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No. 24

**PAPER AND PAPER PULP PRODUCTION
IN THE MADRAS PRESIDENCY**

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NOTE

The Government of India desire it to be understood that the statements made and the views expressed in this bulletin are those of the author himself.

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PREFACE

The question of the supply of paper to India has within the last few years become a matter of great interest to the general public, since, owing to the effects of the war, the imports of pulp and finished material decreased enormously and the mills in India were not in a position to meet all the demands made upon them. The ordinary individual who, when he wished to purchase paper for any purpose, had always been able to obtain just what he wanted without any trouble had never given a thought, perhaps, to the nature of this product and the means by which it is produced, and it was only the abnormal conditions which suddenly arose that brought home to most how essential a supply of paper had become to people in almost every walk of life.

It is only those who are more or less intimately connected with the trade, however, who can realize the enormous variety of the different classes of paper which are on the market, and it is only those responsible for the manufacture in the mills who know how the raw materials are manipulated, blended and treated to yield the different varieties of paper. No mill will attempt to produce and supply all varieties of finished paper, but each restricts itself to the special lines which it finds most profitable and in the manufacture of which it has developed owing to local conditions or special equipment and capacity to meet special demands.

The Indian mills did remarkably well in the difficult circumstances of the last few years but they could not supply all the needs of the market, and the inability of the public to obtain easily what it required and the prices which had to be paid for what was available concentrated attention upon the possibility of Indian products making good the shortage of raw material. Naturally, then, the demand arose that such raw material should be worked up in India and the finished article produced in sufficient quantity to meet all demands. In Madras the enquiries which have been addressed to Government departments and to Government have made it appear advisable that some publication, giving to the public information upon the questions of paper and paper-making, the nature and supply of raw materials and the possibility of this Presidency supplying the same should be issued.

Preface

The Forest Department and the Department of Industries were entrusted with the task and I have been asked to work up the material. Seeing that the question is probably one of great interest to a public but little conversant with technical matters, I have aimed at making the report readable to others than those commercially interested in the manufacture, but have striven to make clear (as far as the material available permitted) the position regarding the prospects of successful pulp and paper manufacture in South India.

F. M.

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RAW MATERIALS

By the term paper we indicate a sheet of thin vegetable material which is slightly elastic and can be bent, twisted or folded without being too easily broken. Suitable examination would show that it is made up of fine fibrous elements, interlacing with each other to form a web, and that the cohesive power of these fibres is generally assisted by the incorporation of glutinous material and the effects of pressure.

In very early days men wrote on stones, metal plates, and smooth-surfaced leaves, and the preparation of sheets by fixing together strips of the inner layers of tissue from certain plant stems probably marks the beginning of real paper manufacture, but where and how paper was first made by disintegrating fibrous materials in water and removing the water under conditions which leave a thin layer of fibres we do not know. There is evidence that it was done in China in this way some 2,000 years ago, and the knowledge of the process spread through Tartary to Arabia and became known in

Europe thirteen or fourteen hundred years back. The material worked upon appears in most cases to have been discarded vestments and not raw plant materials, and, even until very recent times, the chief material from which paper was manufactured was the refuse from spun or woven materials which could no longer be used for their original purpose, such as rags of linen and cotton, old rope. etc. As the amount of paper manufactured grew the demand for these most suitable materials also increased, and it became necessary to supplement them by utilizing others, such as straw, grasses and wood itself. These latter do not produce a paper of such good properties as that made from linen alone, and there are innumerable qualities and varieties of paper (many prepared for specific purposes) depending upon the proportions in which these ingredients have been mixed and the treatment they have undergone.

The reason why linen and cotton rags were found so suitable for paper manufacture was that they were very easily reduced by simple mechanical means to a condition in which in water they formed a mass of fine hairs which, as the water drained away, interlaced and formed a continuous, even-textured web. The old garments from which they had arisen had been exposed to sun and weather and had been repeatedly washed, and all but the most highly resistant material had been removed. We find that this highly resistant fibrous material is obtained when flax and cotton are subjected to very severe chemical treatment, and all colouring matter, sap, and such like products of plant growth are removed, and the 'skeleton' so to say, of the plant cell alone remains. The skeleton forming the cell structure is composed of a material to which the name 'cellulose' has been given, and it is remarkable for the resisting power which it possesses, when pure, to the effects of the natural influences of sun, air moisture, etc

It will be readily understood that the shape of this skeleton or cell will vary with the different parts of different plants, and the usefulness of plant materials in the arts is more or less dependent upon the shape of the cells and the way in which they are associated. The textile manufacturer lays value upon a fibre in which the cells are long and associated in such a manner that spinning yields fine, strong, even threads. To the paper-maker the form of the fibre agglomeration is of little moment; what he requires is that it shall be fairly easily resolvable (approximately) into its individual cells,

as free as possible from non-cellulose matter, and that these cells shall be very small in breadth compared with their length. This ensures that in making the paper they can intertwine and hold themselves together. It is not absolutely essential that the individual cells shall be separated from each other, but it is essential that the fibrous elements shall be so small and fine that the inter-twining in the web of paper is fairly regular, and it is the art of the paper-maker to recognize the nature of his raw materials and to give them just that degree of treatment as will ensure the exact quality of paper which it is his desire to produce.

PAPER-MAKING

The general processes in paper-making may be grouped as follows :

- (1) Preparation of the raw material
- (2) Removal of non-cellulose matter
- (3) Disintegration
- (4) Bleaching, colouring, loading and sizing
- (5) The making of paper
- (6) Finishing

Preparation of raw materials

The raw materials of the manufacture are, it will be gathered, very various, including, as they do, rags and waste materials from the cotton and linen industry, waste jute materials, hemp, straw-grass and wood. All require some preliminary preparation to free them from dirt and other undesirable adhering matter and then they are reduced to a size convenient for further treatment.

Rags are sorted into different qualities and cut by hand or in a machine by knives to a suitable size. They are then passed through another machine in which they are beaten to free them from dust and dirt. Jute and hemp materials are cut and dusted in similar machines to those used for rags. The object of these operations is to free the cellulose fibres as far as possible from superficial mechanically-adhering dirt, and to prepare the material for the important boiling process in which chemicals are employed to remove practically all other non-cellulose matter. Grass requires to be freed from roots and woody matter by being picked over before being cut; straw is usually chopped into small lengths, and wood, when it is not to be used as mechanical wood-pulp obtained by grinding against a wet grinding stone, is prepared for treatment by cutting into small pieces.

Removal of non-cellulose matter

The amount of non-cellulose which has to be removed is very variable according to the raw material taken, and its composition, of course, varies also.

The cellulose content of some representative raw materials is as follows :

| | | per cent. cellulose |
|---------------|-----------------|------------------------|
| Cotton | about | 91 |
| Flax | | 80 |
| Hemp | | 80 |
| Jute | | 60 |
| Esparto grass | | 45 |
| Straw | | 45 |
| Bamboo | | 50 |
| Wood | | 35—50 |

according to the species from which it is obtained. The severity of the treatment required to separate this cellulose from the non-cellulose present, and to remove the latter, varies with the material, and, whilst with cotton and linen rags a comparatively light treatment suffices, with wood it requires to be very severe if a product suitable for making white paper is to be produced.

The non-cellulose matter accompanying the cellulose in plant tissues is generally characterized as fat and wax, lignin or woody matter, pectous substances from the plant juices, and ash. A little colouring matter is also usually present. Fat, wax and pectous-substances are removed by boiling with alkaline liquors, which also resolve the lignin matter when they are employed in sufficient strength and under a high pressure. Mineral matter or ash is also largely extracted, and colouring matter is removed at a later stage in the manufacture by bleaching, but the ease with which the bleaching can be effected depends very materially upon the thoroughness with which this boiling has been carried out.

The alkalies generally used are :

- (1) Lime
- (2) Carbonate of soda
- (3) Caustic soda

and in old days the boiling was conducted in open pans with the milder ones only.

The boiling with alkali is now conducted in large, closed, iron vessels called 'digesters,' which may be spherical or cylindrical in shape and are of sufficient thickness of wall to withstand high internal pressure. Filling and emptying take place through large openings or manholes which can be securely closed by means of covers bolted over them. The material having been filled into the digester the necessary quantity of water and alkali is added, and, the manhole covers having been tightly closed, steam is admitted and the pressure raised to and maintained at the level necessary. The boiling in alkali, removing as it does almost everything but cellulose, should leave the material in such a condition that the fibres are easily separable, but it is not advisable to make the treatment stronger than necessary as the fibres themselves may be injuriously affected; it is usual, therefore, to vary the conditions of

- (1) Strength of alkali taken.
- (2) Pressure under which boiling is conducted, and
- (3) Length of time of boiling to meet the needs of the material under treatment.

Thus, clean cotton rags, being comparatively pure cellulose, may be effectively treated in a very weak alkaline solution by boiling for three or four hours with little or no pressure; whereas bamboo and wood can only be efficiently acted upon by employing much stronger (caustic) alkali at a pressure of 100 lb. or so and for a much longer period.

It has been found that, rather than leaving the material under treatment to lie quiescent in the liquor, it is a great improvement when one part does not remain in contact with one and the same portion of liquor; so, in the case of spherical digesters these are made to revolve slowly while the heating is going on, and in the case of upright cylindrical digesters the liquid is made to circulate, being drawn from the bottom of the vessel and delivered at the top over the material.

From the following illustrations some idea of the size and appearance of these digesters may be obtained.

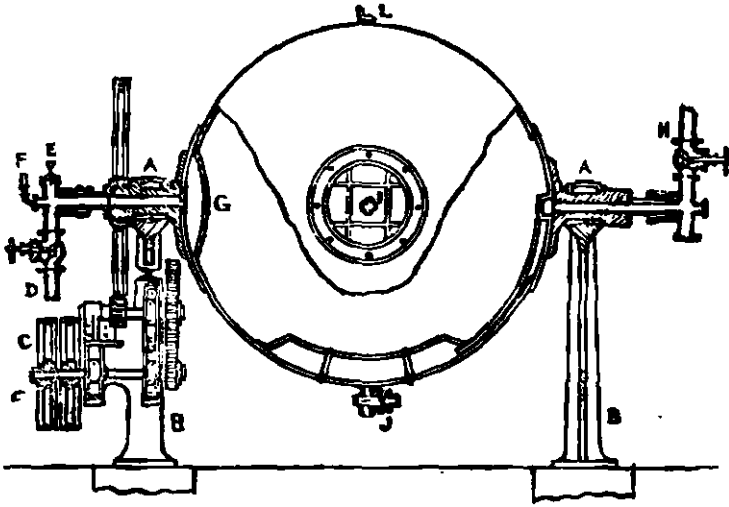


FIG. 1.—SPHERICAL REVOLVING RAG BOILER.
(FIG. 20.—*Paper Making*—CROSS AND BEVAN, 3RD EDITION).

Fig. 1 gives a spherical revolving rag boiler in section to illustrate its working. It is eight or nine feet in diameter and is carried in the frame, B, on hollow trunnions, A, through which the alkaline liquor and steam are introduced. Steam enters by the pipe, D, which is fitted with a safety valve, E, and a vacuum valve, F, and on entering the boiler the steam is spread by a perforated baffle plate, G. Alkali is run in through the pipe, H. The material to be boiled is filled in and emptied through manholes, I, and besides these and a blow-off cock, L, there is a cock, J, for running off the liquor after boiling, the opening to which is covered by a perforated false bottom to keep it from choking up.

The boiler having been filled with rags, the manhole cover is bolted down and the required quantity of liquor is run in. Steam is then turned on and the boiler slowly revolved by means of the gearing, C. Boiling is maintained for a certain time according to the condition of the rags, the strength of alkali taken and the steam pressure: then steam is shut off and the boiler brought to rest with the cocks, L and J, at the top and bottom respectively. The excess of

steam pressure is let off by opening the cock, L, and then J is opened and the alkali liquor drained away. A washing of the boiler contents with water follows and then these are emptied through the manhole into a truck.

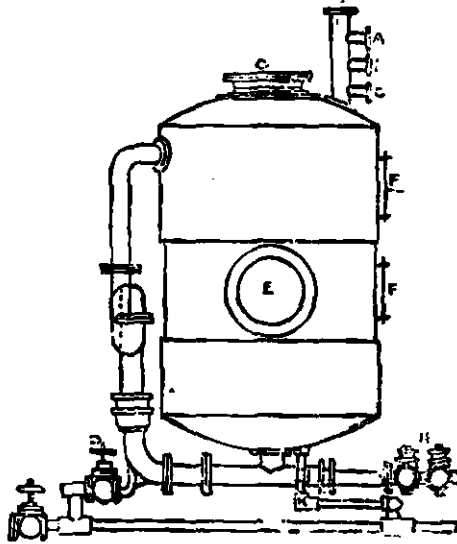


FIG. 2.—UPRIGHT CYLINDRICAL DIGESTER.

(FIG. 25.—*Paper Making*—CROSS AND BEVAN, 3RD EDITION).

Fig. 2 shows a vomiting boiler with external circulation. Such boilers are usually about eight feet in diameter and hold three tons or more. The material to be boiled is filled through the opening, G, and the alkali is run in through the pipe, B; the level of the liquid can be seen through the gauges, FF. The contents are heated at first by waste steam entering through the pipe, K, but the boiling proper is carried out by steam which enters through the valve, D; the liquors which collect at the bottom of the boiler beneath a false bottom are carried up the external pipe by the steam and are distributed over the boiler contents through which they percolate and are thus kept in constant circulation. The boiling being completed, the excess steam is blown off through pipe, A, at the top of the boiler and then valve, H, is opened to drain away the liquor. Wash

water is run in through pipe, C, and after this has run away through H the boiled material is emptied through the door, E.

Disintegration

The material, having now been freed from most of the mechanical and chemical impurities, is in a fairly soft condition in which it can be easily disintegrated and resolved into the finely divided fibrous condition necessary for converting it into paper. This disintegration is carried out mechanically by beating, tearing or rubbing the material whilst suspended in water; traces of alkali, residues of sand which were entangled, etc., are removed with fine sieves, or arrangements which allow the water and some of the sand particles to pass away but keep back the fibrous pulp. The disintegration, therefore, is regulated so that the washing is completed before the fibres become so fine that they also would be carried away.

In the old days the operation was carried out in stamps or stocks, (Fig. 3) a small quantity of material being placed in a wooden trough and subjected to the action of heavy wooden blocks which were made to rise and fall as rapidly as possible. The troughs were made longer and wider at the top than at the bottom, (for example, 4 ft. \times 3 ft. at the top and 2 ft. \times 1 ft. at the bottom) and three or four stamps of very hard wood, six or seven inches square, worked in each. A gentle stream of water, flowing away through a hair sieve in one side of the trough, was maintained, and with vigorous stamping some 25 lb. of rags could be washed and pulped in about 10 hours. The quality of the pulp so obtained was good, in that the individual fibres could be separated in their full length without being torn or broken, and thus very suitable for making good strong paper, but the outturn is far too small, and for large-scale production a machine called a 'hollander' is now everywhere employed.

'Hollanders' or 'breaking and beating engines' are made in various sizes and with various modifications to suit individual ideas regarding rapidity of work, quality of output, consumption of power, etc., but in one and all the principle is the same. The material is suspended in water and made to circulate so that it passes repeatedly between two sets of so-called 'knives,' one set fixed in the bottom of the machine, the others being fixed on the periphery and parallel to the axis of a horizontal cylinder (the 'beater roll'), which rapidly revolves, and can be lifted or lowered so that the distance between

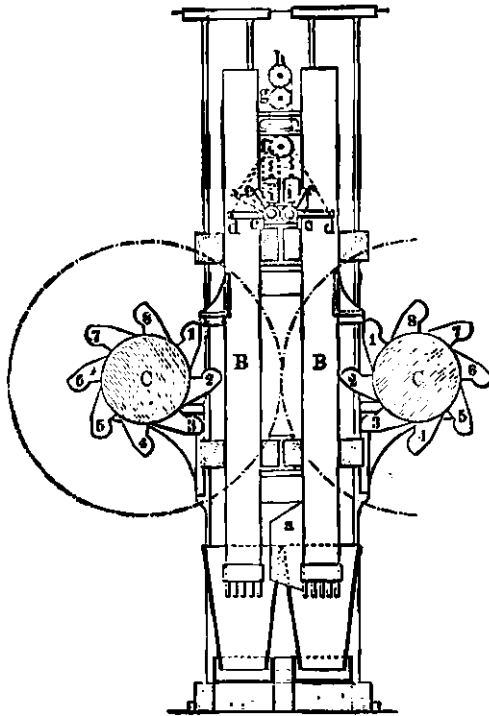


FIG. 3.—STOCKS OR PULPING STAMPS.

(FIG. 3547.—"PAPIER." MUSPRATT'S *Chemie*, 4TH EDITION, VOL. VI.

the fixed and the rotating knives can be made great or small as required.

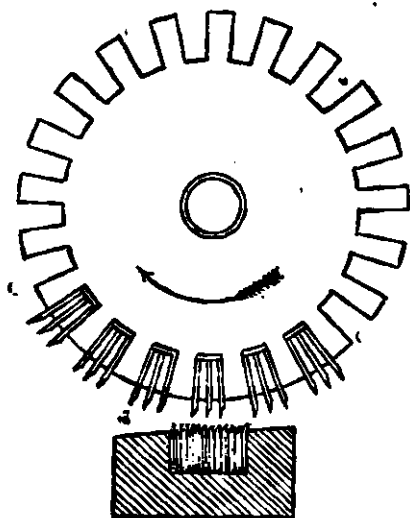


FIG. 4.—BEATER ROLL AND BED PLATE.

(FIG. 33.—*Paper Making*—CROSS AND BEVAN, 3RD EDITION).

In passing between the knives the material is beaten, crushed, torn and cut, and it is in the power of the manufacturer to prepare the stock in this machine in different ways to meet the requirements of his paper when finished. Variations are possible in the number of knives in the cylinder and in the engine bed-plate, their angle of setting and degree of sharpness, the rate at which the breaking is conducted by the alteration of the distance between the two sets of knives, etc. This is one of the most important operations in paper-making and its control only comes with long experience. A general type of hollander is shown in Figure 5.

This breaking and beating engine consists of an approximately rectangular vessel with rounded ends. Down the centre, parallel with the long sides, is a partition. Br the 'mid-feather' around which the material under treatment circulates. A is the beater roll with its knives, G, driven by the wheel, H, which is driven by a belt from the main shafting, and I is the bed-plate with its knives. On this side of the mid-feather the floor of the hollander is not level, as on

the other, but is inclined as shown by the dotted line, D. In this inclined floor, and just in front of the bed-plate, I, is a depression

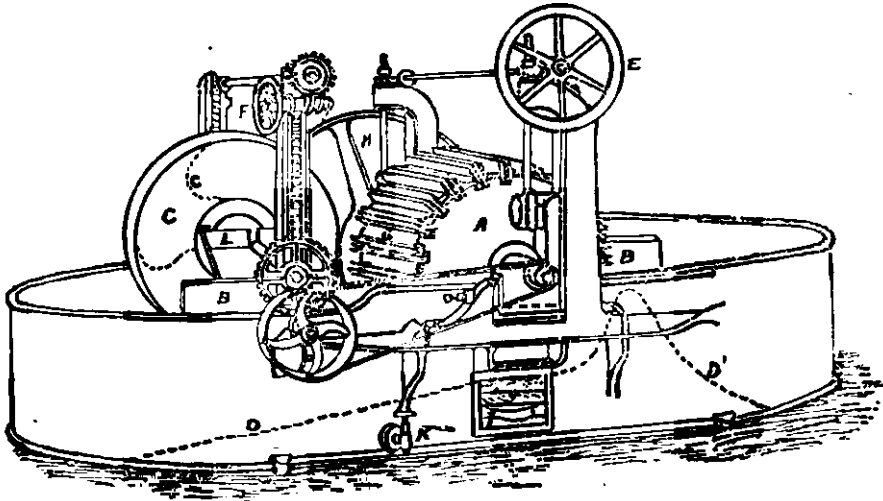


FIG. 5.—RAG ENGINE OR HOLLANDER.

(FIG. 21.—*Paper Making*—CROSS AND BEVAN, 3RD EDITION).

covered with an iron grating in which sand, small pieces of stone, metal or other heavy impurities carried by the raw material are collected and can be removed upon cleaning out the machine. A similar 'catch' with grating lies on the other side of the mid-feather.

The beater roll shaft is carried in bearings which can be raised or lowered together by turning the hand-wheel, E, and the distance of the knives in the beater roll and bed-plate from each other is thus regulated and altered at will.

F is the hand-wheel by means of which the bearings of the drum washer, C, are raised or lowered and the drum lifted clear of the liquid or partially immersed therein and caused to revolve. The drum washer is a cylinder the ends of which are made of wood and the periphery of which is made of a stout sheet of perforated metal which serves as a support for a brass or copper wire gauze of very fine mesh. When the washer is lowered and revolved the dirty water passes through the gauze whilst the material to be pulped is kept back. In the bottom of the hollander are openings, with tightly fitting covers, for emptying the pulp and for cleaning.

In operating the machine sufficient water is run into the trough to cover the bed-plate a few inches, and the roll is lowered so that when set in revolution it causes a circulation which the workman assists by means of a wooden paddle. The material to be treated is introduced in front of the roll in such quantities that they are carried forward and can be maintained in circulation; as the first lots become beaten and disintegrated the pulp assists in carrying the freshly added lots and the filling of the machine to its working capacity is carried out as quickly as possible.

The drum washer is lowered into the pulp, and while the disintegration is going on fresh water is run in to replace that passing through the sieve until the operator considers that the pulp is thoroughly free from alkali and dirt. When this point is reached the drum washer is lifted and the breaking is continued until the pulp is fairly even and the disintegration has been carried far enough. It is not usual to pulp the material to such an extent in this machine that it is ready for making paper, but the operation is stopped when a stage just short of this has been reached and certain necessary treatments can be given without risk of serious loss of fibre. It is now known as 'half-stuff' and it is in this condition that it is bleached for white paper.

Bleaching

Bleaching can be carried out in the breaking engine or the material may be transferred to separate vessels and the breaking engine refilled with a fresh charge. Different materials require very different degrees of treatment, varying with their nature and source and the preliminary treatment to which they have been subjected. Thus, half-stuff from white cotton or linen will require but little chemical to give a good white; with jute the quantity will depend very largely upon the completeness with which all other constituents but cellulose have been removed in the alkali boil, and with wood, also, the bleaching properties of the pulp are intimately connected with the amount of alkali used and the conditions of boiling. Unless the boiling has been thorough and the lignin constituents completely removed, a good white is unobtainable except by using a very large quantity of bleach, and the value of a wood pulp to the paper-maker is largely dependent upon its being prepared in such a way that it is 'easy bleaching.'

Bleaching powder is still in general use in paper mills, the half-stuff being left to lie in a solution of such a strength that it is capable of removing non-cellulose residues and colour without injuring the cellulose fibre itself, but certain advantages are obtained by employing sodium hypochlorite prepared in the mill by the electrolysis of brine.

According to the nature of the material under treatment, acid may be added to the mixture of pulp and bleaching liquor, or souring may take place only after the bleach liquor has done its work and has been largely removed by washing.

The last traces of bleach and acid are now removed, as far as possible, by washing with water, either in separate vessels or in a second hollander, the beating engine, which may differ from the breaking engine only in the arrangement and sharpness of the knives. Even with copious washing, however, it is almost impossible to remove the last trace of bleach, and, as in the manufacture and drying of the paper and on storage even traces would be harmful, they are removed by the addition of just a sufficiency of another chemical, antichlor, which reacts with the bleaching agent and destroys it.

The pulp being now bleached and washed neutral in the beating engine, the disintegration of the fibre is carried on until it is sufficiently fine for the final operations of manufacture. It has already been pointed out that the action of the knives in the beater roll and bed-plate is to break, crush, tear and cut the fibres. In the breaking engine the aim is to crush and tear the fibre agglomerations and separate these approximately into individual fibres without too much of a cutting action being exerted upon them and their length becoming too much reduced. In the beating engine, however, the pulp is treated according to the nature of the paper to be made, and according to this the knives are more or less sharp, giving a greater cutting action, the distance between the beater roll and the bed-plate being decreased at intervals until the knives are practically in contact, and when the beating is finished the roll is lifted. Great experience is required to beat in such a way that the pulp shall contain mainly fibres of approximately the same length, so that the texture of the finished paper shall be even and that the water-retaining and 'felting' properties of the fibres shall be suitable to the quality of paper required.

While still in this machine it is usual to finish the treatments required for 'bleaching for white' and colouring and for loading and sizing.

Colouring

If the pulp were left in the bleached condition, the white of the finished paper would generally be somewhat dull and yellowish, and where a full white is required it is necessary to obtain this by the addition of a little blue or violet colouring matter. Ultramarine, prussian blue or a synthetic dye stuff like methyl violet has the desired effect. If coloured paper is to be manufactured, the pigments or dyestuffs in sufficient quantity to give the shade required are added and thoroughly mixed in.

Loading and sizing

Very important constituents of paper are the loading and sizing materials which assist in giving the finished paper the desired appearance and handle, and close the pores so that sharp impressions are obtained in printing and ink does not spread laterally in writing. For white papers only white insoluble powders, like china clay, can be used as loading material, whilst for brown and dark-coloured papers naturally-occurring coloured earths (ochres) can be employed. They are ground very fine and are added direct to the pulp and well mixed in by the engine. The powder adheres mechanically to the fibres, and with machine-made papers fixation is assisted by the size which is next added.

In sizing for hand-made paper the finished sheets are passed through a tub containing animal size prepared by digesting skin or hide pieces in water, but in the machine-made paper the pulp is generally treated in the beating engine with solutions of resin and alum, and, as a result, each individual fibre takes up a little of the resin. Upon removing the water and drying, this small quantity assists in binding the fibres together and preparing the surface for the finishing operation. The resin is dissolved by boiling with carbonate of soda to form a resin soap. Resin soap will not stand dilution with water without decomposition, so when a quantity of this is added to the pulp the resin again separates to a large extent in very minute particles owing to the large bulk of water with which it becomes mixed, and the deposition is completed by the addition of a solution of alum. The engine is run and the pulp circulated while the solutions are slowly run in and the contents of the engine thoroughly mixed, after which the pulp is ready for being made into paper. It is therefore run off and washed into large wooden vessels,

provided with stirrers, called 'stuff chests' from which it can be passed to the paper-making machine.

Blending, straining, etc.

When for a certain quality of paper it is necessary to mix different raw materials, they may be treated separately up to the half stuff stage and then finished off together in the beating engine, or they may be completely pulped separately and run, in the required proportions, into the stuff chest. In making paper of a definite weight it is, of course, essential that throughout the run the quantity of pulp delivered shall not vary. If it were drawn directly from the stuff chest there would be a constant variation owing to the alteration in the depth of the liquor, so above the stuff chest is a small tank provided with an agitator and an over-flow pipe. The pulp is pumped into this at a rate greater than that at which it is delivered to the paper machine and the excess overflows back into the stuff chest. The level in the small tank, therefore, remains constant and the flow of pulp is regular.

Although at every stage of manufacture provision has been made to remove sand, dirt and other matters which would spoil the machinery or paper, fine particles may still have been held in suspension by the thick pulp. It is now necessary to mix this with an excess of water so that the fibres may float freely and set themselves to a good web on the machine, the pulp becoming so thin that it cannot hold these impurities in suspension and they are removed in the 'sand catcher.' This is a long trough across the bottom of which at short intervals pieces of felt are fastened. The diluted pulp flows along this trough, the fibres floating and swirling in rapid motion, whilst sand and other heavy particles sink to the bottom and are caught and retained by the felt strips. The pulp thus reaches the paper machine proper, but, before it passes on to the wire, knots and coarse fibres which would spoil the paper must also be removed, and the pulp is, therefore, strained in special strainers which are kept in violent agitation, so that the fine fibres pass through without choking the passages, but the coarse, insufficiently treated ones are kept back.

Making of paper by hand

The modern paper machine is a large, complicated piece of machinery introduced only about 100 years ago. Until then all

paper had been made by hand from pulp which had been prepared in small lots at a time by laborious hand processes. It was made on frames of various sizes corresponding with the dimensions of the paper required; fine wire sieves were supported on stouter wires in a strong wooden frame upon which a removable wooden rim, or 'deckle', fitted closely, thus forming a strainer in which a fixed quantity of pulp, giving a definite thickness of paper when the water drained away, could be taken up.

The pulp was contained in a stone, or stout wooden, vessel, the sides of which were of such a height that the workman could lean over comfortably and dip the frame with its deckle into the 'stuff.' The contents were kept agitated to prevent settling, and the frame was introduced and lifted in such a manner that the stuff was evenly distributed on the wire. As it was lifted the frame was kept absolutely horizontal, and while the water drained away the workman shook it gently but sharply backwards and forwards and from right to left to lay the fibres and to cause them to interlace. Needless to say, the production of perfect sheets, one after the other, is not easy and demands great skill and experience on the part of the workman.

The sheet being thus made, the deckle was removed, the frame was set to drain and then taken by an assistant who turned it upside down on to a felt of lightly milled woollen cloth, the texture of which was such that it readily absorbed water without damaging the surface of the wet sheet. The frame was then lifted, leaving the sheet on the felt, and placed ready for use again by the vatman or paper-maker, whilst another felt was placed over the wet sheet, ready for taking the next which in the meantime had been prepared by the vatman.

A pile of sheets and felt was thus built up and was then transferred to a screw press where the bulk of the water was squeezed out, after which the pile was taken apart and the sheets of moist paper laid one upon the other were again placed in a press. Pressure between felt was necessary in the first case as the wet sheet could not be handled without damaging it, but the greater portion of the water being removed and the sheet somewhat consolidated, the felt support could be dispensed with and several pressings of the pile of paper given, reversing the position and altering the order of the sheets with the object of distributing the residual moisture evenly throughout the pile. After pressing the sheets were hung up to dry, and were then sized in a solution of gelatine prepared by boiling

a quantity of hide, skin or bones in water and clearing with alum.

The workman took up a pile of sheets, up to 200, and immersed them in the liquor, moving them so that each individual sheet became evenly impregnated. The pack was then pressed, taken apart, re-arranged and again pressed to give an even distribution, and dried. The operations were repeated until the required degree of sizing had been attained. After drying the sheets were calendered or glazed.

The paper-making machine

On the Fourdrinier paper machine the whole process of paper manufacture is carried out continuously, the wet pulp being fed in at one end and emerging from the other end as a dry sheet of paper which is wound on reels and taken away for cutting and preparation for the market. It will be readily understood that it is, as a whole, somewhat complicated, and is on such a large scale, being some 100 feet long and more, that no small-sized illustration is capable of conveying a conception of its appearance and method of working to those possessing little or no acquaintance with machinery. Leaving out of consideration the driving machinery and certain other adjuncts, the machine consists in the main of two well-defined parts—the 'wet' and 'dry' ends. At the wet end the pulp is run into the machine, drained and pressed and the web of paper formed, and this web is then dried, pressed, calendered and reeled in the remainder of the machine.

We have followed the process of manufacture of the pulp up to the stage where it has been freed from sand in the sand-catcher and passed through the strainers ready to be made into paper. Before it passes on to the wire, however, it is necessary to ensure that the surface carries no 'froth', as this would spoil the surface of the paper. The liquid, therefore, from the strainer flows into a box with a transverse partition in the centre reaching almost to the bottom; all froth and bubbles are retained on the inlet side, and, freed from these, the liquid passes over an apron upon which it is evenly spread by a suspended strip of brass, the edge of which is fixed so as to leave a slit of a definite width above the apron. The layer of liquid passing under the slit is therefore of a uniform thickness and passes directly on to the endless wire bed to form the web. It is prevented from spreading laterally by two thick rubber bands, the deckle straps, which lie on the wire bed, travel forward

with this and can be fixed at definite distances apart, thus determining the width of the sheet of paper to be manufactured.

The 'wire' is a long length of wire gauze, the ends of which are carefully stitched together to form an endless bed, supported by rollers and maintained in an evenly stretched, horizontal position. As the paper web is formed and travels forward it is transferred from the wire, which is carried back under the machine, and the formation of the paper web is thus continuous. Not only is this travelling movement given to the wire, but, while the pulp is still wet and the water is draining away, a side-to-side joggling motion is imparted to the frame, and fibres lying on the wire are thus prevented from settling down lying in one direction only and are made to lie in all directions and inter-lace, a matter of importance to the strength of the finished paper.

At first the water drains away very quickly through the wire, but the pulp would still be too wet when it reached the place for leaving the wire, so a suction box is fixed below the bed and in this a partial vacuum is maintained by means of pumps. As the wire travels over the box a further quantity of water is removed from the pulp, which thus becomes more consolidated but is still fairly soft. Where a 'water mark' is to be given to the paper a light wire gauze cylinder with the required marks woven in rests upon the web at this stage, and the slight pressure leaves the mark impressed upon the moist pulp without disturbing the surface. A passage over a second suction box removes more water and the pulp is now sufficiently compacted to stand the pressure of a heavy roller covered with a felt of special texture, called the 'couch roll,' which squeezes out still more water and leaves the web in such a condition that it can be handled and can travel a short distance without the support of the wire bed. It is, therefore, transferred to the first wet felt; the wire travels back to the front end of the machine and the moist paper is carried on the felt between the first press rolls, where heavy pressure is exerted upon it and more water is squeezed out. The felt travels over rollers back to the couch roll, whilst the paper is taken up on another felt through the second press rolls, and is here squeezed so free from moisture that it can travel without further support, and is passed around a number of steam-heated drying-cylinders and between smoothing and calendering rolls to be reeled up at the end of the machine.

Fig. 6 may give an idea of the wet end of an early machine by Bertrams of Edinburgh, of a total length of some 120 feet and capable of delivering 120 feet of paper 90 inches wide per minute. This capacity was equal, practically, to that of 160 vatmen in hand paper-making.

In the foregoing short account of the processes employed in paper-making no attempt has been made to give a full description of any operation or of the range of machines employed. No two mills are fitted out, perhaps, in exactly the same way, and the precise manner in which the various operations are carried out will vary according to the experience of the management and the special requirements of the paper manufactured. As stated early in this article, the aim has been to give a general account of the conditions which could be followed by a non-technical reader not in a position to obtain and follow the special technical publications. For those who are desirous of more detailed information reference may be made to a *Text-book of Paper-making* by Cross and Bevan published by E. and F. M. Spon, London, while another publication which contains much useful information on the practical side of paper-making is *Practical Paper Making* by Clapperton (Crosby Lockwood and Son, London).

A prominent feature in modern paper-making is the extent and variety of the machinery employed, and, naturally, if this is to function properly and give a proper outturn, it requires to be manipulated and controlled by men who understand it and can keep it in proper running order, that is, by men who have been well trained and have had experience of similar machinery for some years.

Reference has also been made to the enormous variety of qualities of paper recognized in the trade and the extent to which different mills specialize. The quality will depend upon the raw materials and the way in which they are blended, the manner of treatment in boiling, in the beater, in loading, sizing and finishing, etc., and in this direction practical experience of the trade and manufacture alone is of any value in coming to a conclusion as to how any given product is produced.

WOOD PULP AND ITS MANUFACTURE

It may, perhaps, be desirable to devote a little more attention to the question of raw materials and their sources as being one of paramount importance. It has been mentioned how in the early days the supply of paper was obtained from refuse textile materials of flax and cotton, and how, when the supply of these became insufficient, the paper-maker turned to other fibrous materials, such as jute waste, straw, grasses etc., to supply his needs. The demand for paper continually grew, however, and for many years now the demand has only been met by the use of wood to supplement the other materials. A stage has now been reached when the supply of this material, which in Scandinavia and North America seemed inexhaustible, appears likely to fall short of demands.

The wood pulp industry has been developed to the greatest extent in North America and Canada, Scandinavia and Germany. The species which have been drawn upon consist mainly of fir, pine, spruce, aspen, poplar, balsam, hemlock, larch, etc., which in the countries in question grew in extensive forests or have been cultivated in planted areas. The danger of denudation has not been lost sight of, and the maintenance of the supply of timber by afforestation has received much attention. In Canada and the United States virgin forests have supplied the bulk of the timber for wood pulp, whereas in Scandinavia and Germany afforestation has been practised intensively for many years with a considerable gain to the state. The conditions in Germany and North America were, of course, very different as regards population and its contiguity to the forests, and the necessity of ensuring supplies of wood by replanting felled areas was in Germany more quickly recognized. Recognition came too late in the United States, and for some years now the demands there have far exceeded the home supply and Canadian resources are being largely drawn upon. Even these, vast as they are, will not cover prospective future requirements unless replanting is extensively followed. It has been calculated for Canada that to supply a mill with the necessary spruce wood for the manufacture of 15,000 tons of news-paper per annum 100,000 acres would be required for growing the necessary wood. This assumes a period of 40 years

from the time of felling for the recovery of an area after cutting, before it again reaches the productive stage.

Although wood pulp occupies such a predominating position as a general raw material for paper-making, it is not to be assumed that other materials have lost their importance. In fact, for many classes of paper they are indispensable, and a consideration of the imports of classified raw materials into the United Kingdom is interesting. An extract from these returns up to 1913 is given in *Paper-making* by Cross and Bevan, from which it is seen that, although between 1887 and 1909 there was a great increase in the quantity of wood pulp imported and a diminution in the quantity of rags, from 1909 to 1913 there was an increase in all classes. The figures for these two years are given below :

| | 1909 | | 1913 | |
|---|----------------|------------------|------------------|------------------|
| | Tons | Value | Tons | Value |
| Linen and cotton rags | 17,798 | £ 179,446 | 29,538 | £ 312,351 |
| Esparto and other vegetable fibres for making paper | 197,501 | 719,602 | 204,957 | 743,354 |
| Wood pulp :— | | | | |
| Chemical | 315,174 | 2,403,393 | 411,803 | 3,312,413 |
| Mechanical | 434,565 | 1,106,007 | 565,954 | 1,305,326 |
| Other materials | 11,385 | 90,833 | 16,898 | 142,359 |
| Total of paper-making materials | 976,423 | 4,499,231 | 1,229,150 | 5,815,803 |

A study of the statistics seems to indicate that the increased demand for paper will adequately be met only by an increased production of wood pulp or the better utilization of what have hitherto been waste materials. All kinds of vegetable fibrous materials have been considered by paper-makers, such as

| | |
|--------------------------|-----------------------------------|
| Cotton rags | Reeds |
| Cotton waste | Woods of various kinds |
| Linen rags | Wood shavings, saw-dust and chips |
| Linen waste | Megass (Sugar-cane refuse) |
| Hemp waste | Old bagging |
| Manilla hemp | Old bast matting |
| Jute waste | Old canvas |
| Straw of wheat, etc. | Old rope |
| New Zealand flax | Gunny bags |
| Maize stems, husks, etc. | Waste paper |
| Esparto grass | |

but the paper industry as a whole can only take up those of which a regular supply is assured, and which can be delivered to the works at a price, based on the cellulose fibre content and its suitability, comparable with that of the raw materials in established use.

There may be eminently suitable materials in the world which have not yet been used, but unless their collection and transport can be effected at a cost which will permit of their competition with the present raw materials there would be little prospect of their finding a market, and the problem with them would become one of treating the material in such a way as to eliminate all unnecessary charges, so that its cost to the paper-maker is one which he can afford to pay.

The treatment of wood itself is an example, for this takes place generally as near as possible to the area where the wood is grown and far away from the paper mill where it will be finally used. The transport and handling of the logs would be difficult and costly, so these charges are reduced to a minimum. The trees are felled and the logs floated as near as possible to the pulp mill, which is placed on a convenient site, and the timber is there treated to isolate the cellulose, or brought into a form convenient to handle, and the resultant product, the wood pulp, is placed on the market in compressed bales.

The processes for the conversion of wood into pulp are either—

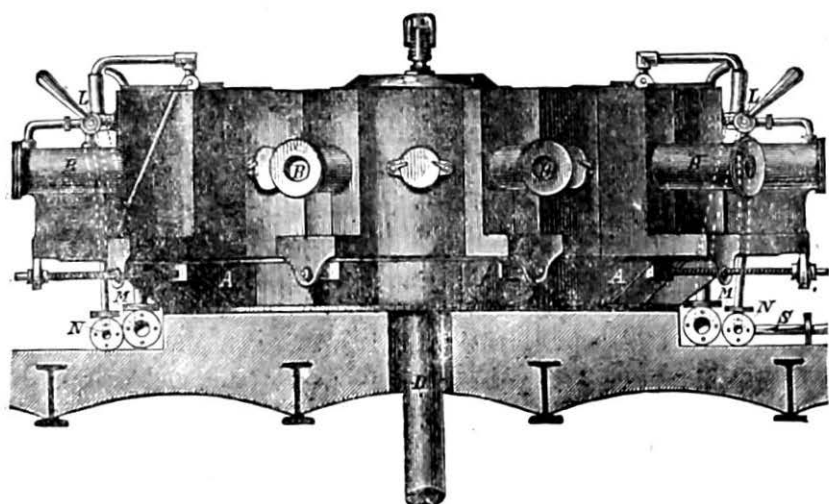
- (1) Mechanical—worked (a) hot or (b) cold.
- (2) Chemical—by digesting with alkalies as in (a) the caustic soda process (b) the sulphate process, or with acid liquors as in the sulphite process.

The following short descriptions of the processes may be of interest and assist in appreciating the completeness of their development.

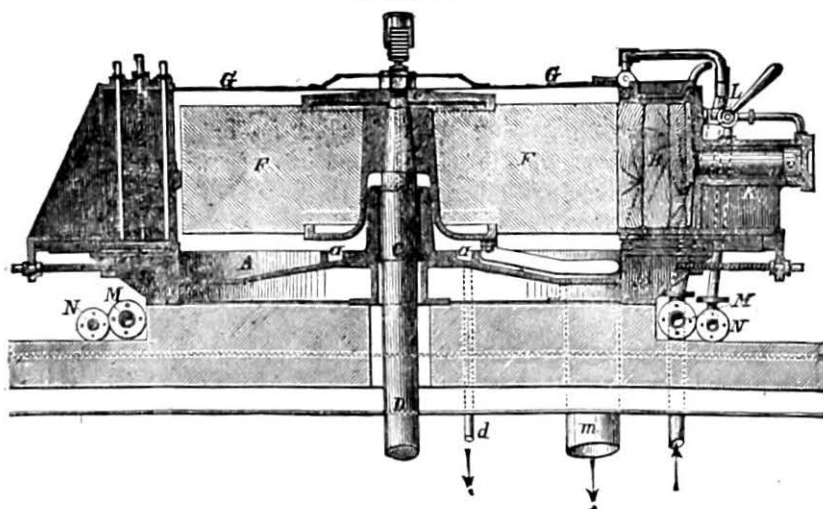
Mechanical wood pulp

The principle of this process is that the wood is disintegrated by mechanical means by being pressed against a rapidly revolving grindstone upon which a stream of water is directed. Various qualities of pulp can be manufactured by varying the conditions regarding the supply of water. The pressure with which the wood is forced against the stone, the sharpness of the stone, the temperature of the water, etc.

The logs of timber are first sawn into lengths of two feet and the bark removed from these short lengths by pressing them against a revolving plate fitted with knives. The clean blocks of wood are then taken to the grindstone, which may be fixed on a vertical or



ELEVATION

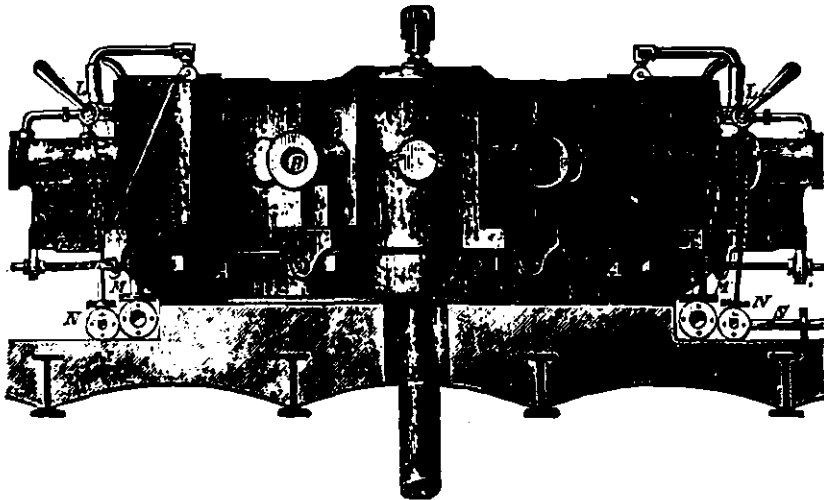


SECTION

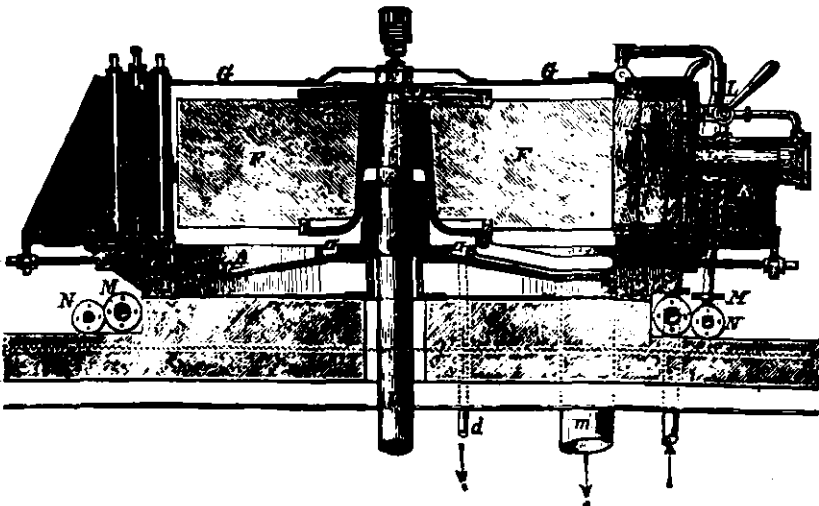
FIG. 7.—GRINDING STONE FOR MECHANICAL WOOD PULP.

(Figs. 3618 AND 3619.—"PAPIER". MUSPRATT'S *Chemie*, 4TH EDITION, VOL VI)

The logs of timber are first sawn into lengths of two feet and the bark removed from these short lengths by pressing them against a revolving plate fitted with knives. The clean blocks of wood are then taken to the grindstone, which may be fixed on a vertical or



ELEVATION



SECTION

FIG. 7.—GRINDING STONE FOR MECHANICAL WOOD PULP.

(FIGS. 3618 AND 3619.—"PAPIER". MUSPRATT'S *Chémie*, 4TH EDITION, VOL. VI)

horizontal axis. The stone may be from 60 to 90 inches in diameter and about 27 inches on the face and is mounted in a strong cast iron cover in which there are recesses for taking the prepared pieces of wood. The wood in the recess is forced against the stone by pistons acting under hydraulic pressure, and a jet of water being run continuously over the block, the wood fibres which are torn from these blocks are carried away by the stream. The thin pulp thus obtained is led away and screened to remove all coarse pieces, and is then run into a vat in which a drum of fine wire gauze revolves. The water passes through the gauze leaving a skin of pulp adhering to it, and as the drum revolves the thin sheet is transferred to a felt and passed between squeezing rollers and is then wound on a large wooden drum up to a certain thickness, when it is cut off and, a number of sheets being placed together, squeezed in the hydraulic press and packed.

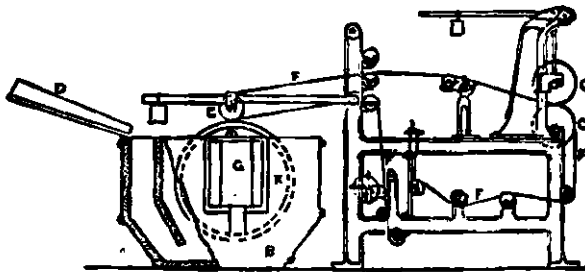


FIG. 8.—BOARD MACHINE FOR MECHANICAL PULP.
(FIG. 32.—*Paper Making*—CROSS AND BEVAN, 3RD EDITION.)

Fig. 8 illustrates the production of sheets of mechanical pulp. B is the vat in which the revolving sieve, K, works. The sheet of pulp which forms on K is transferred to the felt, E F, and carried to the rolls, C. It winds itself round the upper one, and when the layer is sufficiently thick it is cut off and removed for pressing and baling. The process, being purely mechanical, does no more than reduce the wood to a finely divided condition in which it may be used for paper, but cannot, of course, remove non-cellulose matter. The product is not suitable on this account for the manufacture of higher-grade papers, and is therefore most largely used for qualities which are not expected to meet any great demand for strength and permanence.

Chemical processes

In the chemical processes the non-cellulose matter is more or less removed and the final product approximates more nearly to pure cellulose. These chemical treatments, as already mentioned, are either (a) alkaline or (b) acid in character, and the two classes differ materially in the nature of their action.

The oldest chemical process is that in which the wood is subjected to the action of caustic soda; it is comparatively simple, and the other alkaline process, treating with sulphate of soda, is carried out in practically the same manner. The logs of timber are first cut into lengths and the bark removed, and the wood is then cut into small pieces or strips. One machine for this purpose consists of a very heavy circular iron plate in which knives are firmly fastened. This revolves rapidly, and the lengths of wood being pressed end-on against the surface the knives chop off sections of almost an inch in thickness which fall into grooved rollers and are thus crushed and reduced to small pieces. Other effective machines work on the 'guillotine' principle, a heavy knife working up and down in a frame chipping off sections which are further reduced by passing between rotating knives. The small pieces of wood so obtained are fed into digesters similar to those already described and are there covered with the alkali solution and boiled. The strength of the solution will vary, but the weight of alkali commonly used is in the neighbourhood of 20 per cent. of that of the wood.

The resolution of the wood and the completeness of the removal of the non-cellulose matter is greater the higher the strength of the alkali, the greater the pressure under which boiling is conducted and the length of time during which the pressure is maintained, but there is a limit beyond which the cellulose itself is affected and the yield diminished, so the process is conducted under such conditions that the maximum yield of easily bleaching pulp is obtained, the conditions being settled by experiments upon the material to be treated.

During the boiling the solution becomes deep brown coloured from the constituents of the wood which go into solution, (almost 50 per cent. of the weight of the wood) and the cellulose residue itself becomes more or less brown coloured. For commercial success it is essential that the costly alkali employed should not be wasted but should be used again and again, so elaborate arrangements are made for its recovery. The contents of the boiler are blown out and the

dark brown liquor collected. The boiled wood is also washed under conditions which remove a maximum of alkali with the use of a minimum quantity of water.

The wood, which is now soft and easily crushed, is fully washed and pulped in the hollander, after which it is formed into sheets and baled for transport. The dark-coloured boiling liquor and concentrated washings are evaporated and calcined, whereby the organic matter is burned away and carbonate of soda remains. This is re-dissolved in water and treated with slaked lime to re-convert it into caustic soda ready for further use. The success of a factory will largely depend upon the completeness with which the soda is recovered and regenerated with the least expenditure of fuel, but a certain amount of loss is unavoidable.

The sulphate process is in its essentials the same as the soda process, but differs from it in that the loss of alkali is made good by the addition, not of caustic soda, but of sulphate of soda, which is much cheaper. The sulphate of soda, as such, has no action upon the non-cellulose matters, but in the process of recovery (in the calcining) the organic matter reduces it to the stage of sulphide of soda. This has a strong alkaline reaction and is practically as effective as caustic soda in its effect upon the wood.

In the sulphite process of pulp manufacture the active agents are sulphurous acid, obtained by burning sulphur or sulphur ores, or acid salts of the same.

From the working of non-resinous coniferous woods like fir, pine and spruce, fine white pulps are obtained which are used even in better-class papers. The wood requires to be carefully prepared, and not only the bark but also the knots and faulty pieces must be removed, as these do not respond so readily to treatment and would lower the quality of the pulp. In the process as carried out in one way the cooking liquor consists of a solution of acid calcium sulphite, containing an excess of free acid, and is prepared by passing the vapours of burning sulphur up a high tower packed with limestone through which a stream of water percolates. The liquid passing away at the bottom of the tower is led into vats to settle and the clear solution collected for boiling. The digesters consist of iron cylinders, but, on account of the corrosive nature of the liquid used, they have to be coated inside with lead sheet and this again protected by facing with glazed brick. To avoid the expensive renewals which corrosion of the digester walls entails, the arma-

tures for safety valves, pressure gauge, etc., are not fixed in the walls, as with most boilers, but are arranged in the covers of the manholes through which the digester is filled. The heating is by means of closed steam pipes made from hard lead which are arranged within the cylinder so as to give a maximum circulation of the liquors.

The wood is filled into the digester and steam is blown in for some time while the valves are left open. The object of this is to drive out air from the pores of the wood. Upon closing the valves and opening the connection with the cooking liquor supply tank, the liquor rushes in and quickly fills the digester to the required level, upon which the supply is shut off. A full pressure of steam is maintained now in the heating coils in order to heat the liquor in the digester as quickly as possible up to about 110°C., below which little or no action takes place, and then the temperature is maintained at the required level for about twelve hours. The condition of the liquor is tested at intervals to control the process, and upon the completion of the boiling the liquid is blown off and the wood cooled as quickly as possible by running water into the digester. The cooked wood is emptied and washed, pulped and formed into sheet.

There are variations in the pressure and time employed, with consequent variation in the product obtained, but it is possible by this process to obtain a pulp of great purity and suitable for very high grades of paper. One objection to the process may be found in the enormous quantities of water required, owing to the nature of the waste liquors. They very easily create a nuisance unless very heavily diluted, and numerous patents have been taken out for processes which have had as their object the recovery or the utilization of the matter contained in the liquors.

SOME CONDITIONS ESSENTIAL TO A SUCCESSFUL PAPER INDUSTRY

It will, perhaps, have been realized that the successful control of a modern pulp or paper mill demands a great deal of technical knowledge, not only of machinery and processes, but of materials and their possibilities. Such technical knowledge and the capacity to apply it are not easily acquired, but the commercial success of any factory depends primarily upon the men who control it on both the business and the technical sides.

Up to the present the chief responsibility for the successful production of paper has undoubtedly been with the engineer, in devising plant capable of dealing effectively with different materials, both raw and at all stages of manufacture, and, with the aid of the chemist, in evolving processes of treatment leading to the desired end. If this machinery is to function properly it must be maintained in thoroughly good order, and a competent paper-mill engineer must be considered indispensable if breakdowns and consequent heavy losses are to be avoided. Beyond the engineering staff, men are required who have grown up in paper mills and are experienced in the treatment of the material in its various stages, especially in the management of the beating engines and the paper machine. This may appear so axiomatic that no mention need have been made of it, but from a consideration of the history of the only serious attempt hitherto made to start a paper mill in South India (in Travancore) it is the author's opinion that with a competent technical staff and business management, a properly equipped mill on the site selected should have succeeded.

Beyond the human element, however, are other requirements which must be fulfilled to ensure success. We have already realized the importance of an adequate supply of cheap raw material, and the first of these other requirements is in relation to the water supply. According to the raw material worked up and the class of paper manufactured, each ton of paper produced may require a supply of 50,000 to 150,000 gallons of water. The supply must be fully adequate to meet all possible needs and must be free from all coloured impurities, such as iron salts in solution, and free from all suspended matter. For such a supply we are dependent upon the rivers, for a well supply capable of meeting requirements throughout the year

would be difficult to find and pumping would be expensive. With a river supply adequate filtering arrangements to remove all suspended matter are essential. The quantities mentioned above may not represent the total quantity of water required, for it may be necessary to deal with the effluents from the mill, and to render these harmless dilution with a large excess of water may be required.

Another important matter is that of fuel, and in the location of any mill the supply of this requires serious consideration. It is a quite common experience that for the manufacture of one ton of paper the fuel requirement, with coal as fuel, is in the neighbourhood of three tons. But coal is not mined in Madras and is expensive and a mill would most probably be dependent upon wood as fuel. To replace one ton of coal about three tons of wood would be required, so that nine tons of wood may represent the fuel requirements per ton of paper manufactured. To a mill located at any distance from a forest from which this requirement could be easily met, an adequate fuel supply would constitute a very serious item of expense. A paper-mill using pulp as its raw material requires one and a half tons of coal or four and a half tons of wood per ton of paper produced.

The location of a mill, therefore, demands, not only consideration of the question of its water supply, but of its fuel and transport facilities. Beyond the supplies of raw material and fuel, alkalies are required, and, although caustic soda and carbonate of soda, would be obtained in convenient packages from dealers, lime may be required in large quantities at low rates precluding any heavy expenditure on freight. China clay and other loading materials would also be required, and contiguity to a railway or port seems essential for the receipt of supplies of the small-bulk materials and despatch of the finished product. Any long lead for the supply of raw material, fuel or limestone seems out of the question, unless it be by water, for competition in the open market would be impossible unless the mill is assured of these bulk supplies being delivered to it at rates which would permit of the finished paper being sold at a profit.

The general conditions which may affect the successful operation of a mill have been discussed by Sindall* and Pearson†, and reference

* *Report on the Manufacture of Paper and Paper Pulp in Burma.*—R. W. Sindall. Rangoon: Office of the Superintendent, Government Printing, Burma.

† *Note on the Utilization of the Bamboo for the manufacture of Paper Pulp.*—Pearson. Indian Forest Records, Vol. IV., Part V.

may be made to the publications mentioned, but it is evident that this question of location from the point of view of transport facilities is very important, considering that for every ton of paper produced some seven tons of material, when coal is used as fuel, and much more, of course, if wood be used instead of coal, require to be handled. One very competent authority has informed the author that in his opinion the location of a mill on a site suitable for the supply of raw material, and fuel in unlimited quantity at low cost was really more vital than the nature of the raw material itself.

RAW MATERIALS IN MADRAS

Regarding raw materials suitable for paper pulp manufacture, it is incontrovertible that in Madras large supplies are available in the forests, either as timber, bamboo, reeds and grasses, and in other areas from fibrous plants like hemp, cotton stalks, etc., and from cereal straws and other crop refuse. A glance at the short list which has been given above of materials which have been employed for paper-making will show how largely these consist of waste, that is, of products from materials which have a higher value for other purposes. No fibre, for instance, which upon spinning can be converted into a useful strand could economically be taken as a paper material. Only the spinning refuse which cannot conveniently be worked up into threads finds its way to the paper-maker, as also old rope and gunny bags which no longer serve the purpose for which they were originally made. The reason for this is that the prices at which the fibres suitable for spinning are sold bear some relation to the cost of cultivation and preparation, and, at the rates which have been ruling for finished paper, such prices are out of the question to the paper maker. It may be assumed that the cost of raw materials represents no more than about one quarter of the cost of manufacture, so that the paper maker is, in effect, forced to seek his raw material in products which cannot be used in other directions and are obtainable at very low rates.

Although, therefore, it may be quite true that the raw material is present here in quantity, it will not be employed in paper-making unless it can be delivered at the mill at a price, commensurate with its quality, at which it will pay the paper maker to use it, and, if instead of finished paper the object be to manufacture paper pulp for supplying to paper mills, the same condition holds, since only such pulp will find a market as can compete in quality and price with that obtainable from other pulp-producing countries.

A paper mill fitted with a selection of preparatory machines, like rag cutters, willowing and dusting machines, and not working on contract throughout the year to deliver a fixed quality of paper, would, perhaps, be able to keep going on a number of raw materials like rags gunnies, grass, straw and the residue of the field crops from

its neighbourhood, but no extensive manufacture could be expected to develop under such conditions. For an outturn of regular qualities of paper to meet fixed requirements regular supplies of raw materials will be found essential, and to meet this requirement effectively the mill would require, especially if it worked upon materials more or less of a seasonal character, to lay down storage accommodation sufficient to meet all its possible needs. Such materials as plant stalks and grasses are liable to decay unless properly stored, and contain so much pith and non-cellulose matter that the paper yield is low, entailing high costs for chemicals; and owing to their bulky nature and the diminished quantities which can be packed into the digesters materially increase the overhead charges on the production. Local conditions, however, as regards supply and price may justify a mill in taking them up and working them up into paper.

It would appear most natural that, for meeting the demand for bulk supplies of raw material, the forests would be drawn upon, and the question of the utilization of forest grass and timber for the purpose of paper manufacture has occupied the attention of the Forest Department in India for many years; but, except in very few cases, the difficulties in connection with the collection and transport at sufficiently low cost have proved insurmountable.

In the case of grasses the cost of collection will, of course, be intimately connected with the thickness of the stand of grass and its area, whilst the cost of transport will depend generally upon the conditions in the area regarding the possibility of forwarding in bulk by water. In these respects the prospects in Madras appear to be unfavourable compared with those in some other parts. *Sabai* or *Bhabar* grass seems to be widely distributed in the north, and within an economic radius of Calcutta has been collected for delivery to the mills there. In 1902 an attempt was made to utilize the supply of grass available in Ganjam, but the project had to be abandoned owing to the heavy costs for collection and transport. The question of the utilization of *Mudumalai* grass growing in the Wynaad was under discussion about 1911, but no definite test was made regarding its suitability for paper, nor was any estimate made of the quantity available or the cost at which this could be marketed. From the information available it does not appear absolutely certain that Madras areas could support a mill using grass in quantity, for the minimum requirement for economic success has been quoted at

10,000 tons per annum, and from the enquiries made up to now the weight available from any district does not appear to be more than 1,000 tons. In some other provinces, in Assam for instance, conditions regarding grass are much more favourable; an inspection of the Monas river area by the Forest Economist in 1916 showed that compact areas were available from which fully adequate supplies could be obtained and delivered by water to a point 25 miles away at Rs. 6-2-0 to Rs. 8-8-0 per ton, according to the species of grass collected.

A sample of *Jammu* grass from the Kolair Lake has been obtained and forwarded for testing by the Department of Industries, Madras, but the reports upon the cellulose content and the strength of the fibre obtained on treatment were not favourable. The fullest information upon the present position regarding the utilization of grasses for paper manufacture will be found in Vol. V, Part 3 of the *Indian Forest Records*.*

* *Report on the investigation of Savannah Grasses as material for the Production of Paper Pulp.*—W. Raitt.

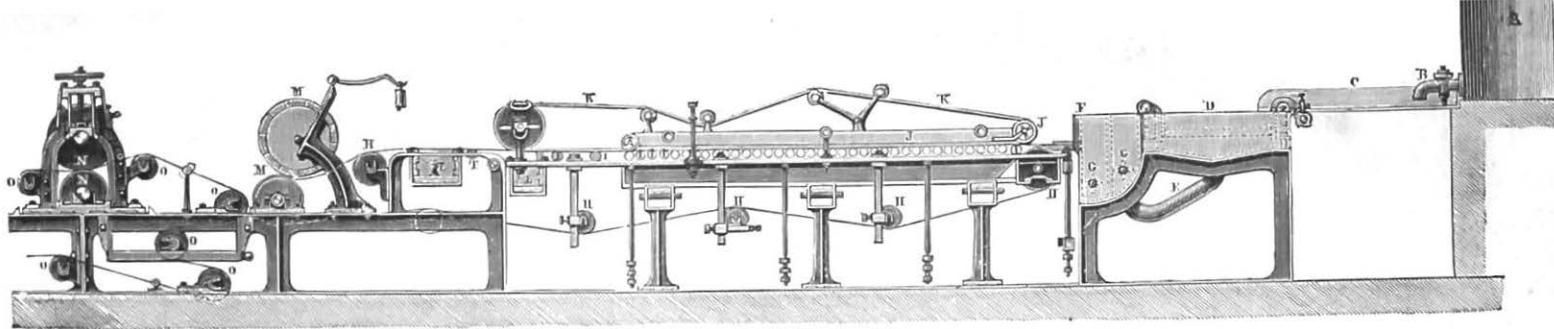
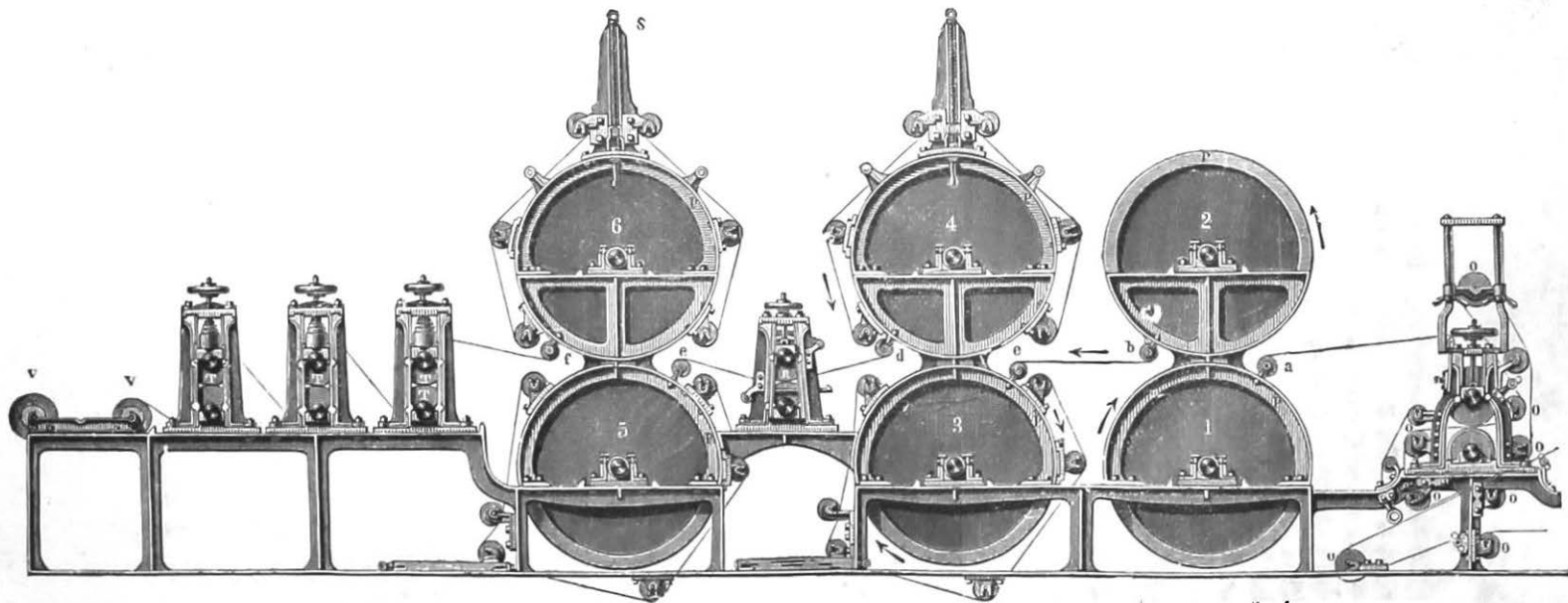


FIG. 6.—FOURDRINIER MACHINE.



SECTION THROUGH THE WET END.

(FIG. 3576.—"PAPIER". MUSPRATT'S *Chémie*, 4TH EDITION, VOL. VI.)

A. Pulp delivery tank.
 B. Outflow.
 C. Sand catcher.
 D. Strainers.
 E. Pipe from D to F.

F. Box or vat.
 G. Stirrers to keep the pulp agitated in F.
 H. Tension rollers for wire.
 J. Rollers supporting wire bed.
 K. Deckle straps.

L. Suction boxes.
 M. Couch roll.
 N. Wet press.
 O. Rollers carrying wet felt.

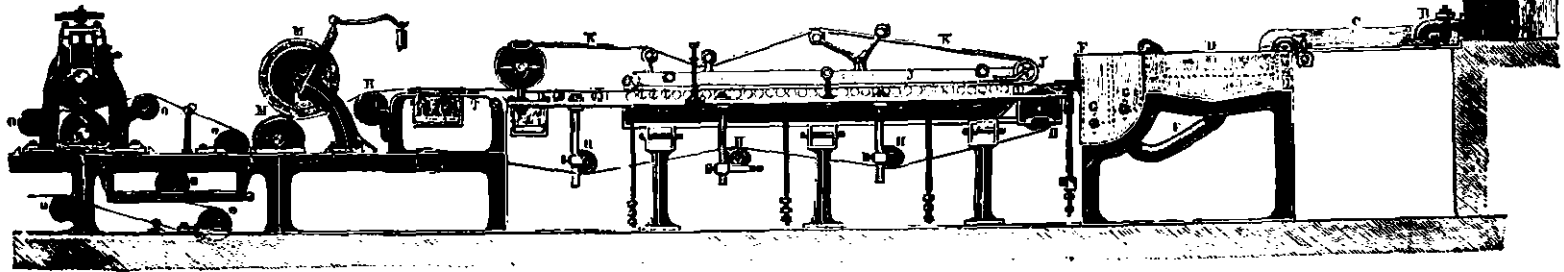
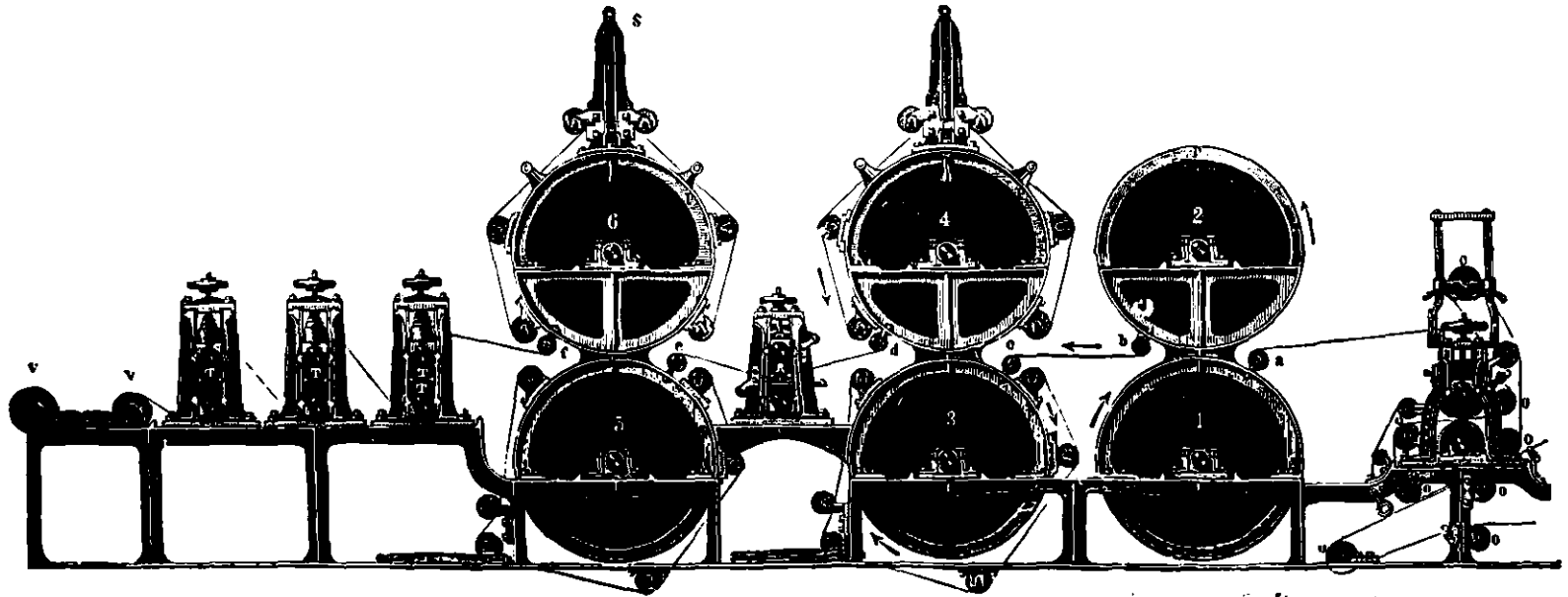


FIG. 6.—FOURDRINIER MACHINE.



SECTION THROUGH THE WET END.

(FIG. 3576.—"PAPIER". MUEPRATT'S *Chimie*, 4TH EDITION, VOL. VI).

- A. Pulp delivery tank.
- B. Outflow.
- C. Sand catcher.
- D. Strainers.
- E. Pipe from D to F.

- F. Box or vat.
- G. Stirrers to keep the pulp agitated in F.
- H. Tension rollers for wire.
- J. Rollers supporting wire bed.
- K. Deckle straps.

- L. Suction boxes.
- M. Couch roll.
- N. Wet press.
- O. Rollers carrying wet felt.

TIMBER FOR PAPER PULP

Attention has been drawn to the extent to which paper makers are now dependent upon timber for their supplies of raw material and the position occupied by Canada and Scandinavia in supplying the pulp market. The varieties of timber operated upon are few in number, consisting mainly of the woods of coniferous trees with which large areas are covered. The uniformity of the material permits of a regular product being obtained, and operations are carried on on such a large scale and the arrangements are so complete that standard products can be placed on the market at low rates and exported all over the world.

The trees contained in the Madras forests are not of the coniferous variety, and many are far too valuable, even when they would otherwise be useful, for conversion into pulp for paper. Not only so, but the composition of the forests is very mixed, and it would be exceedingly difficult to find even a small area covered with timber of one and the same variety, so that the production in large quantities of a pulp of a fixed standard from one and the same timber would be difficult. The possibility, therefore, of developing an export trade in paper pulp from Madras soft wood is hardly worth consideration. Trials have from time to time been made of woods similar to those which are found here† and the results were quite satisfactory as regards yields of cellulose and quality of pulp, and in 1915 the late Mr. A. W. Lushington compiled a long list of woods which in his opinion were worthy of trial.

Assuming that a mill would be able to operate upon a number of timber varieties and find a market for many qualities of pulp, it is very questionable whether the conditions in forest areas in Madras would permit of the delivery of the timbers at a price which would enable them to be worked by the mill at a profit. Sindall calculated that in Burma wood would be delivered at a mill at about two annas per cubic foot, but conditions in Madras are in general very different from those in Burma which Sindall had in view, for the forests from which supplies might be expected are not so accessible and the leads to any centre at which a mill might be located would be very long.

† *Report on the Manufacture of Paper and Paper Pulp in Burma.*—Sindall.

and increase the price materially. Certainly, the delivery of selected varieties from any forests at low rates is not at present possible, and much more information is required to decide the question whether a continuous supply of timber could be assured to a mill at rates at which the conversion into pulp would be remunerative.

The factors of continuity of supply and suitably low costs are best fulfilled by bamboo, and much information has been collected regarding the utilization of this material.

BAMBOO AS A SOURCE OF PAPER

The question of the suitability of bamboo for paper manufacture has been under discussion since 1875, and much information upon all matters connected with it has been collected. The entire information is available, in the main, in five publications :

- (1) *Report on the Manufacture of Paper and Paper Pulp in Burma.*—Sindall. Office of the Superintendent, Government Printing, Rangoon.
- (2) *Report on the Investigation of Bamboo as Material for Production of Paper Pulp.* Raitt. Indian Forest Records, Vol. III, Part III.
- (3) *Note on the Utilization of the Bamboo for the Manufacture of Paper Pulp.*—Pearson. Indian Forest Records, Vol. IV, Part V.
- (4) *The Paper Pulp Industry*, pp. 41-43 of *The Work of the Forest Department in India.* (Superintendent, Government Printing, India, Calcutta.)
- (5) *The Utilization of Bamboos for the Manufacture of Paper Pulp.*—Pearson (Reprinted from the *Indian Forester*, November and December 1920)—Pioneer Press, Allahabad.

Sindall and Pearson deal fully with the question of the growth and yield of the bamboo species common in the areas investigated and discuss the cost of extraction and delivery at selected sites, whilst Raitt deals with the problems connected with the conversion of the bamboo into a pulp suitable for paper manufacture.

In 1906, when Sindall reported, the general impression was that bamboo of less than three years' growth alone could be considered as suitable for treatment, that different species could not be treated together and that the nodes and the internodes would require to be treated separately. His report deals entirely with conditions as they were in Burma, whereas Pearson has included data relating to areas on the west coast of Madras. In his note Pearson gives all the information available in 1916 upon the question of bamboos, their mode of growth and possible outturn, upon the cost of manufacturing paper pulp and upon the suitability of sites in South

Canara, North Malabar and South Malabar for the location of paper-pulp mills.

As a source of paper material bamboo possesses one great advantage, in that for a long period of years — until it flowers—a sustained yield can be obtained from one and the same area by not cutting back all the culms in a clump but, taking note of the observation that in a clump one new shoot is put out annually for every four old ones, so to cut that the area retains its productivity. This would mean 50 per cent. fellings at an interval of five years. The conditions for cutting are fully dealt with, and with the chief species here (*Bambusa Arundinacea*) on a five years' rotation it is calculated that in each of the three Madras areas mentioned a sustained yield capable of keeping a pulp factory at work could be guaranteed.

The South Canara area lies in the Uppinangadi taluq, some 60 miles inland from Mangalore and 40 from Panimangalore, between which points the river is navigable for small boats. The bamboo-bearing blocks in the Uppinangadi and Puttur Ranges cover nearly 36,000 acres, from which an annual yield of 17,000 tons of air-dry bamboo is estimated. Transport would be chiefly by road, but at times the rivers draining the area could be utilized for floating, and the cost of delivery per ton of air-dry bamboo at Panimangalore is stated to be Rs. 6-6-0 from the Uppinangadi and Rs. 9-4-0 from the Puttur Range. Panimangalore is suggested as the site of a factory as it is considered fairly healthy and is within convenient distance of Mangalore, which place is served by steamer and railway and is a convenient point as regards water, fuel and lime supplies.

The second area is in the Kottayam taluq of North Malabar, some twenty miles inland from Tellichery; the acreage at all heavily stocked with bamboo is not large, being estimated at about 3,000 acres, but the size of the culms in the area is large, running about 40 to the ton, and a sustained yield of some 8,000 tons of air-dry bamboo per annum is estimated. The cost is about Rs. 9-10-6 per ton delivered at Kuttaparamba, which has been selected as the most likely factory site. It is at the head of Edayer creek; fresh water could be obtained by damming the river, and lime is available on the coast at Tellichery 12 miles away, to which place supplies of chemicals, etc., could be brought by steamer or rail. Fuel is available in quantity in the neighbourhood but there is a deficiency in carts and labour.

The third area lies about the Chaliar Valley, some 50 miles inland from Calicut in the Nilambur and Amarampalam Ranges. Pearson

estimates the area under bamboo at some 3,000 acres in Nilambur and 6,000 in Amarampalam, and that the combined areas should give an annual yield of 18,500 tons of dry bamboo. The cost per ton at Chaliapuram was estimated by Pearson at about Rs. 8-11-0 from Nilambur and Rs. 5-9-0 from Amarampalam.

Chaliapuram is suggested as a possible factory site, the average floating distance from the forests being 26 miles and the place being in river communication with Calicut, to which supplies of chemicals etc., could be brought by sea or rail. Water, lime and fuel are procurable in quantity, and in general the locality has been considered as eminently suitable.

Negotiations were in fact, in progress for the location of a factory probably at Beypore, by Messrs. Nelson and Co. in 1914, but flowering and seeding of the bamboo in the area developed and no arrangement was come to. The Forest Department, however, made a more extended investigation of the area than Mr. Pearson was able to do, and as a result of this it is evident that, when the area is again in condition, the extraction of bamboo will be a commercial possibility.

The details are given in Madras Government Order No. 2421-Revenue, dated the 20th August 1914, and deal with the extraction and delivery at Chaliapuram, and Beypore on the coast, both during the monsoon and dry season. The average cost of delivery of 10,000 tons in the first year and of 20,000 tons in the succeeding years was worked out, and for Chaliapuram the cost from the Nilambur area was given as Rs. 8-5-4 per ton during the months December—May and Rs. 3-6-8 during the months June—November. From the Amarampalam Range the costs for the same periods would be Rs. 14-9-6 and Rs. 5-1-4, respectively. Delivery at Beypore during the months December—May would cost Rs. 8-11-10 from Nilambur and Rs. 15-0-0 from Amarampalam, whilst during the months June—November the rates from these areas would be, respectively, Rs. 3-8-3 and Rs. 5-2-11.

A further investigation into the cost of cutting and transport was made in 1917, when it was estimated that deliveries of dry bamboo could be made at even lower figures, but the changes in conditions since then have been great, and it would most probably be found that rates materially higher than the above would require to be paid when commercial working started. Recent experience of contractors' rates in another district inclines one to think that

the cost of air dry bamboo is unlikely to be much lower than Rs. 15-0-0 per ton delivered at factory.

Another area which has recently come under discussion lies in the upper Godaveri Division in the Marrigudem, Palusumamudi, and Lakkavaram Ranges, drained by the Godaveri river and its tributaries, the Saberi, Sileru and Gonderu. The quantity of *Bambusa Arundinacea*, the species common on the west coast, appears to be very small, and *Dendrocalamus Strictus* seems to be the commoner variety. The available supply in the area is stated to be about 15,000 tons, which should ensure a supply to a medium-sized factory, the most suitable location for which would appear to be in the neighbourhood of Rajahmundry.

Suggestions have been made for a systematic survey of the Presidency to decide the places which would most probably meet requirements regarding the supply of raw material, fuel and lime, possess an adequate water supply, and near which there is an adequate supply of labour for work in the forests. From the data at present available it cannot be said, considering the nature of the requirements, that many places will be found which are absolutely suitable, and there may very probably be no single locality against which some objection could not be raised. Government officers, however, have shown a willingness to collect the information required, and when they are able to indicate the annual quantity of raw material deliverable and its cost at a given spot, the fuel resources of the area and nature of the water supply, it will become a matter for commercial men with a knowledge of the paper trade to make enquiries of their own into minor, though still important, matters regarding the supply of other necessities, and decide whether there is sufficient prospect of being able, with their knowledge and capital, to erect and run a mill at a profit. Without the active participation of firms interested in finding new outlets for capital in directions in which they are directly interested and have special knowledge, no real development can be expected, and it is to such firms alone that we must look for a full appreciation and utilization of the results of enquiries by Government officers.

Messrs. Heilgers of Calcutta have been experimenting upon bamboo for some years, and, it appears, have taken steps to obtain supplies in Burma. From other quarters, also, it appears that there are proposals to start work in the North Canara area in the Bombay Presidency, but delays have occurred in the erection of plant owing to

some lack of information upon technical details. That pulp and paper can be manufactured from bamboo is an incontrovertible fact, however, and the solution of the technical problems of manufacture, where such exist, lies within the province of the manufacturer.

Under the recent comprehensive reorganization of the Forest Research Institute a Cellulose Expert has been appointed and a special branch to deal with this subject has been instituted. The requisite experimental pulp and paper-making plant has been obtained, and it will shortly be possible to carry out exhaustive experiments in the various kinds of bamboos, grasses and other raw materials which exist in India and Burma and which now await the results of such experiments for their development. The results obtained will be described in the annual progress reports of the Research Institute and will be made public in other ways. Applications for information and advice should be addressed to the Forest Economist, Forest Research Institute, Dehra Dun, United Provinces.

The conditions laid down as most suitable for the manufacture of pulp from bamboo have varied from time to time as further information has been gained by experiment, and, whereas in Sindall's experiments in Burma it was assumed that stems of no more than three years' growth could be taken and that satisfactory pulp could only be manufactured from the internodes, it is now established that stems of any age can be taken and the whole bamboo at that, and by proper treatment and mechanical disintegration can be converted into pulp suitable for almost any purpose.

The most complete information yet published is contained in Vol. III, Part III, Indian Forest Records, in a *Report on the Investigation of Bamboo as Material for Production of Paper Pulp*. Mr. W. Raitt, the author, is an expert who has been interested for many years in the utilization of bamboo for pulp and he here deals with the matter very comprehensively. The general impression at the time when Raitt commenced this investigation was that bamboo was a difficult material to treat, giving a wide variation in the yields of cellulose, to bleach which very varying amounts of bleaching powder were necessary; that the age of the stems was a matter of great importance and that there was great difficulty in obtaining a regular and complete digestion of the pulp. From his experience of the matter he felt that these variations should be easily removable, and his results go to prove this. He made a thorough investigation of five of the most common species of bamboo to determine whether

these are suitable for cellulose manufacture at a reasonable cost, whether each required any special treatment or whether they could be mixed together, whether the condition for success that culms of all ages should be treated together could be fulfilled and whether it was essential to separate the hard nodes from the softer internodes. He found that the variation in results obtained by earlier workers could largely be attributed to a non-appreciation of the physical condition of the bamboo and the nature of the non-cellulose matter.

The bamboo is very porous, due to the sap canals which run longitudinally in the stem. These canals do not collapse on drying but become filled with air which, upon immersion in water, is not driven out but gives the material great floating power. Until the air is driven out and its place taken by the alkaline liquors in digestion no action upon the non-cellulose matters can be expected, and this may have been a common cause of irregularity in the degree of treatment of the wood. If, instead of splitting the stem and chopping into small pieces, the bamboo is crushed between heavy rollers, this capillary condition is largely removed and the fibrous mass sinks readily in water and becomes easily impregnated. It is also found that, by crushing instead of cutting, the difficulties experienced in the treatment of the nodes disappear and the bamboo can be treated as a whole, it being unnecessary to go to the serious expense of cutting out the nodes, as seemed at one time essential. By crushing the bamboo, then, there is a saving in raw material and the regularity of digestion is improved. Not only so, but the period of digestion can be shortened owing to the greater rapidity with which the alkali liquors can penetrate the mass, and this also permits of the use of a weaker solution of alkali.

The constituents of the stem are described, and it is shown that lignification is complete after one year, so that there is no justification for differentiating between culms which are more than one year old; but it is shown that there is a wide variation in the composition of the non-cellulose constituents according to the season of cutting, whether this be in the wet or the dry season. Special attention is drawn to the starch content and its effects during the process of digestion, resulting in the conclusion that it is essential for the production of satisfactory pulp from bamboo that (1) thoroughly seasoned bamboo should be taken for boiling—during seasoning the solid starch is partially resolved and water soluble decomposition products formed—and (2) that the residual starch should be removed

by a boiling water treatment before submitting to the action of alkali for the removal of the lignin and pectous matters and the fat and wax.

The conditions for effective boiling to give the maximum yield of easily bleaching cellulose are discussed and a comparison is made of the effectiveness of the sulphite, soda and sulphate treatments.

It appears from this that the treatment with sulphite is not suited to Indian conditions or where a pulp for bleaching to pure white is required, but that with caustic soda or by the sulphate method good results are possible, and preference is given to the treatment by the sulphate process as being cheaper and giving a better product.

The conclusions at which Raitt arrived are that the common species of bamboo are suitable for pulp manufacture, that culms of all ages may be treated together, that nodes need not be removed by cutting and that the species common in Madras (*Bambusa Arundinacea* and *Dendrocalamus Strictus*) can conveniently be treated together.

The conditions he lays down are :

- (1) The raw air-dry material must not cost more than Rs. 15 per ton delivered at the factory.
- (2) Culms not to be cut until the shoots of the year are full grown.
- (3) Three months' seasoning at least to be given before using.
- (4) The stems to be crushed.
- (5) Starchy matter to be removed.
- (6) Digestion should be by the sulphate process.

(Digestion would require about 20 to 22 per cent. alkali at pressures from 120 lb to 80 lb for a period of 5 to 6 hours.)

He discusses the question of cost, based upon the conditions prevailing at the time, and considers that there is every prospect of Indian-made bamboo pulp competing with imported pulp, not only in India but in other eastern markets. The actual data regarding the costs would require to be revised in view of changed conditions, but the comparative position would, it is thought, be found to be altered but little. As he points out, the forests from which the timber is supplied to the present pulp mills are being cut further back, necessitating extra cost for transport, whereas a bamboo

industry, once established, would go on drawing its raw material from one and the same area for an extended period.*

The general conclusions which may be arrived at, therefore, regarding the production of paper and paper pulp in Madras are that the raw material is available in the form of bamboo and that it is possible by a properly adapted treatment to obtain from this bamboo a pulp suitable for the manufacture of paper. For economic production it appears that the manufacture of pulp should be carried out in mills capable of working up at least some 25,000 tons of bamboo per annum, and that areas conveniently situated for the supply of the raw material required are known, although they are at present but few. No mill can be expected to run at a profit unless, besides the raw material, it can command an adequate supply of fuel at cheap rates and is so situated that it is assured of an adequate water supply and cheap transport for the receipt of supplies and delivery of produce.

Assuming that these conditions are fulfilled and a fully equipped mill erected, it is essential that the manufacture should be in the hands of men with competent knowledge of the machinery and processes employed, and that the business as a whole should be run by technical men with a real knowledge of the paper trade.

* Since the publication of the report referred to Raitt has discovered that by removing the starch and pectous matters *before* attacking the lignin the bleaching quality of the pulp is so much improved that its bleaching cost is less than that of ordinary wood pulp.

APPENDIX I

Note by Mr. W. Raitt

The whole trend of the industry is now for pulp mills to be situated as near to the sources of raw material as possible and for paper mills to be as near to a paper-consuming market as possible. Paper makers are now pulp blenders and require several qualities of pulp to produce the varying grades they are asked for. Hence pulp manufacture should precede paper making. Given the pulp, paper mills are bound to increase in India, for the demand for paper already exists and is rapidly increasing. India now imports about 15,000 tons of pulp per annum, and, with the prospect of local pulp supplies being shortly available, paper mill expansion is already going on; but, even if the latter lagged behind the former for a few years, there is the world's market crying out for pulp and it will be quite possible to export it to Europe, Japan, China and Australia. With a present consumption of 80,000 tons of paper and paper goods in India (increasing by several thousand tons a year) and a local manufacture of only 30,000 tons there need be no fear of pulp manufacture overtaking the demand, even if there were no export market available.

APPENDIX II

List of Books relating to paper or paper pulp manufacture

| Name | Author | Published price |
|---|---------------------------|-----------------|
| | | £ s. d. |
| Chapters on Paper-making, 5 volumes at annas 6. | C. Beadle . . . | 1 10 0 |
| Paper-making and its Machinery, including Chapters on the Tub Sizing of Papers, the Coating and Finishing of Arts and Photographic Paper. 1920. | T. W. Chalmers . . | 1 6 0 |
| Practical Paper-making, Second Edition, revised and enlarged. 1907. | G. Clapperton . . . | 0 6 0 |
| Text-book of Paper-making, Fifth Edition, containing additional matter, and in part re-written, with the collaboration of J. F. Briggs. 1920. | Cross and Bevan . . | 1 10 0 |
| Wood Pulp and its Applications, Second Edition. 1918. | Cross, Bevan and Sindall. | 0 8 6 |
| The Chemistry of Paper-making together with the Principles of General Chemistry. 1894. | Griffin and Little . . | 3 3 0 |
| Paper Technology : An Elementary Manual of the Manufacture, Physical Qualities and Chemical Constituents of Paper and Paper-making Fibres. New (Third) Edition. 1920. | R. W. Sindall . . . | 1 1 0 |
| Testing of Wood Pulp : A Practical Handbook for the Pulp and the Paper Trades. 1912. | Sindall and Bacon . . | 0 6 0 |
| The Art of Paper-making : A Practical Handbook of the Manufacture of Paper from Rags, Esparto, etc. 1918. | A. Watt . . . | 0 8 6 |
| Modern Pulp and Paper-making : A Practical Treatise. 1920. | G. S. Witham . . . | 2 5 0 |

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