

PAPERMAKING

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LIST OF ILLUSTRATIONS

Cover picture is the oldest print representing the interior of a papermill, by Jost Amman, 1568.

- I. Stampers - from V. Zonca, "Novo Teatro di Machine et Edificii" (1607).
- II. Rag Cutting - from Livourne, Encyclopaedia, (1762).
- III. Hollanders - (source unknown).
- IV. Making a Sheet by Hand - from Livourne, Encyclopaedia (1762).
- V. Drying Loft - from Livourne, Encyclopaedia, (1762).
- VI. The Paper Making Machine - from R. Herring, "Paper and Papermaking", (1855).

A BRIEF HISTORY OF PAPER MAKING

Introduction

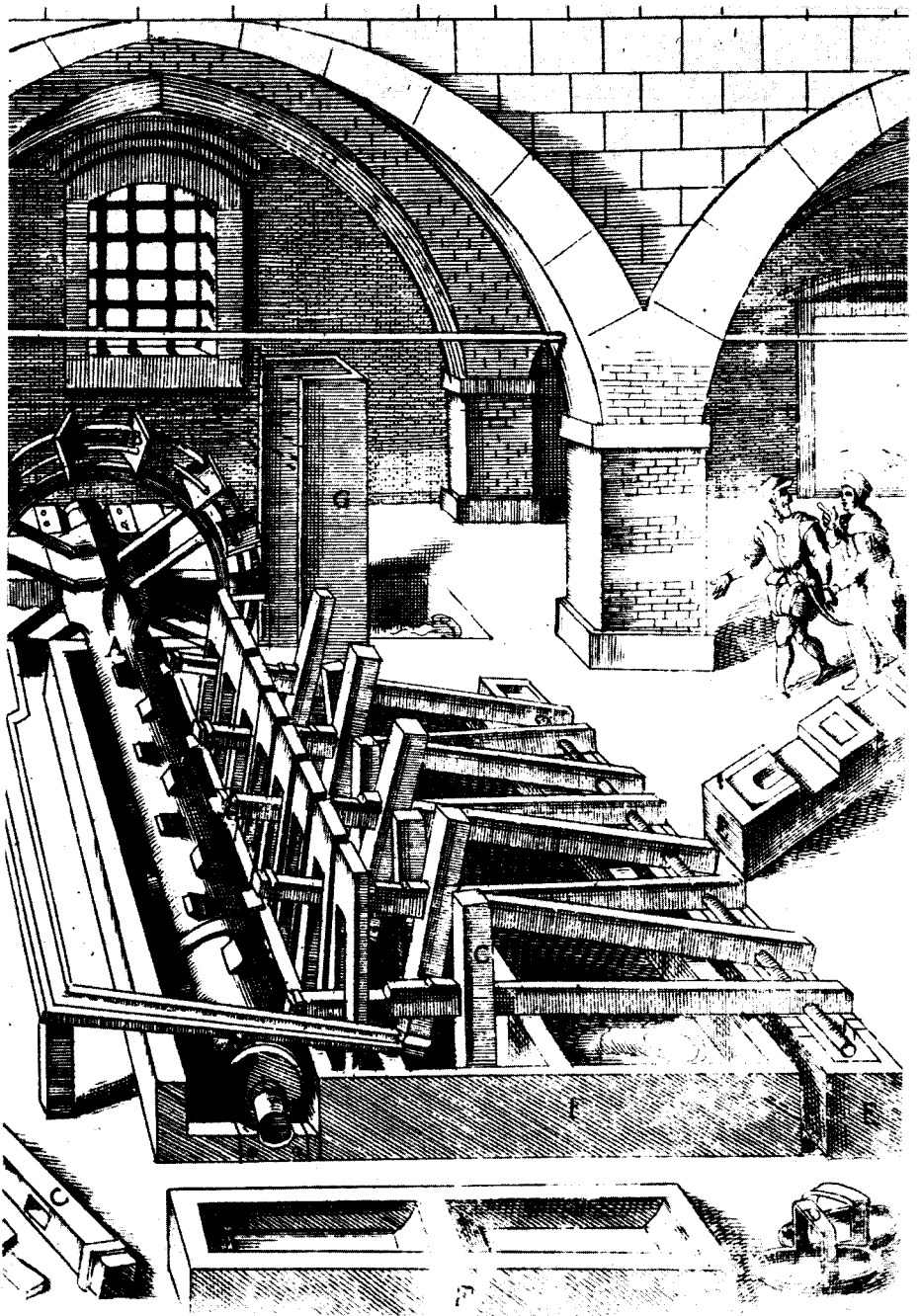
Paper is defined as a matted or felted substance made in the form of thin sheets or leaves from rags, straw, bark, wood, or other fibrous material. To be classed as true paper, the fibrous material must be macerated until each individual filament is a separate unit. These fibres are mixed with water, and, by the use of a sieve-like screen, have the water strained off them so they are left in a matted sheet on the screen's surface. This thin layer of intertwined fibre is paper.

The Egyptians stuck strips of the pith of papyrus, a large reed, together to form a writing material, hence the name 'paper', although they did not macerate it. As well as papyrus, the Greeks and Romans used clay or wax tablets, or parchment made from sheepskin, or vellum made from skins of calf, goat or lambs. Paper, as we know it today, originated in China.

The Chinese drew and painted on all sorts of substances until the Chinese savant, Meng Tien, invented the camel-hair brush in 250 B.C. when woven cloth began to be used extensively as a writing material. However, something smoother than cloth was needed for the painted characters used by the Chinese.

The first paper

In A.D. 105, Ts'ai Lun first proclaimed his invention of true paper. Possibly he made use of the trimmings and off-cuts from cloth intended for writing material to make his first paper. The earliest surviving paper, found on the Great Wall of China, was made from macerated rags. Before long, bast fibres, found between the bark and wood



I Stampers

of trees, especially mulberry, began to be used.

For five hundred years, only the Chinese made paper, but soon after 700 A.D., it spread to Japan. Probably in 751 A.D. some Chinese prisoners of war started making paper in Samarkand, from where it gradually spread westward to Damascus, Egypt and so finally to Europe. England was one of the last to begin a paper industry, it not being established here until just before 1500 A.D.

How it was made

Even the first papermakers must have used water and beaten their cloth or rags in a stone mortar to macerate them. The rags were cut into small pieces, and in order to clean and soften them, were boiled with wood ash. The Arabs, and later papermakers in the West, preceded this by fermenting the rags. The boiled rags were washed to remove the alkali by being placed in cloth bags and suspended in a running stream so the water would remove the dirt and other impurities. After this the rags were beaten to a pulp. The hand pestle and mortar was later replaced by the foot operated tilt-hammer, possibly an Arab invention. This method, where often the rags were pushed under the hammer head by hand, was led tedious but the old methods persisted in many areas.

After a preliminary beating, the pulp was washed again and returned to the stamping mill for further treatment. Around 1151 A.D. in Valencia, Spain, waterpower began to be used for driving the stampers.

The paper-makers mould

Having macerated the fibrous materials into their separate elements, the next problem was how

to make the sheet of paper. To do this, the paper-makers mould was developed. It is likely that Ts'ai Lun at first poured the pulp or "stuff" onto a piece of cloth stretched between a square of four bamboos. The water strained out through the woven material, leaving the fibres as a moist sheet on the surface. The mould, with its cloth backing and paper on the cloth, was left in the sun to dry. This method of making paper was practised until recently in China near Henschow, Hunan Province, where Ts'ai Lun invented paper in 105 A.D.

Another method of making the sheet could have been to dip the mould perpendicularly into the stuff, turn it through ninety degrees, and raise it horizontally, picking up a layer of fibres on the top. The water would drain through the meshes in the cloth, leaving a layer of matted fibres behind. Then the mould and paper would be left in the sun to dry.

The "wove" mould gives one distinct type of surface, and woven wire is used today on paper-making machines, but, almost from the earliest days of papermaking, the "laid" mould has been used as well. It will be realised that there were disadvantages as well as great expense in leaving the paper to dry on the moulds. A smoother mould was needed which would allow the paper to be stripped off while still wet. Very soon a mat made from strips of bamboo was used.

The strips of bamboo were laced together at regular intervals with silk, flax or hair thread. The marks left by these lines of bamboo are called "laid lines" and those by the stitches "chain lines". The bamboo cover resembles a piece of matting which was placed loosely on the wooden framework. Bamboo rods, stitched into the top and bottom of the matting, prevented the stuff running off at those edges, while the vatman held two wood strips at the remaining two edges to prevent the water run-

ing off there. After the sheet of paper had been formed by dipping the mould into the stuff and raising it horizontally, the matting would be taken off the frame and the wet layers of paper deposited flat upon some smooth surface. The matting would be rolled up, leaving the newly deposited sheet firm and unwrinkled. More sheets would be placed on top as they were made.

The pile of wet sheets of paper was then taken outside and the individual sheets brushed on to a wall and left to dry. When dry, they fell off and were taken away for finishing. A good surface for writing was given by polishing. Men or women placed each sheet individually on a board and rubbed it with a smooth stone until the surface was sufficiently polished.

Papermaking in the West

Papermaking, when it arrived in the West, around 1,000 A.D. followed these same basic principles, but soon improvements were made. To begin with, the West demanded a much tougher type of paper. The delicate Eastern papers, which were intended only for camel hair brushes, would have been ripped to shreds by the quill pen. Also, as there were no paper mulberry or other trees suitable for using to make paper, rags had to be used exclusively. Linen made the best paper, but cotton was used as well. As demand for paper grew, serious shortages of rags developed. It was a lucrative, though in times of pestilence dangerous, trade collecting rags. One reason why it took so long to establish the manufacture of paper in this country was that all the rags were purchased by foreigners and sent abroad for processing. It was not until 1495 that John Tate started the first papermill in England at Stevenage, Hertfordshire.

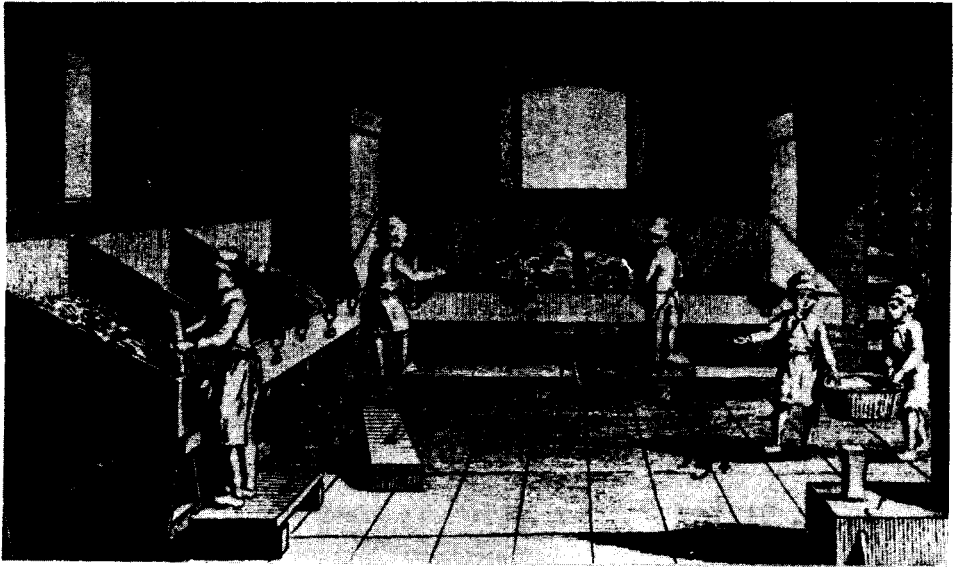
While medieval papermakers did not have to

worry about the inclusion of man-made fibres, they did not have strong bleaches to whiten their product. White linen made the best quality paper, but much was wasted in the fermenting process and in the stamping. Lime was used to hasten the fermentation of the piles of wet rags, but it had a detrimental effect on the quality of the paper. The fermentation helped to soften the rags, and the process was considered to be well underway when traces of fungi appeared on the piles. However, the fermentation tended to discolour the rags, and, although attempts were made to wash it out, it gave early paper its pleasing creamy tint. The rags were cut and prepared for the stampers by women or children who stood at tables and cut up the rags with knives placed vertically in front of them.

The Stampers

After this preliminary treatment, the rags were sent to the stampers which were gradually made much more efficient in the West. Instead of a single stamper, three or four or even five were used in each trough. They were arranged in sets so that the rags could be moved from one trough to the next as they were pulped. The stampers in the first trough were shod with rough iron teeth or spikes which frayed the cloth, while a stream of water ran through the trough to wash away the dirt and alkali. The dirty water ran out through woven horse hair screens to prevent the escape of any fibres. The next set of stampers was not so heavily shod and again fresh water was passed through for cleaning.

When the partly beaten rags were transferred to the third trough, the running water was excluded because the rags were being beaten so fine that a lot of fibres would have been lost through the screen filters. These last stampers were usually made from plain wood without any iron



II Children Cutting Rags



III Hollanders or Beaters

facing. Zonca's illustration of 1607 shows how the West developed the crude foot operated stamper of the East into a complex waterpowered machine.

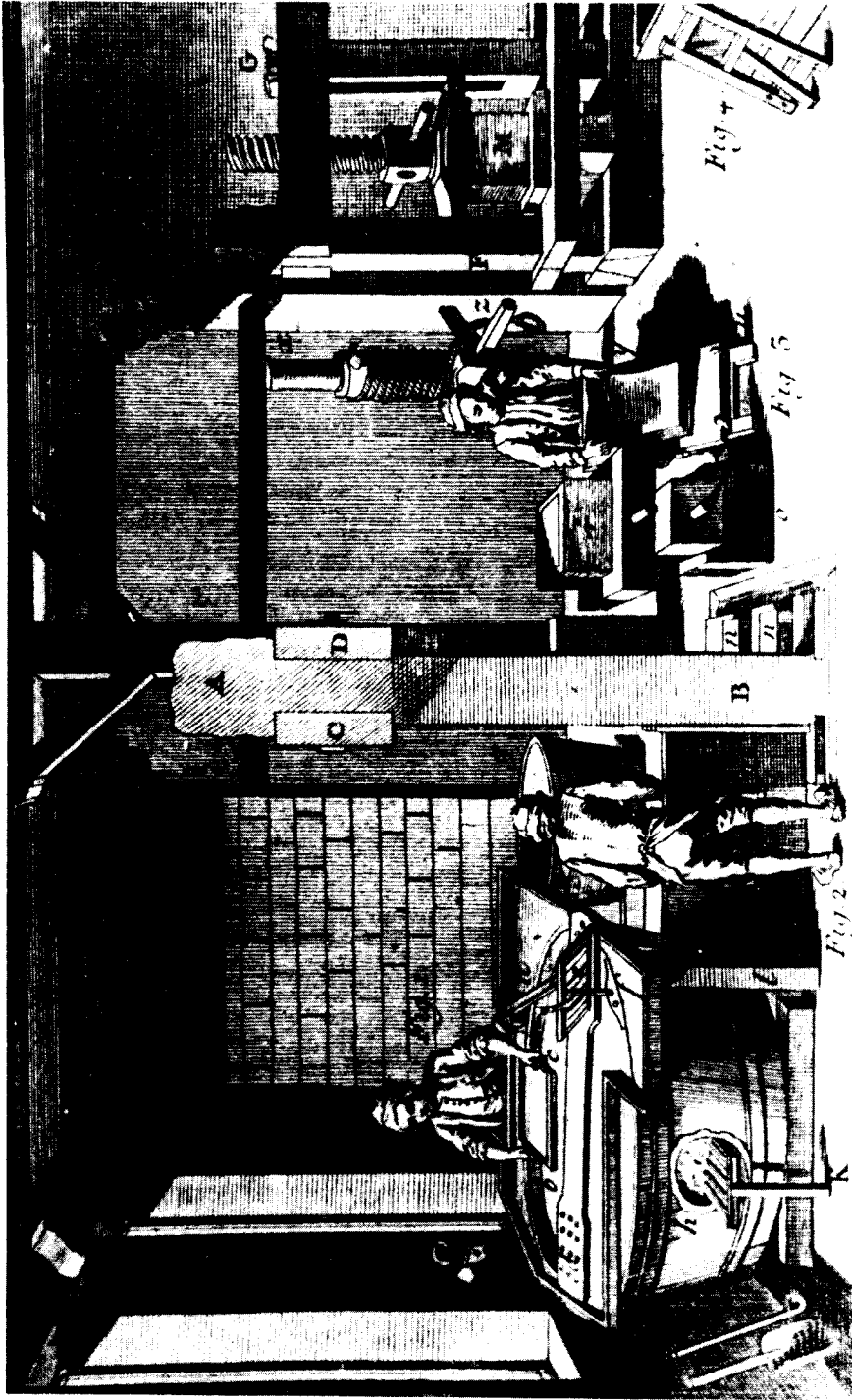
Hollanders

The action of the stampers was still very slow, and the papermakers of Holland with their windmills found difficulty in competing against the abundant waterpower of the Germans. Around 1650, someone in Holland, whose name has been long forgotten, thought out the roll beater or "Hollander". It consisted of an oblong wooden tub, rounded at both ends, with a central feather. A roll, made from a solid tree-trunk, was fitted with knives around its circumference, and was rotated in one part of the tub. The rags were lacerated by the action of the knives revolving against a bedplate made of metal or stone.

The rags were churned round and round until they became pulp. The hollanders lacerated the fibres and cut them, where the stampers rubbed and frayed the material, leaving longer fibres, but speed was the great advantage of the hollander. In 1725 Keferstein, a papermaker in Saxony, wrote, "The Hollander in Freiberg furnishes in one day as much as eight stamper-holes do in eight days". A few stampers remained at work for high grade paper until the 1920s. Hollanders are still used today, but for wood pulp and large scale continuous production "refiners", originally developed by Jordan in the middle of the nineteenth century, are more suitable.

The Western mould

The greatest difference between Eastern and Western papermaking techniques lay in the mould. Very soon after paper began to be made in the West,



IV Making a Sheet by Hand

Vatman

Coucher

Layboy

Press

the bamboo strips were replaced by wires. Instead of being removable like the bamboo matting, they were fastened securely to the mould. This type of mould was more suitable for the heavier European rag papers. Extra wires were added to make patterns on top of the laid wires. These additional wires made "watermarks" in the paper, something which first appeared in the West because this could not be done with bamboo. The earliest watermarks have been dated to 1282, and they have been used ever since to identify paper and, much later, to make pictures in it.

Another alteration to the mould was the method of keeping the stuff on it while it was being lifted out of the vat. A rigid frame, joined permanently at the corners, was placed over the mould when the sheet was to be formed and was removed when the sheet was to be couched. This has come to be called the "deckle", either a Dutch or German term.

The moulds themselves required great skill in their manufacture, for they had to withstand repeated immersions in warm water. Straight grained, well seasoned timber had to be used, which was boiled in water again and again and finally slowly dried. The chain lines were supported by wooden cross ribs which were made tapered to give a suction effect, acting on the top of the mould as it was lifted from the vat. The wires forming the surface of the mould were fastened to the rectangular wooden frame. In a "laid" mould, there must be a preliminary backing of heavy wires, at right-angles to the ribs. On top of these, finer wires were laid, one over each rib. Then the final "laid" wires were put on top, again at right-angles to the ribs, and the whole covering was stitched with fine wire to the ribs. The ends of these securing wires were fastened to the frame with small copper nails, and the edges of the frame were bound

with narrow copper strips.

In 1757 James Whatman made paper on a "wove" mould for a special edition of Vergil printed by John Baskerville. This eliminated the unevenness of the laid lines, and had a smooth surface like a piece of woven silk. This woven covering of brass wire could be used on an ordinary mould and became very popular at the end of the eighteenth century.

Making a sheet

To make paper, the "stuff" was at first tipped and later run by gravity into the papermaking vat. Normally the vat contained 1-2% fibres in the water which had to be stirred continually to prevent them settling on the bottom. At first a pole was used which was soon improved by being made into a paddle. In the later part of the eighteenth century, a mechanical agitator was devised which eventually evolved into the rotating paddle or "hog".

Another important addition was a heater fired by charcoal which was fitted into the back of the vat. In France, this was called a "pistolet", and it became the practise to place the vat against an outside wall so that a chimney could be fitted more easily. Nowadays a steam heated coil is used. By the more rapid drainage resulting from the warm water, the workers could make a greater number of sheets in a day.

Another improvement was the addition of a platform or bridge on which the mould could be left for drainage or a clean mould left ready for the "Vatman".

The vatman placed the deckle on the mould, dipped both perpendicularly into the stuff, and then lifted both horizontally from the vat. Any excess stuff was tipped over the far edge of the

deckle, and the rest was shaken from left to right and back to front so the layer was evened and the fibres matted into each other. This also shook out a considerable amount of water. The vatman then removed the deckle which left the moist sheet of paper, cut sharply along its four edges, on the mould.

The vatman passed the mould along the bridge to the "Coucher" who lent it against the "asp" to continue draining. He took a second mould and the same deckle and dipped into the stuff again. When the wet sheet of paper on the mould leaning against the asp had solidified sufficiently, the coucher took it, turned it upside down, and placed it on a felt. With a quick rocking motion, the paper was left on the felt, and the empty mould was placed on the bridge ready for the vatman. Thus they worked with two moulds and one deckle.

The coucher, who would be assisted by a second person for large sheets of paper, placed another felt on top of the wet sheet of paper and so a "quire" of 144 sheets was built up. Nowadays this goes to an hydraulic press to have the liquid squeezed out, but, in the days of screw presses, six quires would form a "post" which was taken to the press.

Pressing, Drying and Glazing

In the East, a great deal of paper was never pressed. If a press was used, it was normally a weighted type where lumps of stone or something similar were hung on the end of a long lever. In the West, screw presses were generally employed. Also the East did not use felts to prevent the papers sticking together, possibly because their sheets were couched drier. In the West, all the workers in the mill would be called to push against the long lever of the screw press to squeeze out

as much water as possible. Later a small winch called a "samson" was used to pull the large lever.

After pressing, the paper had to be separated from the felts and then dried. The "Layman" separated the sheets and put the felts ready for the coucher to use again. By long diligent work, it was possible for the three workmen to make twenty posts or about five and a half reams of paper per day.

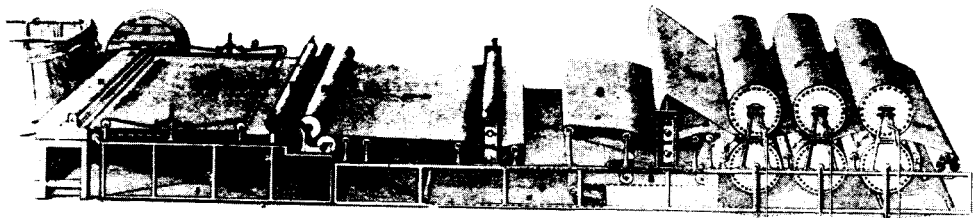
A second pressing, without felts, might take place before the paper was hung on cowhair ropes in the drying loft. Cowhair did not stain the paper. There was an art in drying to prevent the paper crinkling or curving. Papermills were generally set across their valleys to catch as much wind as possible for the winds normally blow up and down. Shutters were arranged to control the draught so it blew on the faces of the papers and not on the edges. Nowadays steam drying cylinders are used for this first drying.

The dried sheets had to be "tub sized" to prevent ink running into the surface like blotting paper. The paper was dipped in a tub of warm glue and then pressed to remove the superfluous gelatine. This was very wasteful as sheets were frequently stuck together or torn. Machines have now replaced this hand process. The sized sheets were dried again in a loft, and careful control had to be maintained or the gelatine turned bad.

Before it could be sold, the paper had to be smoothed. At first it was polished with an agate or other smooth stone by hand, but the Europeans introduced a large waterpowered hammer. This was copied from bookbinders who used this mechanism for polishing the backs of books. Hammers, by their larger size, gave a smoother finish than hand polishing which frequently left streaks.



V Drying Loft for Handmade Paper



VI Papermaking Machine

**Breast
Box**

**Moving
Wire**

Press

**Felt
Blanket**

**Steam
Cylinders**

The hammer was in turn replaced by calender rollers. The paper sheets were placed between smooth sheets of zinc or copper, and this pile was squashed between the rollers, thus giving a smooth surface.

Paper Machines

Making paper by hand has altered little for two thousand years, and remains a slow craft process. In 1797, Nicholas Louis Robert, working at the Essonnes paper mill in France, produced a model of a papermaking machine. Other models followed, and in 1798 he applied for a patent. These machines had a constantly revolving wire gauze from which the paper was taken off in short sheets and hung up to dry. Then Robert quarrelled with Didot, his backer and owner of the mill where he was working, and had to leave.

Didot had contacted John Gamble to see if capital could be raised in England to make a large machine, in spite of England and France being at war at the time. Gamble and the Fourdriniers, London stationers, in 1803 called in Bryan Donkin. In 1807 they patented a greatly improved machine. It had a "breast-box" over which the pulp flowed in a thin even sheet before it ran down on an apron onto the moving woven wire. The wire and pulp passed through a roller press where most of the water was squeezed out. The sheet of paper was transferred to a felt blanket, and passed through a second press before it was wound, still wet, onto a drum. The Fourdriniers claimed they spent about £60,000 developing their paper machines but made no fortune from them.

At last a continuous sheet of paper could be made, but it still had to be dried. A patent specification submitted in 1817 by John Dickinson mentions sizing baths through which the long sheet

of paper could be passed. He also mentions a drying cylinder heated by steam, although this improvement is generally credited to Thomas Crompton in 1820. At last a continuous reel of dry paper could be produced.

Since then, many improvements have been added to speed up paper making, but the basic principles of our present machines can be traced back to the Fourdrinier machine built by Bryan Donkin. At first machine-made papers had no watermarks until John and Christopher Phipps patented the "dandy roll" in 1825. It seems to have been John Marshall who actually made the first dandy roll and started to market them in 1826.

Also in the 1820's a change took place in the method of sizing. Gelatine sizing was applied only to the outside of the sheet after it had been made. M. Illig dissolved rosin or colophony in the wet stock which was fixed by the addition of alum. This rosin was added at the heating stage so it was incorporated into the paper itself, thus avoiding immersing the paper into another liquid and drying it a second time.

In 1836, J. Brown of Edinburgh invented the vacuum box which was placed under the moving wire to suck the water out. George Dickinson had tried a suction roll in 1828 but it was another hundred years before it was generally introduced. The suction couch, improved in the early 1920's, helped to get the paper off the moving wire more cleanly and quickly.

In such a short account, it is not possible to describe all the small but vital parts which have been fitted to paper machines, such as the mechanisms which shake the woven wire to make the fibres interlock, or the differentials driving

the drying cylinders to allow for shrinkage as the paper dries. Modern machines are highly complex engineering products capable of making all the varieties of paper which play such an indispensable part in our lives today.

FOR FURTHER READING:

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