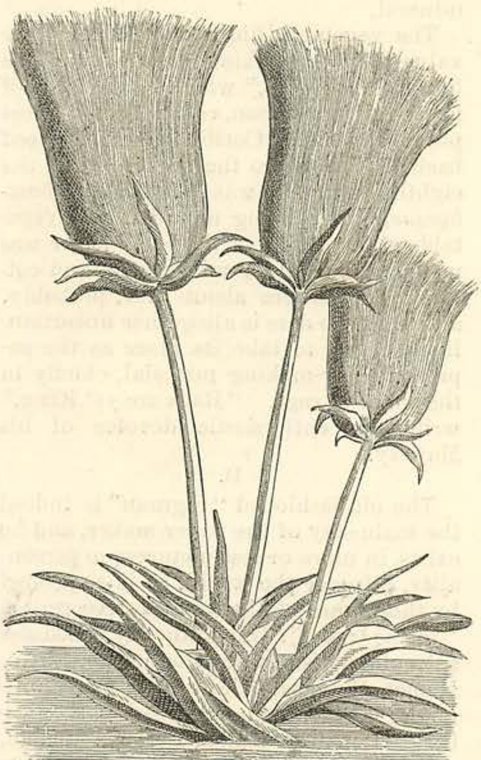
GREAT AMERICAN INDUSTRIES.

VI.—A SHEET OF PAPER.

BY R. R. BOWKER.



The Egyptian Papyrus, or Paper Rush; Taken from Prosper Alpinus.

From a print in Koops's book, 1801.

I.

WITHOUT paper the modern world would be literally impossible. The letter, the newspaper, the bank-note—these three applications of paper alone make a great part of the social and commercial machinery without which we would not and could not be what we are.

Of course the Chinese had invented or discovered paper some time before the Christian era, and to this day our finest paper comes from the far East. So much store do they set by it that a quantity of paper is often part of a bride's dowry. They made and used pulp for the purpose, as we do now, and from them, through the Arabians, the modern processes of paper-making came into Europe about the eighth century. But the earliest paper, with them as with the Egyptians, came from the pith of plants cut into thin scales and patched together. The Egyptian reed *papyrus*, or *byblos* (as the Greeks called it), gave us, indeed, both our word *paper* and our word *Bible* and its cognates. The papyrus is a rush growing in still pools of water to a height of ten or twenty feet, sometimes as thick as a man's arm, below water. It is now scarcely known in Egypt. The thin pellicles of pith under the outer skin below the water-line were carefully peeled off, with the help of a small pin or pointed mussel shell, and the pieces laid together with overlapping edges, crossed with other layers three or more thicknesses deep, pressed, dried in the sun, and "sleeked with a tooth." To this day the so-called "rice-paper" is made by the Chinese in similar manner by deftly cutting a continuous slice from the pith of the *Olrelia papyrifera.* Pliny asserts that the Nile water, having a certain glutinous quality, was necessary to dampen the sheets, but this seems to have been an error.

Twenty layers could sometimes be got from one stalk, and the process of peeling or furrowing off gave us, through the Greek *charasso*, to furrow, and Greek and Latin *charta*, a sheet of paper, our several words *chart*, *card*, *carte blanche*, and the like. Twenty sheets were glued together into a *scapus* by the *glutinatoris*, the ancient bookbinder, and then again into a *volumen*, or roll, whence our word *volume.* In Paris there is one papyrus manuscript thirty feet long. The Romans improved upon the Egyptians by sizing their *charta* with wheaten flour boiled into paste, with a few drops of vinegar added, and by hammering it smooth.

This old-fashioned process of making could not supply a hundredth or a thousandth part of the modern demand. The substitute was simple enough. Instead of laying together the slices of pith, the fibres which exist more or less in most plants were obtained, and these matted or felted together into sheets. Nature herself gives a hint of this process at brooksides where the *conferva* grows. The fibres of this water-plant, disintegrated by the action of water, are said to rise to the surface as a scum, which, matted together by wind and current, and dried and bleached by the sun, is sometimes left on shore, after an overflow, as a veritable sheet of paper. The variety of fibre which can be used for this purpose is shown by the list of English patents on paper-making materials, which includes, aside from rags and old paper, cotton, flax, hemp, and the other textile plants, esparto or alfa, and other grasses, jute, aloe fibre, banana fibre, bean stalks, cocoa-nut fibre and the kernels of the nut, clover, hay, heath, hops, husks of grain, leaves, maize, and sugar-cane, moss, nettles, pea stalks, various roots, straw, sea-weed and fresh-water weeds, thistles and thistle-down, and tobacco stalks, wood, barks, saw-dust, and tan, wool, silk, fur, hair, leather, peat, dung, gutta-percha, and asbestos. This is by no means a comprehensive survey; but perhaps the most curious material ever tried was the bag of "frog-spittle," the curious spume which surrounds the larvæ of the frog-hopper or froth-worm, brought to the Catskill paper-mill about 1800 by one De Labigarre, which was actually made into a rather poor piece of paper, to the great delight of many foolish people, who saw here the germ of a new industry. In the Smithsonian Institution there is a German book of about 1772, in which Schaffers, preacher at Ratisbon, binds together sheets of paper from more than sixty different materials, the result of his own experiments alone, and several American libraries have copies of the very curious "Historical account of the substances which have been used to describe events and to convey ideas from the earliest date to the invention of paper," printed 1800-1801 by Matthias Koops, Esq., "on paper manufactured solely from straw"—an illustration from which is reproduced in this article—with an appendix printed on wood paper. Koops was the first to make over old paper into new. A French manufacturer had, however, obtained a silver medal from the Society for the Encouragement of Arts, in 1788, for several quires of paper made from the bark of the sallow-tree, and the idea of making paper from wood seems to have been suggested by Réaumur, in 1719, as a result of his observations on the fabric of wasps' nests. Schaffers's book included a paper made from hornets' nests. Among several other similar volumes was an early work (1727) by a German naturalist, Dr. Bruechman, on stones, in which he speaks of asbestos, and of which he printed four copies on paper made of that mineral.

The vegetable fibres depend for their value as paper-making materials on the fibrous "cellulose," which is the basis of nearly all vegetation, cotton being almost pure cellulose. Cotton paper is traced back in Europe to the beginning of the eighth century; it was called *charta bombycine*, cotton being regarded as a vegetable silk. Some of the early paper was made from wool, or mixed wool and cotton. Somewhere about 1100, probably, although the date is altogether uncertain, linen began to take its place as the supreme paper-making material, chiefly in the shape of rags. "Rags are yet King," writes an enthusiastic devotee of his Majesty.

II.

The old-fashioned "ragman" is indeed the main-stay of the paper-maker, and he exists, in more or less picturesque personality, all over the world, as is suggested by the names of the qualities recognized "in the trade." One authority schedules as main divisions Japanese rags, Liban, Memel, Smyrna, Alexandria, Constantinople, Trieste, Leghorn, Russian, Königsberg, Hamburg, Dutch, Belgian, British, and domestic rags, all subdivided into mysteriously named, lettered, or numbered sub-classes, *ad infinitum*. "CSPFFF No. 1, cottons," is, for instance, a Hamburg variety; the domestic *genus* includes as *species* "city whites," Nos. 1 and 2, "colors," "country mixed," "country seconds," "country whites," "mill assorted, whites," "new seconds, dark," and a few dozen others, while simpler Japan furnishes chiefly "blues, ordinary," and "blues, selected."

It was only after much coaxing that the world could be got into the habit of saving its rags. A curious petition to the Pope (1471) asked his admiration for the enterprise which had collected rags enough to print 12,475 volumes. An old English writer is pleased that the act of Parliament providing that the dead were to be buried in no other dress than wool—intended to encourage the wool trade—saved about 250,000 pounds of linen annually for paper-making. The early American newspapers are full of quaint appeals, in prose and verse, to save rags.

The Boston *News Letter*, 1769, announced that "the bell cart will go through Boston about the end of next month to collect rags," and added:

> "Rags are as beauties which concealèd lie,
> But when in paper, how it charms the eye!
> Pray save your rags, new beauties to discover,
> For of paper, truly, every one's a lover;
> By the pen and press such knowledge is displayed
> As wouldn't exist if paper was not made.
> Wisdom of things, mysterious, divine,
> Illustriously doth on paper shine."

The Massachusetts General Court, in 1776, required the Committee of Safety in each town to appoint a suitable person to receive rags, and appealed to the inhabitants to save even the smallest quantity. The Norwich *Courier* hoped every man would say to his wife, "Molly, make a rag-bag, and hang it under the shelf where the big Bible lies"; and the Boston *Gazette*, 1798, urged that every child should be taught its "rag lesson." Patriotism and frugality were alike invoked. The postmaster at Troy, New York, in 1801, urged the ladies of New York State to imitate the exemplary saving of those in Massachusetts and Connecticut towns, who "display an elegant work-bag as part of the furniture of their parlors, in which every rag is carefully preserved," in which case "this State would not be drained of its circulating cash for paper and other manufactures which American artists can furnish." About the same time the magistrates of an English town had a similar appeal painted in large letters on boards, which were put up in public resorts. The climax was reached by the appeal from the new mill at Moreau, New York, in 1808, to "the ladies, young, old, and middle-aged." "If the necessary stock is denied paper-mills, young ladies must languish in vain for tender epistles from their respective swains; bachelors may be reduced to the necessity of a personal attendance upon the fair, when a written communication would be an excellent substitute. For clean cotton and linen rags of every color and description, matrons can be furnished with Bibles, spectacles, and snuff; mothers with grammars, spelling-books, and primers for their children; and young misses may be supplied with bonnets, ribbons, and ear-rings for the decoration of their persons (by means of which they may obtain husbands), or by sending them to the said mill they may receive cash."

Our forefathers got as much as 3*d* per pound for clear white rags (2*d* and less for mixed), for which price we can now buy a good deal more than a pound of fairly good paper or a yard of cloth. Our mothers got 3 cents a pound for white and 2 cents for colored rags, until the war came, when 6 cents a pound and more was paid. Now the frugal-minded housewife gets only a single cent. America is not a very ragged country, but it furnishes about half its supply of rags, importing the other half: in 1885-6, 107,976,167 pounds, valued at $2,291,989, or $2\frac{1}{10}$ cents per pound, besides $2,807,987 worth of other paper stock. Rags and most other paper stock are imported duty free.

The increasing consumption of paper started anew the search for fibrous materials other than rags, and about the middle of the century Mr. Lloyd, of *Lloyd's Weekly*, London, introduced the *esparto*, a Spanish grass grown in North Africa and Spain, which has of late years supplied nearly half the material for English paper-makers. The proprietors of one of the London dailies have an esparto farm in North Africa for the supply of their paper-mill, which in turn supplies their presses. This grass is nearly half clear cellulose, and as a mixture with rags it makes perhaps a better paper than any American fibres, but it requires a large proportion of caustic soda and other chemicals to boil it free from resin and gritty silica, and the high cost of these and the distance of production have given it little vogue in America. The demand has now outrun the supply of this fibre, and Mr. Routledge recommends a new source in the young green shoots of the bamboo.

In America and in the northern European countries the plentiful supply of wood has offered another solution to the problem, while straw is very widely used for the cheaper papers. Various woods vary curiously in their proportion of cellulose, from less than forty per cent. in oak to fifty-seven per cent. in fir; it is from the poplar and like woods that the pulp is commonly made. There are two kinds, commonly known to paper-makers as "mechanical" and "chemical" wood-pulp, the one obtained by mere grinding or shredding, the other through disintegration by chemicals.

The first machine for grinding wood-pulp was patented in Germany in 1844 by one Keller, who sold his right to the Voelter firm, by whom an improved machine was patented in the United States in 1858. This invention, which is the basis of the "mechanical wood-pulp" industry, is simply an ingenious device to hold split logs against a revolving grindstone parallel to their fibre, with a constant supply of water and an automatically elastic pressure, so that the wood is shredded into fibre instead of ground to powder. In a succession of tanks this fibre is sorted out according to its length, and it is then matted together (usually on the cylinder paper-making machine to be hereafter described) into sheets of dry "half-stuff," or dried loose and sold in bulk (?). The Voelter patent recently expired, but within its period 187 or more patents for wood-grinders were taken out in this country. One process looks to the softening of the wood and toughening of the fibre by previous boiling in dilute alkali. The mechanical wood-pulp is used chiefly for cheap news paper, and is very apt to prove rather a filling than a fibre.

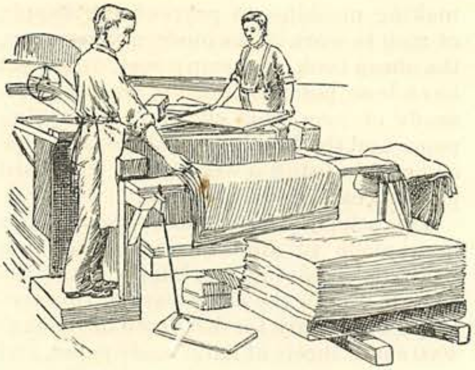
Chemical wood-pulp is made by separating the foreign matter from the fibrous cellulose by the use of chemicals, much like the treatment of rags, yet to be described. The original process was the boiling of the wood chips with about twenty per cent. of caustic soda, under a pressure of from ten to fourteen atmospheres, but the high temperature thus developed weakened and browned the fibres. The later acid processes use a bisulphite of lime or magnesia, requiring a boiler lined with lead, to oxidize the extraneous substances; the cellulose remaining is apt to be hard and transparent, but these difficulties are said to be removed by subsequent treatment with an alkaline solution. Chemical wood-pulp is in this country the chief mixture for good papers.

Great quantities of brown or "Manila" paper—some of it excellent writing or printing papers—are now made from Manila hemp, a fabric from a plant allied to the banana; from the sisal-grass, also called agave and American aloe, grown in Central America; and from jute, the fibre of a reed grown in India, in flooded districts like our own rice fields, which produces also the gunny-bags, largely used to bale cotton, and is used also for other textile fabrics, or in mixture with wool, flax, or silk, or even as imitation human hair in cheap chignons, the best fibre having a fine golden color and silky gloss. Jute butts are the cuttings of the plant below water or at the bottom of the stalk, and these are also a material for cheap paper. Manila and hemp are subject to $25 per ton, sisal-grass to $15, and jute butts to $5, duty, and jute itself to twenty per cent.; nevertheless, we import over 150,000 tons of these, partly for paper-making, valued at over $10,000,000. Some attempts have also been made to use the fibre of cane, disintegrating it by firing it from a gun.

Once made, paper nowadays undergoes a continuous transmigration, such as the Orientals attribute to human souls. Since Matthias Koops succeeded, at the beginning of the century, in utilizing waste or "broken" paper as a paper-making material, the processes for that purpose have been so developed that old paper is now one of the chief kinds of paper stock, especially for use in paper-hangings. The old ink and sizing are easily dissolved out by a solution of caustic soda or other alkali at high temperature, and the paper is then "beaten" back to fibre as any other material would be.

III.

The modern paper-maker has a thousand things to think of, yet the apparently complicated work of the marvellous paper-making machine is a simple enough development from that of the hand-worker centuries ago, which is also that of hand-made paper-making to-day. Whatever fibrous material he used, he had first to rid it of all but the clear, clean fibre, and then reduce that to an even pulp. To this end the rags or bark or what not were cut in bits, dusted, boiled to softness, bleached, and further disintegrated, and finally beaten to a smooth pulp by mallets, or pestle and mortar, or stampers moved by water or wind. At first, indeed, before the use of chemical agents was discovered, and the color of the material determined that of the paper, the process was even more primitive; the cut rags were piled up moist in cellars or vats, and left to rot for from six to twenty days, by which time the vegetable gluten, having fermented or putrefied, could be dissolved out. Water, heat, chemicals, and power were the simple agents in this cookery, which produced what the housewife might call a *purée*, or smooth soup, of fibre. This was now before the paper-maker in a vat. He held in his hand an

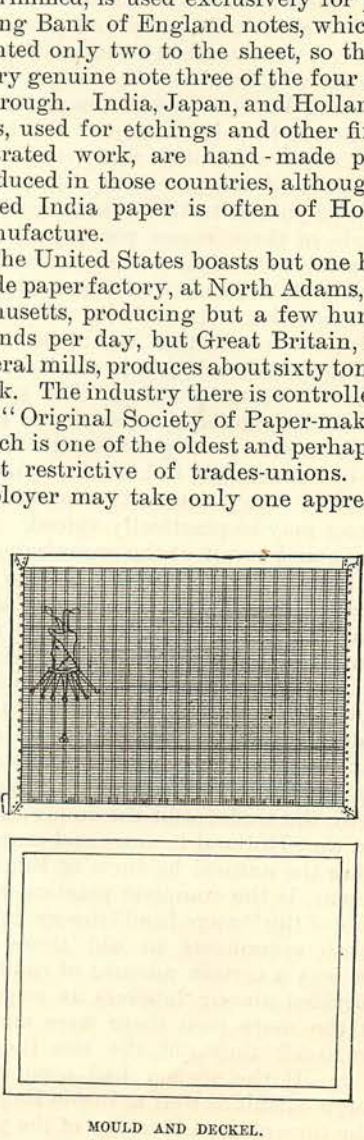


HAND-PAPER MAKING.

oblong sieve, so to speak, called the *mould*, made either of fine wire or, among the Japanese and Chinese, of split bamboo, on the edge of which he placed a frame, called the *deckel*, like the frame of a child's slate, exactly the size of the frame of the sieve or mould itself. When he dipped the mould, thus rimmed, into the vat in front of him, he brought up, of course, as much of the pulp as the height of the deckel permitted; the water at once drained off through the sieve, leaving a thick or thin layer of moist pulp, according as a high or low deckel had been used. As the water drained, the paper-maker shook the mould gently to and fro, to felt or mat together the fibres. In some moulds the wire was closely woven together, in and out like cloth, and paper from such was called *wove* paper; in others the sieve was a series of straight wires crossed an inch or so apart by stouter ones, and paper from such was called *laid* paper. A device showing the name of the maker or some distinctive mark was commonly worked in wire upon the other wires, and here, as the water drained off, the paper was left thinner than in other places, so that when held to the light the *water-mark*, as it got to be called, appeared. A good many forgeries have been proven by showing that a document was written on paper having a water-mark never used so early as the writing purported to be written. Of course these markings appear only on one side—that is, in hand-made paper, the under side. When the pulp is well drained, the *coucher*, as the next man is called, takes the mould, removes the deckel, and turns off the moist sheet upon a *couch*, or sheet of felt stretched over a board. A pile is presently made, first a sheet of pulp, then a sheet of felt, and this *post*, as it is called when it is several quires thick, is put in a press, and the remaining moisture is squeezed out. The felts are then removed, the sheets are again pressed, hung over hair ropes in the drying-loft to dry further, then dipped in size to fill up the pores, which otherwise would absorb ink as blotting-paper does, then pressed and dried again, and perhaps hot-pressed, to give a smoother surface, by passing between heated metal rollers.

To this day hand-made paper, untrimmed, is used exclusively for printing Bank of England notes, which are printed only two to the sheet, so that on every genuine note three of the four edges are rough. India, Japan, and Holland papers, used for etchings and other fine illustrated work, are hand-made papers produced in those countries, although so-called India paper is often of Holland manufacture.

The United States boasts but one hand-made paper factory, at North Adams, Massachusetts, producing but a few hundred pounds per day, but Great Britain, from several mills, produces about sixty tons per week. The industry there is controlled by the "Original Society of Paper-makers," which is one of the oldest and perhaps the most restrictive of trades-unions. An employer may take only one apprentice



MOULD AND DECKEL.

in five years for each seven men in his employ; the son of a paper-maker must always be preferred, but he cannot be apprenticed after he has reached fifteen, and a lad not born into the craft cannot be apprenticed after he is fourteen years old. The apprentice must serve and pay to the society for seven years; he then pays his "freedom fee," and gets his "card." Without this certificate of membership in the society he cannot get work in a hand-made paper mill, nor in a machine mill within the county of Kent, whose pure water makes it the chief seat of paper-making in England. In the other shires society men work with non-society men, but in machine mills only, and providing the wages are at society rates. The society makes a fixed rate for wages, not a minimum, but one which requires all workmen to be paid the same. It is based on the day's work of so many reams of a given size and weight. Thus, "Imperial" size of 72 pounds to the ream is made at the rate of three reams per day; if the same size is to be of only 40 pounds weight, still only three reams would be made, but if, contrariwise, it is to be of 90 pounds weight, the production would be correspondingly reduced, that is, to about two and a half reams per day. For special sizes not scheduled the employer must make a specific arrangement with the society or its members in his mill, before he can safely take a contract; otherwise his contract may be practically vetoed. The purpose and result of the organization is to enforce equality; it puts all the employers on even terms as to cost of labor, and all the employés on even terms as to amount and pay of work. This, of course, checks progress, and keeps the quicker and better workman from rising above the dead level; the apprenticeship rules steadily reduce the membership of the society, and if unmodified would ultimately destroy the trade; and the employers lament that Holland is more and more obtaining the natural business of England. The plan is the complete practical application of the "wage-fund" theory held by English economists in old times, that there was a certain amount of capital to be divided among laborers as wages, so that the more men there were and the more work they did, the less they got for it. If the society had been strong enough outside as well as inside England, at the time of the invention of the paper-making machine, to prevent the supply of men to work it, the modern newspaper, the cheap book, the penny post, would not have been possible, and the tens of thousands of men now engaged in making paper and the hundreds of thousands now engaged in using it would have been hard put to it for work and wages.

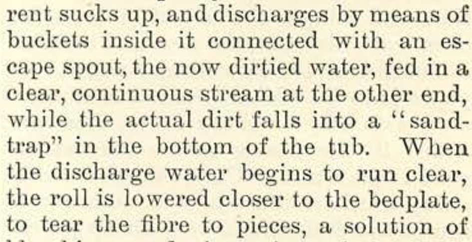
This attempt was in fact made, as it has been made in almost every trade into which labor-saving machinery has entered. It was in the early part of this century a day's work for three men to "make" 4000 small sheets of hand-made paper, and it took about three months to complete the process. Many paper-mills were of two vats only, requiring about $10,000 capital, employing twelve or more men, boys, and girls, and making two to three thousand reams a year. The English proprietors of the new machine stated, in 1806–7, that while seven vats cost to run £2604 12*s.* per year, one of their machines, at the price of from £715 to £1040, would do the work of seven vats for £734 12*s.*—a saving of £1870 per year. It cost to make paper by hand 16*s.* per hundred-weight; by machine, 3*s.* 6*d.* Presently the number of men necessary to work a Fourdrinier was reduced from five to three, and after some improvements it was possible to deliver paper the next day after pulp went into the machine. At first sight all this looked like starvation to the paper-maker; disturbances ensued; machines were attacked and broken to pieces. It was the same spirit which in 1390 caused the Italian workmen in Ulman Stromer's paper-mill at Nuremberg, the first in Germany, to revolt, because he wanted to add a third roller to the two sets, working eighteen stampers, which he already used—a revolt only quelled by the interference of the magistrates. It is a spirit which exists more or less now, but happily, as the facts of progress increasingly show, it is a mistaken spirit which must disappear, as with broader education working-men become better able to apply the experience of the past to the conduct of the present.

IV.

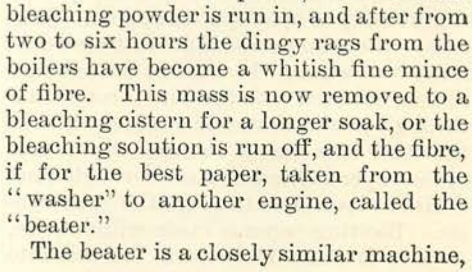
Let us now enter a modern mill and follow a sheet of paper from its beginning to its end. If it is to be of the best quality, such as is used for printing this Magazine, it begins where other things end, in rags. These are waiting, in huge bales, for the knife of the opener, who feeds them into the "thrasher," where, inside an enormous wooden box, revolving arms thrash the dust out of them as they are tumbled round. They go now to the sorting-room, where buttons and other intruders are disposed of, and where large pieces are "shredded" into smaller ones against upright stationary knives, like scythe blades, mostly by women, who toss the different qualities into different boxes in the tables before which they stand. Thence the rags go to the "cutter," where revolving knives chop them into still smaller bits, and some mills here use various ingenious devices for removing foreign substances, magnetic brushes being employed in one machine to attract any bits or dust of metal. They must now be further dusted — if very dirty, first by the "devil," a hollow cone with spikes projecting within, against which work the spikes of a drum, dashing the rags about at great speed; and afterward by the "duster" proper, a conical revolving sieve, through which the rags emerge upon an endless belt, which carries them under one or two pair of sharp eyes, on a final lookout for overlooked buttons or unchopped pieces, along to the boilers. We follow, and find ourselves in a steamy room, where piles of rags are being mysteriously disposed of through holes in the floor. These prove to be the openings of huge rotary boilers, fed by steam, which we see hung from the ceiling on the floor below, some of them eighteen feet long by six feet in diameter, holding over two tons of rags, which, as the boiler revolves, are tumbled about in lime-water ("milk of lime"), or a solution of mixed lime and soda-ash, until their disposition is softened by trouble and their countenance blanched by fear. From thence the mushy material which results goes to the important machines called the "washers" and "beaters," or, in general, the "engines," which make the "stuff" that is the food of the Fourdrinier. The rag engine, invented in Holland about 1750, is often called "the Hollander." The material for fine paper is run through both washer and beater; for coarse, only through one.

"The Hollander" is an oval iron tub, ten to twenty feet long, four to six broad, and about three high, divided for two-thirds of its length by a "mid-feather" or upright partition, which makes a sort of race-course for the rags to chase each other round the edge of the vat. On one side of the mid-feather the floor of the tub is raised in a quarter circle, close to which a roll covered with knives or "bars" revolves, so arranged that it can be lowered closer to the bedplate, furnished with corresponding bars, as it becomes necessary to make the pulp finer and finer. The tub is partly filled with pure water, the disintegrated and decolorized rags from the boilers are dumped in, the roll, set just close enough to the bedplate to "open up" the rags and free the remaining dirt, sweeps the rags up the incline and over the "back-fall," and a drum of wire-cloth partly immersed in the current sucks up, and discharges by means of buckets inside it connected with an escape spout, the now dirtied water, fed in a clear, continuous stream at the other end, while the actual dirt falls into a "sand-trap" in the bottom of the tub. When the discharge water begins to run clear, the roll is lowered closer to the bedplate, to tear the fibre to pieces, a solution of bleaching powder is run in, and after from two to six hours the dingy rags from the boilers have become a whitish fine mince of fibre. This mass is now removed to a bleaching cistern for a longer soak, or the bleaching solution is run off, and the fibre, if for the best paper, taken from the "washer" to another engine, called the "beater."

The beater is a closely similar machine,



Side View.



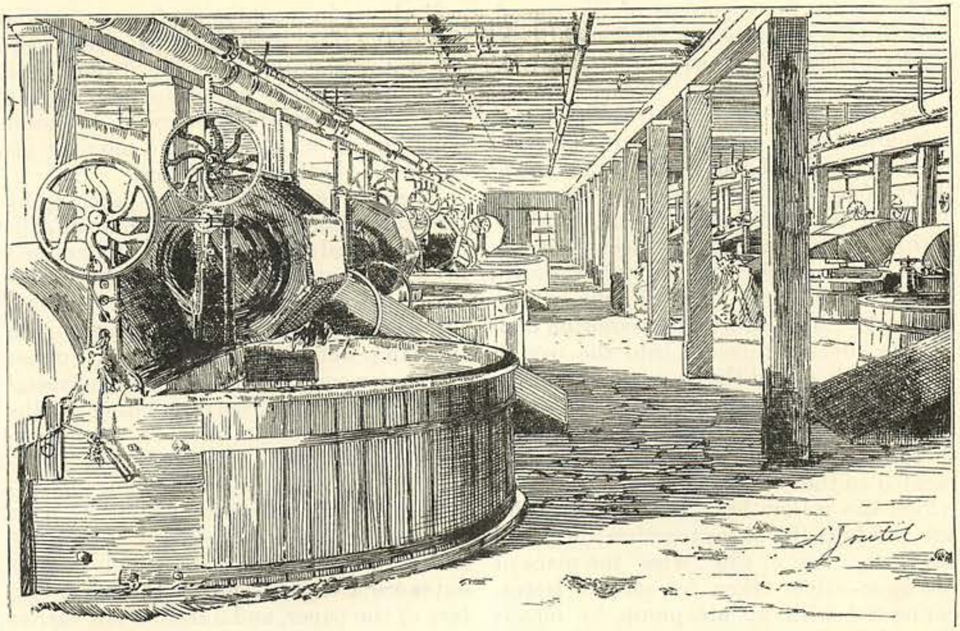
Top View.

BEATING ENGINE.

except that the knives on its roll are grouped three instead of two together, and the roll is set closer to the bedplate, so as to beat the fibre still finer. But here some of the most important processes of paper-making are carried on—the selection of stock, loading, engine-sizing, and body-coloring. To make a certain grade of paper, to keep within a given price, to avoid lumping or discoloration when the chemicals are introduced, the superintendent at the beaters, like the cook with her flour and eggs and salt at hand, must choose and combine rightly the different kinds and quantity of stock, looking forward as well as backward, knowing and thinking of a thousand things—the cost of his rags, his chemicals, his labor, the wear and tear and difficulties of the Fourdrinier ahead. If paper is to be "loaded," that is, adulterated with clay or cheap fibres, these are added in the beater as the fibre swirls round and round. Clay, though a weakening adulteration when in quantity, is sometimes desirable in very cheap papers to give body or opacity to the paper. Then comes the "engine-sizing," distinguished from "tub-sizing," because in the one case the size is mixed with the fibre through and through in the beater or engine, while in the other it is soaked in from the surface of the paper as the web runs through a tub of size in its course through the Fourdrinier. Blotting-paper is made without size, so that it may freely suck the ink into its unchoked pores, and the hard paper, made wholly or chiefly of linen, and pressed by "supercalender" rollers into great compactness, used for the fine illustrated work of this Magazine, requires little or no sizing. But with most fibres, unsized, the ink would be absorbed into the pores, and would partly disappear from the surface, leaving a dingy instead of a sharp, clean print. For "engine-sizing," vegetable size is chiefly used: a soap made of resin is introduced into the beater, and when this is well mingled a solution of alum is added. A chemical combination, sometimes called the resinate of alumina, results, which fills the pores and interstices of the fibre, and makes the paper more or less waterproof when, later on, it is heated and pressed under the pressure of the drying cylinders of the Fourdrinier. If a paper is to be body-colored or tinted, the coloring matter is next introduced into the mass in the beater: for reds, cochineal, Brazil woods, or aniline reds; for yellows, various barks or plants, as barberry root and golden-rod, or chrome-yellow; for blues, Prussian blue or aniline blues; for black, lampblack or a combination of aniline dyes. White paper so called is really dyed with a little bluing and a trace of red. And thereby hangs a tale. About 1746 Mrs. Buttenshaw, wife of an English paper-maker, was one day washing some fine linen, when un(?)fortunately she dropped her bag of bluing into a vat of paper pulp. She thought it safe to keep quiet on the subject; but when Mr. B. admired the unusually white color of the paper from this vat, and in fact sold it in London for some shillings advance, she "owned up"; and this was the origin of bluing paper. The next time her husband went to London he brought back a costly scarlet cloak. What is often called "toned" paper is nearer the natural color—a yellowish shade—of the pulp. At last the fibre is in its final shape, well mixed, sized, colored, and closely beaten, and is now ready for the paper-making machine proper, or Fourdrinier.

V.

The paper-making machjne, usually called a Fourdrinier, performs the remarkable work of receiving a fluid stream of pulp from its "stuff chest" at one end and turning out a dry, smooth, sized, and finished paper at the other, either in a continuous roll or cut into sheets of any size. The machine is an evolution from the invention of a French workman named Louis Robert, in Didot's hand-paper mill at Essonnes, who obtained a patent (No. 329) in 1799, and was also granted by the French government a bounty of 8000 francs for the development of his invention. M. Didot purchased Robert's rights, and to escape the turmoils of his own country crossed with John Gamble, an Englishman, to England, where, with the help of Bryan Donkin, a skilled mechanician, Robert's model was developed into very nearly the present machine. An English patent was secured in 1801, and the first machine mill was successfully started at Frogmore, Herts, in 1803. The brothers Henry and Sealy Fourdrinier purchased the rights in the original patents, made many improvements, in the course of which they spent £60,000, and secured an extension, and thus the machine which should have borne the name of Robert became asso-



BEATING-ROOM.

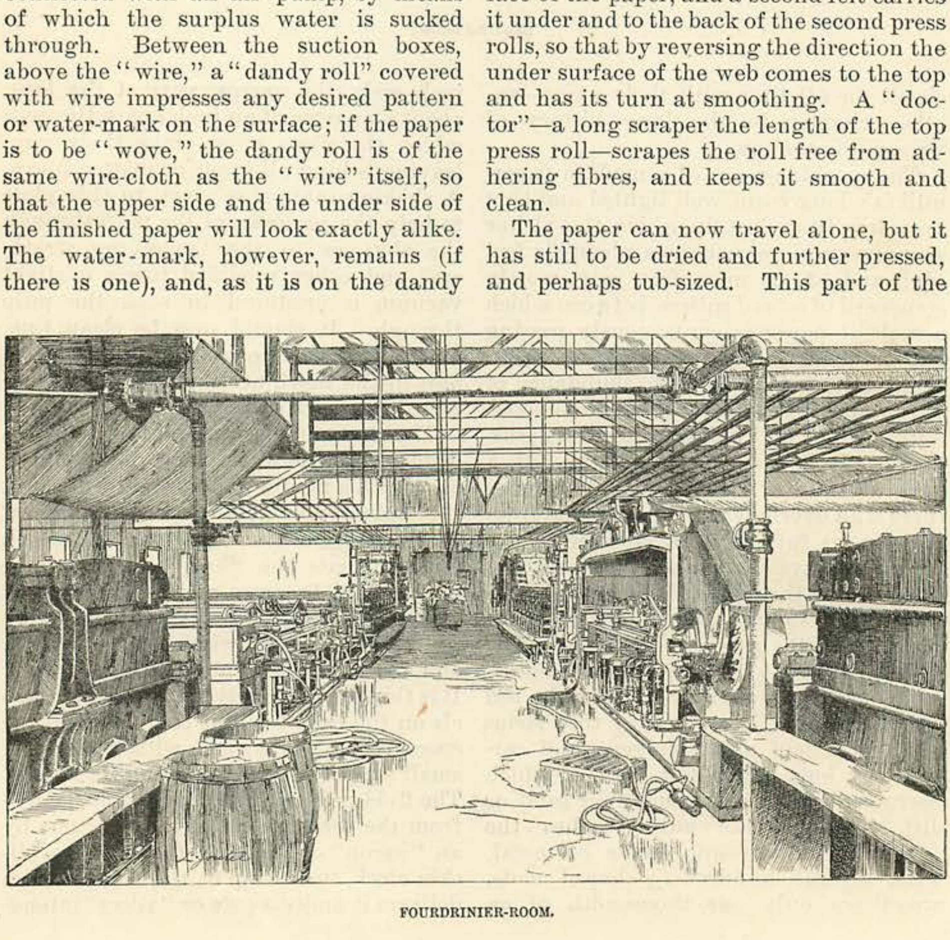
ciated for all time with their name—another chapter in the long history of wronged inventors.

The machine-room of a modern paper-mill is a long room, well lighted and kept very free from dust, in which the visitor sees one or more machines, about six feet high and 120 or more feet long, mostly composed of sets of rollers, between which a web of paper is continuously passing and frequently disappearing from sight. The pulp, made fluid with abundance of pure water, is supplied to the "stuff chest," within which an "agitator" keeps it in suspense. It is thence pumped through a ball-valve into a "regulating box," whence there is an overflow at the top, so that from the always full box the pressure of the pulp is always the same as it flows into the machine through a discharge cock, by which the supply, and the consequent thickness of the paper, is regulated. The pulp passes first over the "sand tables," which are really shallow troughs, the bed of which is partly crossed by thin strips of wood, aslant of the current, and carpeted by long-haired felt, both of which operate to catch any remaining sand or dirt. Thence the pulp reaches the "screen," a horizontal plate of metal, with several hundred Λ-shaped slots, sometimes only one-thousandth of an inch wide (the narrow part at the top), about a quarter of an inch apart, through which the fibres must make their way, leaving behind all knots or matted fibres. A shaking motion is given to this plate to help the progress of the pulp through the slots, or in the "revolving strainers" and other modified forms a slight vacuum is produced to suck the pulp through. It should now be clean, fine, and even, ready to make the sheet, this part of the machine having simply completed the work of the beater.

The next and essential part of the Fourdrinier does the work of the old moulder, as with his mould and deckel he dips out the desired thickness of pulp, strains off the water, and gives the "shake" which felts or mats the fibres together. The wire mould becomes an endless band of woven wire-cloth—always called simply the "wire"—the full width of the machine, and some machines are 110 inches wide. It is thirty-five to forty feet long, and travels on the breast roll at the near and the couch roll at the far end, with the help of small supporting rollers along its length. The fluid pulp is spread over this "wire" from the breast board of the strainers by an "apron" or fan-shaped rubber or oil-skin cloth, turned up at the edges, which delivers it under a gate or "slicer" intended to assure the evenness of the spread, and finally regulate the thickness of the embryo sheet. Two square bands of India-rubber, called the "deckel straps," move with and on the "wire" at either side, and can be adjusted nearer together when it is desired to make a narrower sheet of paper. These and the slicer are attached to the "deckel frame," and together correspond to the deckel of the hand-paper maker. As the "wire" moves on with its layer of pulp, the water, charged with fine fibres, size, coloring matter, etc., drains through into the trough underneath, called the "save-all," whence it is carried back to the stuff chest, to give the pulp the extra supply of fluid it there needs. A shaking motion communicated to the "wire" from the frame on which the rollers bear assists this drainage and felts the fibres together. Toward the farther end of the "wire" the place of the save-all is taken by suction boxes, connected with an air-pump, by means of which the surplus water is sucked through. Between the suction boxes, above the "wire," a "dandy roll" covered with wire impresses any desired pattern or water-mark on the surface; if the paper is to be "wove," the dandy roll is of the same wire-cloth as the "wire" itself, so that the upper side and the under side of the finished paper will look exactly alike. The water-mark, however, remains (if there is one), and, as it is on the dandy roll, shows in machine-made paper on the *top* of the sheet, furnishing an easy means of distinguishing machine from hand made paper. We have now the continuous web of damp felted fibre, in the same condition in which the hand moulder delivers the sheet to the coucher.

The coucher's work is now taken up by this marvellous piece of automatism called the Fourdrinier. As the endless belt of wire disappears underneath the machine, to reappear again at the "apron" for a fresh supply of pulp, it passes with the damp web of paper between the upper and under couch rolls—cylinders of metal jacketed with felt, corresponding to the two felt sheets of the coucher—and delivers the web upon another endless belt called the "wet felt," since the paper is still too tender to travel without support. This felt carries the web between iron rolls, called the first press rolls, which squeeze out more water and smooth the upper surface of the paper, and a second felt carries it under and to the back of the second press rolls, so that by reversing the direction the under surface of the web comes to the top and has its turn at smoothing. A "doctor"—a long scraper the length of the top press roll—scrapes the roll free from adhering fibres, and keeps it smooth and clean.

The paper can now travel alone, but it has still to be dried and further pressed, and perhaps tub-sized. This part of the



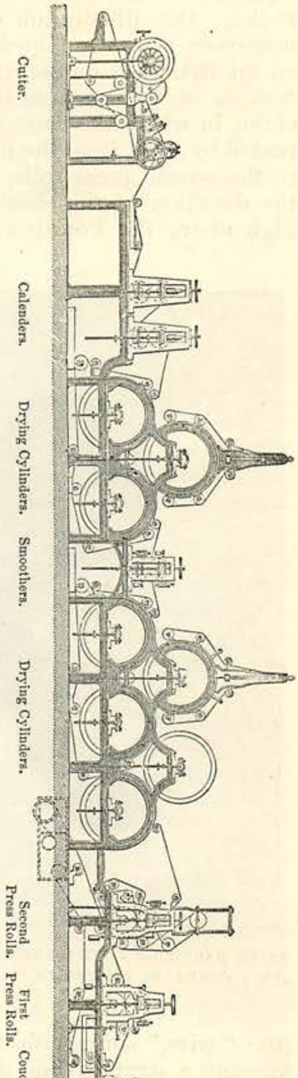
FOURDRINIER-ROOM.

Fourdrinier takes the place of the press in which the coucher puts his "post" of sheets. The web passes above the second press rolls, resuming its original direction, to the drying cylinders—hollow rolls heated by steam—under and over and over and under which, to the number of six or eight or ten, sometimes with the guidance of felts, sometimes without them, the paper passes till it is thoroughly dry. Since the paper shrinks in this process, the successive rolls decrease slightly in diameter. In the midst of the driers there is sometimes a pair of highly polished smaller rolls called "smoothers," also heated by steam. From the driers the paper passes to the "calenders," an upright stack of rolls similar to the smoothers, which are under enormous pressure, regulated by screws on either side, and give the paper an additional hardness and polish. If the paper is for the modern newspaper presses, it is reeled off in a continuous roll; if not, it is cut into strips by a knife-wheel like a circular saw fitting upon another knife-wheel to make a continuous scissoring, and these strips into sheets by a straight knife revolving at the proper interval on a horizontal drum, whence a travelling felt delivers them upon the pile. The speed of a Fourdrinier is from 60 to 240 feet per minute, the latter for cheap news paper demanding little care. Of good paper, the production averages about 80 feet per minute.

The curious illustration on the next page shows the matting or felting of the fibres in a piece of smooth white paper as seen under a microscope magnifying fifty diameters. The curiously ragged black figure is a comma, such as is used in this article, which to the unassisted eye seems so clearly and sharply defined.

Soon after the development of the Fourdrinier machine, Mr. John Dickinson, whose name is still borne by one of the most distinguished firms among English paper-makers, produced a quite different invention for making paper by machinery, which is generally known as the cylinder machine. This is used chiefly for making the cheaper and thicker grades of paper, such as "straw boards." Instead of the supply chest, "wire," etc., of the Fourdrinier, a cylinder covered with wire-cloth revolves with its lower portion dipping into a vat filled with pulp; a system of suction keeps a partial vacuum within this cylinder, which causes the pulp to adhere to the wire until it is detached above upon another cylinder covered with felting. Beyond this the system is materially the same as by the other method. It was patented in 1809. In 1826 a French inventor, M. Canson, applied the suction principle to the Fourdrinier, as has been described, and thus bereft the cylinder machine of its leading advantage—not, however, until he had kept his improvement a secret for six years.

All other paper-making machines are a modi-



THE FOURDRINIER MACHINE.

fication or combination of these two varieties. Our illustration of the Fourdrinier-room shows a Fourdrinier machine on the left, while on the right is the modification of it known as the Harper machine, in which the sheet of paper is supported by a felt from the upper couch roll to the second press rolls, which reverses the direction of the sheet and carries it high above the Fourdrinier part proper

PAPER MAGNIFIED FIFTY DIAMETERS, SHOWING FIBRE, AND A COMMA AS PRINTED IN "HARPER'S MAGAZINE."

(the "wire," etc.), with the purpose of forming a stronger and drier web before it is left to travel alone.

Tissue-papers, the thinnest known, are made from very strong fibres, such as that of hemp bagging and cotton canvas, on a machine so planned that the tenuous sheet of pulp passes through almost in a straight line, without reversing its direction at the second press rolls, at a speed as high as 160 feet a minute. At the starting up of the machine a sheet of dry paper is carried part of the way with the pulp, as it is too thin to be touched by hand.

The bank-note paper used for the United States "greenbacks" was made under the Willcox patent at the mills of that old Pennsylvania firm, whose mills, curiously enough, had also made the paper for the Continental currency of Revolutionary days. It was rendered distinctive by the use of silk fibres of red and blue, the red being mixed with the pulp in the engine, so that it was scattered throughout the substance of the paper, while the blue were ingeniously showered upon the web while on the "wire," so that it appeared only in streaks. This combination was so difficult to copy, and required such expensive machinery, as to call for a skill, patience, and capital not at the disposal of counterfeiters.

VI.

If paper is to be "tub-sized" as well as "engine-sized," an animal size, made by soaking out the gelatine from clippings of horns, hides, etc., is mixed with dissolved alum and placed in a tub or vat, through which the web of paper is run after leaving the first set of driers. It is then passed through squeezing rollers, which press the size into the pores and get rid of the excess, and then along to the other driers. For finer papers tub-sizing is sometimes done after their completion in the Fourdrinier; the paper stands to allow the size to be absorbed, and the second drying is by means of a great number—sometimes 300—of reels made of wooden slats, within which a fan revolving in an opposite direction makes a strong current of air. Or the paper is run through the tub between two continuous felts, which, with the paper, are pressed between rollers, and the paper is then "loft-dried" by hanging over sticks, as with hand-made paper. Writing-paper is often "double-sized"; that is, both engine-sized and tub-sized.

The "finishing" of paper presents many interesting varieties. "Plate-paper" was made by putting each sheet between brightly polished sheets of copper or zinc, and passing a stack of these to and fro through a rolling-press under heavy pressure until a gloss was imparted to both surfaces. This process has now given way to "supercalendering," in which a stack of rolls similar to that of the Fourdrinier, alternately of bright metal and highly compressed paper, between which the web of paper passes and repasses, produces the same effect. These rolls are virtually a great electric machine, so that it is sometimes necessary to attach ground-wires to the stack to carry off the electricity, which otherwise causes the paper to attract all sorts of dust in the printing-room. A jet of steam sometimes moistens the paper as it is run into the stack. Friction-glazing is done by passing the web between a large paper roll and a smaller iron one, the latter revolving at a higher speed. Sometimes beeswax is applied to the iron roll. A high polish is also given to fine printing paper by running the web through, or spraying upon it, a solution of carbonate of lime or magnesia with starch or glue, leaving a permanent coating of lime or magnesia on the surface. "Repped" and like papers are produced by passing the web between rollers on which the rib or other device has been cut. "Morocco," flowered, and like papers of uneven surface or raised devices are embossed in the same way.

Fancy papers are variously finished after leaving the machine, either in the web or in sheets. Colored papers which have the color on the surface only are not treated in the "engine" or tub, as body-color papers are, but are printed or varnished afterward, and then burnished or glossed. An iridescent or "rainbow" surface is given by a wash containing sulphates of iron and of indigo exposed quickly, as it is applied with a brush, to ammoniacal vapors; and a mother-of-pearl effect is produced by floating glazed paper upon a bath of solution of silver, lead, or other metal, exposing it when dried to vapors of sulphide of hydrogen, and afterward pouring collodion upon it, when most beautiful colors appear.

Marbled paper is made in a way even more curious. The "marbler" has before him a shallow bath of gum-tragacanth, on which from a flat brush he sprinkles films of the colors he needs for his pattern. Presently the whole surface of the bath is covered with bands or splashes of color; the workman then takes what is practically a huge comb, and with a wavy motion draws it the length of the bath. Long practice has enabled a good marbler to select and lay the colors and manipulate the comb—for he has no guide but his eye—to copy almost any pattern you can show him; so that, although no two sheets of marbled paper are exactly alike, only a practised eye would note the difference. The sheet of smooth white paper is then deftly laid upon the bath for a moment: as it is raised, the entire film of color comes with it, and the bath must be resprinkled for the next sheet. Books with marbled edges are dipped in the same way.

Sand and emery papers are made by coating a stout paper with glue, and then sprinkling the dust upon it. A water-

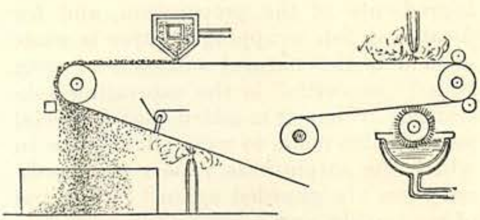


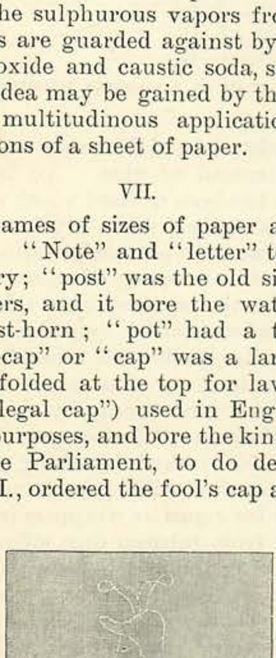
DIAGRAM OF SAND-PAPER MACHINE.

proof variety is made by using water-proof cement instead of glue. An ingenious machine has been devised which coats the paper with glue from a brush revolving in a steam glue-pot underneath, softens the glue with a spray of steam, sifts the sand upon the surface, drops the surplus into a box below as the sanded paper turns over a roller, shakes off other loose particles by the help of a fan motion, and fixes the rest more firmly by aid of a second jet of steam. "Cork-paper," for packing glass, etc., is made by sifting powdered cork on a soft, flexible paper, and a tobacco-paper for cigarette wrappers is similarly made from tobacco dust sifted on the surface of ordinary cigarette paper, and made to permeate it by heavy pressure. A paper for cigar wrappings is also made by using tobacco stems as a fibre, with enough Manila to give strength.

Photograph, telegraph, and lithographic transfer papers are made by surfacing with various chemicals sensitive to light, to electricity, or to other chemicals. A solution of Canada balsam in turpentine renders paper transparent for tracing purposes, or a paper may be made transparent by treating it with a solution of castor-oil in absolute alcohol, and permitting the alcohol to evaporate from it, and the paper may again be made opaque, with the tracing still upon it, by removing the oil in a fresh bath of alcohol. By treating unsized rag paper with dilute sulphuric acid, and then washing it, a parchment-paper, or vegetable parchment, is made, almost like the animal article. A paper whose surface can be washed off like a slate is made by treatment with benzine, and then with a preparation made of lead and zinc oxide, turpentine and linseed-oil, copal and sandarach. There are various processes for water-proofing paper, as soaking in dissolved shellac and borax, but most of these are done in a heated "tub" in the process of making. Resin and paraffine are among the usual ingredients of the preparation, and for meat and fish wrapping a paper is made in which the natural bitumen or wax called "ozocerite" is the saturating substance. When it is added that a special paper is also made to wrap silver-ware, in which the sulphurous vapors from ordinary gas are guarded against by the use of zinc oxide and caustic soda, some imperfect idea may be gained by the reader of the multitudinous applications and adaptations of a sheet of paper.

VII.

The names of sizes of paper are most curious. "Note" and "letter" tell their own story; "post" was the old size made for letters, and it bore the water-mark of a post-horn; "pot" had a tankard. "Fool's-cap" or "cap" was a larger size (which, folded at the top for law use, is called "legal cap") used in England for official purposes, and bore the king's arms until the Parliament, to do despite to Charles I., ordered the fool's cap and bells



FOOL'S-CAP WATER-MARK.

to replace them on paper for its journals. This was a copy of a rude satire of Henry VIII., who, in contempt for the Pope, used a paper water-marked with a mitred hog. The figure of Britannia afterward took the place of the fool's-cap mark. "Crown" bore the water-mark of a crown; "demy" (the half of the old standard sheet), "medium," "royal," "superroyal," and "imperial" are larger and larger sizes; and finally we reach "elephant," "colombier," "atlas," and "antiquarian," the last sheet, 31 by 53 inches, being the largest sheet made by hand. The book-size terms, post, crown, demy or medium octavo, duodecimo, etc., refer to the use of these respective sizes folded in eights, twelves, etc.

VIII.

What are called "boards," as Bristol-board, card-board, binders' board, press-board, and the like, are simply as many sheets of paper as are needed to make the desired thickness, consolidated by pressure. The cheaper kinds, such as "straw-board," are usually made by running together the wet sheets from a number of cylinders, by an ingenious arrangement of felts, between a set of rolls which press all into one sheet simultaneously with the process of drying. Another method is still more ingenious: paper is rolled over and over the lower of a pair of press rolls, of which the upper one is so adjusted as to be raised by the thickening jacket of the lower. When the desired thickness is reached, the upper roll touches a little bell; the machine-tender, a boy, then draws a knife across a guide lengthwise of the roll, and the sheet of board drops off below.

One of the most remarkable uses of paper is the building of paper boats, under the patent, recently expired, of E. Waters, of Lansingburg, near Troy, New York. These boats are made of an ordinary Manila paper of good quality, usually in five thicknesses, in all only one-sixteenth of an inch thick, except in parts where there is the re-enforcement of one or two extra strips. The process of making them is simple. A model of soft pine is made the full size of the boat, the bow end being of two pieces which can be detached. The paper is delivered in long rolls; the model is turned upside down on a long frame; one narrow strip of paper and then a second are first laid on where the keel would be, and then one, two, three, four, five sheets are successively laid along and moulded close to the model, each as it is put on being coated with shellac and with glue to attach the next sheet closely to it. Thus done up in paper, the models are taken to a drying-room, where a heat of about 150° F., continued for five days, consolidates the glued paper into a solid mass.

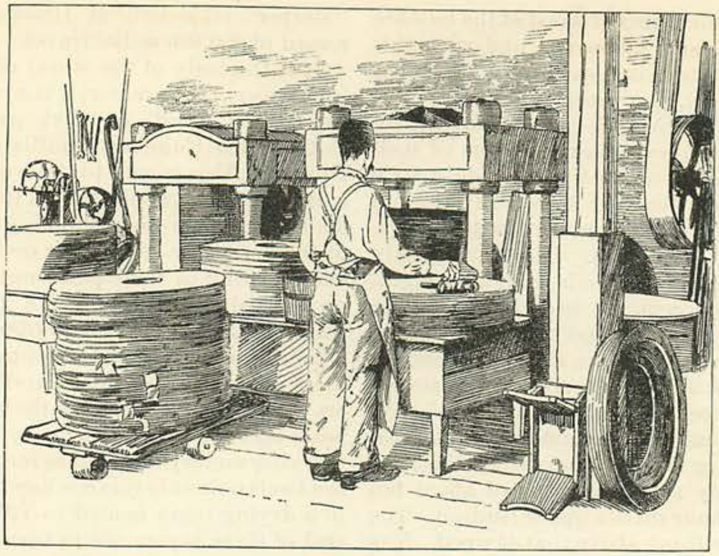
The movable pieces of wood at the bow are unscrewed and taken out, and with this place for a start, it is easy to peel the boat off the model, as a peach-skin comes off a fresh peach. A keel is now fastened inside the boat, several extra layers of shellac are put on outside and inside, a strip of wood is fastened in for a gunwale, and the shell is presently ready for its fittings, seats, and outriggers. They are mostly racing shells, from single-scull up to eight-oar, but one boat has been built as large as 42 feet long by 4 feet 4 inches beam, to hold forty-two persons, this, of course, being stayed by wooden ribs; and a steam-launch 19 feet long, worked by a one-horse-power oil engine, boat and engine together weighing but 430 pounds, was last fall successfully run at a speed of about ten miles per hour on the upper Hudson. The cost is something above that of wood. The single-scull, 21½ feet long by 10½ inches beam, costs from \$65 to \$100; the eight-oared shell, about 60 feet long by 24 inches wide, costs \$400. It is an interesting fact that the racing shells of Harvard, Yale, and Columbia in 1886 were all from the same model from this shop, so that the contest was entirely one of skill, on even terms. A "Long Lake" (Adirondack) boat for ordinary use costs something under \$100, and is much lighter than wood to "carry." The paper boats can be "patched" so that the mending can scarcely be detected.

Not only is travelling by water indebted to paper, but travelling by land. A paper car wheel seems even more a contradiction of terms than a paper boat, yet it is now generally acknowledged to be better, safer, and longer-lived than one altogether of metal. It was the invention of Richard N. Allen, a locomotive engineer, afterward master-mechanic of the Cleveland and Toledo Railroad, who took for his aim in life the production of a better car wheel than those in use. His first set of paper wheels was made at Brandon, Vermont, in 1869, and after much scoffing he was graciously permitted the use of a wood-car on the Central Vermont road, under which they were tested for six months. The Pullman Palace Car Company in 1871 gave the first order for a hundred wheels; ten years after, the Allen Paper Car-wheel Company, with great shops at Hudson, New York, and Pullman, Illinois, produced and sold thirteen thousand in a single year. One of the set first experimented with under a "sleeper" is shown at Hudson, with a record of 300,000 miles' travel.

It is the body of the wheel only which is of paper. The material is a calendered rye-straw "board" or thick paper made at the Allen Company's mills at Morris, Illinois. This is sent to the works in circular sheets of twenty-two to forty inches diameter. Two men, standing by a pile of these, rapidly brush over each sheet an even coating of flour paste until a dozen are pasted into a layer. A third man transfers these layers to a hydraulic press, where a pressure of five hundred tons or more is applied to a pile of them, the layers being kept distinct by the absence of paste between the outer sheets. After solidifying under this pressure for two hours, the twelve-sheet layers are kept for a week in a drying-room heated to 120° F.; several of these layers are in turn pasted together, pressed, and dried for a second week, and still again these disks are pasted, pressed, and given a third drying of a whole month. The result is a circular block, containing from 120 to 160 sheets of the original paper, compressed to 5½ or 4½ inches thickness, and of a solidity, density, and weight suggesting metal rather than fibre.

The "paper wheel" is made up of this disk of compressed paper, surrounded by a steel tire, and fitted with a cast-iron hub, which is bored for the axle; wrought-iron plates protect the paper disk on either side, and all are bolted together by two circles of bolts, one set passing through a flange of the tire, the other through a flange of the hub, and both through the paper centre and its protecting plates.

The steel tires have been very accurately made, and are on the inner circle slightly bevelled. The rough paper blocks which we have seen made are now turned accurately in a lathe, whence shavings like leather and a cloud of yellow dust fly off, to a diameter slightly greater than the inner circle of the tire. The hole in the centre is also made on the lathe, and after the paper has received two coats of paint to prevent moisture working its way within, the cast-iron hub is pressed through, by the aid of the hydraulic press, and the wrought-iron back-plate is clamped on. The suasion of enormous hydraulic power now drives the paper centre into the tire, by help of the bevel. Once there, it is firmly caught. The other wrought-iron disk is now attached, bolt holes are drilled



MAKING PAPER CAR WHEELS.

by machinery through the mass, and the bolts, milled to the exact diameter, are driven through with the rat-tat-tat of sledge-hammers worked by brawny arms. The nuts are put on and screwed close by an ingenious machine, which automatically applies just the needed power, and which is also used to unscrew the nuts when a wheel is to be taken to pieces. Another machine drills away all superfluous metal at the end of the bolts; the bolt ends are riveted by another rat-tat-tat of hammers; a powerful drill re-bores the axle hole absolutely true to the centre; the wheel is painted, and is ready to travel.

The real service of the paper is in interposing a non-vibrating substance between the axle and the tire, so that the vibrations, which in some unknown way re-arrange the atoms of metal so that it brittles and breaks after long wear, are prevented. Nature always provides some way of wearing things out, whether it be man, lest he lag superfluous on the stage, or "the everlasting hills" themselves, but in the case of compressed paper, art seems to have got ahead of nature, for it seems not to wear out at all. The steel tires of these wheels do wear down, and are then re-turned in a lathe to smaller diameter; but when they are gone and are taken off, the paper block appears again as good as new, and ready for a new tire. The paper wheel has the one disadvantage of greater cost, but its longer life and greater safety are in its favor.

"Straw lumber," so called, is a similar application of paper for building purposes; it is used, not for posts or beams, but in place of lath and plaster, for sheathing, etc. An ordinary "straw-board" paper is made on the cylinder machine—the refuse bedding of stables being very largely utilized as the material—and is run through a vat of resin and other water-proofing material heated to 350° F. A number of sheets are then placed together between metal plates, and subjected like the car wheels to enormous pressure in a hydraulic press. The result is a very hard and solid blackish board, about three-sixteenths of an inch thick, which can be cut with a saw or chisel, and is marketed in slabs 12 feet by 32 inches, at a price of about $40 per thousand feet. This is now in use also for the interior of railway cars and for perforated chair seats. "Building paper" of the ordinary sort is a coarse paper of straw or waste used for sheathing or lining wooden houses. It was put to good use immediately after the Chicago fire, when a Western paper company lined the 10,000 houses, 16 by 20, which were run up to accommodate the homeless, with this material, at a cost of $5 for each house.

The non-conducting quality of paper has caused a curious development in America of the paper-box industry, so that the lover of oysters may "take home a fry in a box" to keep it hot, or a brick of ice-cream to keep it cool. The Chinese and Japanese are said to make paper clothes, and their handkerchiefs and napkins are well known to us, but American achievements in this direction have been confined chiefly to paper collars, cuffs, and "bosoms," sometimes with a backing of cloth, which may be pasted on after making, but which is conjoined with the paper at some mills by reeling the cloth off parallel with the web of paper, and pressing the two permanently together between rollers. The use of paper bags and paper boxes by shopkeepers has reached enormous proportions, and the latest product of American ingenuity is a "self-opening bag," completed automatically from the web of Manila paper by a machine on which its owners had been at work for eight years. This is folded flat as it comes from the machine, but a single dexterous flap with the hand opens it into an absolutely square-cornered bag which will stand upright on the grocer's counter to be filled. Paper buckets, barrels, and other household utensils are either made by joining the edges of a flat sheet into a cylinder, or by stamping out the form from paper pulp, which last was the basis of the *papier-maché* of old days, which was moulded soft into the desired shape, coated with successive layers of asphalt varnish, and polished down. Paper pulp is also used in one process of stereotyping to make a matrix for the type-metal.

IX.

The paper industry in the United States, according to the latest statistics in Lockwood's *Paper Trade Directory* for 1886, numbers over 800 establishments, with over a thousand mills. In the census year 692 establishments were reported, New York State leading with 168, and Massachusetts following with 96, Pennsylvania with 78, Connecticut with 65, Ohio with 60. The paper city *par excellence* is Holyoke, Massachusetts.

The growth of the industry in recent years is suggested by the following census returns:

PAPER MANUFACTURE: STATISTICS FROM UNITED STATES CENSUS.

	1850.	1860.	1870.*	1880.
Whole number of establishments....	443	555	669	692
Persons employed	6,285	10,911	17,910	24,422
Capital........................	\$7,260,864	\$14,052,643	\$34,365,014	\$46,241,202
Wages.........................	\$1,497,722	\$2,767,212	\$7,148,513	\$8,525,355
Value of materials used	\$5,553,929	\$11,602,266	\$30,029,063	\$33,951,297
Value of product	\$10,187,177	\$21,216,802	\$48,676,935	\$55,109,914
Wages per employé..............	\$239	\$253	\$399†	\$349

* Currency. † Currency=\$320 gold.

Of the material used in 1880, 187,917 tons were rags, 87,840 old paper, and 12,083 cotton waste, 84,786 tons Manila stock, and 245,838 tons straw, while pulp to the value of \$1,681,762 was purchased, and \$3,628,798 worth of chemicals was used. Of the product, 149,177 tons were printing, 134,294 wrapping, and 32,937 writing paper, besides 20,014 for binders' boards, and 14,734 for hangings. Over 7000 tons of colored papers, 4000 of tissue, about 150 of bank-note paper, and 89,000 tons unspecified, make up the enormous total of over 450,000 tons—a consumption of paper reaching nearly 18 pounds per head of the entire population. Our imports in 1885–6 of paper and its manufactured products were but \$1,802,482 worth, there being a duty averaging 22 per cent., while our exports amount to about half our imports.

Labor in a paper-mill is continuous, Sunday or a part of it excepted, for the stopping of a Fourdrinier and the necessary "washing up" means great waste. The "machine-tenders," of whom there are two to each Fourdrinier, work in "tours" or "shifts" twelve hours each. In the "engine" or beating rooms, and in the sorting rooms, where most of the hands are women, the work-day is the ordinary one of ten or twelve hours. The need of pure water for treating the pulp located paper-mills mostly on the banks of streams, and caused them to depend on water-power, so that of old there was apt to be no work for the hands in dry months; but the building of reservoirs or the use of steam-power has now made work steady through the year. There have been almost no strikes or lock-outs in this industry; paper-makers have no distinctive labor organization in this country, nor is there any combination of employers regarding labor.

There is considerable difference of pay in different mills. The census figures, averaging all paper hands, show a rise of yearly earnings from $239 in 1850 to $253 in 1860, to $399 currency ($320 gold) in 1870, to $349 in 1880—for the latter is probably a real gain in purchasing power. Wages really reached their highest point in this country about 1873 (though paper was highest in 1865, and then steadily fell with the cost of material), and since that time they have fallen here, though they have risen in England, where in this trade they average little above half our day wages. Colonel Wright found the Massachusetts average for all paper hands to be $8 63 weekly in 1860, $9 77 in 1872 (when it was $3 60 in Great Britain), $8 17 in 1880 (when it was $4 57 in Great Britain). But the actual labor cost per pound of paper has either remained stationary or fallen with the rise in wages. One large mill reports that on machine-finished book paper which had fallen from 19 cents a pound in 1865 to 9 cents in 1880, and on super-calendered paper which had fallen from 20 cents to 10 cents, "the labor cost per pound is precisely the same in 1880 as in 1865," being 1¼ cents for the first-named and 1¾ cents for the other. Other mills report a definite decrease, especially as between 1850 and 1880, reaching from a fifth to nearly a half in that period, though in some of these same mills day wages have doubled in the thirty years. Owing to the improvement of labor-saving machinery since its introduction about 1832, says one mill-owner, "an amount of manual labor which prior to 1830 would have produced one ton of paper will now produce ten tons," yet there has been a steady increase in the number of hands. The percentage of wages to total cost varies from ten to twenty-five per cent. on various papers, the average being about $1 labor to $4 materials.

There is no more remarkable example of the great fact that the growth of civilization means a fall in prices than in the history of paper. Of old times it was a luxury; now it is one of the most universal, commonplace, and cheap necessaries of life. It is almost impossible to give close data for comparison, and the ups and downs because of the temporary scarcity caused by wars, or by increase of demand the world over before improvements in machinery could meet it with a supply, have been very considerable, but the fall in prices has been as sure as the rise in wages, and paper was never so cheap as to-day. The first bill extant is probably one of 1352, "for one quartern [quire] of royal paper, to make painters' patterns, 10*d*.," when the penny was worth a good many times what it is now. In 1854 the average price of all paper produced in America was about 10 cents per pound; by the census of 1860 it was 8⅓ cents; by the census of 1880 it was close to 6 cents per pound. Of course during the war paper was enormously high: writing papers cost from 40 to 60 cents a pound; book papers, 25 to 40 cents; news, 20 to 25 cents. The paper-makers made the most of the situation, and to overcome the "monopoly" Congress was memorialized to take off the duty, which, starting at seven and a half per cent. in 1789, had ruled since 1816 for the most part, with occasional reductions, at thirty per cent. It was reduced in 1863, on printing papers, to three per cent., and in 1865 the duty was removed, but the high rate of exchange minimized the relief. In 1870 writing papers sold at 22 to 32 cents per pound, book papers at 16 to 24 cents, and straw news at about 12 cents; to-day, writing papers bring 12 to 20 cents per pound, book papers from 8 to 12 cents per pound, and the daily papers of New York pay between 4 and 5 cents for news paper. It may be safe to say that what was a dollar's worth of paper in 1850 could have been bought in 1860 for about 70 cents, would have cost at least $1 50 at the height of war prices, and can now be had for within half a dollar.

There are now over a million tons of paper produced annually in the world, of which the United States makes over one-third, or probably more than any other two nations combined. If "the consumption of paper is the measure of a people's culture," as one writer says, we have reason to be proud of our record.

NOTE.—The best single work on paper-making is Hofmann's *Practical Treatise on the Manufacture of Paper*, Philadelphia, 1873; the later work of Davis, *Manufacture of Paper*, Philadelphia, 1886, is valuable only for some descriptions of later machinery. Koops's *Historical Account* of substances used for writing, London, 1800–1, and Munsell's *Chronology of Paper and Paper-Making*, 5th ed., Albany, 1876, are useful historically. The reports on paper at the Centennial Exposition (Vol. V., Group XIII.) are of interest. Lockwood's Paper Trade Directory and Geyer's similar annual give lists of American mills, and the *Paper Trade Journal* and *Paper Trade Reporter* are the American trade newspapers.