Esq.,
> William Somerville, Esq.,
> William McMurray, Esq.,
> Treasurer: George Chater, Esq.,
> Cannon Street, W.
> Hon. Secretary: W. McMurray, Esq.,
> 39 Queen Street, Cheapside.
> Bankers: Prescott, Groter and Company,
> 26 Threadneedle Street.

Among the subscribers:	£	s.
The proprietors of *The Times*	100	0
The proprietors of *The Weekly Times and London Journal*	100	0
Messrs. Spalding and Hodge	100	0
Messrs. William Joynson and Sons	100	0
The proprietors of *The Illustrated London News*	10	0
Messrs. Alexander Pirie and Sons	50	0
Messrs. Alexander Cowan and Sons	50	0

	£	s.
Messrs. Grosvenor, Chater and Company	50	0
W. Somerville, Esq.	10	0
W. McMurray, Esq.	50	0
His Grace the Duke of Sutherland	20	0
The Rt. Hon. The Earl of Harrowby	5	0
P. Ibbotson, Esq.	5	0
Messrs. Balston and Company	10	10
Messrs. Lepard, Smith and Company	2	2
Messrs. J. and E. Saunders	1	1
Messrs. Venables and Company	10	10
Messrs. Whitehead Bros.	5	5
James Matthew, Esq.	20	0

Altogether there were about seven hundred subscribers. Very small annuities were bought for Henry Fourdrinier's surviving daughters.

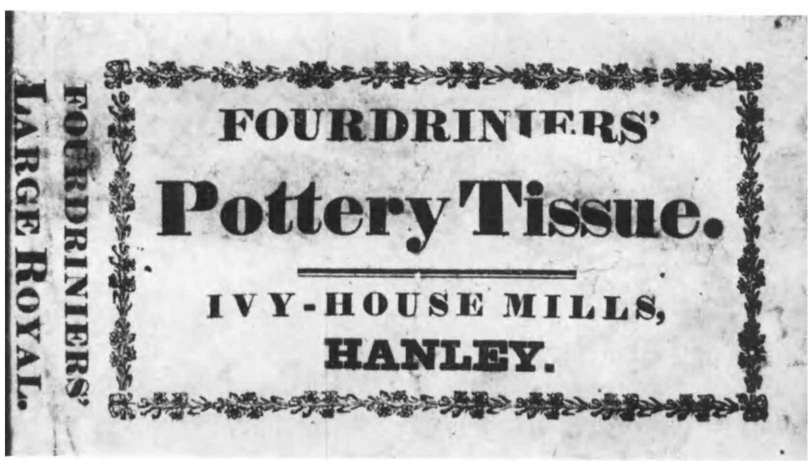
On the 9th September, 1854, Henry Fourdrinier died at the age of 88, at The Old Rectory, Mavesyn Ridware, Rugeley. It was a very poor house, but he was locally regarded as a very nice old gentleman, who never showed in any way that he was well-off!

George Henry Fourdrinier, Henry Fourdrinier's son, had, at the time of his father's death, the Ivy House Mill at Hanley, nearby, which was subsequently taken over by Brittain. Brittain, who was the originator of the very well-known firm of Brittains Ltd., makers of fine tissue papers, purchased the Ivy House Mills from the Fourdriniers in 1855, a year after Henry Fourdrinier senior's death. It was stated that Brittain had previously been associated with the banking profession at a private bank in Newcastle-under-Lyme, and tradition has it that Brittain as a banker was aware that the Fourdriniers were personally extravagant, and concluded that the paper-mill could be worth buying. This case is rather similar to the Towgood case, when Henry Fourdrinier, senior, became indebted to Matthew Towgood, who was his banker, and who eventually took over the mill from him. Messrs. Brittains Limited still have two chairs at the mill which belonged to the Fourdriniers when they had Ivy House Mills.

From this it would appear that the Fourdrinier family ended their connection with the paper-trade entirely one year after the death of Henry Fourdrinier, senior, and there seems to be little record of what happened to the family after this, except that the name continued in the paper trade as Fourdrinier Hunt and Co., for many years, as stationers.

Although Henry Fourdrinier did not invent the paper-making machine, there seems to be very little doubt that had it not been for his dogged persistency in sticking at it, through thick and thin, whether he had money or not, the machine would never have come to the perfection which it reached in the first quarter of the nineteenth century.

A Fourdrinier Ream Label of 1836. Ivy House Mill No. 630.



Fourdrinier Ream Label for Pottery Tissue. Ivy House Mill No. 630.

Extract from "History of the Borough of Stoke-on-Trent" by John Ward (1842)

As an object of the first rank, among the many mechanical improvements of modern times, we must place the Ivy House Paper Mill in Hanley, belonging to Messrs. Fourdrinier, seated on the banks of the Caldon Canal, worked by steam power and employed in making the tissue paper used by the potters in the printing of their copper plate engravings, and coarse papers for wrapping and common purposes. This undertaking was set on foot here in the year 1827 by the enterprising family who had for many years before, at their establishments in Hertfordshire, bestowed the most unremitting labour, and expended a large capital, in improving the process of paper-making. The elder Mr. Fourdrinier obtained a patent for his important invention, and afterwards an Act of Parliament, to prolong the period of its exclusive use; but the other paper-makers, finding themselves thrown into the background by the superiority of Mr. Fourdrinier's process, combined to deprive him of the benefit of it; infringed his patent-right; involved him in long and expensive litigation to maintain it; and finally brought him to the brink of ruin. Hereupon he petitioned Parliament for compensation for his losses, and remuneration for his invention, which had so greatly benefited the nation at large. He pressed his claims for a series of years; and at length, in the session of 1839 obtained partial justice, by a vote of the House of Commons, granting him £7000; a sum which, on all hands, was admitted to be very inadequate to the public benefit derived by means of his invention. The machinery so introduced has been adopted by nearly all the paper-makers in the United Kingdom; has been carried abroad, to America, Russia, and other Continental nations, and affords as complete an example of the superiority of mechanism over mere manual operations, as the silk, cotton, and worsted manufactures can lay claim to. The paper is produced, quite sound dry, and perfect, from mere pulp in the space of a few minutes, in sheets of ample breadth and endless extension.

The water-works of John Smith, Esq., a gentleman of large landed property, in this neighbourhood, adjoin the Paper-Mill of Messrs. Fourdrinier. They were set on foot in 1820. The water is pumped by a steam-engine of 48 horse-power from a well thirty-six yards deep, and also works a forcing-pump, by means whereof the water is conveyed up a steep acclivity (138 ft in vertical height), to the summit of the hill which overlooks the town of Hanley onto a reservoir adjoining the windmill. . . .

A Silk-Mill, worked by steam was erected by —— Baddeley at East Wood, South of Hanley, in 1824, but abandoned after an unsuccessful trial of a few years, and is now converted into a mechanical work, and employed by Mr. Joseph Fourdrinier, in making machines and movements for the use of the paper-manufacturers generally.

V

John Hall, 1764-1836

THE first connection of the Hall family with Dartford occurred thirty years before the Hall Engineering Works were started, for in 1755 William Hall, father of John Hall the founder of the works, was working in Dartford as a millwright; later he went to Laverstoke in Hampshire, and there worked in the paper-mills of Portals, where bank-note paper was made. He there brought up four sons to the trade of millwright. In after years William Hall came back to Dartford, lived his last years with his son John, and died at the age of eighty-four. He is buried in the old burial ground on East Hill.

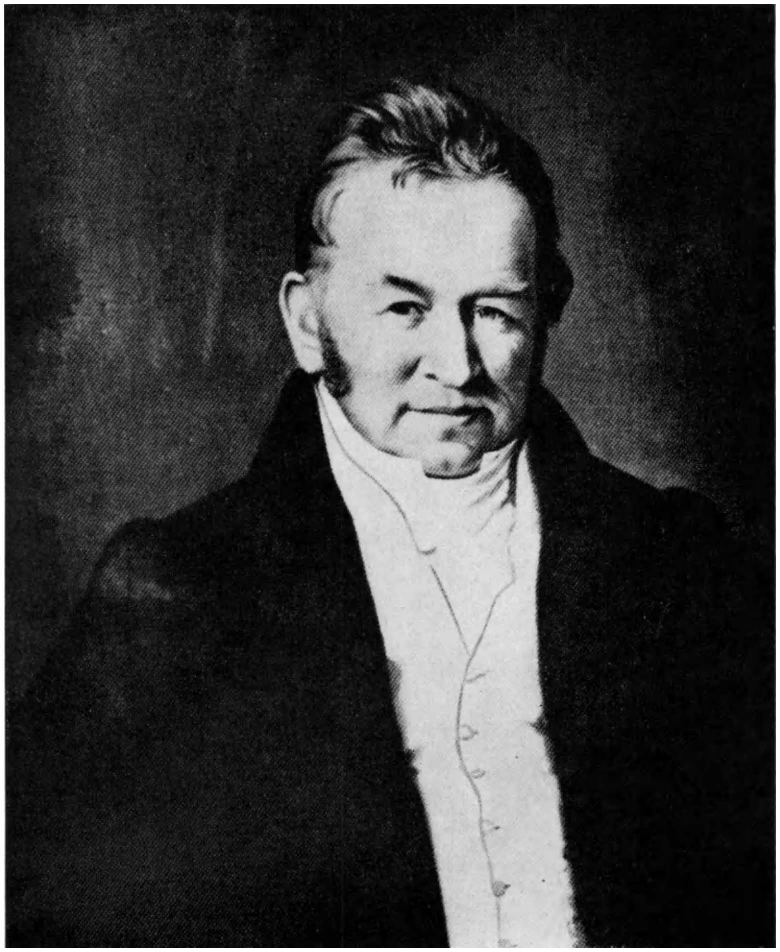
John Hall, the founder of the firm, was the second son of William Hall, and was born at Laverstoke in 1764. On the 9th April, 1784, at the age of twenty, having completed his apprenticeship with his father, he walked into Dartford seeking work. His skill as a mechanic was soon recognized by the mill owners in and around the Darent Valley, and he was induced by them to set up in Dartford. Accordingly, in 1785, he started a small blacksmith's shop in Lowfield Street. After a few years his business prospered so much that he required larger premises; he obtained possession of an old tanyard in Hythe Street (then called Waterside) and there set up a foundry, which still forms part of the works of the present day. Adjacent to this site is land forming part of the old demesne of Dartford Priory, and in 1789 it was sold by auction to Peter Brame, a descendant of an opulent Flemish family. Brame settled down there as a market gardener with his wife and family, and Hall became very friendly with his neighbours and their four pretty daughters. At the firm's celebration of its one hundred and twenty-fifth anniversary in 1910, Canon Nolloth of Beverley, a descendant of the Hall family, related how difficult John Hall found it to choose which of the daughters should be his wife. Paying a visit early one morning, he found three of the young ladies had not yet risen, but Sarah was up, active and attentive. He said that was the one for him, and she became Mrs. John Hall in 1791. They had ten children. Another daughter married Bryan Donkin, and a third daughter John Nolloth. As Mrs. Hall was the mother of John and Edward, it is not inappropriate that her portrait should appear amongst the founders of the firm.

Even at this time John Hall was so well known as a paper-mill engineer that he was carrying out work for paper-mills in Scotland, at Duns and Penicuik.

There was a considerable stream of water running down Waterside Street, and in 1801 John Hall obtained an order of the justices to divert this water into his premises so that he could obtain power from it to drive his machinery. Prior to that he was dependent upon the uncertain power of a windmill. The reservoir fed by this stream is shown in a reproduction of a plan dated 1807.

Several well-known names are among those who learnt their business at Hall's works, such as Richard Trevethick, Humphreys (of Humphreys and Tennant), and the Bertrams of Edinburgh.

John Hall, who had six sons and four daughters, died in 1836 at the age of seventy-one. At the time of his death, besides his engineering works at Dartford he owned gunpowder works at Faver-



John Hall of Dartford.

sham, which he bought from the government; paper works at Horton Kirby; a flour mill at Chislehurst; and a stall at Covent Garden Market, kept supplied from a market garden at Dartford, which devolved to him in right of his wife, née Sarah Stainton Brame. Since 1900 this garden has been absorbed by the extensions of engineering works. These businesses were divided among his sons, and the engineering works were left to John and Edward. John junior died in 1850, and left the works to his sons John and Edward, who gave their names to the well-known firm of J. and E. Hall, of Dartford, which enjoys a world-wide reputation at the present time.

It is interesting to note that William and James Bertram served their time under John Hall, and afterwards started work at Edinburgh and, as Bertrams Ltd., are still famous the world over for paper-making machinery.

The first machines for reeling paper, and a guillotine machine for cutting the reels, were invented and made in these works, but John Hall's interests in other matters caused him to allow this trade to fall into other hands: Bryan Donkin, the Bertrams, and Tidcombe (of Watford), all of whom he had trained.

In 1805, John Hall, with Simpson, Penn, Donkin, and other celebrated engineers, started the society of master millwrights.

In 1810, John Hall, in association with Donkin and Gamble, bought for £1000 a French patent by a chemist named Appert for preserving meat and other foodstuffs by canning (see also under Bryan Donkin, pp. 307–8). Although unsuccessful at first, improvements were introduced until, in 1813, the process was so far perfected that a canning factory was set up in Bermondsey, and later one in Cork. The products were supplied to the Royal Navy and to the general public; and it is interesting to note that Ross and Franklin used these preserved foods in their Polar expeditions. Several tins which had been buried in the ice for years were brought back with other Franklin relics by McClintock in 1857. This appears to have been the pioneer of the present huge canning industry in Australia, Canada, America, and now in our own country. But Halls were destined to do far more than this in food preservation three-quarters of a century later in the refrigerating business.

In March, 1821, Hall must have suffered from a serious fire at his works, judging from a notice which still exists. He says in a letter of thanks to his neighbours who helped him that "he is deeply sensible that human exertions were never more strenuously exercised. . . ." Anyone who has seen a manual fire pump at work can well believe this. Some doubters wondered whether the small squirt of water pumped exceeded the gallons of beer consumed!

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.

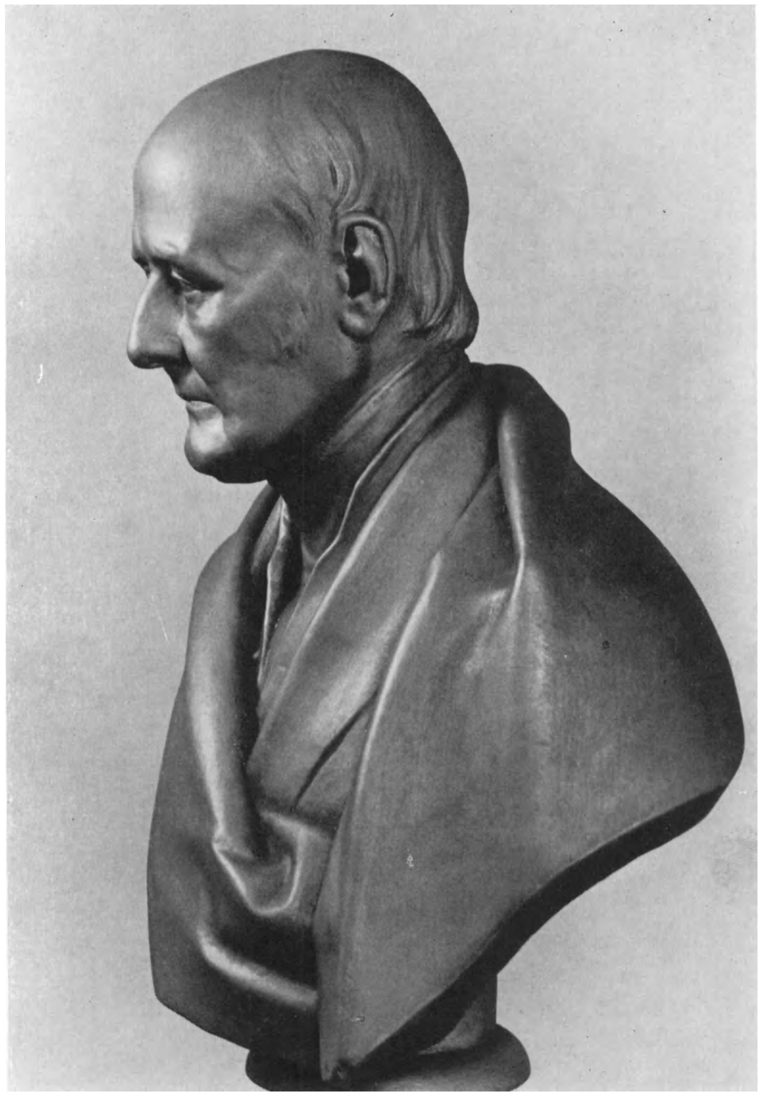
At the age of twenty he came south, and obtained the post as agent to the Duke of Dorset, at Knowle Park, Sevenoaks, where he remained for about two years.

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 1½ 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 2½ 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 2½% 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 70 ft long and 20 ft 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.

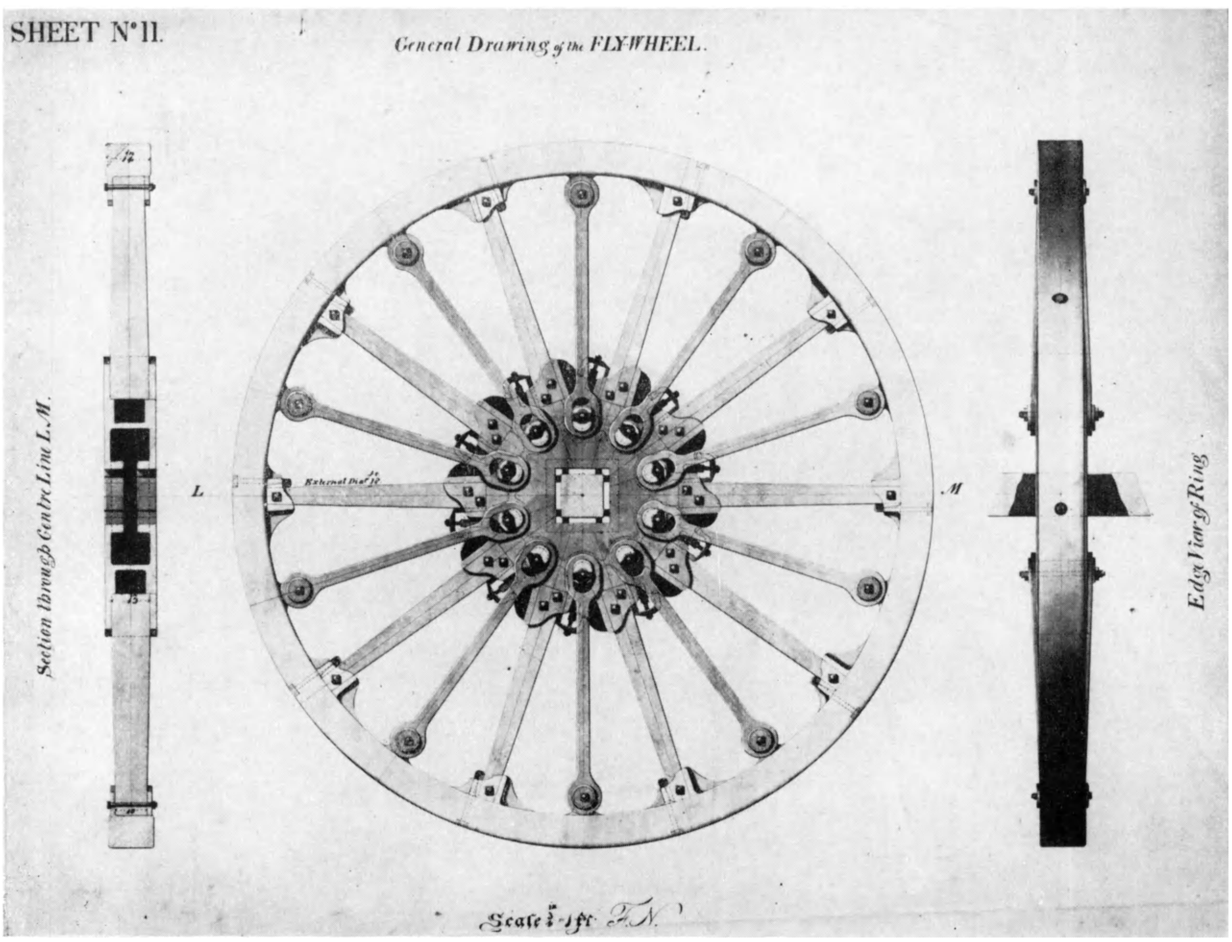
Donkin invented and made a dividing machine for dividing scales in minute and exact graduations, and this may be seen at the Museum of Science and Art at South Kensington.

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.

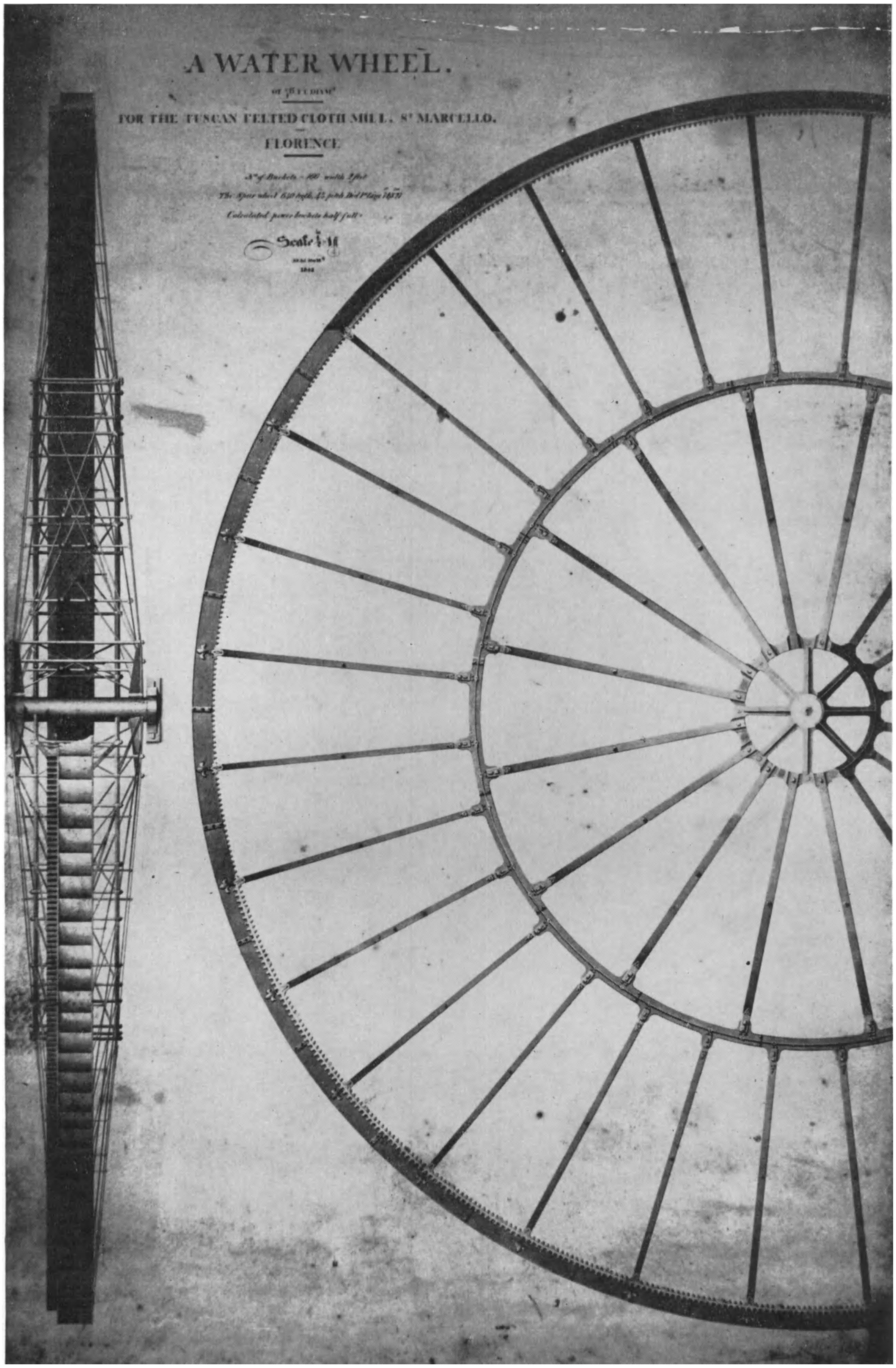
During the first half of the century, although steam power was rapidly being adopted as an auxiliary, the paper and other mills with which the firm did its principal business depended chiefly on water power. For this purpose many water-wheels were built at Bermondsey, one of these being of a very special 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.

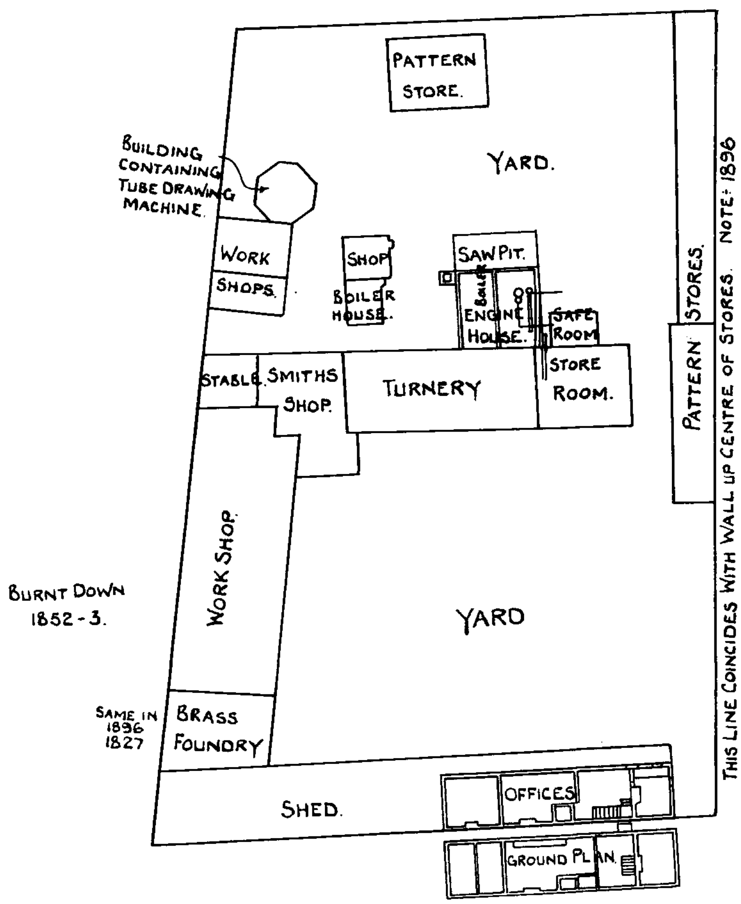
In 1820, Congreve obtained a patent for printing in two or more colours, the immediate object being to make imitation and forgery more difficult, particularly in connection with printing official stamps, notes, registered designs, and trade marks from dies.

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.

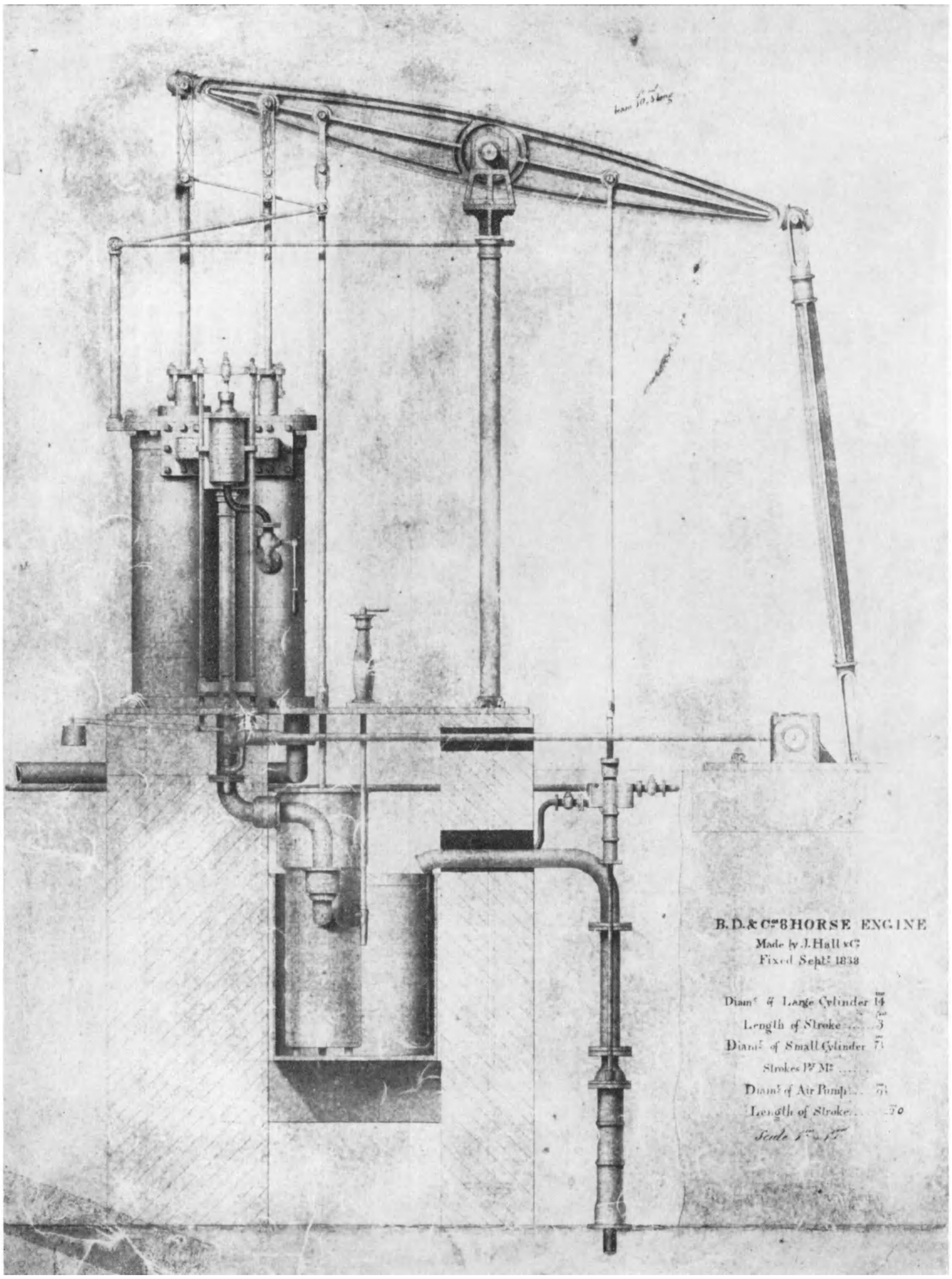
In the Science Museum, South Kensington, there are many examples and models of the inventions of Donkin, namely:

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."

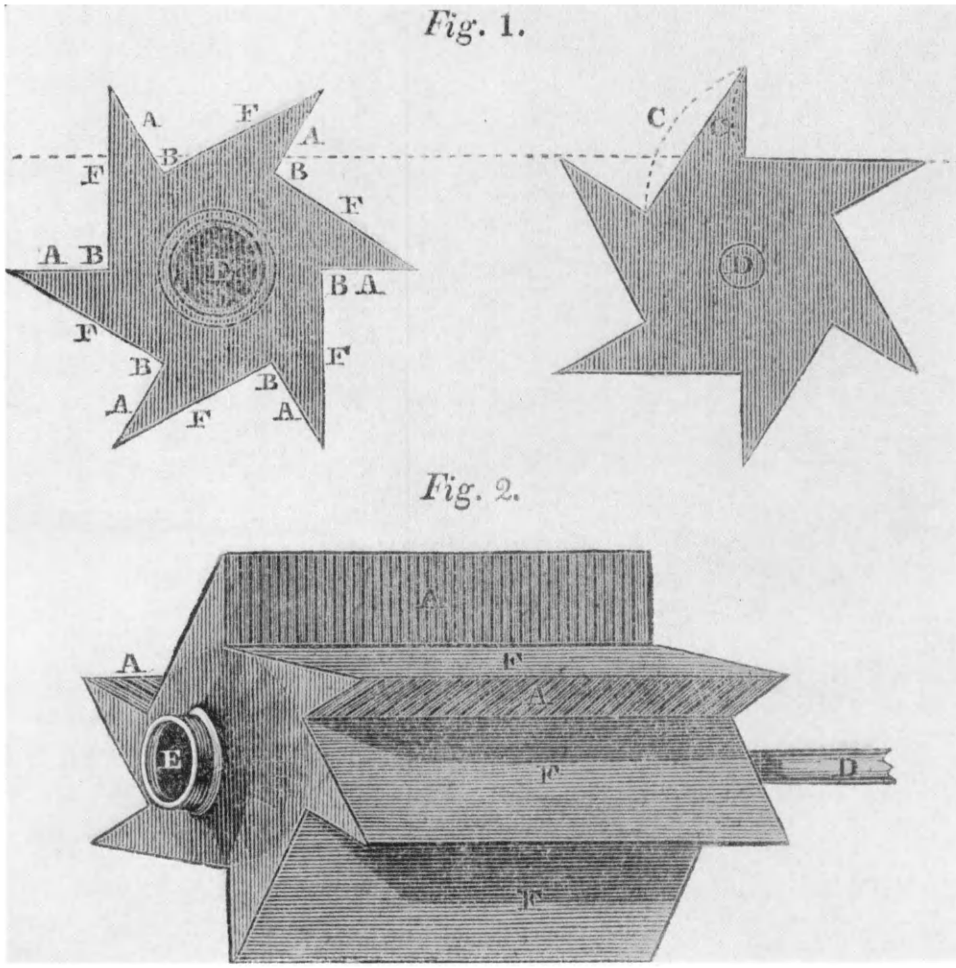
It was about midday when I left Mr. Brunel. I went up the Thames to Old Wapping Stairs, the nearest ferry crossing to Donkin's Bermondsey shops.

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 new-fangled 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.

VII

John Dickinson, 1782-1869

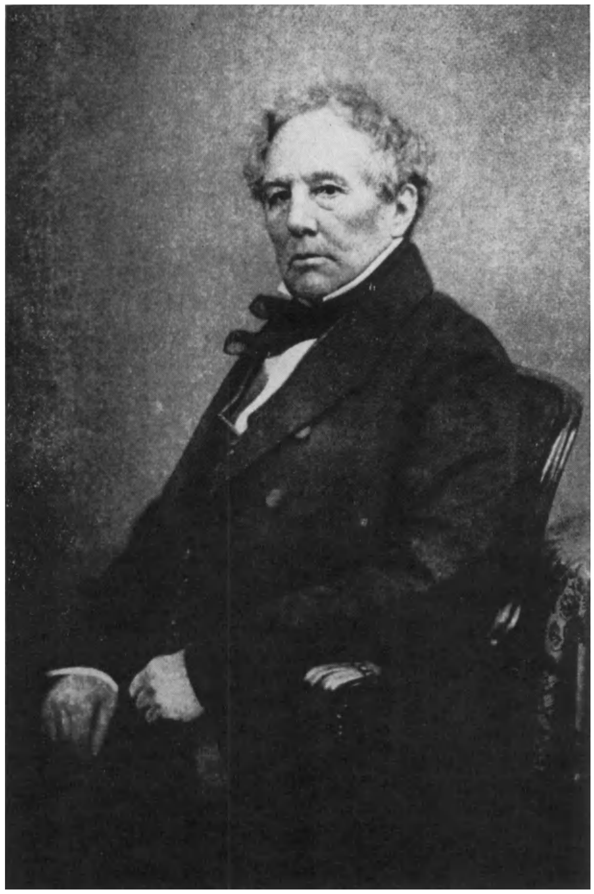
JOHN DICKINSON was the eldest son of Captain Thomas Dickinson, R.N., and Frances, his wife, whose maiden name was de Brissac, and who came of a family who were of pure French extraction and, as Huguenots, had been compelled to emigrate at the end of the seventeenth century, on the revocation of the Edict of Nantes. As with so many of the mechanics, inventors, and men of science in this country, John Dickinson, therefore, had a strong infusion of the best French blood in his veins.

He was born on March 29th, 1782, and after passing through in the ordinary course of education at private schools, was apprenticed as a stationer to Messrs. Harrison and Richardson. In making his choice of a profession, the fact that Andrew Strahan, who at that time held the office of Queen's Printer, was one of the most intimate friends of his parents, had, no doubt, considerable weight.

The business of a wholesale stationer was in those days very different from what it is at the present time. Paper, instead of being run off on continuous rolls at the rate of many hundreds of feet per minute, was made by hand, sheet by sheet. There were then no railways, electric telegraphs or telephones, and as the paper-mills were scattered over all parts of the country, most of them in secluded rural valleys, the stationer who relied on a number of mills for the papers which he sold, passed most of his time on the top of coaches, in his gig, or on horseback going from mill to mill to give orders, and to see that these orders were duly executed.

In 1806, Dickinson commenced business in Walbrook, having entered into partnership with George Longman, who for some time represented in Parliament the borough of Maidstone, one of the centres of the paper-making industry. Shortly afterwards the house of business was transferred to 65 Old Bailey, where it remained until the building was destroyed in World War II. It was not long, however, before Dickinson perceived the desirability of having a paper-mill of his own, so as to be in some measure free of the anxiety of having to confide to others the execution of any special orders that he might receive. Accordingly, in 1809, aided probably by Mr. Strahan, he purchased Apsley Mill, near Hemel Hempstead, in Hertfordshire, from George Stafford, and there commenced to manufacture paper on his own account. He had already shown his inventive turn of mind by producing a new kind of paper for cannon cartridges which, unlike the paper ordinarily in use, did not smoulder, and thus obviated a constant source of danger from external explosion. For this he obtained a patent in November, 1807. The new paper proved of immense value during the Peninsular War and the Waterloo campaign.

The idea of the continuous manufacture of paper by machinery was in the air at this time, and in 1806 Henry Fourdrinier had taken out his first patent for a machine making paper on an endless wire of an indefinite length. As we already know, this machine was erected at Frogmore, on the same stream, the Gade, as Apsley Mill, and immediately above it. We have earlier described in detail



John Dickinson.

the machine which Dickinson invented as an answer to the Fourdrinier machine for making paper continuously, and this was quite different from the Fourdrinier patent.

Dickinson had, to a certain extent, been anticipated in his idea by Joseph Bramah, the inventor of the hydraulic press, but the former carried his cylinder-mould machine to a state of great perfection, and it was definitely the forerunner of the multi-cylinder board machines of today. Dickinson claimed that one of the advantages his machine had over the Fourdrinier was that in the finished paper there was a much less prominent wire mark made on his cylinder-mould machine; that the two sides of the paper were much more nearly alike, and that the satin-like character which resulted from the large proportion of fibres being laid in the same direction, namely that in which the cylinder revolved, was of great advantage to the printer. This cylinder-mould-made paper of Dickinson had certain characteristics which made it very popular with printers, who wished to have justice done to type, ink, and woodcuts. Modified forms of this machine are still being used in America.

While Dickinson was residing at Apsley Mill, he became acquainted with Miss Ann Grover, the daughter of a solicitor and banker in the neighbouring town of Hemel Hempstead, to whom he was married in 1810. They had a numerous family, but only three arrived at maturity. A few years after the acquisition of Apsley Mill, Dickinson was able in 1810 to purchase the adjoining Nash Mills, which are situated about half-a-mile lower down on the same stream, and had a considerably larger amount of water power. Dickinson lived in the dwelling-house attached to Nash Mills for many years, and introduced into the manufacture of paper numerous improvements, gradually enlarging the sphere of his operations. Many of his patents in connection with the paper-making machine have been described earlier in the book.

Early in the year 1812 he had to contend with a strike among those employed in his mills. Being a very determined man, he made short work of the matter by discharging all the discontented workmen and filling their places with ordinary labourers from the neighbourhood. In an incredibly short time he was able to train them to efficiency in their new work, as the whole process of making paper by machinery had grown up under his care and guidance, and he knew every detail of the work. There is the legend that "Dickinson could make a paper-maker out of a hedge!" As so frequently happens the introduction of machinery for the manufacture of goods to replace older methods led to a great discontent among the workmen, and in the paper trade there was much trouble from the sections making paper by hand, which finally culminated in violence.

In 1814, Dickinson hired the two Fourdrinier machines at Two Waters Mill for £100 a year from Bloxham, the Fourdriniers' assignee, and he continued to run them for some years. These were the original machines following the Fourdrinier patent of 1807, and were built and rebuilt by Donkin. In 1815 Dickinson had a steam engine installed at his Apsley Mill and by 1822 he was weaving his own machine wire there. In this year M. and Mme Didot stayed with the Dickinsons and Mrs. Dickinson found them rather difficult to entertain, as they did not understand each other's language. This did not prevent Didot from coming again in 1829. In April, 1822, Dickinson also had a visit from M. Conson of Canson and Montgolfier. Lewis Evans, a great-nephew of Dickinson, says of him that "he seems to have been able to swear at everything and everybody, and on every occasion and when he was in a bad temper, which he often was, his ability in this direction seems to have been greater".

George Dickinson, John's youngest brother, with whom John was saddled, owing to a loan he had from his mother, left and went to Buckland Mills, Dover, which he rented. During the year 1823 P. M. Taylor was installed as supervisor at Apsley Mill. He knew nothing about paper-making, but was given a book with the names of the workmen and their jobs and a description of the process. Two years later, in 1825, the name of the firm was changed from Longmans and Dickinson to John Dickinson and Company.

Dickinson built Croxley Mill in 1830 and started it up the same year. This would be about the time of the Swing Riots, when a large gang of machine-breakers marched to his Nash Mills from the neighbouring county of Buckinghamshire, intent upon destruction. The story is told that fortunately they were met by a party of foxhunters, members of the Old Berkeley Hunt, dressed in pink, and the rioters, mistaking these for soldiers, thought that discretion was the better part of valour, and dispersed. Had they arrived at Nash Mills, however, they would have found the place in perfect readiness to give them a warm reception, a complete system of defence having been organized under the direction of General Beckwith, an old Peninsular War officer staying with the Dickinsons at the time.

Among other difficulties with which Dickinson had to contend was the necessity of defending at law the water rights of his mills. The Grand Junction Canal, as originally constructed, ran in a channel of its own, distinct from that of the river Gade, from above Apsley Mill to below Nash Mills, where it joined the river after passing through a series of locks. This portion of the canal seems to have been badly constructed, and to have been constantly losing water; to make good this loss the company abstracted water from the river, thus injuring the water-power of the stream and affecting the paper-mills. Action after action for the damage that ensued had to be brought by Dickinson, who was helped in these matters by Donkin, until an intimation from the Court made it plain to the canal company that an end must be made of their illegal abstraction of water. They then agreed that the course of the canal should be changed, that the bed of the river and of the canal should, near the two mills, be as far as possible one and the same. Dickinson, with his usual energy, undertook the contract for carrying out the work, which involved the construction of at least three new locks; and in this he was helped by Donkin, who was an expert at the building of locks, and was also affected to a certain extent by the trouble from the canal company on account of the Frogmore and Two Waters Mills.

As the river Gade was a chalk stream and depended for its flow on rain which fell a long time previous to its arriving in the river, Dickinson was the first to construct percolation gauges and draw practical conclusions from them. If, for instance, 12 to 14 in. of rain fell during the winter months and found their way through the 3 ft of soil in the gauge, he knew that there would be a full supply of water in the river during the summer. If, on the contrary, only 3 or 4 in. passed through the gauge, he knew that a short-water time was certain to follow in due course. The series of observations of percolations at Apsley and Nash Mills have been continued and extended by Dickinson's successors, and the method is well known to engineers. It formed the subject of communications by him both to the Institution of Civil Engineers and to the Royal Society. Like Donkin, he was elected a Fellow of the Royal Society of London on account of his intimate acquaintance with the question of water supply, as also his well-known mechanical ingenuity. He was a Fellow of the Society of Antiquaries, and a member of various other learned societies as well as of the Athenaeum Club.

Among his other inventions was the joining together of two webs of paper made on different cylinders, one of very fine material for the face, the other of coarser nature for the backing. These were for taking the impressions from engraved plates, and were better than any paper that had hitherto been manufactured by machine. All this has been fully described in the earlier chapters. Mention must also be made of his invention which related to the cutting of cards by machinery by means of circular cutters, a process now in universal use. There was also a machine for the continuous pasting of webs of paper together to form cardboard or paste-board. This process is still in use with modifications. He was responsible, too, for the invention of a cylindrical knotter and strainer for cleaning pulp, which has been fully described in earlier chapters; this was the forerunner of numerous forms of inward-flow revolving strainers that are now in use, the principle of which has been more than once re-invented. He patented this strainer in 1832.

Dickinson patented paper offering security against forgery, and he devised the process for the introduction of cotton, flax, and silk threads into the body of the paper which, although first patented in 1829, was not brought to perfection until ten years later, when it was again patented. On the introduction of the penny post about 1840, envelopes and flat sheets of notepaper were sold at post offices to the public. To prevent spurious imitations, the paper was manufactured so that each envelope contained within it two silk threads, one of pink and the other of twisted white and blue. Each sheet had three threads, one blue and one white, and the other pink and white. Exchequer bonds were printed on a thicker paper, on the body of which seven or eight threads of coloured silk were embedded, the arrangement of the colours varying with each issue. The Mulready envelopes, covers much valued by collectors, were made of paper of the kind just mentioned. This was the forerunner of the security thread contained in the bank-notes of the present day. Among his other ingenious contrivances were the application of magnets for the extraction of small particles of iron from the pulp; the process of continuous tub-sizing with gelatine on the machine; and that of the continuous drying of paper by a series of cylinders heated by steam. All these are mentioned and described earlier in this book.

Dickinson also paid a great deal of attention to the commercial aspect of the paper trade and continually extended his business relations with the principal publishers, where his sociableness and general intelligence rendered him deservedly popular. He found that to meet the demands of his business it was necessary to increase production, and in those days, when water-power was valued more than steam, the increase meant the acquisition of other mills rather than the enlargement of those already in his possession. Finding that water-power existed which was not utilized, on the Gade below Apsley and Nash mills, he succeeded in buying land and water rights, and Home Park Mills, near King's Langley, and Croxley Mills, between Watford and Rickmansworth, were successfully erected, the latter being set to work about 1830 and the former some four or five years previously. Both these mills were provided with machines for the manufacture of paper, and Batchworth Mill, near Rickmansworth, formerly a cotton mill, was purchased and converted into a half-stuff mill, where rags and other materials were prepared and broken in, etc., so as to be ready for conversion into paper at the other mills. A half-stuff mill was erected at Manchester, where the waste arising from the cotton manufacture was cleansed and prepared as a paper-making material.

While much of this work was going on, Dickinson had not been entirely single-handed. Charles Longman, the second son of Thomas Longman of Paternoster Row, came to the mills while Croxley Mill was in process of construction, and became a partner about 1830, devoting himself mainly to the manufacturing part of the business. On his marriage in 1836 he came to reside at Nash Mills. Dickinson at that time was building for himself, and without the assistance of an architect, a new dwelling on a neighbouring site, to which he gave the name Abbots' Hill; this mansion he began to occupy about 1839, and it remained his country seat until the time of his death. In 1833 Dickinson's balance sheet was as follows:

	£	*s.*	*d.*		£	*s.*	*d.*
Stock of paper in hand London	10,907	19	5	Bills accepted	17,844	6	5
Debts owing to J. D. & Co.	74,154	0	0	Debts owing by J. D. & Co.	6,987	9	2
Bills & cash belonging to firm	25,172	14	7	Debts in Mill a/cs.	23,102	14	9
Stock of rags	34,408	13	5				

Leaving a balance in his favour of £96,708 17*s.* 1*d.*

This was a very great deal of money for the time, and shows the success of the business and the large profits which he must have been making.

On visiting Edinburgh in 1833, Dickinson, who had a large business in Scotland, found that the Scottish paper-makers were making very good paper. In fact, he says "They are turning out capital paper, better than I ever saw before." By the year 1835 Dickinson had substituted a large machine for the small one at Apsley, and Croxley Mill was enlarged to make 14 tons of paper per week.

In 1837 the wages being paid by Dickinson were as follows:

Apsley	£47	10	0	per week for 815 reams
Nash	£42	0	0	per week for 860 reams
Home Park	£39	0	0	per week for 910 reams
Croxley	£52	10	0	per week for 1440 reams
Batchworth	£90	0	0	per week for 36 tons of half-stuff.

In 1843, a new wire weaving shop was built at the Nash Mills, and it is interesting to record that wires were woven by Dickinson's until 1893. John Dickinson himself retired in 1859, having attained the age of seventy-seven. After his retirement he continued to take an interest in public affairs and in literary and scientific pursuits, though from physical causes he was unable to make much use of the fine observatory that he erected at Abbots' Hill. He died at his London house in Upper Brook Street, on January 11th, 1869, having nearly completed his eighty-seventh year.

VIII

The Ibotson Family

THE Ibotson family were well-known paper-makers and paper-merchants in England during the nineteenth century. Percy Ibotson had Poyle Mill, Colnbrook, near Reading, and Richard Ibotson had Wraysbury Mill, near Staines, and Rivelin Mills, near Sheffield.

Percy Ibotson ordered one of the earliest machines from the Fourdriniers in 1807.

In the early references the name is spelt with one "b", but later they write it as Ibbotson.

One of the most important inventions of the early days of the paper-making machine was the patent slotted strainer plate of Richard Ibotson, in 1830. This helped paper-makers very greatly in eliminating knots from the paper, and the slotted strainer plate is in use all over the word at the present time.

There was also the mill of Ibbotson and Langford, at Darwen, Lancashire. In 1852 they owned Turn Lee Mills, Glossop, and Dover Mills, Glossop. They had a financial interest in John Slack's Mill at Hayfield, and they also owned the Whitehall Mills at Chapel-en-le-Frith, for which a paper-making machine was bought from the Fourdriniers in 1818. In 1831, it was noted by a contemporary writer that the largest sheet of paper ever made in England had been made at the Whitehall Mills by John Ibbotson, and supplied for printing papers in London. It was claimed that the sheet of paper would cover nearly $1\frac{1}{2}$ acres of land, and that it measured 13,800 ft long × 4 ft wide.

Walter Ibbotson left the Whitehall Mills at Chapel-en-le-Frith—he also owned the Rock Paper and Pasteboard Mills at New Mills—and retired, at the age of thirty-nine, from this part of the country, and took his family to Cartmel in North Lancashire, where he became interested in the Ulverston Paper Mills. Here he lost most of his money, and when he was fifty he had to start again. This time he went to London and founded the well-known firm of Ibbotsons Limited, Goswell Road, E.C.1.

Thos. H. Ibbotson had No. 54 mill at Charlestown, Lancashire, in 1860.

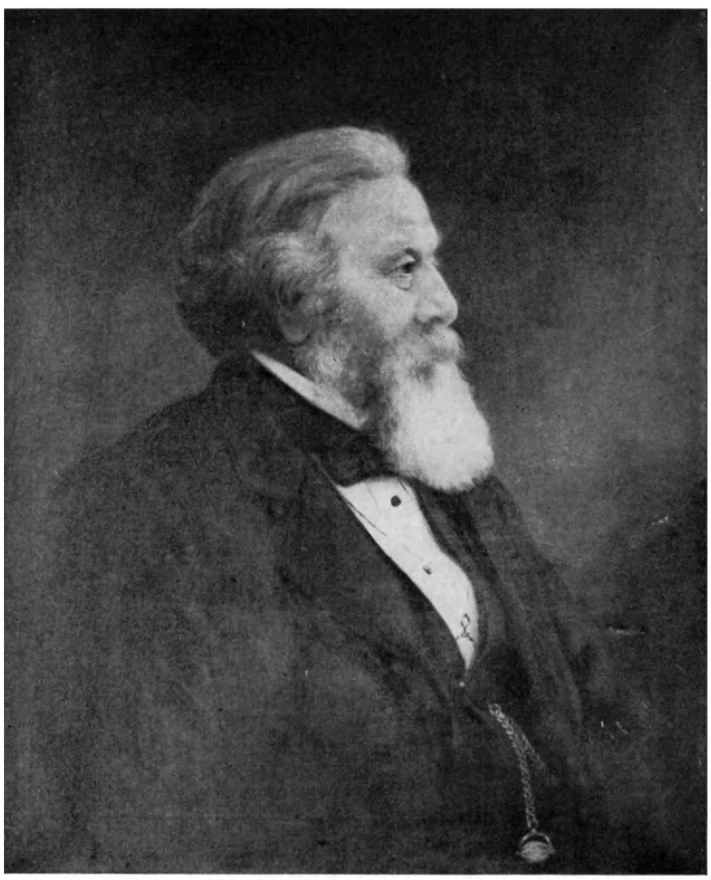
Three of Walter Ibbotson's sons became very well known in the paper trade. Thomas started a paper business in Manchester in 1877. Walter also started business in Manchester in 1885 as an importer of foreign papers; and Robert joined his father in Ibbotsons Limited, London.

In 1870 Ibotsons Patent Strainers were in general use in Britain, France, and America, and were said to be a great improvement over previous strainer arrangements. The chief reason for this was the fact that Ibotson used two main strainers and an auxiliary strainer, and this latter was fed from the stuff which could not pass through the main strainers, and which overflowed from them, thus enabling the main strainers to be kept clear of stuff which would not pass and so ensuring a much longer run on the machine without having to shut down to clean the strainers.

IX

The Bertrams

THE records of the Bertram family go back to about 1744 when William Bertram was born. Nothing is known of him except that he was described as a wright in Grange (Newlands Parish), and that it has been said that he was a mechanic at Esk Silk Mills. He had a family of two sons and two daughters. The elder son, George, who it will be convenient to call "George the first," was born on 16th April, 1773. It is recorded that from 1798 to 1802 he was engaged as a millwright in Penicuik, and from 1804 to 1835 at Boghead and Springfield (both in Lasswade Parish). He died on 14th April, 1835, at the age of sixty-two, and was buried in Lasswade. By his marriage to Janet Ferguson, in 1797, he had a family of four sons and seven daughters. Three of



George Bertram.

the sons, William, George and James, all became very important names in the paper-mill engineering business.

William was born on the 20th November, 1798, at Penicuik. An engineer and millwright, he was the founder of the works in Sciennes in 1821. Shortly afterwards his brother George (the second) joined him at the Sciennes. George was born in Lasswade on 15th April, 1808. His occupation was that of millwright and engineer, although it seems likely that he also worked as a paper-maker in Dalmore mills before joining his brother at the Sciennes.

Shortly after the start in new premises across the street from the original workshop, William Bertram retired and died in 1860, leaving the business to his brother George whose second son, William, was later assumed as partner, the title of the firm becoming George and William Bertram.

In 1878 George Bertram retired, handing over the business to his three sons, William, David, and John. He died in 1881 at the age of seventy-three.

The firm was converted into a limited company in 1888, the shares being held chiefly by the family. The style of the Company became Bertrams Limited.

At first the management of the Company was in the hands of William and David Bertram as acting Directors.

After William Bertram left the Company in 1890, control of its affairs was in the hands of David Bertram, M.I.M.E., third son of George Bertram, one of the founders of the business, and he continued in this office until his death in 1907. William Bertram's untimely death was the result of an accident in a steam engine pit at the Clondalkin Paper Mill, near Dublin. He was only forty-one years of age.

There is a very close and interesting connection between James Bertram and the Sciennes firm, for James was a younger brother of William and George Bertram, the former of whom was the founder of the Sciennes works in 1821. At that time James was only five years old, but he eventually served his apprenticeship under his older brother, and in 1845, at the age of twenty-nine, he left Sciennes for Leith, where he founded the firm of James Bertram and Son Limited, and died sixteen years later, in 1861. His sons William and James subsequently successfully carried on the business.

The George Bertram, who was the co-founder of the Sciennes works, had a tremendous reputation as a paper-maker's engineer in his day, and at the Great Exhibition held in London in 1862 he was awarded a gold medal for the paper-making machinery exhibited by him, and as proof of the excellence of the workmanship this identical paper-making machine was taken direct from the exhibition and erected at Ivybridge Paper Mills, Devon, where it is still working today. While he

LLOYDS PAPER WORKS,

BOWBRIDGE, LONDON.

No. 21 PAPER MACHINE

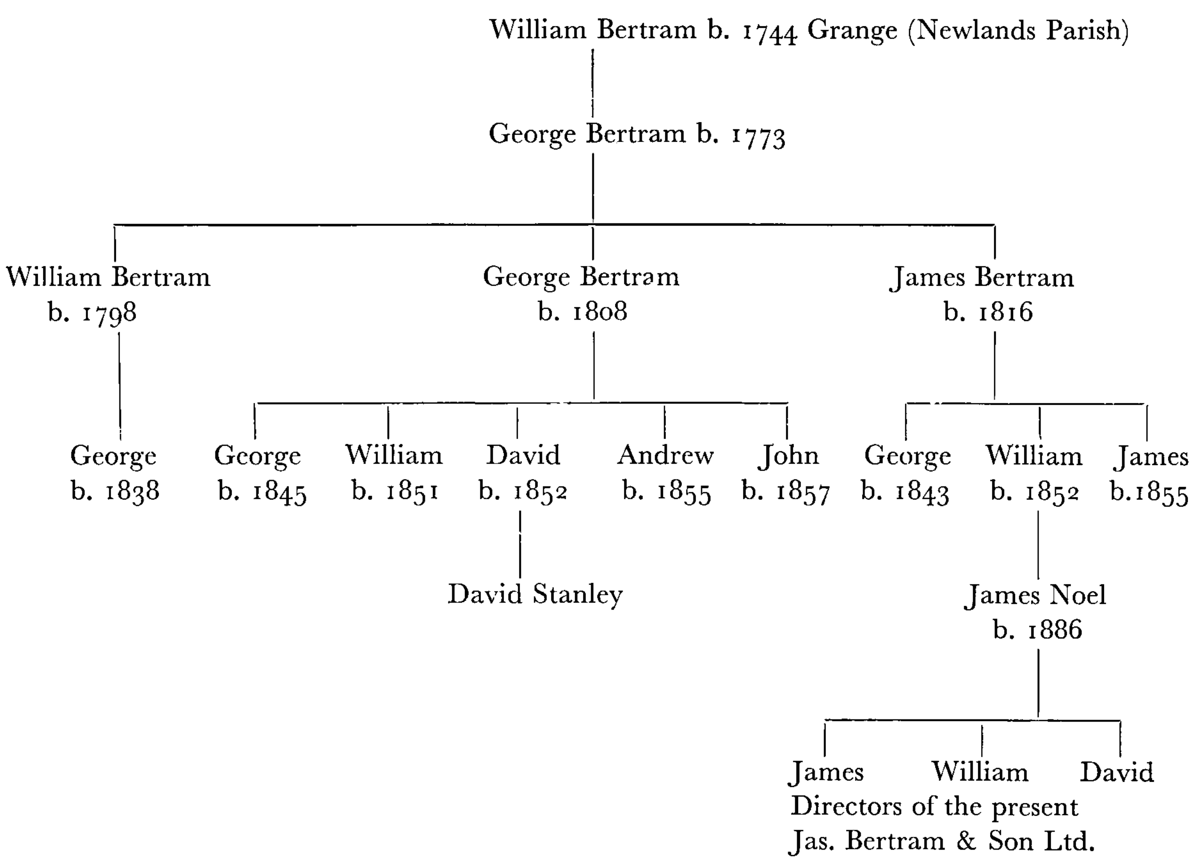
1861.

Facsimile of cover from Bertram's quotation for Lloyd's paper-making machine of 1861.

was carrying out big contracts for William Joynson at St. Mary Cray, Joynson persuaded him to start business in London, a suggestion which his sons acted upon later. George Bertram was also associated with Edward Lloyd, and in 1875 he built a very large machine for Lloyd with a wire 123 in. wide. George Bertram was also associated with Thomas Routledge, of Ford Paper Mills, Sunderland, in producing machinery for the manufacture of fine printing papers from esparto grass, after Routledge had introduced this from North Africa. He also built a very large air-dryer for Messrs. Cowan, of Valleyfield Mills, which was said to contain a mile-and-a-half of paper on it at once! When he retired in 1878 George Bertram handed over the business to his three sons, William, David, and John. They manufactured paper-making machinery for countries all over the world, including Canada, France, Germany, Greece, Havana, India, Japan, Mexico, and Russia, in addition to many machines for the home mills.

In 1885, they opened St. Katherine's Works, Bow, London, but they never seemed to make a great success of this, and eventually these works were closed down, and the machinery removed to Edinburgh in 1888, when the business was converted into a limited company.

It will be seen that the firm of Bertrams has been associated with the paper trade for almost one hundred and fifty years, and they have certainly left their mark on the development of paper-making machinery. Many of the different members of the family having invented and patented paper-mill machinery of various kinds, much of which enjoys world-wide reputation at the present time; and many of their paper-making machines are still running after at least one hundred years' constant operation. Invention is quite traditional with Bertrams of the Sciennes and the flair for invention is still evident in the many refinements and improvements in the Sciennes products.



List of early paper-making machines built by Bertrams Limited, Sciennes, Edinburgh*

No.	Supplied to	Details
9	Ed. Towgood, Sawston Mills	Wire 74in. wide × 32/33ft long. 4 cylrs. 42in. diam. arranged 2 and 2. (Still running almost unaltered.)
10	Moscow	
11	Moscow. Nov., 1851	Wire 88in. wide × 32/33ft.
12	Little Eaton. Oct., 1854	Wire 76in. wide.
13	Delane Magney Co. Faverham. June, 1855	Wire 84in. wide × 29ft long.
14	St. Leonard's Mill, Lasswade	
15	Clyde Mill, March, 1857	Wire 80in. wide. 6 cylrs. 48in. diam.
16	F.G. St. Petersburgh. Feb., 1859	Wire 68in. wide × 32ft long. 4 cylrs. 42in. diam. arranged 2 and 2.
17	Standish Mills, Crompton. July, 1859	Wire 84in. × 33½ft long.
19	Bitton. Feb., 1860	Wire 76in. wide × 32½ft long.
20	F. and G. St. Petersburgh. 1860	Wire same as No. 16 but reverse hand.
21	Lloyds Paper Works, Bow Bridge, London, 1861	Wire 90in.
23	Ivybridge, 1862	
24	E. Collins, Kelvindale Mills. Aug., 1863	
27	Soho Mill. Nov., 1863	Wire 68in. wide × 28ft long. 8 cylrs.
28	Valleyfield. Mar., 1864	Wire 80in. wide × 32½ ft long 11 cylrs.
30	Kelvindale	
31	Thetford Mills. Mar., 1866	6 cylrs. 5–3ft diam. 1–4ft.
32	Clyde Mill. 1866	Wire 84in. wide × 32½ft long. 10 cylrs. 3ft 6in. × 7ft long.
33	John Baines, Kilbury Mills. 1866	Wire 68in. wide × 6 cylrs. 3½ft diam.
34	Springwell. 1866	Wire 7ft 7in. wide × 34ft 8½in. long. 11 cylrs. 40in. diam. × 6ft 9in. long.
35	Loch Mill, Linlithgow. May, 1867	Wire 76in. wide × 33ft long. 6 cylrs. 3ft 6in. diam. 3 before and 3 after smoothers.
36	John Miller, Esq., Carron Grove Paper Co. Sept., 1868	Wire 35ft long × 6ft 9in. wide. 8 cylrs. 4ft diam.
37	S. Evans and Co., Derby. Dec., 1868	Wire 70in. wide × 28ft long. 5 cylrs. 3ft 6in. diam. × 5ft 10in. long.
38	Spicer and Co., Catteshall. Apr., 1869	Wire 80in. wide × 33ft long. 15 cylrs. 4ft diam. × 6ft 10in.
39	McDonnell and Co. Ltd.	Wire 80in. wide × 33ft long. 8 cylrs. 3ft 6in. diam. in 2 sects.
40	McCorquodale and Co., Oakenholt. Apr., 1870	Wire 80in. wide × 29ft long. 10 cylrs. 3ft 6in. diam. × 6ft 8in. in 2 sects.
41	Russia. Nov., 1870	Wire 67in. wide × 33ft long. 10 cylrs. 40in. diam. × 5ft 7in. in 2 sects.
42	A. Buntin and Co., Canada. Feb., 1871	Wire 5ft 9in. wide × 33ft long. 8 cylrs. 3ft 6in. diam. × 5ft 9in.
43	Dimmock and Co., Over Darwen. June, 1873	11 cylrs. 4ft diam. × 7ft 11in. long in 3 sects.
44	Michael Healy, Suebla, Mexico. 1872	Wire 52in. wide × 28ft. 5 cylrs. 40in. diam. × 5ft 2in. long.
45	Vargounin Freres, Russia. May, 1872	Wire 84in. wide × 33ft long. 8 cylrs. 4ft diam. × 7ft long.
46	J. Felber and Co. July, 1872	Wire 72in. wide × 35ft long. 8 cylrs. 4ft diam.
47	Hendon Paper Mill Co. Nov., 1872	Wire 90in. wide × 35ft long. 12 cylrs. 4ft diam. × 7ft 6in. long in 3 sects.
48	Scottish Pulp and Fibre Co., Kilbagie. May, 1874	Wire 100in. wide × 35ft long. 11 cylrs. 4ft diam. × 8ft 4in.
49	Guardbridge Paper Co., Guardbridge. May, 1874	Wire 95in. wide × 35ft long. 11 cylrs. 4ft diam. × 7ft 11in.
50	Eskside Paper Works, Musselburgh. June, 1873	Wire 90in. wide × 35ft long. 10 cylrs. 4ft diam. in 3 sects.
51	De Jersey and Co., Manchester. Dec., 1873	Wire 88in. wide × 35ft long. 8 cylrs. 4ft diam. × 7ft 4in. long in 2 sects.
52	Daily Telegraph Co., Dartford. Dec., 1873	Wire 100in. wide × 35ft long. 11 cylrs. 4ft diam. × 8ft 4in. in 2 sects.

* No record can be found for P.M. machines 1–8.

X

George Tidcombe and the Watford Engineering Works

THE history of these works is very interesting. They are one of the oldest paper-makers' engineering works in the country, and were originally established in the early portion of the last century by the late Mr. G. Tidcombe, who died in 1891 at the venerable age of ninety-one years. George Tidcombe was known throughout the paper-making trade as "Old Tidcombe", in order to distinguish him from his son who, although he was by now approaching his eightieth year, was still referred to in 1906 as "young Tidcombe". The works were established by George Tidcombe in 1827, when the firm was known as Tidcombe, Strudwick, Brewer and Company. George Tidcombe was the son of a brewer in the West of England, and a descendant of the old family of Tidcombe of Wiltshire. On his mother's side he was of Welsh extraction. His father apprenticed him to the firm of Messrs. Hague and Topham, one of the earliest firms of well-known engineers in London; and he came to London on March 1st, 1814, and served his time there. Subsequently he removed to Dartford, where he perfected his experience with the celebrated engineer, John Hall, and worked with the equally celebrated Bryan Donkin, the man who made the paper-making machine workable. George Tidcombe was also a great friend of Richard Trevethick, the inventor of the locomotive and high-pressure steam engine, and it was at Hall's that Trevethick made many working drawings and models. When Donkin got the paper-making machine into working order at Hall's, George Tidcombe and Strudwick went to Watford to erect one for Hamper Mill. It was then that he and Strudwick decided to start at Watford. They built many Fourdrinier paper-making machines for Britain, and some of the earliest for Belgium. His other partner, Brewer, was one of the earliest wire-weavers, and to manufacture the travelling wire perfectly was one of the first difficulties in connection with the paper-making machine.

Strudwick and Brewer died, and by the industry and perseverance of George Tidcombe the business became his own under the name of Tidcombe and Son. They built paper mills in Russia and France, which are still doing good work and bear his name. The Watford gas works were originally built by the firm of Tidcombe and Strudwick, as may be seen on the tablets still preserved there.

Like most of the early engineers, Tidcombe did not confine his energies to one branch of engineering, for if a mill or factory wanted a steam engine or pump he was quite prepared to build them. Until comparatively recently his engines, mainly horizontal, slow-running, reliable machines, could be found not only in paper mills but in breweries, flour mills, saw mills and elsewhere. One of the most notable jobs that he carried out was a deep-well pumping plant at Clutterbuck's Brewery at Stanmore, where the pumps are 350 ft from the surface and driven through gearing by an inverted table engine worked at 40 lb per sq in. steam pressure. The pumps were driven by eccentrics possibly because the forging of a crank of the size necessary was beyond the scope of Tidcombe's works. When, at a depth of 400 ft water was struck, it was decided to drive several headers horizontally, and when one of these was partially completed, water broke in suddenly with the result that tools and tackle had to be abandoned and are there to this day.

Tidcombe's paper-making machines, judged by present-day standards, were small, that is to say capable of making paper only 50 in. to 70 in. wide. He acquired considerable reputation for these and built them not only in this country, but also for Russia, France, Portugal, Belgium, and Holland. Some of the machines are still working.

Reference to Spon's *Dictionary of Engineering*, 1870, will show that Tidcombe and Son—as the firm had then become – had acquired some reputation for their paper-mill plant, for not only is one of their machines illustrated, but also dusters, glazing calenders, slitters and sheetcutters. The output of their Fourdrinier machine 60 in. wide is given as 5 tons in 24 hr.

A few years ago a Tidcombe machine was still running in a Berkshire mill, and there is one still running at Abelheira Mill in Portugal.

The equipment of Tidcombe's reflected considerable credit on the owner and his mechanics in that they managed to turn out machinery of very high quality. One machine was a pit lathe with thirty-two gear changes, and arranged with a bedplate flush with the floor, in front of the pit, to which long slide rests could be bolted, the saddles of which were actuated by ratchet gear driven from an overhead shaft. When it was intended to turn up a cylinder, this was chucked on the face-plate and an outboard bearing bolted to the floorplate to carry the other end journal. If on the other hand the lathe was required for a face-plate job, the rest was shifted onto the front edge of the floorplate at right angles to the first position. Judged by modern methods, the procedure was cumbersome, but mechanics' wages in those days were not high so that there was little inducement to economize in labour.

The other machine was a grinder for buffing rolls used in the paper-making machines. The rolls were revolved on their own journals in bearings at each end of the main bed and an arched saddle carrying an emery wheel driven from an overhead drum traversed the length of the bed. It was necessary to put a camber on these rolls to compensate for deflection, and the method of effecting this in the old machine was to drive a taper pin between the bottom of the bed and the centre supporting pedestal so that the carriage of the emery wheel would, at the centre, rise somewhat above the axis of the roll. Tidcombe himself gauged the rolls with a pair of extra large size calipers.

The Watford Engineering Works is still making many different kinds of plant and equipment for paper-mills in all parts of the world.

XI

Bentley and Jackson

BENTLEY AND JACKSON LTD., engineers, of Bury, Lancashire, have recently celebrated their centenary, and during the last hundred years they have been making paper-making machines and other paper-mill equipment continuously.

In 1860, Daniel Bentley in association with Redfern and Smith commenced business as paper-mill engineers, trading under the name of Redfern, Bentley and Smith. After a few years however Redfern and Smith left the partnership and started again with another partner Law, as Redfern, Smith and Law, engineers, millwrights, and paper machinists.

Daniel Bentley, who had been a foreman mechanic at Wrigleys' paper mills at Heap Bridge, Bury, had a good deal of practical experience as a paper-mill engineer, and was therefore well qualified to carry on the business alone. Wrigleys was one of the largest paper-mills in the country at that time, and as early as 1870 had no fewer than eleven paper-making machines.

Eventually Bentley found another partner in John Broad Jackson, an experienced business man, and the name of the company was changed to Bentley and Jackson, and has remained unchanged in name ever since, that is for more than ninety years.

Daniel Bentley, after twenty-five years as head of the company, handed over the direction to his eldest son, George, who was succeeded by his younger brother John, who became chairman when the company was registered in 1894. Bentley and Company were making complete paper-making machines after being established for only five years. Their first machine was made for the Lord Paper Works Company, near Sunderland, in 1865, and by 1870 they had made four more machines for Wrigleys, the mill where Bentley worked before starting on his own. Then followed, in 1870, his first export order, when he made a board machine for Munksjo Aktiebolag, Sweden. This machine was still in use a few years ago. Another machine which went abroad and which worked for seventy-seven years was made in 1872 for Dalum Mill, Denmark.

It is recorded that from 1865 the company was never without at least one paper-making machine on which to work, and there were often as many as five machines being built at the same time. In addition the company made all the various kinds of paper-mill machinery required to completely equip a mill, including many items which they themselves designed. Some of their well-known products include the Marshall refining engine, one of the earliest refiners after the Jordan; Nuttall's patent rag-cutter; the Coburn-Taylor rag-cutter; Hollander beaters, and, of course, M.G. cylinders for which the firm has always been famous. In 1884 they made their first M.G. cylinder for Smith, Stone and Knight, the diameter being 9 ft. In 1874 Bryan Donkin and Company and Bentley and Jackson were both advertising their paper-making machines.

In 1884 Bentley and Jackson were advertising paper-mill machinery of all kinds in America, including M.G. cylinders 12 ft diameter.

Other makers of paper-mill machinery in the early days were J. and R. Shorrocks of Darwen, Lancs., who made complete paper-making machines. The firm of Redfern, Smith and Law had the following advertisement in the *Illustrated Guide* of 1869.

REDFERN, SMITH AND LAW
Iron and Brass Founders
Engineers, Millwrights & Paper Machinists
BURY, LANCASHIRE

Makers of Steam Engines, Mill Gearing and Water Wheels, Paper-making Machines, all sizes and constructions. Improved Rag Engines, for Washing and Beating. Steel Bars for Rag Rolls, and Steel Bottom Plate for Rag Engines. Sole makers of Coop and Partington's Patent Half and Parallel Willow; also Partington's Patent Half Stuff Press
Drying, Sizing, and Cutting Machines; Re-reeling or Winding Off Machines
Friction, Glazing, and other Calenders for paper and Millboards
Improved Rope Cutting Machines; Willows and Dusting Machines
High Pressure Revolving Rag Boilers; Bowking Kiers & Esparto Boilers
Water, Pulp, Steam and Chemic Pumps
Equilibrium and Diminishing Steam Valves
Hydraulic Presses
Hoists, Felt Washing Machines
Brass Knotter Plates, etc.

They were still advertising in 1884 as Smith and Law. One of their machines is still running at Melbourne Mill of Australian Paper Manufacturers and the cylinders are dated 1872.

XII

Early Pioneers in the United States

THE Gilpins, Joshua and Thomas, were well-known and famous paper-makers in America at the end of the eighteenth century and the beginning of the nineteenth century. Originally they made paper by hand at their mill on Brandywine Creek in Delaware. Joshua travelled extensively in Europe, and kept a voluminous journal, showing that he was a very acute observer of industrial processes, and particularly of paper-making. Thomas, Joshua's brother, stayed at home and devoted his time to managing their mill, and he also patented several of his inventions connected with paper-making.

In their early days the Gilpins specialized in bank-note paper, but their mills were damaged by floods and destroyed by fire. However, in spite of this they changed from making paper by hand to the more profitable method by introducing a paper-making machine.

The Gilpins had earlier become familiar with the steps being taken in Europe to mechanize paper-making. In his two tours of Europe Joshua Gilpin had become acquainted with Bryan Donkin, John Hall, John Dickinson, and Henry Fourdrinier, all of whom were of course connected with the early development of the endless-paper-making machine.

The machine which Thomas Gilpin invented in 1816 closely resembled Dickinson's cylinder-mould machine, which Joshua Gilpin had seen when in England.

The Gilpins had made every endeavour to secure information about machine paper-making in England, and they also did everything in their power to keep it secret.

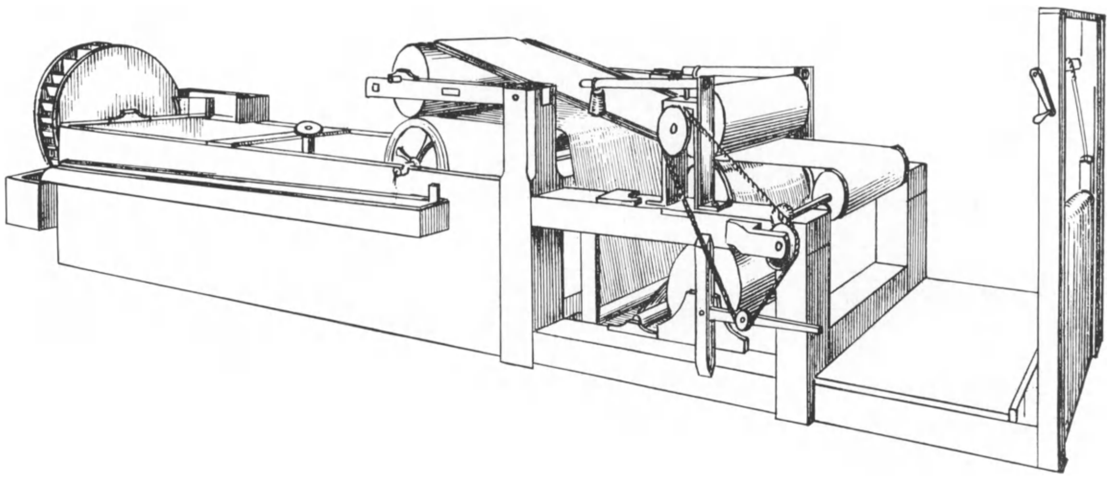
Lawrence Greatacre, the Gilpins' paper-maker, also visited England to obtain information about the paper-making machines being developed at the time. He was a friend of John Dickinson and spent three days with him, and examined the Fourdrinier machine which Dickinson had at Apsley Mill and also the cylinder-mould machine at Nash Mill, which he described in great detail when he wrote home to the Gilpins. Greatacre's most difficult task was to obtain a drawing or a model, but he eventually obtained a drawing of a Fourdrinier machine, and is believed to have got Dickinson's permission to make a drawing of his cylinder machine, although Dickinson did not think he would get the details sufficiently correct.

After examining the reports and drawings from England, Thomas Gilpin, with the assistance of Greatacre, perfected a cylinder machine, which he patented in December, 1816.

The first machine-made paper was sent to market in February, 1817. It is recorded that the machine was in no respect an advance upon or even the equal to the Dickinson machine of England. Lyman Horace Weeks, in his book *History of Paper Manufacture in the United States*, says that news of Gilpin's invention speedily leaked out, for its tangible results began to have their natural effect on the paper trade. A wide and substantial reputation accrued to the Gilpin mill for the quantity and quality of the new kind of paper which they were able to produce. The Gilpins made every effort to keep their machine a secret, but it was impossible to hide it permanently.

Eventually, by obtaining scraps of information from workpeople and by careful study of the patent, sufficient ideas were obtained to render evasion of the patent possible.

The story has been generally accepted that John Ames of Springfield, during a visit to New York, heard of the Gilpin machine, and thereupon took means to find out about it with the result that he was soon able to make a better machine for his own mill. Ames patented his machine in



May, 1822. A great deal of litigation followed which resulted in Ames being unable to maintain a monopoly in the new process.

Experiments were made by other proprietors of mills and they were soon able to profit by the new idea.

Within a few years the Gilpins found that they could not permanently retain the advantage over competitors that their cylinder machine had for a time given them.

Unfortunately, it is not possible to discover the details and drawings of Thomas Gilpin's patent, because the American Patent Office was burned in 1830. However, an artist's impression of a drawing of Thomas Gilpin's cylinder machine which was used in a lawsuit in Boston in 1833 is reproduced herewith by courtesy of The Hagley Museum, Wilmington, Delaware, through the good offices of James L. Anderson of *The Papermaker*.

Several new and improved cylinder machines were brought out before 1830. Eventually the cylinder-mould machines were generally introduced into mills everywhere and the prestige of the invention and the credit of having begun the making of paper by machinery in the United States have never been fully accorded to Thomas Gilpin.

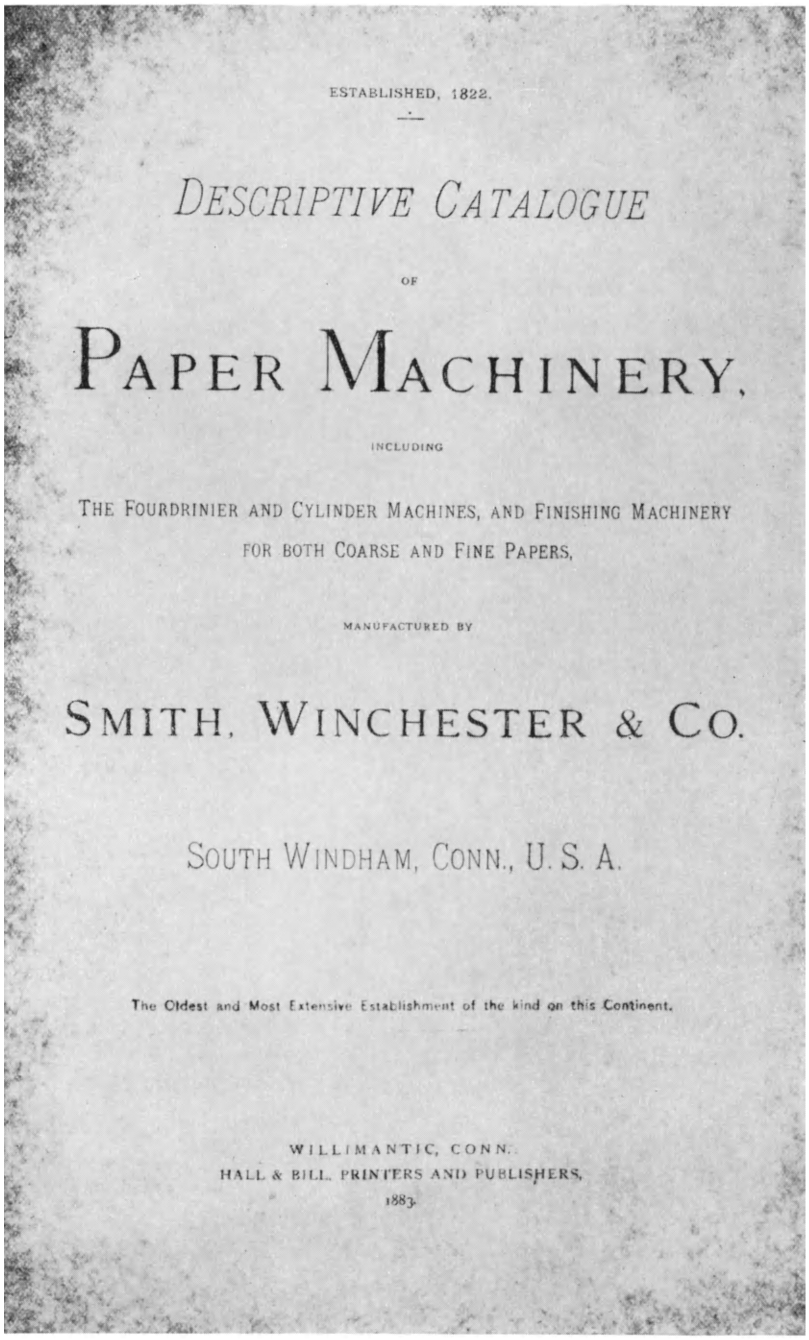
The names "Smith" and "Winchester" are connected with paper-making ever since the making of paper in America shifted from hand-made paper to machine-made paper.

A very interesting account of this company has been written for this book by Mr. Eden C. Cook of South Windham, Connecticut:

Machines in France and England were making paper in the early 1800's, and in December, 1827, one Joseph Pickering imported the first Fourdrinier paper-making machine for erection in his shop in North Windham, Connecticut. For this project, Pickering engaged George Spafford of South Windham, Connecticut, a man renowned in this area for his mechanical insight, to direct the erection of this paper-making machine. The project was completed in 1828 and Spafford returned to his home in South Windham, filled with dreams of the impact which this machine could have on the paper-making industry.

Spafford planned improvements but hesitated to contact the builders of the Fourdrinier in England. Cost of importing the machine, delay in obtaining repair parts, difficulty in long distance business arrangements and unknown problems led Spafford to one conclusion—build a machine in America.

He joined with James Phelps in 1828 to form the firm of Phelps and Spafford in South Windham, Connecticut, where there was water power. Phelps was an experienced paper-mill builder. The executive ability and mechanical cleverness of a boy of nineteen was noticed by the partners, and



ESTABLISHED, 1822.

DESCRIPTIVE CATALOGUE

OF

PAPER MACHINERY,

INCLUDING

THE FOURDRINIER AND CYLINDER MACHINES, AND FINISHING MACHINERY
FOR BOTH COARSE AND FINE PAPERS,

MANUFACTURED BY

SMITH, WINCHESTER & CO.

SOUTH WINDHAM, CONN., U. S. A.

The Oldest and Most Extensive Establishment of the kind on this Continent.

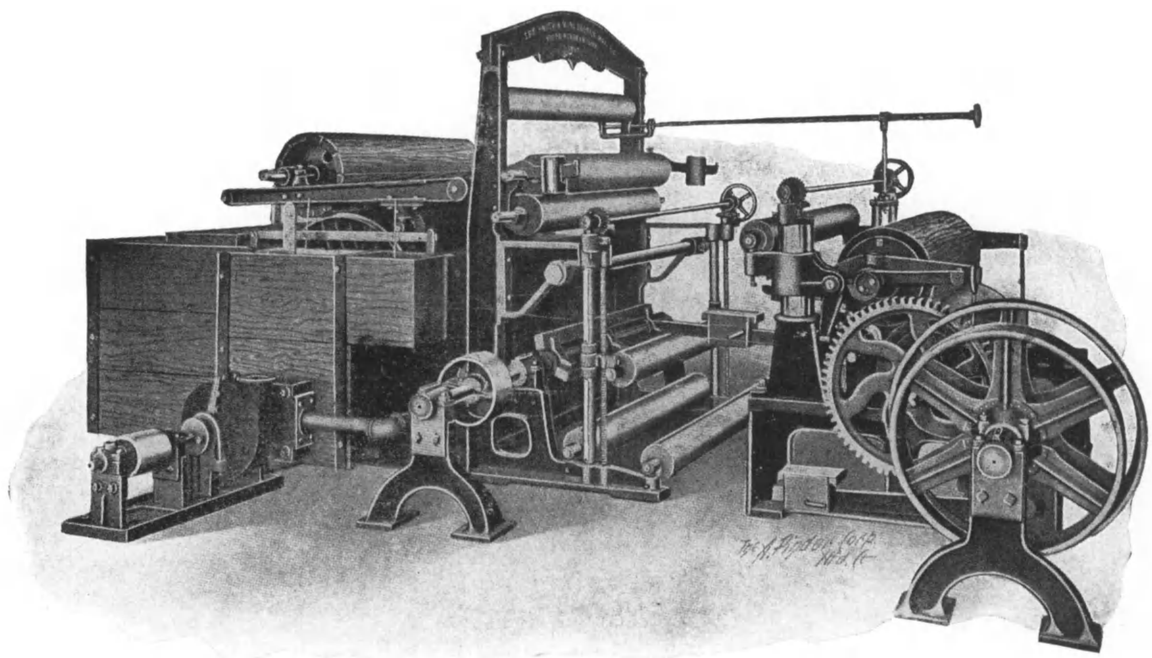
WILLIMANTIC, CONN.
HALL & BILL, PRINTERS AND PUBLISHERS,
1883.

Frontispiece of catalogue of Smith and Winchester paper-making machinery of 1883.

he was engaged to take charge of the production. This lad was Charles Smith, a name to have a lasting effect on paper-machinery changes and growth.

An old school-house was moved to a site below a dam on a small stream. A crude lathe was installed in the building and this, with hand tools, comprised the shop's equipment. Power came from overshot water wheels. As time passed, the need for power tools was evident but the tools were non-existent. Smith and his men made wood patterns from which tools were cast, machined, and assembled into pioneer lathes, boring mills and whatever was needed to build the machines for the paper industry. These tools were later copied by the machine tool industries.

Designs for paper-making machines were made on smooth pine boards. From these the machines were built and assembled. Upon completion, the drawing was planed off and a new design started on the same board. (Not much danger of drawings being stolen or copied and workmen were secure with the details available only from memory.)



The Smith, Winchester mould machine of 1870 showing centrifugal fan pump, wood lagged couch roll, and maple press rolls.

Castings were an early problem. Spafford had the nearest foundry and the twenty-mile cartage was made by ox-cart. But these men were accustomed to problems. Their pioneer trust and enthusiasm for the project produced an improved machine which out-performed the original Fourdrinier. This machine was sold to Amos D. Hubbard and installed in May, 1829, at Norwich Falls, Connecticut. The plant was already famous as the first paper-mill in Connecticut, founded in Colonial days by Christopher Leffingwell.

Successful machines were installed in East Hartford, Connecticut, and Bloomfield, New Jersey.

George Spafford invented the first cylinder dryer in America in 1830. This rotating, steam filled vessel accomplished in minutes a process previously requiring hours in time and labour in drying lofts. He also was first to build a rotary cutter to sever the web into uniform sheets. Thus was devised the first continuous paper-making machine in America, built by Charles Smith and his men Paper was now reduced to sheets of desired sizes, in an uninterrupted process ready for finishing. The knowledge of paper-making, inventiveness, manufacturing ingenuity and faith changed the American paper-making process in a few years into one of the largest industries in the country.

The pioneering of Phelps and Spafford flourished until the financial crash of 1837. Lack of finances at this crucial time resulted in suspension of work.

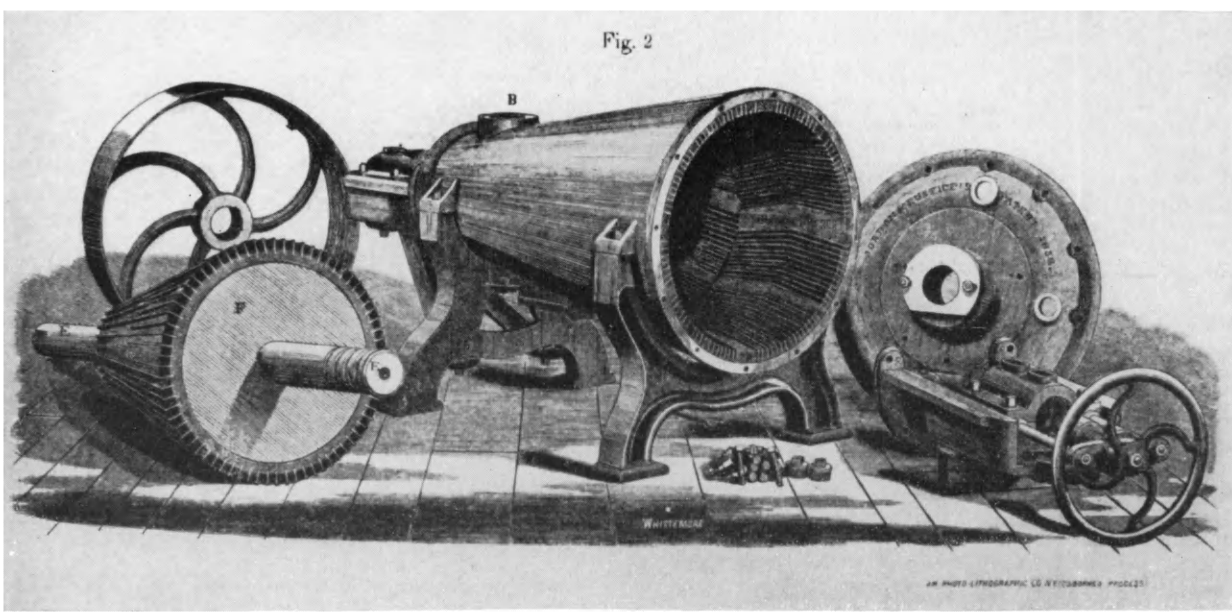
However, Charles Smith visioned a successful future regardless of current reverses. He and Harvey Winchester bought out the business and reorganized under the name of Smith, Winchester and Company. The talents of Charles Smith were well known by the paper industry and this confidence carried the new company through the depression.

Within the next few years the company developed and built stuff pumps and beaters. With the westward expansion of the country went the reputation of Smith, Winchester and Company so that their fame spread from Maine to California. Transportation was by boat or ox-cart and records indicate that a machine went from Connecticut to Maine by ox-cart.

In 1853 Samuel P. Taylor "struck it rich" in California and, descending from a line of paper-makers, decided to pioneer paper on the west coast. He came east and placed an order with Smith, Winchester and Company for a Fourdrinier machine. This was the first paper-making machine to be installed west of the Mississippi. The journey was via ox-cart to New London, Connecticut; via sail-boat to the Isthmus of Panama; via donkey drawn skids across the Isthmus; via sail-boat to Yerba Buena (later called San Francisco), California; via donkey drawn skids to the pulp forests. Thus the Pioneer Mill of the west coast came into existence.

This installation was so successful that Mr. Taylor returned to Connecticut in 1884 and ordered another Fourdrinier.

The demand grew and machines were exported to England, Cuba, Mexico and South America. Ingenuity was taxed to the limit. One machine had to be designed for transportation across mountains by burros.



Jordan and Eustace refining engine of about 1870, showing the plug and shell with their fillings, end cover and regulating gear, built by Smith, Winchester & Co.

In 1854 the company obtained patents of Joseph Jordan and Thomas Eustace and introduced the Jordan and Eustace refining engine to the trade. The refiner was universally adopted by the paper manufacturers and is still being used today as the Jordan Engine. Clever changes in design enabled owners to operate these Jordan Engines sixty or more years by periodically replacing knives.

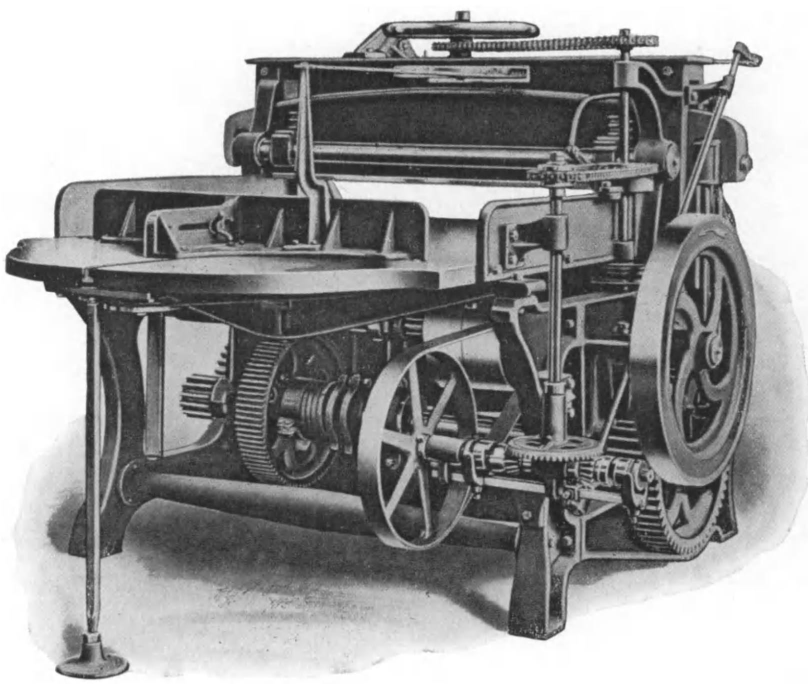
The little school-house had grown in the last thirty years into a lively manufacturing enterprise. Due to the accumulation of patterns, raw material, parts for customers' machines and need for manufacturing space, new buildings were constructed from material obtained from local saw mills.

Not only was Smith, Winchester changing the methods of paper-making of this era, but it was feeling the pressure of change. Charles Smith's son Guilford was showing his fitness for a leader. He had entered the company as a clerk when nineteen and worked his way up. Likewise, Arthur S. Winchester, son of Harvey Winchester, entered the company and soon demonstrated his ability with the financial side of the firm.

Besides personnel changes, progress was affecting manufacturing facilities. Electricity replaced the wavering oil lamp and turbines replaced water wheels.

Charles Smith died in 1896 and leadership of the company passed to his son, Guilford Smith. Necessary readjustment of Smith, Winchester and Company resulted in a search for more diversification. This time it led to the processing and use of paper. Demand was for cut sizes of paper. The grocers' cornucopia (a very unstable package) was replaced by the pasted paper bag.

To enter this field in 1899, Smith, Winchester and Company purchased the Frank A. Jones Company of New York, the holder of the Charles Cranston patents on paper trimmers and paper bags. The most important of these patents was for the "Undercut" trimmer (guillotine). This trimmer has dominated the paper-making trade in the accurate trimming of fine papers. The automation, speed and accuracy of the Undercut has changed radically since 1899, but the principle of clamping from above and cutting from below has never been surpassed.



Smith, Winchester Undercut paper trimmer of 1880. This machine is designed for cutting water-marked papers to register, and is capable of cutting sheets up to 90 in. long.

In 1830 there were few specialities. A machine builder was obliged to produce nearly all of the parts going into his product. His ability and facilities had to be very broad. By 1900 specialists were beginning to take their place in manufacturing. Smith and Winchester was no exception and the company was known for leadership in paper-making machines, paper cutters, stuff and centrifugal pumps, winders, Jordan engines, bag machines for flour and cement bags, and the Undercut paper trimmer.

With the diversification of speciality machines by 1900, the company had grown beyond the capacity of one man to manage all phases of the business and new names appeared.

Carl E. Oman took charge of trimmers and bag machines. He was connected with the Frank A. Jones Company and rose to be Vice-President of Smith, Winchester and Company.

William P. Barstow had been with the company for many years. His alertness and experience made him ideal for the position of General Manager. With the co-operation of George Hatch and H. Edward Card, the loyal executives who managed the production in the plant, a new era was begun which laid the foundation for growth for years to come.

The Beloit Iron Works at Beloit, Wisconsin, were building paper-making machines towards the end of the nineteenth century and are, of course, today one of the world's leading makers of paper-making machines and equipment. In 1893, however, they built a famous machine which they exhibited at The World's Columbian Exposition at Chicago (see p. 352), and which was described as "The Novel Fourdrinier Machine of the Beloit Iron Works, one hundred and twelve inches wide, with a capacity of ten tons of paper a day, having a deckle frame with slice and pulleys of aluminium, so light that two men can lift it from the machine."

After the fair the machine was eventually purchased by Nekoosa Paper Company for nineteen thousand two hundred and forty dollars and installed by Nash at Nekoosa on the Wisconsin river. The machine was probably installed in 1894, and in 1895 Nash approached Beliot about increasing the speed of the machine, which was running well at 250 feet per minute on newsprint, and making 12 tons per day.

Beloit agreed that with some changes which they suggested should be made, it could be run safely at 300 to 320 feet per minute but that if quality were to be maintained more sulphite pulp should be added to the furnish!

In 1923 the "Columbian" machine, as it had come to be called, was dismantled and reassembled at the Port Edwards Mill of the Nekossa Edwards Paper Company, and it had several subsequent re-builds, additional dryers, etc.

More recently in 1963 it had another re-build resulting in its being possible to run it at 950 feet per minute on fine quality papers, instead of the original speed of 250 feet per minute on newsprint.

There are, of course, many instances of the very long life achieved by paper-making machines in many parts of the world, testifying to the excellent quality of the materials put into these early machines.

Among the early pioneers of paper-making machinery in the United States of America, besides those already mentioned earlier, were three companies who started work in three river valleys where paper-making had already taken root, namely the Miami River Valley in southern Ohio, the Black River Valley in northern New York, and the Brandywine Creek area of south-eastern Pennsylvania, where the first paper-mill in the United States was located.

To provide machine maintenance for Ohio paper-mills, Peter Black, joined two years later by Linus Clawson, founded a roll grinding shop in 1873 in Hamilton, Ohio. The partnership quickly prospered and by 1878 Black and Clawson were building many and varied machine components, and by 1880 the firm built its first Fourdrinier machine for the Harding Paper Company. Three


THE UNITED STATES OF AMERICA
BY ACT OF THEIR CONGRESS HAVE AUTHORIZED
THE WORLD'S COLUMBIAN COMMISSION
AT THE INTERNATIONAL EXHIBITION HELD IN THE CITY OF CHICAGO, STATE OF ILLINOIS, IN THE YEAR 1893,
TO DECREE A MEDAL FOR SPECIFIC MERIT WHICH IS SET FORTH BELOW OVER THE NAME OF AN INDIVIDUAL
JUDGE ACTING AS AN EXAMINER, UPON THE FINDING OF A BOARD OF INTERNATIONAL JUDGES, TO
BELOIT IRON WORKS, - BELOIT
WISCONSIN
EXHIBIT: PAPER MACHINE
AWARD
FOR VERY HIGH STANDARD OF WORKMANSHIP AND PRODUCTIVENESS, MAKING 2,000
POUNDS OF PRINTING PAPER PER HOUR. MACHINE SHOWS VERY GREAT
ADVANCEMENT IN THE ART OF PAPER-MAKING.
JOHN A. ROCHE,
MARCELLUS GOULD,
VENEZUELA
BOLIVIA
ECUADOR

years later the firm was incorporated as the Black-Clawson Company, and embarked on its long and highly successful course of development.

In 1853, George Goulding, proprietor of a machine shop in Watertown, New York, in order to obtain capital for expansion, entered into partnership with George Bagley and Edward Sewall; the firm being called Goulding, Bagley and Sewall, and specializing in maintenance and new equipment for paper-mills. By 1882 the partnership was incorporated as the Bagley and Sewall Company, and new buildings were erected and machine tools installed for the exclusive purpose of building Fourdrinier and cylinder machines.

These machines were sent widely across the United States and were also exported to Europe, Japan and many other countries.

In 1880 the Miller brothers of Downingtown, Pennsylvania, were early leaders in the paper industry in the Brandywine Creek, and one of them became a paper-maker, establishing the Downingtown Paper Company, while the other brother Guyon Miller started the Downingtown Manufacturing Company, expressly to build machinery for his brother's new board mill, and also to serve the other paper-mills in the area, one of his most successful products being the Downingtown soft and hardboard Fourdrinier machine. All these three machinery companies prospered in their several fields, and, as is well known, became eventually united in recent years to form the world-renowned Black-Clawson Company of today.

Prominent among the early manufacturers of American paper-making machines and machinery was the firm of Rice, Barton and Fales, still after well over a century very well known as builders of paper-making machines, especially in the United States. The firm was started in 1837 by two paper-makers, Henry P. Howe and Isaac Goddard, in Worcester, a small village in Massachusetts, but now a large town where the present firm still continues to operate. George M. Rice joined the firm in 1846, and George Sumner Barton, who at that time was an apprentice with the firm, became a partner and the name of the firm became Goddard, Rice and Company, which firm it is recorded were among the first engineers to make use of steam engines for power, in place of the traditional water-wheels. They also built many paper-making machines for the Middle West, in the days when railways were almost unknown. In 1853 Holyoke, now known as one of the most important paper-making centres of the world, had its first paper-making machine, but soon afterwards many mills were built there in rapid succession and Goddard, Rice and Company built them all, and acquired the manufacturing rights to many of the early and valuable inventions. It is interesting to note that the name of the American workman who was associated with the invention was attached to each: Harper Fourdrinier, Hulton wire guide, Gavitt cutter, Phelps cylinder dryer, Van de Water water-wheel, Kneeland layboy and Barrows tentering machine.

In 1862 the company redesigned and modernized its works and made machinery of new and heavier patterns, and the new firm of Rice, Barton and Company came into existence, with their former manager Fales as partner. In 1867, after the Civil War, the business was incorporated as Rice, Barton and Fales Machine and Iron Company, and by 1897 they had built the largest machine in the world at the time, a Fourdrinier to make 152 in. width of finished paper, which ran at a speed of 500 ft/min.

XIII

Escher Wyss of Zürich

ONE of the earliest engineering firms in Europe to build paper-making machines was Escher Wyss of Zürich.

This firm started as silk manufacturers and in 1803 Caspar Escher designed a spinning machine. He had travelled extensively in France and England whence he brought back a great deal of information and also drawings of machinery already in use there. Eventually the firm became interested in general engineering, hydraulic engineering, and the making of water-wheels and eventually of water-turbines and steam engines. As early as 1841 they built at Zürich a complete paper-mill installation.

It was the provision of water-wheels which gave Escher Wyss their entry into the paper-mill machinery business. Water was the only means of power, and it was water power which was needed by every paper-mill, so that it was quite natural that their knowledge of general mechanical engineering should lead them to make paper-mill equipment.

Escher Wyss made their first complete paper-mill installation in 1841, including their first paper-making machine. This was made in Zürich. Between 1841 and 1890 they made one hundred and seventy paper-making machines of which there are unfortunately few records, although it is known that they supplied a machine to Messrs. Turner, Symons and Company of Totnes, England, in 1888. This was a machine of the Sembritzki type already mentioned and illustrated earlier in this book. They also made an interesting machine in 1884 for the German paper-mill Limmritz-Steina, which was a combination of two Fourdrinier parts and is illustrated between pp. 250 and 251.

They eventually transferred their paper machinery side to Ravensburg and there they made paper-making machines to make cigarette paper and bank-note paper. For the latter they made single cylinder-mould machines, such as had been invented by John Dickinson. Escher Wyss have continued through the years to make paper-mill machinery and still enjoy a world-wide reputation for the excellence of their modern manufactures. They are among the oldest in time of any engineering firm in the world to make paper-mill machinery continuously.

As mentioned elsewhere in this book they had early associations with Bryan Donkin when he was making paper-making machines for several countries in Europe and their name occurs frequently in his diaries.

XIV

Johann Voith

ONE of the well-known paper machinery manufacturers who were among the early makers of paper-making machines is the firm of J. M. Voith of Heidenheim in Germany.

Born in 1803, Johann Matthaüs Voith was a skilled workman who at first made his reputation as a repairer of church clocks and public weighing machines, and on his travels in pursuit of his trade he noticed an increasing use of machines, and referred to himself as a "mechanikus". At that time the textile manufacturers imported machines from abroad and they needed someone to assemble them and keep them in repair. He was introduced to paper-making machinery at the local mill of Heinrich Völter, where in 1837 he assembled the first paper-making machine, the majority of the parts being purchased from outside manufacturers. In 1842, however, on the occasion of a local Industrial Exhibition, he first made a name for himself as an engineer in his own right by the introduction of a paper cutter.

His association with the owner of the paper mill, Heinrich Völter, had a great influence on the development of his business. It was this relationship which directed Voith's interests towards a new aspect of engineering, namely wood-grinding.

Up to that time paper could only be manufactured from rags or the re-processing of waste paper, but Völter had acquired the patents of the "ground wood" system from its inventor, Friedrich Gottlob Keller. After numerous trials and experiments, Völter and Voith between them finally produced the first mechanical wood-grinder, which was built in Voith's workshop in 1852.

Towards the end of that same decade Voith invented a machine to refine the ground wood into a substance suitable for paper-making. In this way Heidenheim became the birthplace of the "ground wood" system, which quickly spread throughout the world, so that paper-making was soon recognized as an industry of increasing importance. Johann Matthäus Voith, who built the first grinders sold by Völter to the paper industry, thus gained a reputation beyond the confines of Heidenheim and he soon began constructing other machinery for paper mills.

Voith's son Friedrich, born on 3rd July, 1840, studied at the Stuttgart Polytechnic. He was subsequently employed as a junior engineer with the Maschinenfabrik Escher Wyss in Ravensburg and later worked with Völter, for whom he travelled extensively abroad. During this period he acquired wide experience in the field of paper-making and the construction of paper machinery. In 1864, he returned to his father's works where 25 men were now employed and to which a foundry had been added in the previous year.

Voith entrusted his son with the execution of orders for the rebuilding of Völter's factory, which had been burnt down. He very soon realized that his son was capable of managing the whole works on his own and, as a result, handed over the business to him on 1st January, 1867.

The Voith Company consider this date as their official "Birthday", as Friedrich Voith on taking over the management from his father, entered the firm's name in the Trade Register. Friedrich,

Gemmrigheim Paper Mill on the Neckar, 1881.

however, had always regarded his father as founder of the firm and in consequence named it after him rather than in his own name. Thus did the firm of J. M. Voith originate.

The majority of orders were for machinery used in the manufacture of paper, particularly wood-grinding plant. Friedrich Voith had also invented a vibration screen, and 2300 of these screens were built and shipped all over the world. It was this invention in particular which made Voith's name recognized beyond the borders of Germany, besides tiding the firm over the deflationary period of the early eighties. After a while Voith gave up his other interests and concentrated entirely in the manufacture of paper-making machinery.

Another account states that the master mechanic Johannes Voith supplied machine parts for Völter's paper mill in 1822. The conversion of the hand-made rag paper mill into a mechanized paper mill followed in 1830 with the installation of a "continuous paper-making machine", the parts for which were supplied by Heilbronn for whom Donkin had supplied machines. There Gustav Schäuffelen had constructed a new type of flat wire paper-making machine with only one large drying cylinder and had put it into operation in his mill in 1828 after it had been rebuilt after a fire. The engineer who worked with him, Johann Widmann from Heilbronn, installed a similar machine in the Völter mill in 1830 and it made much better writings and printings than those imported from England and those made on the much more expensive Donkin paper-making machines, which were built on the principles of the Frenchman Louis Robert.

In 1837 Johann Matthäus Voith built many parts for a second, wider machine, which was supplied chiefly by Heilbronn and installed in the Völter branch mill in Gerschweiler. By this close co-operation the progressively minded Völter and Voith provided a good example for the introduction of machine-made paper in Württemberg, where more paper-making machines of the Donkin and Schauffelen types were installed up to 1840.

Heilbronn had been one of Donkin's earliest customers in Germany and supplied him with several machines and much equipment, including beating engines and water wheels.

There is a further account which states that it is now a hundred years since the late Albert Bezner acquired the Gemmrigheim mill on the Neckar and converted it into a machine mill. Here in 1866–9 he installed three water turbines made by Decker Bros. of Cannstatt to replace the old water wheel. For this mill Heinrich Voelter of Heidenheim supplied a grinder installation for aspen pulp that comprised three so-called defiberers as well as screens and preese-pâtes. The prepared aspen pulp was sent to the paper mill and mixed with rag pulp to make writings. Albert Bezner decided in 1870 to add a paper mill, and for this purpose acquired from Heinrich Voelter the so-called Meyh-Voelter patent process for making paper from steamed wood pulp without the addition of rag pulp. A 150 cm wide paper-making machine with two cylinder moulds and two felt presses was acquired from the Golzern, Saxony, machinery works and the dry part with five drying cylinders was supplied by the firm of Miller and Herbert of Edinburgh (?). In 1874, Bezner installed a spherical iron digester of diameter 3 m, from Hilt and Metzger of Cannstatt, for cooking spruce wood. Albert Bezner was killed when the digester exploded as it was being brought into operation. It appeared that in the suppliers' works the manhole cover had developed a crack at a pressure below 10 atm: and this had irresponsibly been plugged with lead. This mishap later contributed to the founding of the Württemberg examination association.

In 1878-80 Voith supplied three new water turbines to Gemmrigheim. Meanwhile the flat wire machine supplied by Erkens of Düren was used for making various types of paper, including sugar paper, and had a high output. Since this machine was operating at maximum capacity it was decided to install a new paper-making machine, mainly for making wallpaper.

In 1863 the high-speed rotary press was invented. Ten years later Georg Haindl of Augsburg installed a Donkin newsprint machine for the newly developed MAN rotary printing press. At the same time (1873) Bischof constructed a reeler which could produce uniform, tight reels. In spite of this example of specialization, at that time there were only the so-called "omnibus machines" on which many different types of paper could be made. The operating widths were 150–160 cm, speeds were 5–35 m/min and the corresponding outputs were 1500–2000 kg per day. In 1881 Voith built his first paper-making machine for the firm of Raithelhuber, Bezner & Co. of Gemmrigheim. This had a wire 235 cm wide and its operation will be discussed briefly with reference to the diagram. On the extreme right the stuff containing the finely divided fibres flows through a screen, the perforated plate of which is shaken, in a final cleaning stage, before passing to a distributor at the head of the machine. It is blocked so much across the whole wire width and by baffles that it flows through the gap between the last baffle and the wire table at about the same speed as the wire. To begin with the water passes through the meshes of the wire under gravity and is later sucked through. On the first part of the wire the fibres move freely in the water, then they become entangled by the shake of the wire and felt together as drainage proceeds. At the end of the wire there is a roll press (the couch) which makes the web stronger by removing more water so that it can be taken up and transferred to the first wet felt. The paper is still wet and weak and is carried through more presses and compressed. At the last press the paper web is reversed so that the side marked by the wire and the wet felts comes into direct contact with the smooth upper roll.

The sheet passes over drying cylinders and is pressed against the polished surfaces of these by dry felts. It is then smoothed by the rolls, dried, slit and reeled up.

The most difficult production process can be expressed roughly by a few figures. For example the stuff flowing on the wire has a consistency of 0·5 per cent, the fibrous web at the end of the wire is 20 per cent, entering the dry part 35 per cent and the end of the machine 95 per cent dry solids content. Voith's invoice for this machine had only a single line:

1 Paper-making machine 235 cm wide .. .. .. Marks 70,000

With the installation of this modern machine with conical pulley drive the paper mill, which can be seen in the picture, was equipped in 1884 with a new grinder installation with three grinders and three Voith turbines. As a result of the improved raw material position, in 1889 and 1892 two more paper-making machines were bought from Voith.

The Voith No. 1 paper-making machine was converted several times and ran for 45 years, that is until 1926, when it was almost completely rebuilt. The machine, however, continued to make wallpaper base. The supply of Voith paper-making machines to Gemmrigheim resulted in Voith also providing ancillary equipment such as Hollanders, kollergangs, etc. Apart from the steam plant only Voith machines were used in the extension of the paper mill and these had a splendid opportunity of proving themselves in Gemmrigheim. In this way a friendly relationship and close business connection grew up between Heidenheim and Gemmrigheim and this has continued to develop over many decades.

There were several narrow, fine paper-making machines among the first 25 paper-making machines made in Heidenheim up till 1900.

Specialization in the paper industry had already begun and there were soon fine paper, newsprint, printings, packing, tissue and cigarette paper mills. All machines have wire, press and dry parts but differ from one another in detail. In general several improvements resulted from tests and investigations—wire parts mounted in leaf springs for easy shake; granite top rolls for wet presses; closed dry parts with two rows of opposed cylinders connected on the drive side by cogwheels.

J. M. Voith, Maschinenfabrik, Heidenheim, Württemberg
Paper-making machines supplied and large-scale conversions
Machines marked * were supplied by St. Pölten

Current No.	Year of Manufacture	Customer	Wire Width m/m	Remarks
1	1881	Raithelhuber & Co. G.m.b.H., Kirchheim a. X. N., Württbg.	2350	complete paper-making machine
2	1888	J. W. Zanders Papierfabrik, Berg.-Gladbach bei Köln a. Rh.	2350	,, ,, ,,
3	1889	J. W. Zanders Papierfabrik, Berg.-Gladbach bei Köln a. Rh.	1850	,, ,, ,,
4	1890	E. Holtzmann & Cie. AG., Weisenbachfabrik im Murgtal, Baden	2440	,, ,, ,,
5	1891	Papierfabrik Wolffegg AG., Wolffegg, Württbg.	2350	,, ,, ,,
6	1892	Raithelhuber & Co., G.m.b.H., Kirchheim a. N., Württbg.	2350	,, ,, ,,
7	1892	Zellstofffabrik Waldhof, Mannheim-Waldhof	2620	,, ,, ,,
8*	1894	Teisnacher Papierfabrik AG., Teisnach, Nieder-bayern	2400	extension of dry part
9	1895	Papierfabrik Dobrusch Sr. Hoheit des Fürsten Paskévitsch, Dobrusch, Rußland	1750	complete paper-making machine
10	1895	C. G. Schönherr, Floßmühle bei Bostendorf, Sachsen	2450	,, ,, ,,
11*	1895	Papierfabrik Steyrermühl AG., Steyrermühl, Ober-Österreich	1850	wet and dry part and conical drum drive
12	1896	Züricher Papierfabrik a.d. Sihl, Zürich-Wiedikon, Schweiz	1900	complete paper-making machine

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