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S. CHAS. PHILIPPS, M.S.C.I.,

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THE USE OF WOOD PULP FOR PAPER-MAKING.

(Extracted from the Journal of the Society of Arts, Vol. LIII, May 19th, 1905.)

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THE USE OF WOOD PULP FOR PAPER-MAKING.

By S. CHAS. PHILLIPS, M.S.C.I.

IT was with peculiar pleasure that I accepted the compliment you were good enough to pay me, when you invited me to read a paper on the subject of "Wood Pulp." I have been reminded of the fact that there are in this Society many members who have no practical acquaintance with paper-making or with the subject I am trying to deal with to-night, and, therefore, I hope to avoid technicalities as much as possible, although I think you will readily see it is necessary in a paper of this kind to deal in a general way with the evolution of the wood pulp industry, and particularly in its application to paper-making, and in this connection, to deal historically with the progress of pulp-making, and its chemical treatment. (I think, perhaps, I need scarcely say at the outset, that in the cheaper forms of paper, as we know it to-day, the raw material is substantially wood.) I am aware that if you were to ask "the man in the street" of what paper is made, you would probably be told "rags"; but although that used to be the case, the use of paper to-day is so extensive that it would be impossible to meet the demand for one-thousandth part of the total consumption, if the paper-maker had to rely on rags, and I think I may here say that it is due to the engineer and to the chemist that we owe our cheap Press, and largely to the fact that wood has been taken full advantage of in its application to paper-making. For reasons which I may refer to later on, it is obvious that although England holds its own very comfortably at present as a paper-making country, it is not at all probable that Great Britain will ever produce wood for paper-making on a commercial scale. Not long ago, one of our leading paper-makers, whilst referring to this subject, observed that we might hope to make wood pulp here when we had the waterfalls and timber forests of Canada, Norway, or Sweden. There was a great deal of truth in that remark, and although there are gentlemen who are sanguine that we might make very much more use of our forests and unproductive land than we do, that we might turn it to good account for timber growing, I do not think that for practical purposes we need, at the present moment, take that into consideration. We may (and I am speaking from practical knowledge) dismiss Great Britain out of the calculation when we are dealing with the great countries which are providing us with timber for the production of wood pulp, and are likely to do so for very many years to come. It may, I think, be said, roughly, that the wood-pulp industry has established itself and attained its present position during the past quarter of a century. There was a time within my own recollection when the manufacturers of high grade papers in this country looked askance at wood, and I know of a gentleman in the wood-pulp business who told me that about twenty years ago when he waited upon a well-known Maidstone firm, and tried to induce them to give a trial to good chemical wood pulp, the owner of the mill was very rude to him, and almost ordered him away from the place. But times have changed since then, and at the present moment many of the mills which in the early days of wood pulp derided its possibilities would not hesitate to place a very large order for the same, at what they might consider a reasonable price. To those who are uninitiated in what I may term the elementary details of the wood-pulp industry, it may be necessary to mention that for the purposes of a paper of this kind, we must bear in mind that there are, to put the matter broadly, two methods of transforming raw wood into pulp.

Mechanical and Chemical.

I have, I may say, travelled a great deal in the principal pulp-producing countries, particularly Sweden, Norway, Finland, the United States, and Canada, visiting the most up-to-date mills where all classes of wood pulp are made, and so have had excellent opportunities for studying and comparing the various processes now in use. Sweden and Norway are countries from which we have for years derived our principal supply of wood fibre for paper-making. Years of practical experience have taught the Scandinavians to produce the best wood pulp in both mechanical and chemical varieties; but although both Sweden and Norway claim to have enormous forests of pulp wood, yet in spite of the law in Sweden which compels the replanting of six saplings for every tree cut down, it seems to me that at the rate at which the forests are being denuded of their timber for other purposes besides the conversion into wood pulp, in less than twenty-five years from now the maintenance of the timber supply will become a grave question. While in South Germany timber fit for pulping can be grown in fourteen or fifteen years, in Scandinavia it takes about forty years.

During the past dozen years our great Dependency in the Western Hemisphere, *viz.*, the Dominion of Canada—of which our distinguished Chairman, Lord Strathcona and Mount Royal, is the representative in this country—has come forward as a pulp-producing country, much to the relief and satisfaction of British paper-makers; for, with the growth of Canadian competition, it has become an important factor in keeping the prices of pulp from Sweden and Norway from being advanced higher than was justified in normal times. So that the advent of Canada into the wood-pulp business is likely to have a steadying influence in the matter of prices. I am pleased to say that Canada is making great progress in the industry by the construction of new mills, and the extension and improvement of existing mills. Our Chairman (Lord Strathcona) takes a keen interest in the wood-pulp industry of Canada, and has been largely instrumental in its development. As a frequent visitor to Canada, I trust that the Canadian Government will not be long before it adopts the replanting system of Sweden and Germany. At present there is but little attempt to protect the colossal and magnificent forests of the great Dominion of Canada, which are the envy of the whole world. What with the enormous wastage that goes on, and the serious inroads made by forest fires and indiscriminate cutting, Canada will have to take speedy steps to take care of the magnificent and great wealth which Nature has endowed her with in her forests, or otherwise she will, long before the present century closes, be bereft of that grand birthright.

In an essay published by Reaumur in the eighteenth century there is a suggestion that it might be possible to make paper from wood, and in 1750 paper was made from the bark, leaves, and wood of various trees in France. The class of wood generally used for the manufacture of chemical pulp is known as soft wood, and belongs to the order Coniferæ, or cone-bearing trees. The common spruce and the silver fir are the chief species that supply the chemical pulp of Europe, while the white spruce, black spruce, Canadian Hemlock, white American pine, and the silver fir furnish the bulk of wood pulp in America. For mechanical wood pulp, poplar, aspen, spruce, and fir are mostly used. Although almost every class of wood can be converted into pulp, only the soft coniferous trees are economically suitable. Trees having a diameter of from 6 inches to 20 inches at the base, and of about twenty years' growth are considered best. Smaller logs are not so economically worked, and larger timber is usually cut for lumber. Within the last few years a great number of pulp mills have been started in the southern and western States of America, and other parts of the world, which, in order to utilise the particular class of wood growing in those districts have adopted somewhat special methods, and we now find wood pulp being produced from a great variety of woods. The great majority of pulp mills obtain their supply of wood in the form of round logs about 6 to 10 feet long, while many in the lumber cutting districts use edgings and other waste wood from sawmills.

Sawdust has also been experimented with for the purpose of producing chemical fibre, but owing to the difficulties of getting the solvent liquor to circulate readily through it, and other troublesome features, it has been found to be impracticable. Shavings would be more suitable for converting into wood fibre, and are employed by some, although their bulkiness prevents any substantial weight being dealt with in each boiling operation. They might, however, be more conveniently used if they were first put through some form of machine similar to a hay-cutting mill, and reduced to small lengths.

Like ordinary lumber, the logs employed for pulp-making are generally cut by gangs of woodmen, who camp out in the forest during the winter months. In the early spring, when the snow and ice begin to melt, the logs are easily conveyed to the banks of the river, which, being at this time naturally swollen, carries them down to their destination. The log-driving men's duty is to keep them off the banks, and clear of obstacles, until they reach the saw or pulp mill, where booms, consisting of a number of logs chained together endwise, are stretched across the river to prevent them from being drifted any further. By this means millions of feet of logs are annually brought from the centre of the forests down to the mills. The result of being in the snow and water, and the friction in driving, is such that the logs generally arrive at the mill with the bark entirely removed.

In Europe, Scandinavia, Russia, Austria, and Germany possess the largest wood pulp forests, which, in the former countries, are the natural virgin growth, and still very extensive, in spite of the enormous quantity annually cut. In Germany the original natural forests have been almost exhausted, but owing to the wisdom and foresight of the authorities, they have been replanted and grown under Government supervision. Undoubtedly the American continent has the largest supply of pulp wood, but even the extensive forests of the Adirondacks and similar districts round the large paper-making centres are rapidly becoming depleted by the pulp manufacturers. The State of Maine and other New England States have still enormous quantities of uncut pulp wood, but unless measures are taken to preserve and cultivate them, the present rate of cutting cannot be indefinitely continued. The immense virgin forests of pulp wood in Canada and Newfoundland are practically untouched at present, but the day is not far distant when great demands will be made upon these forests.

Pulp wood is generally bought by measurement; the fact that the amount of water contained in the wood varies so considerably prevents any method of dealing with it by weight. The method of measuring timber is also very troublesome and unsatisfactory, more especially by the tape or quarter-girt system. Measuring in fathom frames is costly work, and, like pile measurement, varies according to the skill or otherwise of those piling the logs. In America, wood is generally bought by the cord, which equals 128 cubic feet pile measurement. In Great Britain and Scandinavia it is usually bought by the fathom, which is a cubic pile of logs 6 feet long, and piled 6 feet high, containing 216 cubic feet. In many of the Continental countries it is purchased and sold at so much per cubic metre.

The appellation, wood pulp, includes two distinct varieties having different chemical compositions and properties. These are known in commerce as mechanical or ground wood pulp, and chemical wood fibre or wood cellulose. The former is simply wood ground, washed, and made into layers or sheets; while the latter, or chemical wood pulp, is produced by treating the wood with various chemicals to remove the ligneous and mineral compounds, leaving the soft, pliable cellulose fibres almost pure. Of the chemical pulps, there are also several varieties, named according to the chemical solvent employed in the manufacture —we have sulphite wood fibre, soda fibre, and sulphate fibre, or pulp prepared by the action of sulphate of lime, caustic soda, and a solution of sulphates of soda, respectively.

Wood-Stuff, or Mechanical Wood Pulp.

Dr. Joseph Bersch, a well-known authority, describes mechanical wood pulp as wood converted by purely mechanical means into a fine-fibred mass, which by itself may serve for the production of coarser grades of pasteboards as well as for the manufacture of various articles. Its chief use, however, is as an addition to paper stock for the manufacture of inferior grades of paper. Although wood stuff, if properly prepared, is sufficiently fine-fibred to be made into paper in the paper machine, it is not used by itself for this purpose, because such paper possesses the undesirable property of becoming darker and acquiring, in a short time, a brown colouration when stored exposed to the light. The cause of this phenomenon is, in Dr. Bersch's opinion, found in the fact that the wood-stuff still contains nearly the entire quantity of encrusting substance—lignin, etc.,— originally present in the wood, these substances being subject to great changes. Hence, in the course of time efforts were made to remove these substances from the wood, so that only pure cellulose remains behind, which, as it does not show the already mentioned defects, can be used practically by itself for the manufacture of paper.

Wood for Grinding.

Although practically every kind of wood may be made use of and put into the grinder, some woods are far preferable to others, and of the European varieties of wood, ash, linden, fir, pine, and birch are particularly suited for the purpose; whilst beech may be used, but is considerably less suitable.

The views on the screen will convey a good idea of the practical operations.

Mechanical Wood Pulp as made in 1844.

In 1844 there was patented in Germany a machine for grinding wood for the manufacture of pulp. The inventor, Keller, sold the patent to the firm of Henry Voelter's sons, who afterwards used the pulp in the manufacture of "news" paper.

The Voelters made numerous improvements in Keller's invention, and a quarter of a century after it was patented in Germany by Keller; this wood pulp-machine was destined to play an important part in the United States, when, in response to the demand for the rapid printing of daily newspapers, the web press was to come into use. The Voelters —Christian and Henry—made numerous improvements in the machine, Christian Voelter obtaining patents in various European countries—in France even as early as April 11th, 1847. Henry Voelter patented his improvement on the pulp machine in Würtemburg, Germany, on August 29th, 1856, and in the United States on August 10th, 1858.

Various methods of treating wood previous to submitting it to the action of the grinders have been proposed and used. By one process the logs of wood, after being cut into suitable lengths for grinding are treated by first steaming them, then removing the acids generated in the steaming operation, next treating the steamed wood with alkali, and, finally, grinding or reducing the pieces to pulp. Steaming has been resorted to for the purpose of removing the bark from wooden blocks preparatory to grinding the solid parts; and wood has also been treated with water sprinkled on it from above, and steam simultaneously applied from beneath it, in order to soften and cleanse it preparatory to grinding.

But the process which we shall now describe, which is that of Mr. George F. Cushman, of Barnet, Vermont, is intended to facilitate the disintegration of the fibres, when submitted to the action of the revolving stones by a preliminary cooking of the block of wood in a bath of boiling hot water with lime, soda-ash, or equivalent chemical agent in solution, to soften the block, toughen the fibres, and lessen their lateral adhesion. By this process the block is reduced to pulp with much less power than is required to grind a block not so treated; and the pulp produced is claimed to be softer, stronger, and more desirable, since the fibres are not broken up or comminuted, but are more nearly in their natural condition, with their lateral beards or filaments preserved, so that when re-united in the paper sheet special toughness and tenacity are attained.

In carrying out this method, I believe it is usual to immerse the solid wooden blocks in a strong solution of lime, soda-ash, chloride of lime, or equivalent chemical agent, kept boiling hot by the introduction of steam or otherwise, and adapted to soften the blocks in readiness for grinding, and retain the blocks under treatment from ten to twenty-four hours, or until the liquid has had time to penetrate all parts of the block, and the lateral adhesion of the fibres is so weakened that they will readily separate by the attrition of the grinding stone without being broken short or reduced to a mere powder; and as the chemical action is most rapid in the direction of the length of the fibres, it is desirable to cut the block much shorter than is usual, or to form transverse saw-scarfs at intervals between its ends, in order that the solution may readily penetrate from each end to the centre, so as to loosen and toughen the fibres throughout the block. The pressure of steam above the liquid in the tank tends to force the solution into all the pores of the immersed blocks; then remove the blocks from the tank and subject them to the action of the grinders in the usual way, keeping a constant steam of water upon the stone, and the disintegration will be found to be effected with great rapidity, owing to the preliminary treatment received by the blocks, and also that no washing is required beyond what results from wetting down the stone. The pulp produced is claimed to be of superior quality, and as the blocks have absorbed only so much of the chemicals as is beneficial to the fibre, it is in condition for the successive steps in the production of various grades of paper of special strength, and for numerous other purposes in the arts. If preferred, however, this fibre may be mixed with hard stock made of other material, such mixture producing paper or board of exceptional toughness.

Voelter's Machine for Cutting or Grinding Wood and reducing it to Pulp.

The art of reducing wood to pulp by subjecting the same to the action of a revolving stone is not a new one, machinery for grinding wood while a current of water was applied to the stone having been patented in France by Christian Voelter as early as 1847 (*see* "Brevets d'Invention," vol. x., second series), and in England by A. A. Brooman, of London, in 1853 (*see* "Repertory of Patented Inventions," for May, 1854, p. 410).

A large number of inventions for cutting or grinding wood into pulp have been patented; but the enormous development of the paper-making industry, and the cheapening of paper during the last fifteen years are largely due to the general introduction of the machine for disintegrating blocks of wood and assorting the fibres so obtained into classes according to their different degrees of fineness, invented by Mr. Henry Voelter, of Heidenheim, Würtemburg, Germany, and for which invention he received letters patent on August 10th, 1858, from the United States

In all the processes known or used prior to Voelter's invention the wood had been acted upon by the stone in one or two ways, *viz.*, either by causing the surface of the stone to act upon the ends of the fibres, the surface of the stone moving substantially in a plane perpendicular to the fibres of the wood ; or, secondly, by acting upon the fibres in such a direction that they were severed diagonally, the surface of the stone moving diagonally across the fibres. The first plan, in fact, made powder of the wood—an obviously unsatisfactory result. The pulp had no practical length, and on trial proved worthless, or nearly so. The second plan was carried out by the use of a stone revolving like an ordinary grind-stone, the wood being applied upon the cylindrical surface thereof, the fibres perpendicular, or nearly so, to planes passing through the axis of the stone and the point or locality where the grinding was performed ; and this plan also failed, because the fibres were cut off in lines diagonal to their own length, and were consequently too short to make good pulp. There were other difficulties attending the process not necessary here to mention. Such was the state of the art prior to Voelter's invention ; and his improvement in the art consists in grinding or milling away in detail from the bundles of fibres which make up a piece of wood by acting upon them by a grinding surface which moves substantially across the fibres and in the same plane with them. In carrying out this improvement upon the art Voelter splits a log of wood and applies the flat side upon the stone, and then the stone so revolves as to cause points upon its surface to pass the fibres in lines perpendicular, or nearly so, to the length of the fibre. By this mode of procedure it is possible to obtain a sufficiently long fibre and save much power. Voelter's improvement in the art consists, further, in re-grinding the fibres by causing them, after being separated from the block, to pass under other blocks of wood, which are being reduced to pulp, upon the same stone. The fibres torn out at the first operation are thus rolled over and crushed again and separated into smaller fibre.

Voelter's improvements in the machinery are in an arrangement of pockets, with reference to the grinding surface, so as to hold the blocks of wood in such position that their fibres may be separated from the blocks in the manner described, and whereby fibres may be reground, and in a contrivance for feeding up the blocks by a positive feed instead of by force derived from weights or springs, as formerly practised; and a contrivance for causing the feed to cease automatically.

On May 22nd, 1866, Mr. Voelter was granted another patent for improvement in his machine for reducing wood to paper pulp, which patent was re-issued on April 23rd, 1872.

Bachet-Machard Process of Disintegrating Wood.

Messrs. Iwan Koechlin & Co. have carried on the Bachet-Machard Patent at the Isle Saint Martin, near Chatel (Vosges), France, and it has also been experimented with on a large scale at Bex and at St. Tryphon, Switzerland. At the start the inventors had in view the saccharification of wood, the paper pulp being intended to be only a secondary product of the manufacture of alcohol; but in practice the inverse result has been obtained, the paper pulp becoming the principal product, and alcohol the secondary one.

The wood, previously sawn in thin discs, was thrown into tubs, the filling of which was then completed with water and sulphuric acid, the latter in the proportion of one-tenth. Each tub would contain 188 cubic feet; eighteen hours' boiling was needed; the discs were then washed as well as possible in order to eliminate the acid, then passed through the crushers and the mills. Each 31⅓ cubic feet produced about 330 lbs. of dry pulp; 65 lbs. of acid and 136 lbs. of coal were used for the production of 220 lbs. of pulp. Calculating the value of the wood at 38 cent per cubic foot, the cost of production of 220 lbs. of pulp would be 8*s*.

With the Bachet-Machard method a brown pulp is obtained producing a good brown folding paper costing about 3*s*. 6*d*. per 100 lbs. dry pulp. This brown pulp is easily transformed by a half bleaching into a blond pulp costing about 8*s*. 4*d*. per 100 lbs., and this can be utilised with or without mixing, for the manufacture of wrapping paper and of all the coloured papers. Up to the present time a method for economically transforming this into white pulp had not been found (1. "Dictionnaire de Chimie," Wurtz, tome ii., p. 749, *et seq*.).

The inventors think that the tenth of acid, which they cause to react at 212 F. upon the wood, saccharifies the ligneous, or rather the incrustating substance without touching the cellulose fibres; thus the cellulose becomes easily separated into fibres by mechanical means. It is probable that the acids modify the incrustating substance and render it friable, and that at the same time certain principles of the wood are converted into glucose.

The process is the same as with straw and esparto, when alkaline washes are used; but it requires more energetic boiling; the proportion of alkali is doubled, and the boiling done at a pressure of 165 lbs.

A little more chlorine is also required for the bleaching. In this country common "news" requires to have about 20 per cent. of sulphite to hold it together on a fast-running machine. In America it can be produced with 100 per cent mechanical, the reason being that mechanical coming direct from the grinders has greater felting powers than if converted into pulp and shipped to this country. This point is a matter of considerable economical importance, and probably accounts for the difference got with fast-running machines between England and the United States of America.

I have explained that mechanical or ground wood pulp can only be used alone for inferior grades of paper, and must be used direct from the grinders on to the paper machines. A combination of about 70-80 per cent. of mechanical wood pulp fibre, and 20 to 30 per cent. of chemical produce the "news" on which our daily newspapers are printed.

The manufacture of wood pulp is undoubtedly a most interesting study which has closely occupied the minds of eminent scientists and experts for years, and new facts are being brought to light. Indeed, wood pulp as a field of research, seems inexhaustible.

Quite recently I visited the important paper and pulp mills of the Munksjö Company at Jönköping, in Sweden, where the manufacture of what is termed "Kraft" paper was discovered, tradition says by accident, although Mr. Hagborg says that the method was arrived at after long and careful experiment.

Wood pulp is used solely in the production of many thousands of tons of boards, which are used by bookbinders, paper boxmakers, and others. I might mention that in the various pulp-producing countries many millions of pounds sterling are invested in the production of pulp. A large proportion of this is British capital.

Reverting to the question of

Ground Wood,

or, as it is generally known in this country, mechanical, it may be said that the method of logging and of conveying the cut timber from the place where it falls into the mill, is governed largely by local conditions, which I shall deal with subsequently. But when once the wood is at the mill, the method of transforming it into mechanical wood pulp is to-day a simple one. The blocks of wood are put into a barking machine, a common form of which is provided with three knives upon a rapidly revolving drum. The blocks of wood are brought in contact with these knives, and it is essential that the bark is thoroughly cleared away, otherwise the pulp will show dark spots. Knotty wood is also objectionable, and as far as practicable, knots have to be removed, and in many mills this is achieved by means of a revolving auger or a spoon-shaped auger. The wood is cut into blocks by circular saws, and it should be finally split in order that the inside of the wood may be examined, as it is undesirable that any decayed timber shall be made use of. Only sound wood should properly be used, as the effect of rotten wood is sure to be detrimental to the pulp. The actual process of grinding the wood is simple. Every kind of machine for grinding consists of a grindstone (of sandstone), which runs at a very rapid rate, and against the surface of which the wood is pressed, the latter being kept constantly wet by a copious water supply. The wood is fed into what are termed pockets, and placed so that its vascular bundles lie parallel to the surface of the grindstone. The latter, in revolving, tears from the wood individual vascular bundles, and occasionally large splinters. The mass is carried by the water into a vat, in which the revolving stone is placed, and from there to the sorting contrivances, by which various sized particles of wood are separated from the other. In some modern grinders, the stone is fixed to a vertical shaft, but most authorities consider a horizontal position preferable. If time permitted, I would like to have described in detail the various types of machine in use in various countries, of which the principal ones are: Voelter's, Oser's, Voith's, Freitag's, Abadie's, and others. In this connection it is highly essential that the water used shall be pure and free from suspended solid bodies, sand or clay being particularly objectionable, as they cling to the pulp, and affect it considerably when it gets into the paper-maker's hands. It is, therefore, of course, highly necessary that in establishing the site for a pulp-making centre, there shall be a suitable water supply, otherwise the water used for grinding must be carefully filtered, and in some mills where the water is not all that could be desired, the water, after it had passed through the sorting screens, is collected, filtered, and again used.

Sorting Pulp,

which follows the grinding, is a very important detail. The sorter is, in fact, a kind of sieve or series of sieves, and Voith's shaking sieve is probably one of the best types in use. The frame rests on steel springs, and the cranked axle, by an ingenious arrangement, secures uniform running, whilst the sieves jerk and shake rapidly, 400-500 motions per minute. The application of springs reduces the wear and tear very materially, and also minimises the noise. The particles of brown wood, having thus been mechanically sorted, the pulp is conducted to the settling vats, the dehydrating apparatus, or the board machines, as may be desired. There are various processes for dealing with the particles of wood which would not pass through the sieve, and, generally speaking, it may be said that they are re-ground and again passed through a fine meshed sieve.

The removal of water from pulp is a very important element, which has to be taken into consideration, especially, where the question of freight has to be considered; and as a considerable quantity of pulp has to be shipped over large distances, it is obvious that it is not desirable to carry more water in the pulp than circumstances necessitate. Therefore, the importance of this is a matter which has a considerable bearing on the immediate advantage which accrues to a mill in the position of making up its paper from pulp on the spot, but the full consideration of this subject is a matter which is rather outside the scope of this paper. There are many forms of drying apparatus, and the preparation of perfectly dry pulp is now quite practicable. As bearing upon the importance of selecting wood of the right class for the particular purpose intended, I may here observe that Prof. Winkler made interesting experiments with pulp from different varieties of wood, which was exposed to the action of the air at a temperature of between

30° to 50° F., and he obtained most interesting results, which are fully set out on page 42 of Bersch's book.

To those of my audience who desire to go thoroughly into the chemistry of paper-making, I can recommend a publication on this subject by R. B. Griffin and A. D. Little, published by Howard, Lockwood & Co., New York. From memory, I believe the book I refer to was published in 1894. It contains a mass of information of a very useful character. Other valuable books to those who desire to go into the matter of wood pulp thoroughly are:—"Vegetable Physiology" (Goodale), also Schubert's "Die Cellulosefabrikation," and amongst our British authorities, the writings of Mr. Clayton Beadle, Messrs. Cross and Bevan, Dr. Stevens, and Mr. R. W. Sindall are amongst the most instructive; whilst the lectures delivered before this Society not very long ago by my friend, Mr. Julius Hübner, of the Manchester Technological School, also afford much information on the subject of paper-making generally, and on the treatment of wood pulp from the paper-maker's point of view.

Crushing.

Another interesting process in the preparation of mechanical wood pulp was known as the crushing process, and the effect is the preparation of pulp from steamed wood without the necessity of grinding. This has been known as the Rasch-Kirschner method. The steamed wood was first converted into small pieces by means of a chopping machine of special design, and then the wood was cut by a knife mechanically driven lengthways into shavings of fixed size, or lengthways as well as crossways. The small pieces of wood were then further reduced by mechanical means, having first been subjected to the action of a stamping mill, and eventually were put into the Hollander, and I am told that a very decent class of brown boards or stout wrapping papers could be made in this way, and it is stated that boards and paper especially suitable for roofing purposes made by this process had special advantages. Some of such boards, impregnated with coal tar, were said to be specially adapted for resisting the action of the weather, and are described as "perfectly indifferent to water as well as to changes of temperature." Attempts have been made to bleach the pulp made from steamed wood, but so far as I can learn the results were not commercially successful.

Although it may possibly, strictly speaking, be somewhat beyond the natural scope of a brief paper of this kind to go into the commercial details of wood pulp making as regards cost, I have been favoured by a gentleman who is in a special position to obtain information of this kind with some very interesting figures. I am told that it requires 80 h.-p. to make one short dry ton per day, or say, 90 h.-p. to make one long dry ton per day, so that a mill developing 1,800 h.-p. on the turbines should produce 20 tons of dry mechanical pulp per day, or say, 12,000 tons per year of 300 working days. Some Norwegian mills have very small horse-power on the stones, but the latest and most modern mills have at least 250 h.-p., whilst the Canadian mills are calculated on a basis of 300 to 350 h.-p. per stone, and very large stones are used. On the subject of the actual cost of producing mechanical pulp, I am told that a pretty reliable estimate of the cost of the wood necessary to make a ton of dry pulp is appoximately :—

Dry Pulp.

In East Norway	from	25*s*.	to 30*s*.
In North Sweden	„	22*s*.	to 25*s*.
Canada: Lake St. John and portions of Nova Scotia	„	13*s*. 6*d*.	to 15*s*.
St. Maurice River and other districts	„	15*s*.	to 22*s*.

Wet Pulp.

The net cost, allowing for depreciation, is given approximately as follows :—

	Per Ton. Dry Weight. £ *s*. *d*.
Modern mills in Norway, C/a	3 0 0
Modern mills in Sweden, C/a	2 15 0
Lake St. John	1 17 6
St. Maurice District	2 10 0

On this subject, it should be borne in mind that the capitalisation of a modern pulp mill is very high, and for a mill making, say, in Scandinavia 6,000 tons wet, and 3,000 tons dry, f.o.b., value (roughly) £10,800, the mill capitalisation would necessarily be from £20,000 to £25,000 ; and hence it follows that to make 10 per cent. on the capital a net profit on the produce of from 20 to 25 per cent. is necessary.

Small mills such as these form the majority in Scandinavia; but mills of this class could not be made to pay in Canada, where the biggest mill (Chicoutimi) made 48,000 tons of short wet pulp in six months. The entire capitalisation on this basis is 27 dols. per short ton dry per annum, or, say, £6 5*s.* per ton dry wet (2,240 lbs. per year), making the value of a short dry ton to be 13·50 dols. f.o.b. On this basis, a good return will be shown, *viz.*, a net profit of 20 per cent. on the article yielding 10 per cent. for the purposes of dividend.

In the matter of the general cost of good bleaching pulp, of course, local conditions here, as in the case of mechanical pulp, have a considerable influence; but I am told that good bleaching pulp may be produced at a cost net (including everything, with the exception of interest and depreciation) at about the following figures.

In Norway, at modern mills, about £6 per ton at the mill; unbleaching qualities would probably cost about 10*s.* per ton less. In Sweden the cost varies considerably, but about £5 may be stated for "news" pulp, and £5 10*s.* for bleaching; and this is, I think, a low estimate and can only be applied where the most favourable conditions are in operation. So far, practically, no success has attended the Canadian pulp mills in the manufacture of chemical pulp, and this I attribute largely to lack of knowledge of the technicality of sulphite-making, and through the lack of organisation as to timber supply. Mills have been put down where timber could be had before building for 2·50 dols. to 3 dols. per cord in limited quantities, but owing to lack of organisation and adequate security for the continuity of supply, prices have been forced up in Canada to 5 and 6 and even 7 dols. per cord, which is higher than in Scandinavia On the subject of capitalisation, a modern mill would be doing well if capitalised so that every £5 of capital produced one long dry ton per year; but most mills are, I think, capitalised on a great deal higher basis than this, and the fact is, of course, obvious. This, however, is much better than mechanical making, as 10 per cent. net on the article will nearly always give more than enough for a 10 per cent. dividend.

The Use of Wood in Paper-making.

The first time, perhaps, that wood was used to any appreciable extent in the manufacture of paper was when Koops published his book, in 1800; but at that period it could not be made to compete successfully against rags. The European wars had the effect of raising the price of rags at the beginning of last century, so much so, that there was a law which prohibited the burial of the dead in linen shrouds.

Mechanical wood, or mechanical pulp, as we know it to-day, is, as I have already said, produced by keeping short cut pieces of wood by hydraulic pressure against the surface of a rapidly revolving stone, and was the first form in which wood was used in any considerable quantity.

Mechanical wood has very little felting power, and is only capable of producing a weak paper, which contains practically all the ingredients of the original wood, and from the time of its discovery up to the present it has only been used for lower class papers. It, however, constitutes the great bulk by weight of our paper-making materials, as a common newspaper contains upwards of four-fifths of this substance.

Chemical Pulp.

A great change took place in the manufacture of paper on the development of the sulphite process. This process consists in treating chips of wood under a pressure of about seven atmospheres with a solution of bi-sulphite of lime or magnesia for a period of from eight hours to three days The first patent was undoubtedly taken out by Benjamin G. Tilghman, of Philadelphia, in 1867. His original specification practically covers the various methods employed by subsequent inventors. He started by boiling in lead-lined cylinders. Although an excellent fibre was obtained the engineering difficulties rendered it necessary to abandon his original process.

The preparation of wood for the chemical process is somewhat similar to that employed in preparing the wood for grinding. The wood is brought from the river or from the stacks in the mill yard, sawn into suitable lengths, past through the barking machine, then through the knotting machine, afterwards fed into the chipping machine, which, at a great rate, reduces the wood into small chips. It is then screened, and any further knots which appear are removed, and then the wood is taken along by a conveyer from the screens to the top of the digester house, and fed into the digesters through the manhole at the top. I have seen, at the modern Chemical Pulp Mills, in Sweden, Norway, Finland, United States, and Canada, digesters with a capacity of 15 tons dry pump, and I have heard of a mill in North Sweden with a digester which will carry at one cooking 20 tons of dry pulp.

The Pioneers of Chemical Pulp.

The actual date of the invention of wood pulp is more or less problematical, as the evolution of wood pulp has undoubtedly extended over a very considerable period, but the reference to Tilghman may be accepted as established. Some years ago a very interesting correspondence appeared in *Papier Zeitung*, and Professor F. Fittica asserted that (*a*) Mitscherlich was entitled to the honour of being recognised as the inventor of sulphite. The editor of *Papier Zeitung* apparently did not wish to share the responsibility for that statement, and I think the editor of our esteemed German contemporary was well advised in the view he took, and in the course of a very intelligent correspondence, various more or less authoritative people put forward the names of Ekman, Tilghman, Rismuller, and others, and various information was forthcoming regarding priority, but the consensus of opinion seemed to controvert Professor Fittica's original argument, and *Wochenblatt* mentioned C. D. Ekman as the father of the sulphite industry. About the year 1872 a well-known publication, in discussing this particular matter, argued that it was due to Ekman that the manufacture of Mitscherlich's cellulose on a large scale was rendered chemically possible. Prof. Fittica, however, who stuck to his guns in championing Mitscherlich, said that Ekman did not operate with calcium sulphite according to Mitscherlich's process, but he used magnesium sulphite, a salt that was without value owing to its inconstancy, and, consequently, was of no technical consequence as compared with calcium sulphite, but subsequently Ekman undoubtedly made a success of the magnesium sulphite process. However, his method was kept secret so that even for that reason the same could not have been, in Fittica's opinion, used by Mitscherlich. In this connection it is worth while remembering that originally Ekman's mill was in operation from 1874 to 1897, but was, of course, re-opened later. Fittica further stated that Tilghman was ahead of Mitscherlich, in so far as he used diluted sulphurous acid for transforming wood into cellulose, and it is significant that in the year 1886 Tilghman, in his patent, No. 2924, mentions that "that an addition of bi-sulphite of calcium to sulphurous acid is advantageous." However, it subsequently appeared that he had not used the salt alone, nor did he use the comparatively low temperature recommended by Mitscherlich. Moreover, he was unable to surmount the technical difficulties combined with these stated processes, and subsequently discontinued his experiments in the year 1867, after struggling for two years, and losing 20,000 dols. or over. In the year 1882, Ritter and Kellner took out a patent, and at this time Mitscherlich's factory in Munden was flourishing, having been started in 1875, and having made considerable progress, and the friends of Mitscherlich claim that the early manufacturers, in a general and theoretical way, operated on the Mitscherlich principles, their process differing only in insignificant arrangements. Prof. Kirschner states in his work, "Zellstoff," that F. A. Rismuller was the first to produce practically valuable cellulose on a considerable scale, under Mitscherlich's direction, in his factory. The names of O. Vogel, in Zell, is also alluded to by Prof. Kirschner, but there is no evidence that Vogel played any great part in the actual invention, although there is evidence that at one time he was assistant to Mitscherlich, and subsequently Vogel put down his own plant, which was arranged according to the Mitscherlich process. In 1884, in favour of Tilghman, Mitscherlich's patent No. 4179, was suspended by the German Court, and history would support Tilghman's contention. Some reliable authorities point out that sulphurous acid and its preparations had formerly been used only for bleaching cellulose wood pulp, and as late as 1867, after the issue of the Tilghman patent, Mr. Krieg—whose opinion is worth something—emphasised the fact "that wood pulp was not suitable for fine papers." Heldt states that in 1869 sulphurous acid should not only be called bleaching material, but bad bleaching material, because it imparts a yellow colour. At about that time, apparently new methods were discovered to change the wood into cellulose by the use of alkalies, and it is recorded that in 1872 considerable progress was made in this direction. A year later, in 1873, Menzies published a new process, according to which wood was treated in the damp state with chlorine, and in that same year Aussedat seems to have paid considerable attention to bringing wood and chlorine together in steam pressure. Blyth and Suthby made combinations of both the first and last mentioned methods by first submitting the wood to the action of alkalies, and subsequently to high steam pressure, and this method was amplified and improved by Ungerer. Then Mitscherlich came into the market with a new arrangement to use bi-sulphite of calcium, and demonstrated that by a solution of calcium sulphite with strong acids, he prepared a solution of calcium di-sulphite. Following this success, and assisted by the use of

Swedish Patent No. 2939, he succeeded during that year in the performance of technical trials on a large scale, and in 1875 he obtained a directly prepared solution of di-sulphite, such as he had previously obtained from calcium carbonate. At that time he obtained the action of pure calcium bi-sulphite on wood, preparing the salt by running sulphurous gas over pieces of carbonate of calcium. Afterwards he constructed a tower for making the bi-sulphite of calcium. This method seems to have been considerably followed, and in 1866 a sulphite mill was built in America on Mitscherlich's lines and according to a report from Thilmany (1894), the Mitscherlich process had been favourably adopted, and to such an extent that about that time there were forty boilers in operation in the United States and four in Canada; and the total yearly product in the States at that time was about 50,000 tons. On turning to Muspratt's technical handbook of that time, Mitscherlich is mentioned as the inventor of sulphite cellulose. Without committing himself to Stohmann, whose opinion has been freely quoted, it is significant that this authority mentions Tilghman and others, but merely to show that their experiments, as compared with Mitscherlich's success, had no weight, since they were not performed in a practical manner, and because they gained no technical success.

Stohmann, however, was subsequently reminded that the earliest edition of Muspratt contained no mention of Mitscherlich, although his mill in Munden was then in secret operation. Prof. Fittica, on this subject, summarises his opinion in these words: "Tilghman used the sulphurous acid, or he intended to use the same; but he did not use the sour calcium salt of the acid, and did not prepare or use the same in its pure state, in which condition only is it practicable for that purpose. For this reason, Tilghman had to discontinue, after ten years of restless activity." Ekman's magnesium sulphite, however, undoubtedly and finally proved to be a suitable preparation. Several other experimenters also failed to comprehend the action of the temperature, so that also in this respect we must give Mitscherlich the credit due to him. As might have been expected, Prof. Fittica's contentions provoked very considerable criticism, and some rather severe comments, and returning to the fray, Fittica says in 1904: In my history, in the manufaturing of sulphite stuff, I mentioned especially that it was Tilghman, besides others, who had already undertaken to make experiments to make sulphite fibre by means of sulphurous acids, but that it was Mitscherlich who provided a practical foundation to these experiments, and he must be called the first inventor in case the question arises as to a really practical invention. The germs of the idea of a new invention, a new principle, a new law, a new conception of the universe only take root gradually. Each idea has its forerunner, and these forerunners are present in every direction. . . . The person, however, who forms these ideas in the practical shape must be considered the inventor, because his forerunners have not performed a technical realisation. . . . "Consequently," adds Prof. Fittica, "I repeat that it was Tilghman, besides others, who furnished the idea of manufacturing sulphite fibre, but it was Mitscherlich who added hand and foot to the practice, and, therefore, must be called the real technical inventor of the sulphite cellulose fabrication." Quite recently, Prof. E. Kirschner added a very important contribution to this controversy, and wrote that Ekman, in Bergvik, Sweden, produced regularly large quantities of the valued sulphite pulp in 1874. That was long before Mitscherlich, and Prof. Kirschner adds that Fittica did not apparently seem to be aware that magnesium bi-sulphite, and also sodium and potassium compounds, produced not only the same effects in the sulphite process as calcium bi-sulphite, but would be even preferable to the latter, were it not for the higher cost of the bases contained in the former. Prof. Kirschner went at some length to substantiate his arguments by giving interesting chemical details, and went on to observe that "seeing that Ekman, in Bergvik, had not only magnesite, but also lime close at hand, and the latter could be bought at a lower price, we are justified in concluding that Ekman was well aware of the technical conditions offered by a magnesium bi-sulphite liquor in contrast to one prepared from lime. From 1875 and onwards, Ekman pulp was to be found in European markets. Later on in 1878-1880, the Ekman pulp was certainly of a higher quality and fetched a higher price than the impure irregular material from Hann-munden, where the Mitscherlich process was being worked." Kirschner further controverted the suggestion that the poor qualities attributed to Ekman pulp by Fittica were not justifiable, and he argued that Mitscherlich was largely a copyist of Rismuller and Vogel. To those who are sufficiently interested in the subject, a perusal of Ekman's and Francke's patent specifications for the manufacture of sulphite pulp will probably be of considerable historical interest, and I am indebted to Mr. Clayton Beadle for a perusal of the same. This patent seems rather to bear out the contention that at a certain period quite a number of distinguished men were struggling to place what we now term chemical pulp on a commercial basis, and that Ekman contributed considerably to the solution of the difficulty.

C. D. Ekman (a persevering Swedish chemist), who died last year at Gravesend, therefore appears, in my judgment, to have been the first to make a commercial success of the sulphite process. He set to work in 1872, using a solution of bi-sulphite of magnesia. His process was worked secretly until about 1879, when it was introduced into the Ilford Mills, near London; after which, in 1884, the proprietors of the patent erected large mills at Northfleet, where the process was conducted by the Ekman Pulp and Paper Company, and was finally abandoned in this country in 1903-04, it being no longer possible to compete with foreign countries, on account of the cost of timber.

The great difficulty in the way of making the sulphite process a success was due to the corrosive action of the sulphite liquor. This liquor quickly eats through iron, and has a certain amount of action upon lead. Lead linings were at first used at Northfleet, but owing to the difficulty of "creeping," lead had to be abandoned. The "creeping" is due to the difference in the expansion of the lead and the outer lining, causing the lead to "packer." I am informed that the first lining came away completely, like a jelly out of a mould. Many linings were substituted, among them cement. The difficulty was finally overcome by introducing a brick lining.

Wood pulp for paper-making was manufactured at Guardbridge, in Scotland, very many years ago on the site of the Guardbridge Paper Company's mills. It was also made at Bruce's, at Kinleth Paper Mills. The Messrs. Tait have made wood pulp at their paper mills at Inverurie for over twenty years past. Then a plant was erected at Inverkeithing.

In England, Ekman made pulp at Ilford. Mr. Edward Partington, one of the most experienced authorities on wood pulp in this country—who would have been with us to-night but for the fact that he is leaving for the Continent—made pulp for years at Glossop. The Kellner-Partington Paper Pulp Company also made pulp at their mills at Barrow-in-Furness.

Mr. (now Sir John) McDougall, ex-Chairman of the County Council, made wood pulp at Millwall.

Then there was another company at Goole—which made pulp in

1890, but is now discontinued—and the West Hartlepool Company, which also made wood pulp. Some seventeen or eighteen years ago, I remember being invited to the mills of the East Lancashire Paper Company, where in a small building I saw wood pulp being made by what was then known as the Graham process.

A Scotch friend tells me that the Guardbridge Soda Pulp Mill was erected in 1870-71, and it worked for about two years or so. The boilers were of Mr. Sinclair's patent vertical, having conical ends, the fire being underneath, having spiral flue so that the gases ascended and passed through an iron-funnel chimney on the top. To prevent the burning of the wood, there was provided a perforated cage having 1½ inch space between said cage and outer shell for the liquor. There was a down-take pipe about 5 inches diameter to take down the liquor through the centre of the cage. This down-take pipe was removable, so that it could be taken out when the boiler was being filled. These boilers were 10 or 12 feet deep, and about 4 feet diameter, the working pressure being about 200lb per square inch. Caustic soda was used, and the wood was boiled off in three hours.

The Goole Company commenced making pulp in 1890, but has not been in operation for some time. The North Eastern Pulp Company also turned out pulp, but is not now doing so.

Messrs. Brown, Stewart & Co. had digesters at Newton Paper Mills and at Dalmarnock Mills for making their wood pulp; but this also has all been discarded. This was about twenty years ago.

In those days the cost by Francke's process of wood and chemical plant for the production of 30 tons of sulphite pulp per week was estimated at £8,000, and with the Ekman process—then just at work at Ilford—£13,000 to £14,000 was spent on plant, machinery, and wood to produce 20 tons per week. The cost of raw wood to make a ton of paper at Hull or Liverpool was estimated at £5.

In the early days of sulphite pulp manufacture I went to Sweden and studied the bi-sulphide process at Francke's mills. Mr. Edward Partington and Mr. James Galloway about this time visiting the same mills, with the view of adopting the process. Subsequently Mr. Partington erected a sulphite wood pulp plant at Glossop, and worked a system of his own. In 1844 Keller took out letters patent in Germany for a wood-pulp grinding machine, but for want of capital sold it to Voelter. J. Macfarlane, of the Canada Paper Company, told me that he first introduced wood to the country in 1874, that he offered some bass-wood to Bruce's of Kinleith—and was laughed at. He finally offered them a farthing per pound over and above the market price for the paper; the pulp was eventually accepted, and proved such a success that the Bruces, very naturaly, kept the matter to themselves as long as possible.

The Partington process acquired by the American Sulphite Pulp Company about 1884 was the first to be made use of in the United States of America. It was also conducted in this country by the Kellner-Partington Paper Company, but was, I believe, abandoned a few years ago.

Mitscherlich, who by the way, was Professor of Chemistry of Munich, began his experiments with the sulphite process about 1876, and later on went to Thodes Mill, near Dresden, and has already been referred to. He started commercially about 1881.

Many lawsuits were fought in respect of the rival patents, which showed very close resemblance in their claims. Behrend, in 1883, disputed the validity of the Mitscherlich patents on the grounds of the priority of Tilghman British patents, and the German Board of Patents concluded that the Mitscherlich process did not differ from that of Tilghman's to entitle it to protection. There were numerous patents in connection with the lining and the digester which we need not refer to in detail.

The treatment by the sulphite process consists first of all in preparing the liquor. This is done by causing the vapour of sulphurous acid obtained by burning either "pyrites" (sulphide of iron) or sulphur in ovens, and conveying the vapour up from the bottom to the top of a tower of about 105 feet in height, packed with limestone—a spray of water is introduced at the top and trickles through the limestone. The vapour combines with the water to form sulphurous acid, which acts upon and dissolves the limestone, forming bi-sulphite of lime. In the Ekman process, a stone consisting chiefly of magnesia is used, whereby bi-sulphite of magnesia is produced. The liquor, standing at about 11° Tw., and containing about two-thirds of the sulphurous acid in the free state and one-third in combination with lime, is run into a sulphite digester, which is closely packed with chips of the wood until the liquor just covers over the wood. The lid is put on, steam is introduced until the temperature slowly rises to about 100°C. This causes all the air from the pores of the wood to escape and the solution to take its place, and takes a few hours. The temperature is then increased by the introduction of further steam until it slowly rises to, say, 117°C.; 115° is about the temperature at which chemical action begins to take place; 120° is the maximum temperature above which it is unsafe to go. The temperature therefore must be maintained within these limits during the process of boiling. The progress is judged by withdrawing samples of the liquor and examining their colour, sedimentation, and by other means. When the process is complete, the digester is blown off, the pulp washed with hot water, after which it is put into potchers, where it is further washed, and then it is passed through screens for separating out any untreated particles, and collected in the machine in the form of sheets containing 50 per cent. moisture, packed into bales for shipment.

If required in the bleached state, when in the potcher, it is mixed with solution of bleaching powder from 10-20 per cent. of the weight of the material, emptied into "steeping" tanks. When the chlorine is exhausted, the liquor is allowed to drain away, and the bleached product restored to the potchers and treated in the same way as the unbleached product.

Chemical wood pulps now enter into the manufacture of the highest class papers, and such a degree of excellence has been achieved in this that only an expert could tell the difference between a chemical wood fibre paper and an expensive all rag paper.

Soda Process.

The heating is effected either by means of coils or live steam. When the latter, allowance must be made for the amount of condensation. Little makes the statement that the temperature can be raised quickly. I have, however, reason to know that with soft soda aspen the temperature has to be raised slowly and with the utmost care, and also lowered again. The filling of the boiler is similar to that of the sulphite; the full pressure is, however, reached as quickly as possible, and maintained until the end of the treatment, the pressure formerly adopted being from 60 to 75 lbs. per square inch, but latterly it was employed at about 100 lbs. per square inch, and sometimes 110. The time of boiling is from eight to ten hours: as the pressure is increased the strength of the liquor can be somewhat diminished. Unlike the sulphite pulp that obtained by means of the soda process is of a greyish brown colour, whilst the liquor is a darkish brown and of a peculiar odour. This liquor contains the incrusting and resinous matters in combination with the soda as a soluble soap.

Caustic soda, being an expensive chemical, has to be recovered. This is effected by evaporating the liquor down to a thick syrup, after which they are made to flow into a revolving furnace, where they catch on fire, their own organic matters supplying a large amount of heat necessary for the incineration as well as for the evaporation of the weaker liquors. The evaporation is much economised by the adoption of what is known as the triple or quadruple effect evaporator, by means of which the water is removed at the least possible expenditure for fuel. The incinerated ashes as discharged from the furnace appear in greyish and blackish masses in the form of a sort of clinker. This mass, consisting of carbonate of soda mixed with carbon, is "lixiviated" or treated in hot water, whereby the soluble carbonate of soda goes into solution, leaving a black mud of charred and useless matter, from which the liquor is freed by sand filtration. The clear liquor standing at from 16-20°Tw. is heated in iron coppers, and causticised by treatment with caustic lime, whereby the carbonate of soda is converted into caustic soda, and the caustic lime into carbonate of lime or chalk. The chalk forms a sludge at the bottom of the vessel, from which the remainder of the liquor can be removed by filter pressing.

The sludge is pumped into a filter press to remove the liquor still remaining, and water caused to percolate through to remove the last traces. A clear caustic liquor is ready to be used again in the process of boiling. The process of recovery results in a certain amount of loss of the soda, amounting to about 15 per cent. This has to be made good by the addition of a certain amount of caustic or carbonate of soda. Soda wood pulp is generally of stuff of the nature of sulphite, and though of darker colour, is, as a rule, easier to bleach. Of recent years the soda process has gone to a large extent out of use and has been replaced by the sulphate process. This process consists in treating wood chips in an iron digester with sulphate of soda containing in the first instance a certain amount of caustic. The process is conducted very much like the soda process. It is carried up to the stage of the recovery process in a similar manner; in the soda process, however, the recovered ash consists of carbonate of soda, whereas in the sulphate process the recovered ash consists of sodium sulphide and sulphate of soda. The liquor ready for using again consists of caustic carbonate, sulphide, and sulphate of soda. The process is cheaper than the soda process, because instead of making up for the loss of the soda by the addition of caustic or carbonate, it is made up with sulphate of soda, which is a much cheaper chemical; sulphate passing through the recovery process is reduced by the organic matter to sulphide; a considerable amount of this sulphide is decomposed through the treatment of the wood, giving rise to sulphuretted hydrogen. The gases emanating from a sulphate factory render it necessary to conduct the process in districts where noxious factories are not interfered with.

A great deal of the wood pulp sold as soda pulp is, I am assured by a leading expert, in reality sulphate, and he tells me the proportion appears to be increasing every year. On this subject I am unable to express an opinion, but I am quite certain the British paper-maker secures delivery of chemical pulp capable of being used for the purpose intended.

Possibilities of Wood Products.

Prof. E. Pfuhl has recently published a very interesting book on "Paper Yarn: Its Production, Properties, and Uses." In this book, Prof. Pfuhl gives an account of the progress that has been made in producing yarn from threads prepared by a wet felting of fibres, and the results are most interesting. The raw material, consisting largely of chemical wood pulp, is dealt with in a special manner in the beating engine, so as to reduce the length of the fibres to the necessary extent, and convert the whole into a good felting paper pulp. The pulp is then brought on to a Fourdrinier machine, and a layer of this pulp produced in the ordinary manner, after which it is divided into a number of narrow bands, which bands are twisted by mechanical means, and converted into threads. According to Prof. Pfuhl there are two processes in practical working. One is for the production of a material known as "xyloline" based on the patents of Claviez & Co. In this the strips of pulp, as they come away from the machine, are wound on to reels, and these reels are then fixed to revolving forks, so that on winding the strip off the reel, it receives the necessary twist, and is mechanically treated otherwise. The material produced yields a strong yarn, and is so cheap that a complete suit of clothes can be sold for 7*s*. to 10*s*. It is further stated that it can be washed without being damaged in any way. Silvaline is also produced at Golzern-Grimma on the lines invented by Herr R. Kron. Here paper is divided into strips and subsequently spun into threads, and the machinery is very delicate and beautiful. The first factory was erected in Spain, near Bilbao, and another factory has been erected in Holland. Other factories at Rattimau and Mesterlitz, in Germany, are being erected, and the enterprise is extending to Russia, and there is no doubt that silvaline and xyloline will enter into direct competition with jute, and possibly coarse cotton yarn.

The rapidity of the progress made in this branch of technology is a marvel among modern enterprises, and it is doubtful if, in the history of the nations of the world, any one industry has achieved such a success in comparatively so short a period of time. Probably few realise what an amount of wood pulp the publication of our daily newspapers requires. I may here remark that one London "daily" has recently entered into a contract for the purchase of 10,000 tons of paper per annum for three years, and I think it would be fair to estimate that each day one of our large London daily papers consumes 10 acres of an average forest. Wood pulp owes its wide range of application to the fact that it is a material that can be made to any degree of consistency, from a delicate almost intangible fabric to a dense mass as hard as metal. It can be dyed to any colour or shade; it can be rendered fire and waterproof; and in the hands of the chemist may be converted into a number of very useful combinations.

Ekman, it is not generally known, succeeded in producing a substance which he called "Dextrone," from sulphite liquors. This substance had special qualities. It could be mixed with glue and precipitated in the form of leather when diluted with water only. It could be used in giving strength to brown papers, in weighting jute, or as a mordant for dyes. It was of the nature of tannin, and yet it had quite distinct properties. Seeing that for every ton of chemical wood pulp produced about a ton of dextrone would be recovered from the liquors, an enormous quantity could be produced if required. This substance was not, I think, manufactured in England after the Ekman works stopped making pulp. Captain Partington has recently made use of sulphite liquors for watering the roads, and claims to get very excellent results.

Wood pulp is now used for the manufacture of nitro-celluloses.

For explosives the pulp has to be of a special nature. It is also used under the name of "Cellulose Wadding," prepared under Feirabend's Patent No. 3061, where it replaced cotton wool for surgical bandages, giving most excellent results. It is also, as Pfuhl reminds us, coming into use in the form of paper in narrow strips, which are afterwards spun into filaments and woven into garments, such as under Kellner-Turq processes and the Silvaline Yarn process. Then, of course, it is used in considerable quantities now for manufacture of artificial silk. According to the Stern process, it is converted into viscose by Cross, Bevan and Beadle's process, and then spun into fine portions through a special solution from which it emerges in the form of filaments. For this product the inventors—all three British by the way—were awarded the Grand Prix at the last Paris Exhibition. They have also received numerous other valuable awards.

In America, where they have no esparto, the printing papers for process blocks can be produced by the aid of aspen, which fibre under the soda process makes a good substitute for esparto. I think, perhaps, not sufficient attention has been paid to the subject of the great differences in the qualities of papers made from wood pulp according to the kind of pulp used and the process adopted. Thus, on the one hand, we were able to produce soft and spongy papers, excellent for filter papers, and, on the other hand, imitation parchments from Mitscherlich pulp, close, transparent, grease-proof, the latter being produced by the aid of the basalt lava beater roll.

Then we have the milk of lime process, whereby bi-sulphite liquor is now produced by passing the fumes of sulphur through milk of lime instead of by allowing it to pass up towers filled with limestone, which is the general system in use in Sweden and Norway. The liquor made by the milk of lime process is identical with that of the ordinary method, but it has the great advantage that it produces a solution of absolute uniformity in strength, a difficult thing with the limestone, but a very important thing for ensuring regularity in the cook.

Digester Linings.

One of the most important things in the history of wood pulp has been the question of digester linings. The Mitscherlich lining in 1894 consisted of tarred pitch to protect the shell, then a layer of thin sheet lead, and on top of this two courses of specially acidresisting bricks, formed with tongue and groove, cement being used sometimes with the bricks. Some foreign mills place the lining of lead between the two courses of bricks. In a digester heated by indirect heat, a coating of the sulphite of lime can be produced on the surface, which gives a protection for the metal. Jung and Lindig used the coating of double silicate of lime and iron. Kellner took out numerous patents for cements, consisting either of ground slate and silicate of soda, or powdered slate and glass and Portland cement. One of the earliest, and one of the most successful, linings was prepared by Wenzel, consisting of a special cement, for the most part a manufacture of Portland cement and silicate of soda, set in blocks in wooden moulds made to conform to the shape of the digester. Finally, excellent results were obtained by the use of Portland cement alone, which in many cases is reinforced by a facing of special brick or tile, the usual thickness of the cement lining being 4 in. All cement linings are more or less porous when applied, but in use soon fill up with sulphate and sulphite of lime. After numerous years of work, a great many failures, a great many patents, lawsuits, and infringements, a brick has been introduced for lining which answers the purpose. Until a suitable lining could be devised, the sulphite process could not be regarded as a success. As the early troubles with the linings made it impossible to make pulp cheaply, and the corrosion of the shell contaminated and discoloured the pulp, most of the pulp on the market now as soda pulp is in reality made under the sulphate process, which consists of a liquor containing sodium sulphate, sulphite, carbonate, caustic, which before burning to ash is fortified by the addition of sulphate of soda, the sulphate being reduced to sulphite during the process of recovery. This process is cheap, but the nauseating gases evolved during the process at one time made it a difficult matter, except in out-of-the-way districts.

Methods in the Mill Revolutionised.

I think I might point out that the introduction of wood pulp has had a considerable effect upon the way that mills are constructed nowadays in this country. Before the introduction of wood the raw materials were treated from beginning to end in the mill; now a mill buys wood pulp, which is put direct into the beaters, all the preliminary processes being obviated (except if bleached).

As to the permanency of wood papers, there is still difference of opinion. Mr. Clayton Beadle tells me he would not like to recommend even the very best bleached wood in paper required to be of an absolutely lasting character, but would give the preference to mixtures of cotton and linen. But it should be remembered that every year sees improvements in the treatment of wood, resulting in a more lasting and durable fibre. In course of time we may be compelled to alter our views.

The complete statistics bearing on the subject are much too lengthy and complicated to attempt to read in the limited time at my disposal. They will be found in the Appendix. I may, however, trouble you with one or two figures :—

In 1903, we imported into Great Britain 211,823 tons of chemical dry pulp, of the stated value of £1,842,082. This came chiefly from Sweden and Norway, and only 1,356 tons were sent to us from British possessions. Of chemical wet pulp we introduced, in 1903, 21,279 tons almost entirely from Sweden and Norway, and value was £82,012. In the same year we imported mechanical dry, 8,268 tons, of the value of £30,192 ; and of mechanical wet, we imported, in 1903, 336,788 tons, of the value of £752,297.

It is worth noting that Canada supplies us with a by no means insignificant portion of the mechanical wet pulp.

In 1901, Canada sent us 48,551 tons, and in 1903, Canada supplied us with 71,664 tons of the value of £157,918. In this class of pulp, Sweden, in 1903, sent the pulp of the value of, roughly, £101,000 ; but Norway received £490,949 for the mechanical wet wood pulp sent to us for that year.

According to official figures, British paper makers paid :—In 1903—£1,642,082 for chemical dry pulp ; £82,012 for chemical wet ; £30,192 for chemical dry, and £752,397 for mechanical wet, being a total of £2,506,583.

I should be very sorry indeed to trespass on any contentious ground or to encroach on political subjects, but without taking any side in the matter I may say that in connection with the fiscal controversy, in the event of a duty being put upon manufactured articles coming into this country, it may be somewhat difficult to classify certain kinds of wood pulp in this connection. It is a rather debateable point as to whether certain classes of wood pulp are manufactured articles or not, or to what extent it may be termed "raw material." I believe Mr. Chamberlain is credited with having been good enough to look upon wood pulp as raw material, but I do not think that this is exactly a subject which is likely to cause paper-makers or pulp producers many sleepless nights in the immediate future, although the time may come when the questions will have to be considered from the point of view to which I have alluded.

Appendix I.—Patents.

As will be understood, a very large number of patents have been taken out by those concerned in the development of wood pulp making, and in importance relating to the same. The following may be taken as covering some of the most important patents from 1867, when Tilghman was granted the initial patent :—

Archbold, George. 1883 ; manufacture of paper pulp.
———————— ; manufacture of paper pulp.
Biron, Jean B. 1867 ; disintegrating wood to form pulp, etc.
Ekman, Carl D. 1882 ; treating wood.
———————— ; method of treating wood.
———————— ; treating fibrous vegetable susbstances to obtain fibre suitable for paper making.
Francke, David Otto. 1884 ; manufacture of paper pulp.
Graham, James Anthony. 1883 ; treating fibrous substances.
Haskell, J. R. 1867 ; treating and separating vegetable fibres. [Not on sulphite process, but his claim covers first steaming the fibres and then condensing steam by shower of cold liquor so as to force liquor into the wood, as in later patents of Mitscherlich.]
Kellner, Charles. 1886 ; method of sizing paper to prevent the sulphite and ground pulp from turning yellow. [He precipitates the rosin size with a sulphite salt.]
Minthorn Daniel. 1885 ; treating vegetable fibre.
Mitscherlich, Alex. 1886 ; boiling fibres with sulphite.
———————— 1886 ; paper pulp (process for manufacturing).
———————— 1889 ; manufacturing thread from short fibre.
Pictet, R. P. 1885 ; manufacture of pulp from wood matter.
Pond, Goldsburg H. 1886 ; manufacture of paper pulp from wood.
———————— 1886 ; machine for manufacture of wood pulp.
———————— 1886 ; manufacture of wood pulp.
Ritter, Eugen Baron, and Carl Kellner. 1885 ; apparatus and manufacture of cellulose from wood.
———————— 1885 ; progress of manufacturing cellulose.

Ritter, Eugen Baron, and Carl Kellner. 1886; progress for manufacturing sulphites.

Tilghman, B. C. 1867; treating vegetable substances for making paper pulp.

——— 1869; progress of treating vegetable substances to obtain fibre.

Wheelwright, Charles S., and George E. Marshall. 1884; apparatus for treating wood.

II.—The Pulp Imported into Great Britain during the month of April 1905, was:—

Quantities.

	Month ended 30th April.			Four months ended 30th April.		
	1903.	1904.	1905.	1903.	1904.	1905.
Mechanical:—	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Dry	473	228	628	2,284	2,548	2,168
Wet	26,666	19,145	15,770	81,953	86,597	60,538
Total .	27,139	19,373	16,398	84,237	89,145	62,706
Chemical:—						
Dry	14,226	11,478	13,650	51,983	46,215	53,149
Wet	3,745	1,859	985	7,949	8,049	6,260
Total .	17,971	13,337	14,635	59,932	54,264	59,409
Total of Pulp of Wood .	45,110	32,710	31,033	144,169	143,409	122,115

Value.

	Month ended 30th April.			Four months ended 30th April.		
	1903.	1904.	1905.	1903.	1904.	1905.
Mechanical:—	£	£	£	£	£	£
Dry	2,348	1,047	3,141	12,273	12,443	11,058
Wet	60,515	42,412	36,244	191,135	189,874	140,230
Total .	62,863	43,459	39,385	203,408	202,317	151,288
Chemical:—						
Dry	111,340	90,587	115,076	411,132	362,507	443,869
Wet	13,761	7,278	3,193	30,607	30,800	25,353
Total .	125,101	97,865	118,269	441,739	393,307	469,222
Total declared value of Wood Pulp .	187,964	141,324	157,654	645,147	595,624	620,510

III.—Great Britain.

Imports of Wood Pulp compiled from the Blue Book of Annual Statement of Trade: Years 1901, 1902, 1903.

	Quantities.			Value.		
	1901.	1902.	1903.	1901.	1902.	1903.
Chemical, Dry.	Tons.	Tons.	Tons.	£	£	£
From Russia	—	2,404	3,907	—	18,443	29,906
„ Sweden	84,955	102,174	127,510	746,237	824,825	971,665
„ Norway	52,161	57,413	62,446	457,074	466,213	490,354
„ Germany	2,324	3,870	5,362	21,950	32,665	45,843
„ Holland	3,535	5,309	4,669	35,000	46,776	40,615
„ Portugal	1,635	1,576	1,884	13,908	12,984	14,521
„ United States of America	7,500	2,878	3,785	63,491	23,848	31,254
„ Other Foreign Countries	2,984	695	904	25,640	5,991	7,179
Total from Foreign Countries .	155,094	176,319	210,467	1,363,300	1,431,345	1,631,337
From British Possessions .	18,707	9,124	1,356	154,742	76,210	10,745
Total .	173,801	185,443	211,823	1,518,042	1,507,555	1,642,082
Chemical, Wet.						
From Sweden	5,638	4,587	4,908	36,986	20,994	19,908
„ Norway	8,383	8,358	16,339	42,371	42,281	62,846
„ Other Foreign Countries	351	216	32	3,151	1,929	158
Total from Foreign Countries .	14,372	13,161	21,279	82,508	65,204	82,012
From Canada	774	—	—	5,322	—	—
Total .	15,146	13,161	21,279	87,830	65,204	82,012
Mechanical, Dry.						
From Sweden	4,122	3,957	3,067	31,500	23,861	13,557
„ Norway	2,464	2,394	2,278	16,784	12,539	10,785
„ Germany	75	55	36	421	397	224
„ Holland	710	858	245	5,605	8,450	2,258
„ United States of America	3,789	1,727	160	27,667	11,743	1,022
„ Other Foreign Countries	62	100	464	337	550	2,288
Total from Foreign Countries .	11,231	9,091	6,250	82,314	57,540	30,134
From Canada	2,078	2,012	13	14,503	8,740	58
Total .	13,309	11,103	6,263	96,817	66,280	30,192
Mechanical, Wet.						
From Sweden	8,847	32,014	46,000	27,929	73,203	100,863
„ Norway	187,386	211,196	217,933	532,942	516,059	490,949
„ Other Foreign Countries	87	—	1,191	295	—	2,567
Total from Foreign Countries .	196,320	243,210	265,124	561,166	589,262	594,379
From Canada	48,551	72,635	71,664	137,789	169,420	157,918
„ Other British Possessions	1,328	247	—	4,440	494	—
Total from British Possessions .	49,879	72,882	71,664	142,229	169,914	157,918
Total .	246,199	316,092	336,788	703,395	759,176	752,297

G. I. C. P O.—No. 1039 I. G. For.—22-8-1905.—1,100.—G. R.