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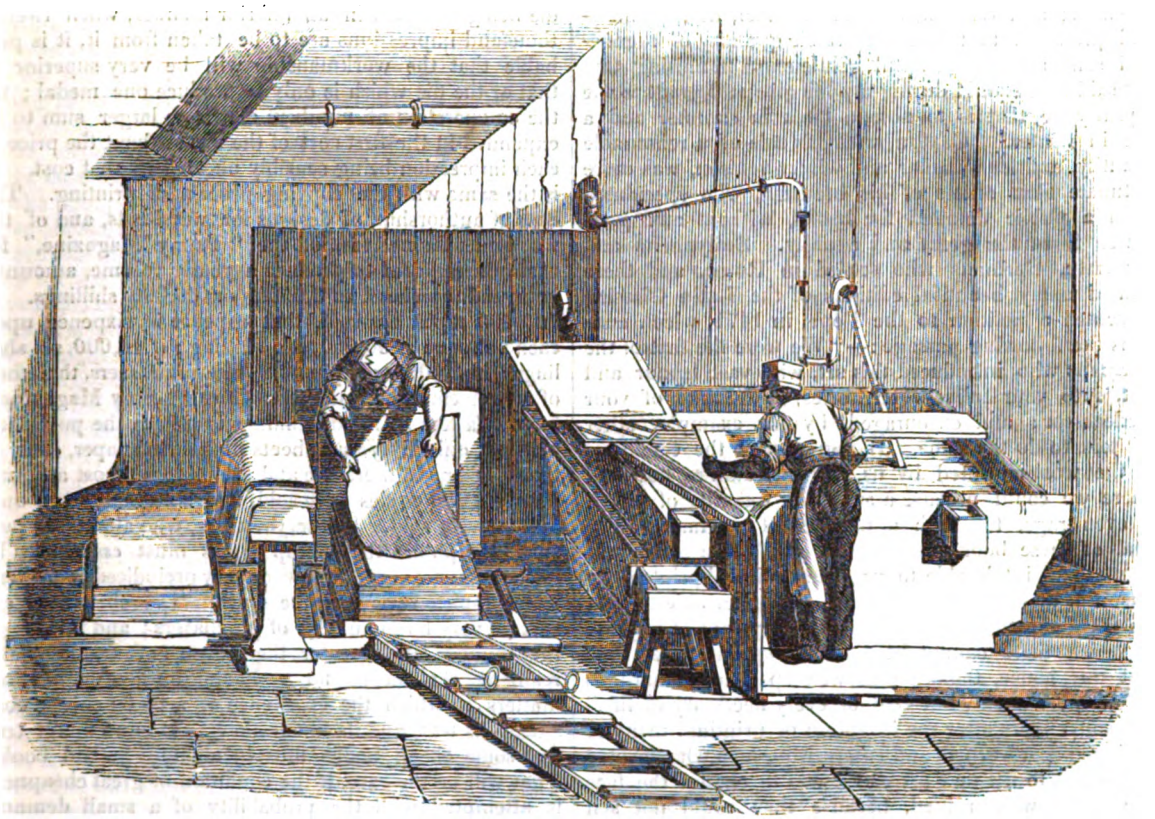
INTRODUCTION.



[Paper Making, by Hand.]

William Caxton, the first English printer, at the end of the first book which he printed, uses the following remarkable words:—

"Thus end I this book, which I have translated after mine author, as nigh as God hath given me cunning; to whom be given the laud and praising. And forasmuch as in the writing of the same my pen is worn, mine hand weary and not stedfast, mine eyes dimmed with overmuch looking on the white paper, and my courage not so prone and ready to labour as it hath been, and that age creepeth on me daily and feebleth all the body; and also because I have promised to divers gentlemen and to my friends to address to them as hastily as I might this said book: Therefore I have practised and learned, at my great charge and dispense, to ordain this said book in print, after the manner and form as ye may here see. And (it) is not written with pen and ink as other books be; to the end that every man may have them at once. For all the books of this story, named the 'Recule of the Histories of Troyes,' thus imprinted as ye here see, were begun in one day, and also finished in one day*."

In this passage we find most of the conditions expressed which mark the superiority of the invention of printing over the old mode of multiplying books by the pen. The transcriber of a manuscript had to contend with the weary hand and the dim eye; he could not satisfy the wishes of "divers gentlemen" by producing his book "hastily;" and, above all, he could not meet the instant demand for copies of an admired production, by allowing every man to "have them at once." The slow process by which he worked was necessarily an expensive process: and thus the written books were immoderately dear; and so much importance was attached to them as property, that in many cases a volume was conveyed from the seller to the purchaser by legal assignment. On the contrary the printer, after certain processes had been gone through which were equivalent to the labours of transcribing three or four copies, could produce as many books as he pleased; and as far as taking off the impressions was concerned (to which the old printers peculiarly applied the name of their art), a small book, such as that first printed by Caxton, might be "begun in one day, and also finished in one day."

The process of printing, when compared with that of writing, is unquestionably a cheap process; provided a sufficient number of copies of any particular book are printed, so as to render the proportion of the first expense upon a single copy inconsiderable. If, for example, it were required, even at the present time, to print a single copy, or even three or four copies, only of

* Ames' Typographical Antiquities, by Herbert. We have changed the old orthography of the passage.

any production, the cost of printing would be greater than the cost of transcribing. It is when hundreds, and especially thousands, of the same work are demanded that the great value of the printing press in making knowledge cheap, is particularly shown. It is probable that the first printers did not take off more than two or three hundred, if so many, of their works; and, therefore, the earliest printed books must have been still dear, on account of the limited number of their readers. Caxton, as it appears by a passage in one of his books, was a cautious printer; and required something like an assurance that he should sell enough of any particular book to repay the cost of producing it. In his "Legends of Saints" he says, "I have submysed (submitted) myself to translate into English the 'Legend of Saints,' called 'Legenda aurea' in Latin; and William, Earl of Arundel, desired me—and promised to take a reasonable quantity of them—and sent me a worshipful gentleman, promising that my said lord should during my life give and grant to me a yearly fee, that is to note, a buck in summer and a doe in winter." Caxton, with his sale of a reasonable quantity, and his summer and winter venison, was more fortunate than others of his brethren, who speculated upon a public demand for books, without any guarantee from the great and wealthy. Sweynheim and Pannartz, Germans who settled in Rome, and there printed many beautiful editions of the Latin Classics, presented a petition to the Pope, in 1471, which contains the following passage:—"We were the first of the Germans who introduced this art, with vast labour and cost, into your holiness' territories, in the time of your predecessor; and encouraged, by our example, other printers to do the same. If you peruse the catalogue of the works printed by us, you will admire how and where we could procure a sufficient quantity of paper, or even rags, for such a number of volumes. The total of these books amounts to 12,475,—a prodigious heap,—and intolerable to us, your holiness' printers, by reason of those unsold. We are no longer able to bear the great expense of house-keeping, for want of buyers; of which there cannot be a more flagrant proof than that our house, though otherwise spacious enough, is full of quire-books, but void of every necessary of life." For some years after the invention of printing, many of the ingenious, learned, and enterprising men who devoted themselves to the new art which was to change the face of society, were ruined, because they could not sell cheaply unless they printed a considerable number of a book; and there were not readers enough to take off the stock which they thus accumulated. In time, however, as the facilities for acquiring knowledge which printing afforded created many readers, the trade of printing books became one of less general risk; and dealers in literature could afford more and more to dispense with individual patronage, and rely upon the public demand. After the experience of three centuries and a half, the power of reading has become so generally diffused, that a work like the "Penny Magazine," which requires a sale of 60,000 or 70,000 copies, before any profit can accrue, may be undertaken, with a reliance alone upon the general demand arising out of the extended desire of knowledge. The periodical sale of 160,000 copies of this work is the extreme point which literature has yet reached, in contrast with the promise of the Earl of Arundel to our first printer, to take of him a reasonable quantity of copies, and give him a buck and a doe yearly.

It has been said, that "the bent of civilization is to make good things cheap." There can be no doubt whatever, that in all the processes in which science is applied the article produced is not only made better but cheaper; and the more "the bent of civilization" leads to an extension of demand, the more will scientific knowledge, and the division of labour, be called into employment. But this is peculiarly the case in all *copying* processes, among which printing is the foremost. If a medal be executed for the use of one person only,—that is, if the whole expense of making the die be borne by one impression from the die,—the cost of one medal must be very great. But if many thousand copies of that medal be required, as was the case when the British soldiers who had been present at the victory of Waterloo each received a medal, the cost of the die, as apportioned to each medal, is scarcely anything. Now, instead of the die being executed in an inferior manner, when twenty thousand impressions are to be taken from it, it is probable that the workmanship will be very superior to that of the die which is only to produce one medal; for the co-operation of numbers allows a larger sum to be expended in the first cost of the die, without the price of each impression being sensibly affected by that cost. It is the same with the copying process of printing. The cost of authorship, of designs for wood-cuts, and of the wood-cuts themselves, of the "Penny Magazine," for example, required to produce a yearly volume, amounts, in round numbers, to 3,000*l.*, or 60,000 shillings. If 120,000 copies are sold, that expence is sixpence upon each volume; if 60,000, one shilling; if 10,000, six shillings; if 3,000, one pound. The purchasers, therefore, of a twelvemonths' numbers of the "Penny Magazine," for which less than four shillings is paid to the publisher, buy not only sixty-four sheets of printed paper, but as much labour of literature and art as would cost a pound if only 3,000 copies were sold, and six shillings if only 10,000 were sold. Those, therefore, who attempt to persuade the public that cheap books must *essentially* be bad books, are very shallow, or very prejudiced reasoners. The complete reverse is the truth. The cheapness ensures a very large number of purchasers; and the larger the number the greater the power of commercially realizing the means for a liberal outlay upon those matters in which the excellence of a book chiefly consists,—its text, and its illustrations. It is no doubt true that some cheap books must incidentally be bad books. That will be the case, if the condition of great cheapness is attempted with the probability of a small demand. Under such circumstances, the book must either be worthless, or the publishers must sustain severe loss. In cheap publications, the great object to be aimed at, is *certainty* of sale; and that certainty can only be attained by carrying the principle of excellence as far as can be compatible with commercial advantage. The first element of this certainty is an adequate demand.

The almost universal circulation of our "Penny Magazine" in the United Kingdom; its republication in the United States of America; the establishment of works of similar character, (in all respects imitations,) in France, Belgium, Germany, and Russia; and the plans already formed and announced for extending such publications to Italy, Holland, Poland, and the Brazils,—these circumstances have led us to think that a popular account of all the processes necessary for its production would be of very general interest. It is, therefore, our intention to devote the present Supplement, and the three following Supplements, to this undertaking. About twenty wood-cuts will be employed in illustrating the subject.

SECTION 1.—PAPER MAKING.

IN the petition of Sweynheim and Pannartz to the Pope, which we have already quoted, one passage shows that the demand for paper, which had been created by the new art of printing, was supplied with difficulty. "If you peruse the catalogue of the works printed by us, you will admire how and where we could procure a sufficient quantity of paper, or even rags, for such a number of volumes." The total of their books amounted to 12,475

volumes. If we average each volume at 50 sheets, of the same size as the "Penny Magazine," (which is indeed the size of the early folios,) we find that the quantity of paper thus printed upon was about 1250 reams. Now, this is as near as may be the quantity required for three numbers only of the "Penny Magazine;" or one twentieth of the quantity annually consumed in printing sixty-four numbers. In weight the quantity for our annual consumption amounts to 500,000 lbs. But then the total annual production of first class paper (that is, writing and printing paper), in the United Kingdom, is about 50,000,000 lbs., or about 100 times as much as that used for the "Penny Magazine," and more than 2000 times as much as the paper used in the 12,475 volumes of the poor German printers. It is not unlikely, therefore, that some of our readers may admire how and where *we* can now procure a sufficient quantity of rags for such an immense production of printing and writing paper. We will endeavour to explain how this is managed.

The material of which the sheet of paper which the reader now holds in his hand is formed, existed, a few months ago, perhaps in the shape of a tattered frock, whose shreds, exposed for years to the sun and wind, covered the sturdy loins of the shepherd watching his sheep on the plains of Hungary;—or it might have formed part of the coarse blue shirt of the Italian sailor, on board some little trading vessel of the Mediterranean;—or it might have pertained to the once tidy *camicia* of the neat straw-plaiter of Tuscany, who, on the eve of some festival, when her head was intent upon gay things, condemned the garment to the *straoci-vendolo** of Leghorn; or it might have constituted the coarse covering of the flock bed of the farmer of Saxony, or once looked bright in the damask table-cloth of the burgher of Hamburgh;—or, lastly, it might have been swept, new and unworn, out of the vast collection of the shreds and patches, the fustian and buckram, of a London tailor,—or might have accompanied every revolution of a fashionable coat in the shape of lining—having travelled from St. James's to St. Giles's—from Bond Street to Monmouth Street—from Rag Fair to the Dublin Liberty—till man disowned the vesture, and the kennel-sweeper claimed its miserable remains†. In each or all of these forms, and in hundreds more which it would be useless to describe, this sheet of paper a short time since might have existed. The rags of our own country do not furnish a fifth part of what we consume in the manufacture of paper. France, Holland, and Belgium prohibit, under severe penalties, the exportation of rags, because they require them for their own long-established manufactories. Spain and Portugal also prohibit their exportation. Italy and Germany furnish the principal supplies of linen rags, both to Great Britain and the United States. They are exported from Bremen, Hamburgh, Rostock, Ancona, Leghorn, Messina, Palermo, and Trieste. They arrive in our ports in closely packed bags, containing each about four hundred-weight, which, according to the respective qualities of the rag, are marked SPFF, SPF, FF, FX, and FB. There are many varieties of rag even in these divisions; and their qualities are pretty clear indications of the state of comfort and cleanliness in particular districts and countries. The linen rags of England are generally very clean, and require little washing and no bleaching, before they are ground into pulp;—the Italian rags, on the contrary, are originally so dirty, that they are washed in lime before they are fit for the foreign market. The greater portion of the rags from the north of Europe are so dark in their colour and so coarse in their texture, that it is difficult to imagine how they could have formed part of any inner garments; while those, on the other hand, which are collected at home, evidently belong to a people who are clothed in "fine linen" every day.

In a rightly-managed paper-mill no substance but rags enters into the composition of first-class paper. Dishonest manufacturers have, indeed, employed plaster of Paris in large quantities; but we believe the practice is very generally discontinued. Many experiments have been made upon substances proposed as substitutes for rags in the manufacture of paper. The bark of the willow, the beech, the aspen, the hawthorn, and the lime, have been made into tolerable paper; the tendrils of the vine, and the stalks of the nettle, the mallow, and the thistle, have been used for a similar purpose; the bine of our own hops, it is affirmed, will produce paper enough for the use of England; and several patents have been granted for making paper of straw. The process of bleaching the coarser rags, so as to render them fit for the purposes to which only those of the finest qualities were formerly applied, will, however, render the use of these inferior substances unnecessary for many years. But the time may probably come when we shall obtain no rags from other countries. The advance of a people in civilization has not only a tendency to make the supply of rags abundant, but, at the same time, to increase the demand for rags. The use of machinery in manufactures renders clothing cheap; the cheapness of clothing causes its consumption to increase, not only in the proportion of an increasing population, but by the scale of individual expenditure; the stock of rags is therefore increasing in the same ratio that our looms produce more linen and cotton cloth. But then the increase of knowledge runs in a parallel line with this increase of comforts; and the increase of knowledge requires an increase of books. The principle of publishing books and tracts, to be read by thousands instead of tens and hundreds, has already caused a large addition to the demand for printing-paper. In 1829 the excise-duty on paper amounted to £728,000; in 1832 to £815,000. If, therefore, the demand for books, not only in England but in all civilized countries, should outrun, which it is very likely to do, the power of each individual to wear out linen and cotton clothing to supply the demand, paper must be manufactured from other substances than rags.

The paper upon which the "Penny Magazine" is printed is chiefly manufactured at Albury Mill, near Guildford, belonging to Mr. Magnay. Paper-mills in the south of England are set in motion by water-power,—that is, they are placed upon some small stream, which, being dammed up, sets the wheels in motion, as in a flour-mill. In the north of England, where coal is abundant, paper-mills employ steam-power; and in the present mode of manufacturing paper, in which heat is essential, it is probable that the article can be produced at a lower rate by this process. A paper-mill, moved by water-power, is generally a very agreeable object. It is in most instances situated in some pretty valley, through which the little river glides;—and as it is important that the water, (which is not only employed for turning the wheels, but for converting the rags into pulp,) should be of the purest quality, the stream is generally one of those transparent ones which are so common in England—now bubbling over pebbly shallows, and now sleeping in quiet depths. The paper-mill at Albury is of this picturesque character. We think it better to describe the process of paper-making as we saw it at this mill, than to adopt a more general description, which might appear to have less reality about it.

The first process is strangely in contrast with the general appearance of cleanliness which distinguishes a

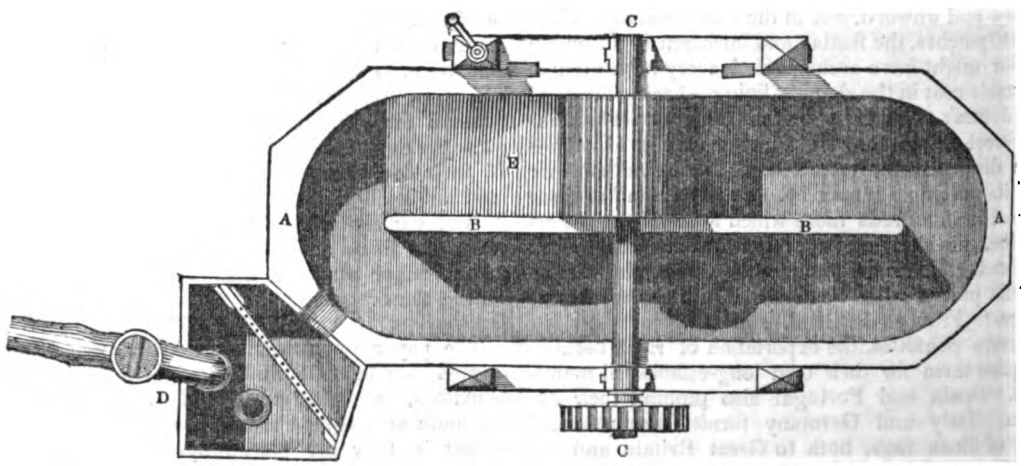
* Rag-merchant. The rags of Italy, as well as of other countries, are collected by travelling dealers, who convey them to the depositories in the towns.

† The *chiffonniers* (rag-dealers) of Paris rose against the police, a year or two ago, because it was ordered, in certain municipal regulations, that the filth of the streets should be taken away in carts, without time being allowed for its examination by those diligent savers of capital.

paper-mill. In a long room, filled with dust, are some twenty or thirty women employed in sorting and cutting rags. Each woman stands at a frame, or table, whose top is covered with wire: on her left is a quantity of rags; on her right a box divided into three compartments. On a part of the table an upright knife, about a foot long, is fixed. This formidable instrument looks like the broken blade of a scythe, and we believe it is so. It is the business of the woman to sort and cut the rags. She spreads a few on the wire frame before which she stands; and as she shakes them a great deal of the dirt passes through the wire to a box beneath. If the pieces are small enough,—and they are required not to be larger than three or four inches square,—she throws each piece into one of the compartments of the box on her right, according to its quality. If a piece requires to be cut, she draws it across the blade of the knife, by which it is instantly divided. She is particularly careful to put all seams by themselves; for the sewing thread, if not thoroughly ground, would produce filaments in the paper. These operations are performed with great rapidity. An active workwoman can sort and cut about a hundred-weight a day. When cut and sorted the rags are weighed, and removed in bags containing each a hundred-weight.

In looking at the operations of the rag-room, the first impression of the visitor is, that the rags which he sees are for the manufacture of the coarse brown paper which is used for so many commercial purposes. He cannot believe that the dingy bits of linen cloth, many of them originally of the colour of a sack, and others so dirty as to appear as incapable of being purified as the blood-spotted hand of Macbeth's wife, should become that beautiful fabric, a sheet of white paper. But so it is. This wonderful change is gradually brought about by very certain and simple processes. We leave the sorting-room, and are conducted to a shed, in which there are several large square chests filled with rags. We see the muddy-looking mass heaving up and somewhat agitated. Steam is being admitted into the chests; and here they are boiled with lime for a few hours. At the end of that period they are still very discoloured; but the inexperienced observer begins to have hopes that they may at least serve for *whited-brown* paper. From the washing shed we are conducted into an upper room in the mill We hear a deafening noise, and see that it is produced by the movements of a large horizontal wheel, which is connected with several oval cisterns, or troughs, about ten feet long, and four or five feet broad. These troughs, and the machinery within them, are technically called *Engines*: their uses are most important in the manufacture. Previous to their introduction into this country, which was about sixty years ago, the rags were first washed by hand;—then placed wet in close vessels till they became half-rotten;—and after the fibre was thus nearly destroyed, they were reduced to pulp, either by hammers in a mortar, or by a cylinder grinding against the sides of a circular wooden bowl. All these operations were slow and expensive, and very destructive of material. In these engines, which wash, tear, and beat the rags, every particle is preserved; and the whole process, by the aid of machinery in making the sheet, is so rapid, that a bag of rags may easily leave the port of Hamburgh on the first of September, and be converted into paper—nay printed upon and distributed through the United Kingdom in the form of a "Penny Magazine"—by the first of October.

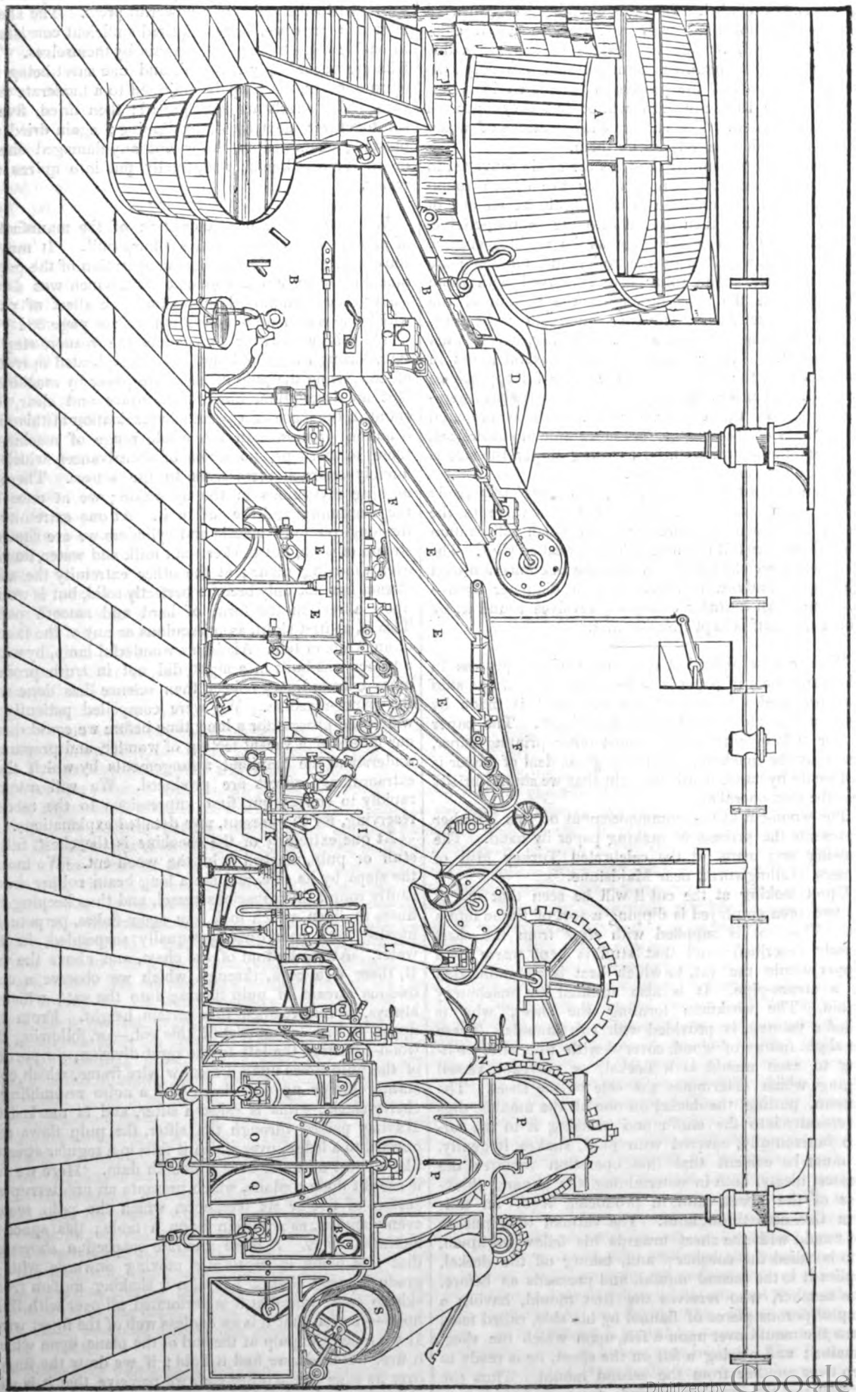
Into one of these engines, then, the boiled rags are first placed to be washed. If the white linen rags of England only are used, they are not boiled, but are at once placed in the washing engine. The following wood-cut may assist the description:—



A is the trough, ten feet long, four and a half feet broad, and two and a quarter feet deep. It is made of wood, lined with lead. B is a longitudinal division of the engine; C is an iron roller, twenty-two inches in diameter, and twenty-six inches wide. D is an apparatus for conveying pure water into the trough, and for carrying off the foul water. The roller being set in motion, about a hundred weight of rags are put into the trough, and as much water is let in as will raise the whole to within an inch or two of the brim. The roller is not a plain cylinder, but its surface presents a number of bars, or knives, projecting more than an inch radially from its axis; and beneath the roller is a plate composed of bars, or knives, of the same kind as those of the roller. When the roller commences its revolutions, of which it makes about 160 in a minute, the rags are carried with great rapidity through the knives; and as the roller is depressed upon the plate, or elevated, are the rags drawn out, or bruised, or cut, as may be required. Above the roller is a cover, (not shown in the cut,) in which are two frames of wire cloth, communicating with the pipes at D. When, therefore, the whole mass is in agitation, the rags, after passing through the knives of the roller and the plate, are carried up the inclined plane of the division E; and the foul water, passing through the frames, is removed by a pipe at D, while a clear stream is continually pouring in from the same point. In this way the rags are bruised down, and washed, in the first engine. After this operation has been continued for a sufficient time, the water is let off; and the cleansed mass is removed to a press, for the purpose of driving out the greater part of the water which remains in it. In this state, the foreign rags, though not white, are clean, and have somewhat the colour of the cloth called brown holland. The visitor has now hopes that something like white paper may be produced from them.

The discoveries of modern chemistry have assured to us

the perfect completion of these hopes. The process of bleaching reduces every description of linen rag to an uniform whiteness; and if the operation is properly conducted, the quality of the fabric is uninjured. The rags,



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 Reel.

being removed from the press, are placed in a receiver or chamber made of wood, from which the external air is carefully excluded. Into this chamber are conveyed pipes, communicating with a retort, in which chlorine is formed, by the application of heat to a due proportion of manganese, common salt, and sulphuric acid. This part of the process is completed in a few hours. The rags are now white; but they have an intolerable smell. The subsequent operations of washing and bruising entirely purify them.

From the gas chamber the rags are again conveyed to the washing-engine. In this they are driven round as before, till the chlorine is thoroughly forced out of them. They are then let off into the beating-engine. This is of the same construction as the washing-engine, except that the knives of the roller and the plate are closer together. The roller here is moved with more rapidity. In the washing-engine the motion of the rollers produces a harsh growling sound—in the beating-engine the noise is that of a loud humming, which is not unpleasant. Having been ground for several hours in this machine, the rags assume the beautiful appearance of pulp. In this state the preparation somewhat resembles milk. In this engine, the *size*, which is prepared from pieces of sheep-skins, and other animal substances, is sometimes introduced. In writing paper the size is applied after the sheet is made.

From the last engine the pulp, now completely ready to be formed into paper, is conveyed by a valve to the chest. This is a large circular vessel which will contain several engines full of pulp, technically called *stuff*. The chest which we shall presently describe in connexion with the *paper-machine*, is twelve feet in diameter by five in depth. An *agitator* constantly revolves round it, by which the stuff is kept from sinking.

We are now arrived at that stage of the process in which the sheet of paper is to be formed out of the stuff thus prepared. In some cases the sheet is made by hand in a mould; in others by machinery. The paper of our "Magazine" is, like most other printing-paper, made by the machine. But as a great deal of paper is still made by hand, it will be right that we should briefly describe that operation.

The wood-cut at the commencement of this Number represents the process of making paper by hand. The drawing was made at the celebrated Turkey Mill of Messrs. Hollingworth, near Maidstone.

Upon looking at the cut it will be seen that one of the two men employed is dipping a sort of frame into a vat. This vat is supplied with *stuff* from the chest already described; and that stuff is kept warm by a copper within the vat, to which heat is communicated by a steam-pipe. It is also agitated by machinery within. The workman forming the sheet, who is called a vatman, is provided with two moulds. These are slight frames of wood, covered with fine wire. Fitting to each mould is a deckel, or moveable raised edging, which determines the size of the sheet. The vatman, putting the deckel on one of the moulds, dips it vertically into the stuff; and bringing it to the surface horizontally, covered with pulp, shakes it gently. It must be evident that this operation requires the greatest nicety, both in determining the general thickness of the sheet, and in producing it of an uniform thickness throughout. The vatman then pushes the mould with the sheet towards his fellow workman, who is called the coucher; and, taking off the deckel, applies it to the second mould, and proceeds as before. The coucher, who receives the first mould, having a heap of porous pieces of flannel by his side, called felts, turns the mould over upon a felt, upon which the sheet remains; and placing a felt on the sheet, he is ready to turn over another from the second mould. Thus the vatman and the coucher proceed, the one moulding a sheet of paper, and the other placing it upon felt, till they have made six or eight quires. The heap is then subjected to the action of a powerful press. The sheets, after this pressure, have acquired sufficient consistency to enable them to be pressed again by themselves. The felts are accordingly removed, and one sheet being laid upon another, the heap is subjected to a moderate pressure. The sheets are next parted; then dried, five or six together; next sized, by dipping; again dried and pressed; examined to throw out any damaged sheets, or to remove knots; and, finally, put into quires and reams.

We now resume our description of the manufacture of paper, as we saw it at the Albury mill. It may be convenient, before describing the operation of the paper-machine, to refer to a wood-cut of it, which was drawn from the one employed in making the sheet of paper which the reader now looks upon. (See page 381.)

We will endeavour to conduct the reader, step by step, through the rapid but most complicated operation of converting the pulp of rags into paper by machinery. But no description, however accurate and clear, can stand in the place of a personal examination of this most beautiful process. In the whole range of machinery, there is, perhaps, no series of contrivances which so forcibly address themselves to the senses. There is nothing mysterious in the operation; we at once see the beginning and the end of it. At one extremity of the long range of wheels and cylinders we are shown a stream of pulp, not thicker than milk and water, flowing over a moving plane; at the other extremity the same stream has not only become perfectly solid, but is wound upon a reel in the form of hard and smooth paper. This is, at first sight, as miraculous as any of the fancies of an Arabian tale. Aladdin's wonderful lamp, by which a palace was built in a night, did not in truth produce more extraordinary effects than science has done with the paper-machine. We were compelled patiently to watch the process for a long time before we could divest our minds of a vacant feeling of wonder, and prepare to understand the manifold arrangements by which these extraordinary effects are produced. We will attempt rapidly to convey our first impressions to the reader; reserving, for the present, any detailed explanations.

At one extremity of the machine is the chest, full of stuff or pulp, marked A in the wood-cut. We mount the steps by its side, and see a long beam rolling incessantly round this capacious vessel, and thus keeping the fibres of linen, which look like snow-flakes, perpetually moving, and consequently equally suspended, in the water. At the bottom of the chest, and above the vat, B, there is a cock, through which we observe a continuous stream of pulp flowing into the vat; which is always, therefore, filled to a certain height. From the upper to the lower part of this vat,—or, following the wood-cut, from the left to the right division,—a portion of the pulp flows upon a narrow wire frame, which constantly jumps up and down with a noise resembling a cherry-clack;—this is called a sifter, and is marked C. Having passed through the sifter, the pulp flows still onward to a ledge, over which it falls in a regular stream, like a sheet of water over a smooth dam. Here we see it caught upon a plane, which presents an uninterrupted surface of five or six feet, upon which the pulp seems evenly spread, as a napkin upon a table; this space is indicated by E. A more accurate inspection shows us that this plane is constantly moving onwards with a gradual pace; that it has also a shaking motion from side to side; and that it is perforated all over with little holes—in fact, that it is an endless web of the finest wire. If we touch the pulp at the end of the plane, upon which it first descends, we find it fluid; if we draw the finger over its edge at the other end, we perceive that it is still soft—not so hard, perhaps, as wet blotting-paper,—but

so completely formed, that the touch will leave a hole, which we may trace forward till the paper is perfectly made. The pulp does not flow over the sides of the plane, we observe, because a strap, on each side, constantly moving, and passing upon its edges, regulates the width; these straps are marked F. After we pass the wheels upon which these straps terminate, we perceive that the paper is sufficiently formed not to require any further boundary to define its size;—the pulp has ceased to be fluid. But it is yet tender and wet; and we see that a wire cylinder, G, which presses upon its surface, leaves a succession of lines marked upon it in its passage. The paper, we perceive, is not yet completely off the plane of wire: before it quits it, another roller, I, which is clothed with felt, and upon which a stream of cold water is constantly flowing, subjects it to pressure. The paper has at length left what may be called the region of *Wire*, and has entered that of *Cloth*. A tight surface of flannel, or felt, is moving onwards with the same regular march as the web of wire. Like the wire, the felt is what is called endless,—that is, united at the extremities, as a jack-towel is. We see the sheet travelling up an inclined plane of this stretched flannel, which gradually absorbs its moisture. It is now seized between two rollers, L, which powerfully squeeze it. It goes travelling up another inclined plane of flannel, and then passes through a second pair of pressing-rollers, M. It has now left the region of cloth, and has entered that of *Heat*. The paper, up to this point, is quite formed; but it is fragile and damp. It is in the state in which, if the machinery were to stop here, as it did upon its first invention, it would require (having been wound upon a reel) to be parted and dried as hand-made paper is. But in a few seconds more it is subjected to a process by which all this labour and time is saved. From the last pair of cloth-pressing rollers, the paper is received upon a small roller marked N. It is guided by this over the polished surface of a large heated cylinder, O. The soft pulp tissue now begins to smoke; but the heat is proportioned to its increasing power of resistance. From the first cylinder, or drum, it is received upon a second, P, considerably larger, and much hotter. As it rolls over this polished surface, we see all the roughness of its appearance, when in the cloth region, gradually vanishing. At length, having passed over a third cylinder, Q, still hotter than the second, and having been subjected to the pressure of a blanket, which confines it on one side, while the cylinder smooths it on the other, it is caught upon the last roller, R, which hands it over to the reel, S,—the perfect substance which the reader now holds in his hand. But there is no division in the paper thus formed; it is an uninterrupted roll of yard upon yard, which has no necessary termination but the power of reeling it. A supplementary machine (see the wood-cut in the last page) receives it off the reel; and as it mounts upon the drum, T, a circular knife cuts it into two breadths; while, having descended to the point V, a series of sharp teeth, which strike against it within, divide it, by a stroke of invariable regularity, into the requisite lengths. The sheet of paper for a "Penny Magazine" is now made. The process is as rapid as it is beautiful. It has taken us two hours to write this very imperfect description of it. From the commencement of the process, when the pulp flows out of the vat upon the web of wire, till the paper into which it is formed is received upon the reel, somewhat less time than two minutes is occupied. We ascertained the fact by drawing our finger across the wet mass before it left the web, and tracing the rent into the final stage of the formation of the paper. The web of wire travels at a rate which produces twenty-five superficial feet of paper per minute.

In all machinery which takes the place of handiwork there must be certain points of resemblance, or of contrast, between the one process and the other, which are instructive to examine. Up to the formation of the pulp or stuff, the process of paper-making is the same, as we have seen, whether the pulp is to be converted into paper by hand or by machinery. The vatman dips his mould into the vat, and produces a soft sheet of paper, of uniform thickness, by that delicacy of touch whose perfection constitutes the best workman. But as this regularity essentially depends upon manual dexterity, it must necessarily be incomplete. It may vary with the health of the workman; with the temperature in which he is placed; with the time of day at which he labours. In the machine the thickness of the paper is regulated by the quantity of stuff which is allowed to flow out of the chest; and all that is required to render this thickness invariable, is an invariable speed in the motion of the machine. If the web of wire travel at a rate that will make twenty-five feet of paper a minute, and the chest discharges (we will say) five gallons of stuff in the same period, there can be no change in the thickness of the sheet. But let the machine move with greater speed,—let the web travel at the rate of making thirty feet in a minute, while the chest still discharges only five gallons of stuff,—and the paper will be thinner by one-fifth. Again, let the pace of the machine be unaltered, but let the chest discharge ten gallons instead of five in the minute, and it is manifest that the thickness of the sheet will be doubled. So far the machine has an advantage over the workman. It goes on to copy his movements. As the water drains through the web of wire in its inward passage, leaving the pulp upon the surface, the machine imitates the action of the vatman, who holds his mould for a space over the vat; and as he gently shakes the mould to distribute the pulp evenly over its surface, so has the web a shaking motion, from side to side, to produce the like effect. The vatman loses none of his material; for every particle of unused fibre returns through the mould into the vat, with the sized water, with which the stuff is often prepared: the machine is equally economical;—for all that drains through the wire web is collected in a cistern near the point H, where the web returns, and is lifted up and discharged again into the vat by the lifter D. As the vatman also defines the size of his sheet by the deckel fitting to the mould, so the deckel straps of the machine, constantly moving onward, and pressing tightly upon the edges of the moving pulp, regulate its width. In hand-made paper that sort which is technically called laid,—that is, marked with lines,—receives this appearance from wires crossing the web. The same appearance, if it be thought desirable, is imparted in the machine by the wire cylinder G, called a dandy. The coucher, whose functions we have already described, removes the sheet made in a mould from the vatman, and places it between two felts. The same absorption is caused in the machine, by the sheet travelling over a large felted surface, and passing between felted rollers, at I, at L, and at M. These rollers, be it observed, do the work also of the pressure to which the hand-made paper is subjected before it is dried. So far the operations of making paper by hand and by machine have a certain general resemblance. But here the parallel ceases. The beautiful contrivance of drying and smoothing the sheets by hot cylinders, O, P, and Q, are a modern application to the machine; and they certainly give the process a perfection which is unattainable in the system of drying each sheet, either by exposure to the atmospheric air, or to steam, upon poles. Mr. Fourdrinier, who perfected the machine as far as making the paper upon an endless web of wire, and pressing it in various felts, did not attempt the great modern improvement of drying the sheets without removal. Each cylinder is heated by steam, from a pipe communicating with its hollow part within. The heat, as we have mentioned, is gradually imparted to the paper. If the first cylinder which receives the sheet be taken at

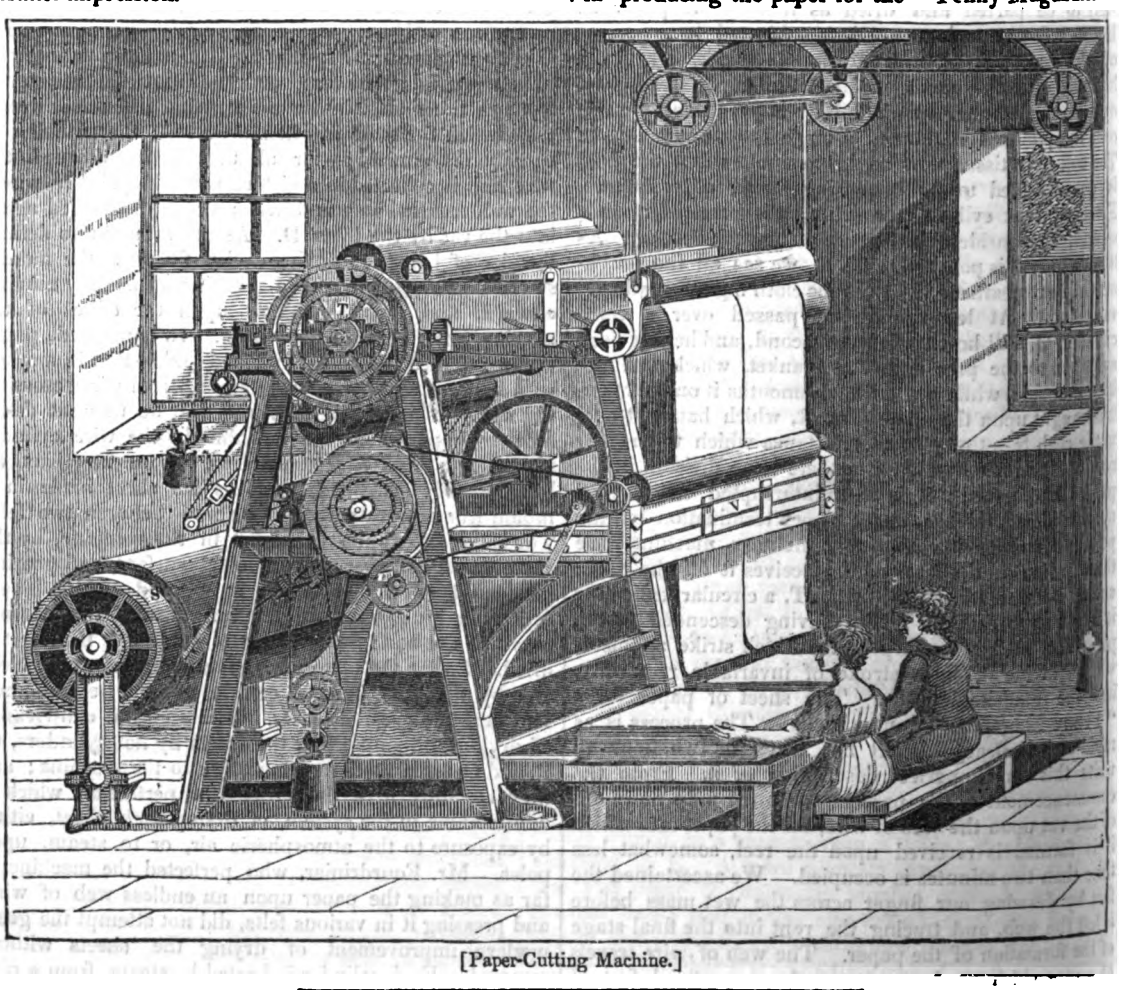
the temperature of 80°, the second would be 100°, and the third 120°.

The cutting machine, which may or may not be applied to the paper-making machine, is an extremely beautiful contrivance, invented by Mr. Edward Cowper. Its object is chiefly to save material. It was usual, after a certain quantity of paper had been reeled, to cut it through while upon the reel. But it is evident that the sheets would consequently be irregular in their size, so that the inner part of the roll, when cut, might be an inch or two smaller than the outer part, according to the quantity reeled.

Mr. Dickinson, one of the most ingenious and successful manufacturers of paper in the kingdom, has constructed machines differing essentially from those of Fourdrinier's invention, as regards the formation of the pulp into paper upon the web of wire. This machine is thus briefly described in Dibdin's "Bibliographical Decameron."—"Mr. Dickinson employs a hollow cylinder, the surface of which is pervious, and is covered with woven wire; and this revolves in a vat of pulp, though not completely immersed; but by the axis, which is a hollow tube, there is a communication from some internal apparatus to a pair of air-pumps, and by their action the paper is formed, and made to adhere to the cylinder, and afterwards detached from it to an endless cloth, which conducts it to the pressing-rollers. The pulp for this machine is much more dilated than for any other mode of making paper, and therefore admits of the fibres which compose it being longer, which has a beneficial effect with regard to the texture of the paper, and renders it better adapted to receive a clear and distinct impression."

When the sheets of paper, completely formed and cut by the process we have described, are taken from the machine-room, they are subjected to a very careful examination. This work is performed by young women, who are as neat in their persons as the upper workwomen in a well-regulated cotton-mill. It is their business to remove every knot or speck in each sheet, and to lay aside those which have any rent or hole. The sheets, thus finished, are next subjected, in their full size, to the action of a powerful press. They are then cut round the edges, by what is called a plough; for it is essential to the beauty and regularity of printing, that the edges of the paper should be perfectly smooth. The open sheets are then counted into quires of 24 sheets; then folded in quires; then put into reams of 20 quires; then pressed in reams; and, lastly, tied up in wrappers. The exciseman now steps in, and charges each ream with a duty of 3*d.* per lb. before it can be removed for sale.

We have already mentioned that the web of wire in the paper-machine travels at a rate to produce twenty-five superficial feet of paper per minute. In a working-day of ten hours, 15,000 feet will consequently be produced. This quantity is equivalent to about twenty-four reams, or 11,520 sheets, of paper twice the size of a "Penny Magazine." Our yearly consumption is about 14,000 reams; so that, taking the number of working days throughout the year at 312, it will require the constant working of two machines all the year round to produce the paper for our yearly demand. A paper-mill with only one machine, and no vats, is held to carry on a respectable business, employing about forty hands. Two mills of this description would be wholly engaged in producing the paper for the "Penny Magazine."



[Paper-Cutting Machine.]

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