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PRACTICAL GUIDE

FOR THE

MANUFACTURE OF PAPER AND BOARDS.

BY

A. PROTEAUX,

CIVIL ENGINEER,

GRADUATE OF THE SCHOOL OF ARTS AND MANUFACTURES, AND DIRECTOR OF THIERS' PAPER-MILL, PUY-DE-DÔME.

WITH ADDITIONS BY L. S. LE NORMAND.

TRANSLATED FROM THE FRENCH WITH NOTES BY

HORATIO PAINE, A. B., M. D.

TO WHICH IS ADDED A CHAPTER ON

THE MANUFACTURE OF PAPER FROM WOOD IN THE UNITED STATES.

BY HENRY T. BROWN,

OF THE "AMERICAN ARTISAN."

Illustrated by Six Plates,

CONTAINING DRAWINGS OF RAW MATERIALS, MACHINERY, PLANS OF PAPER MILLS, ETC. ETC.

PHILADELPHIA:

HENRY CAREY BAIRD,

INDUSTRIAL PUBLISHER.

406 WALNUT STREET.

LONDON: SAMPSON LOW, SON, AND MARSTON,

MILTON HOUSE, LUDGATE HILL.

1866.

PHILADELPHIA:
COLLINS, PRINTER.

PREFACE.

THE volume on the MANUFACTURE OF PAPER AND BOARDS, here presented to the American public, is believed to be the first practical treatise of the kind published in this country. It consists of a translation of the valuable work of Proteaux, which appeared in Paris about a year since, additions from the "Nouveau Manuel" of Le Normand, notes by the translator, and a paper by Henry T. Brown, Esq., of the "American Artisan." It is hoped that it will be found an acceptable and important aid to the American manufacturer of paper, and a creditable addition to the industrial literature of the United States.

Wide-spread intelligence and well-nigh universal education, as they are the glory, so have they been found the bulwark of this nation in the hour of its greatest peril. They will in the future prove to be the elements which will carry it up to the highest stage of development ever known to any country, and far beyond anything which has ever been imagined by the most enthusiastic lover of free institutions. The measure of the education and intelligence of our people, as compared with those of other countries, has only to be looked for in the consumption of paper. In this respect, it need hardly be added, we far surpass any other nation in the world.

The paper question has within a few years past assumed much more than ordinary importance. A scarcity of raw materials, arising out of a state of war, a short supply of cotton and cotton rags, and other causes, combined to place this branch of industry in a very awkward and trying position. The American paper-makers, however, showed themselves quite equal to the emergency. They availed themselves of and utilized nearly every raw material which could be used for the purpose, and kept supplied a large and growing market, at prices lower than other commodities which were affected by the scarcity of cotton.

The energy, enterprise, and success thus manifested deserved all praise and encouragement, and yet received but little. On the contrary, the most determined efforts were made to crush the authors of the great results attained, and actually to discriminate against these, our own people, who were aiding and supporting the government, and in favor of those foreigners, who, in a majority of cases, were either indifferent to us and our cause, or wholly and bitterly hostile to us. Few more selfish or indefensible attempts at legislation have disgraced our country within the past few years. Happily, these attempts, vigorous and determined though they were, did not succeed. Had they done so, and had the American paper industry been crushed, those who were most active in inaugurating and urging this movement would have been among the earliest and most severe sufferers by it. It would soon have been demonstrated to them, and at heavy cost, how utterly impossible it would be for this country to rely upon Europe for any considerable portion of its supplies of paper. The emergency has, however, passed; and in the early future, with the new raw materials, especially wood and straw, and the former quantity of rags, our own producers of this important aid to our civilization will be found fully capable of supplying the enormous quantity of paper which we shall require.

H. C. B.

PHILADELPHIA, June 15, 1866.

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CHAPTER I.

A GLANCE AT THE HISTORY OF PAPER-MAKING.

THE word paper is derived from the Greek word πάπυρος, papyrus, an Egyptian plant, which, for a long while, served among the ancients as a material for writing.

The manufacture of papyrus paper was in high repute among the Romans. It was superseded about the fifth century of our era by the cotton paper called *carta bombycina.*

Several manuscripts having an authentic date belong to the tenth century, and judging from the appearance of the writing, others seem to go back to a period still more remote. The great libraries of Europe, almost all of them, possess works of the eleventh and twelfth centuries, written on bombycian paper.[1]

[1] See the following works for a description of the processes of making papyrus and other kinds of paper among the ancients :—

Pliny, lib. xiii., chap. xi.

Theophrastus, lib. ix., chap. ix.

Bartholinus, "Dissertatione de libris legendis."

Polydorus Virgilius, "De rerum inventione."

Le Père Hardouin, "De re diplomatica."

Prideaux, "Connectione."

Scaliger.

Saumaise.

Comte de Caylus, "Mémoires de l'Académie des Sciences," tome xxvi.

The processes employed at that time to effect the transformation of cotton into paper are not known; but it is fair to suppose them analogous to those which were later employed in the preparation of paper from rags, and whose discovery dates from the second half of the twelfth century. Such, at least, is the opinion of most men of learning who have written on this subject.

In 1762 M. Miermann offered a prize for the oldest manuscript written upon rag paper.

The different minutes of the proceedings of this competition, printed at the Hague in 1767, unite in admitting that paper of this kind was used before the year 1300.

It is not known to what nation this important discovery is due. Scaliger gives the credit to the Germans. Maffei to the Italians. We believe that Dr. Prideaux is nearer right in considering the Arabs, if not as the inventors, at least as the importers of this manufacture into Europe.

Some historians admit that the crusaders brought home into France this branch of industry, which was soon to be so prodigiously developed, and contribute more than any other to the progress of modern civilization.

Up to the end of the eighteenth century rag paper was made at the vat, or by hand, through processes which are still in use in France, in some departments, as, for instance, Puy-de-Dôme.

The first idea of making paper by machinery is due to France. In 1798, *Robert*, a workman attached to the paper-mill at Essone, took out the first patent for manufacturing paper continuously.

The machine, set up in 1799, was very imperfect; it could not be worked. *M. Lejer Didot*, proprietor of the paper-mill at Essone, bought the patent from Robert, introduced some improvements upon the original model, and went over to England to have the plans executed.

After many experiments, and powerfully aided by the mechanical knowledge of *Mr. Donkin*, employed in the workshops of Mr. Hall, he was enabled, in 1803, at Frogmore, in Herefordshire, to work the first paper-machine.

In 1804 a second machine was set up at Two Waters. *MM. Berthe* and *Grevenich* established the first French paper-machine in their paper-mill at Sorel (Eure-et-Loir) in 1811.

They were the first makers who introduced into commerce paper made by machinery and sized in the vat.

The labors of *Berthollet* having thrown great light upon bleaching the stuffs, chlorine soon began to be adopted as a discolorant of the pulp.

In 1827 there were as yet but four paper-machines in France. In 1833 the number exceeded twelve.

At that time, however, the paper-machine was far from having received its latest improvements. The manufacturers complained of the frequent obstruction of the wire-gauze, of too rapid destruction of the felts, &c.

The paper too retained upon what is called the wrong side the impression of the wire-gauze. A system of cylindrical presses, suggested by *Mr. Donkin*, set aside this defect.

M. Firmin Didot at the same time established the first drying presses at his paper-mill at Mesnil-sur-l'Estrée (Eure).

French paper-making then received a new impetus. A large number of manufacturers established cylinders and engines in the place of their mortars and mallets.

Everywhere the vegetable sizing, composed of a mixture of alumino-resinous soap and starch, took the place of the sizing made of gelatine.

About 1840 *M. de Bergue* suggested the use of sand-traps, which, as their name implies, receive the gravel and other impurities, whose presence in paper would injure leaden type, woodcuts, copper plates, &c. *M. Canson*, of Annonay, applied suction-pumps to the paper-machine, which, during the formation of the paper, carry off by degrees a great portion of the water contained in the pulp from under the wire-gauze. The usefulness of this improvement was so evident that the suction-pumps were at once generally employed.

The introduction of kaolin (porcelain clay) into paper, rendered it more fit to receive the impression of type and engravings. Rags, too, growing daily more expensive, this became one means of preventing an increase in the price of paper.

As the scarcity of the raw material began to be felt more and more, an attempt was made to use substances other than rags for the manufacture of inferior papers.

In 1839 the paper-mill at Echarçon sent to the "Exposition Nationale" samples of paper made with sea-wrack, wood, etc.

M. Cardon de Buges (Loiret) manufactures tarred paper for packing out of old ship ropes.

These products, when they first appeared, were very much esteemed as wrappers for articles of hardware and cutlery, which they preserve from rust.

At the paper-mill of the Marais, M. May makes paper of plantain leaves.

M. Heryjoyen uses rye straw for common wrappers.

An important improvement in paper-making was the adaptation of washing-drums to the rag-engines, which rid the pulp of the traces of chlorine it might contain at the beginning of the refining process. The first idea of this invention belongs to *MM. Breton frères.* It was not generally adopted until after it had undergone the modifications due to *M. Blanchet*, of Rives, who made the washing-drum what it is at the present day.

In 1844 the machine-made papers thrown into the market were extremely white, but unfortunately inferior in tenacity to those made by hand.

The employment of chlorine in excessive quantities injuriously affected the resisting power of the fibres. In many mills the washing of the pulp was imperfect; some kinds of paper contained free chlorine. From all this there resulted a depreciation in French paper, which it was important to remedy.

So after the abuse of chlorine as a gas, liquid chlorine (a solution of the hypochlorite of lime in water) returned into use, and is more easily manipulated by manufacturers unfamiliar with chemical preparations.

In 1849 paper-making, enlightened by the errors committed from 1834 to 1845, began to advance more steadily. The composition of the pulps was better studied. The common printing and writing papers were made of a mixture of gray linen rags and cotton formerly only employed in preparing coarser kinds. From that time white rags were kept for fine papers of a superior quality, whose sale became considerably greater.

The World's Fair at London, in 1851, afforded an opportunity of appreciating the development of paper-making at the beginning of the second half of the nineteenth century.

We quote the following statistics from the report of the commission:—

	Paper-machines.	Vats.	Cylinders.
France	210	250	——
England	322	266	1616
Scotland	58	19	286
Ireland	33	15	86
Zolverein	140	1024	800

Which is subdivided thus:—

	Machines.	Vats.
Prussia	72	503
Bavaria	11	257
Saxony	6	68
Grand Duchy of Hesse	1	27
Electorate " "	6	39
Duchy of Baden	14	33
Nassau	6	30

The statistics for Wirtemburg, Brunswick, and several other States, are wanting.

OTHER EUROPEAN STATES.

	Machines.	
Austria	48	900 vats.
Denmark	6	20 "
Sweden	7	8 "
Belgium	28	80 paper-mills.
Low Countries	—	168 " "
Lombardo-Venetian Kingdom	6	
Kingdom of Two Sicilies	12	12 vats.
Roman States	3	
Kingdom of Sardinia	12	50 vats.
Tuscany	2	
Spain	17	250 vats.
Switzerland	26	40 "
Turkey	1	
Russia	25	

In 1860 the number of paper-mills in 24 States of the United States was 555, producing annually 113,294 tons of paper and boards, of the value of $17,148,194.

Estimating the daily product of each machine at 610 kilogrammes (1,344.88 pounds avoirdupois), and of a vat at 50 kilogrammes (110.23), we should have the following yearly product for these different countries:—

England . .	62,900,000 kilog.	(61,968.8578	tons of	paper.)
Scotland . .	14,300,000 "	(14,074.8839	"	"
Ireland . . .	3,309,000 "	(3,256.9062	"	"
France . . .	41,608,000 "	(40,666.4888	"	"
Zolverein . .	37,300,000 "	(31,506.8165	"	"
Austria . .	22,320,000 "	(21,968.6290	"	"
Denmark . .	1,600,000 "	(1,574.8120	"	"
Spain . . .	5,330,000 "	(5,246.0924	"	"

Since 1851 paper-making in France has increased, but the improvements, notwithstanding the great number of patents obtained, are unimportant. It should be observed, however, that there has been a tendency to substitute large machines for small ones, which produce from 2600 to 3000 kilogrammes (1.5774 to 2.9527 tons) in twenty-four hours. The machinery has been more carefully studied; the number of wet presses and drying cylinders increased; and printing paper has been made by mixing with the rag-pulp a considerable proportion of wood, straw, and particularly esparto (broom), which is very generally used in England for news and common printing papers.

The most elegant English papers are sized with gelatine, which gives them a greater sonority and strength than could be imparted by vegetable or resinous sizing.

The first French paper-machine furnished with the necessary apparatus for using this kind of size, was put up about 1857 by M. Outhenin Chalandre, at the paper-mill of Savoyeux (Haute-Saône). As the employment of animal sizing allows a very large proportion of cotton to be used in the paper, a considerable profit accrues to the manufacturer, which greatly compensates for the original outlay required by this system of sizing.

CHAPTER II.

RAW MATERIALS.

THE raw materials used in a paper mill are numerous; they may be classified as follows:—

1. Rags.
2. Products of the vegetable kingdom taking the place of rags, entirely or in part; the most important are:—
   - Esparto (Spanish broom).
   - Acacia.
   - Aloes.
   - Jute.
   - Wood.
   - Straws of cereal and leguminous plants.
   - Oats.
   - Hops.
   - Ferns, &c. &c.
3. Materials required in boiling:—
   - Unslacked lime.
   - Soda (carbonate, $NaO\,Co_2$) at 80° (alcalimeter).
   - Crystals of soda at 30°.
   - Salts of potassa.
4. Materials required in bleaching:—
   - Hydrochloric (muriatic) acid.
   - Sulphuric acid.
   - Manganese (peroxide, MnO_2).
   - Chloride of lime (hypochlorite of lime, $CaO,ClO + CaCl$).
   - Common salt.
   - Antichlorine (sulphites of soda, NaO, SO_2).

5. Materials required for sizing:—
   Resin.
   Carbonate of soda.
   Starch (fecula).
   Alum.
   Gelatine.
   Sulphate of zinc (white vitriol).

6. Mineral substances:—
   Kaolin (porcelain clay).
   Sulphate of lime (plaster of Paris).
   Sulphate of baryta.
   Chalk.
   Clays.

7. Coloring materials, or substances used to produce them; the principal ones are:—
   Ultramarine (called bleu guimet).
   Cochineal.
   Brazil wood.
   Nitrate of lead.
   Acetate of lead (sugar of lead).
   Chromate of potassa.
   Sulphate of iron (green vitriol).
   Prussiate of potassa (ferrocyanide of potassium).
   Salt of tin (protochloride of tin).
   Safflower (Spanish red).
   Logwood (Campeachy wood).
   Lampblack.
   Nutgalls.
   Ochre.

We will examine the first group of this classification more particularly in the next chapter. The others will be taken up in connection with the processes which they characterize.

The importance which the second group is daily assuming, obliges us to enter into some details, and, therefore, we will not touch upon the subject until we have completely studied the actual manufacture of rag paper, where the aggregate of the processes employed constitutes the type of all paper-making.

§ 1. Rags.

The rags most employed in a paper-mill are of hempen, linen, or cotton thread. Woollen rags are not made use of except for common wrappers. Besides this they are now sold to the woollen factories to be unravelled and worked over.

The rags arrive at the mill in bales weighing from 200 to 500 kilog. (440.94 to 1102.36 lbs. avoir.) either unpicked or having undergone a first sorting. In that case they bear the following denominations:—

1. Fine whites (of thread).
2. Common white.
3. White cottons.
4. Colored cottons.
5. Gray rags and packcloths.

As the commercial value of these various kinds is very different, it is of the greatest importance for a manufacturer to assure himself that each delivery really contains the rags intended.

In case no preparatory sorting has been made, in order to settle the price, the relative proportion of each kind must be ascertained. To discover this, it is necessary to examine the interior of the bales, which are frequently found made up of inferior qualities.

In Germany, they are satisfied with three classes:—

1. Whites.
2. Half whites.
3. Colored rags and packcloths.

In Belgium, on the contrary, the great rag dealers find it an advantage to have a precise classification, which allows them to fix a more exact price for each kind.

Some of them adopt as many as seventeen numbers:—

1. White linen.
2. Brown Holland.
3. Gray, brown, or blue linen.
4. White cotton.
5. Colored cotton.
6. House-cloths.
7. Coffee-bags.
8. Flax-wastings, 1st quality.
9. " 2d "
10. Ropes and packcloths containing straw.
11. " " " 2d quality.
12. Hempen ropes.
13. Aloes ropes.
14. Small grays.
15. White parings.
16. Half white parings.
17. Gray parings and old paper.

We should like to see this method adopted, as it would facilitate business and put an end to the interminable discussions between paper manufacturers and rag dealers. This is not a time when industry thrives by sharp practice; on the contrary, it can only live by free competition.

To increase the weight of their rags, some dealers wet them. M. Piette, formerly a paper manufacturer, tells us that he has seen ragmen take their wares to the bank of a stream, spread them out in layers, sprinkle them successively with water and fine sand, and then shove the whole into a bag.

We mention this fact, which we desire to believe is of very rare occurrence, in order to show how far a want of good faith may be carried.

Rags always contain a certain amount of natural moisture, varying according to the fineness of the texture; but the proportion should never exceed 7 or 8 per cent. for the common and coarser kinds. One needs only a certain amount of practice, to recognize by the feel whether they are in their natural condition of moisture. It is well, however, and important for counter-registering, to make sure by actual weighing of the number of pounds of water contained in a given quantity of rags, at the time of their arrival at the mill.

The quality of rags varies very much according to the source from which they are obtained. Those collected from great centres of population are fine and white, but not strong. The use of concentrated lyes in bleaching the clothes has considerably injured the resisting power of the fibres. They are, so to speak, burnt, tear easily between the fingers, and suffer a considerable waste during their transformation into paper.

Country rags, on the other hand, are coarse, of a grayer appearance, but strong, and containing many mending pieces nearly new. As we shall see later, these kinds are very valuable to give body to the paper.

If the rags are moist, it is absolutely necessary to dry them before heaping, otherwise heat would be generated and in consequence fermentation occasioned which would be injurious to the toughness of the fibres and produce a still greater loss in the manufacture.

The value of rags is proportional to the toughness, whiteness, cleanness, and to the character and degree of fineness of the texture.

CHAPTER III.

MANUFACTURE.

The work of a paper-mill in effecting the transformation of rags into paper, is divided as follows:—

1. Sorting and cutting.
2. Dusting.
3. Washing and boiling.
4. Reducing to half stuff.
5. Draining.
6. Bleaching.
7. Composition of the pulp.
8. Refining, beating.
9. Sizing.
10. Coloring.
11. Conversion into paper.
12. Finishing.

We will examine in detail each one of these operations successively.

§ 1. Sorting and Cutting.

The rags are not sorted in all mills before being cut. Upon their arrival, they are weighed, unpacked, heaped, and delivered every day, to the cutters in bags containing 100 kilog. (220.47 lbs. avoird.).

Sorting is almost useless if the rags arrive at the mill already picked; but, as it very often happens that whites, cottons, and grays are all mixed together, it seems to us absolutely necessary that they should be divided into classes the better to appreciate the contents of the delivery, and to give the choicest rags to the best cutters.

If the price by the cwt. is fixed in advance, we avoid the complaints of the working women, and any partiality which might be shown by giving to some of them sacks requiring less work.

Such a division also allows us to surround the woman with fewer cases for the separation of the different sorts.

The dimensions of the cut rags ought to vary from 3 to 5 inches upon each side. The tougher kinds should be shorter, those worn and soft longer, say from 4 to 5 inches.

It is essential that the rags should be cut in the direction either of the warp or the woof; if cut obliquely or bias, they will unravel and produce a considerable waste.

Before cutting, which is done by means of a fixed knife, inclined at an angle to the floor in front of each work-woman, she should wash the soiled parts and carefully pick out buttons, hooks and eyes, pins, &c. She begins by ridding the piece of seams and hems, then cuts it into bands of from two to four inches wide, which she afterwards recuts crossways in bunches differing in thickness according to the nature of the rags, the sharpness of the knife, and the strength of the woman.

She distributes the pieces among the boxes around her, according to their number, which she ought to be able to decide without much hesitation.

We recommend the adoption of the following classification, and even that the principal headings should be subdivided into first and second qualities, which would carry the numbers we may find it useful to employ for the sorting of the rags, before using them in the mill, as high as seventy or eighty.

Classification of Cut Rags.

THREAD, HEMP, AND FLAXEN RAGS.

1. Fine whites.
2. Fine whites, half worn, clean.
3. Whites, half fine.
4. Coarse whites.
5. Fine whites, soiled.
6. Whites, half fine, soiled.
7. Seams and hems, clean, fine, half fine.
8. " " soiled, coarse.
9. Ticking.
10. Drilling.
11. Thirds, new and clean.
12. " worn.
13. " containing some hemp.
14. " coarse.
15. " containing a large proportion of hemp.
16. White cord, twine.
17. Rope containing straw.
18. Tarred ropes.
19. Hemp wastings, oakum.
20. Leavings of rope-walks.

COTTON RAGS.

21. New whites, clean.
22. Half worn whites, clean.
23. Soiled whites.
24. Scorched whites.
25. Seams and hems.
26. White muslins.

27. Embroidered muslins.
28. Knit stockings.
29. Unbleached cotton checks.
30. " light colored.
31. " dark "
32. " blue "
33. " pink.
34. Cord and fringes.
35. Wasting from cotton mills.
36. " " the duster.

WHOLE OR MIXED WOOLLEN RAGS.

37. Yarn and wool.
38. White woollen.
39. Colored "

SILKS.

40. Silk.
41. Velvet.

PAPERS.

42. Clean white papers.
43. " colored "
44. Soiled papers.
45. Pasteboard parings, etc. etc.

Starting with this classification at the outset, it is evident that we shall not always have all the sorts enumerated. The mill only using cottons and thirds or white rags exclusively, will adopt a nomenclature corresponding to its appointments.

What we have desired to give is a general table of the different kinds of rags, which may be met with in a large paper-mill, working several machines, or using all the rags collected within a certain radius.

Many manufacturers reduce enormously the operation of cutting, on the ground that it is a very expensive one. This is a false principle. Careful cutting results in great purity of the pulp, economy in the use of chemical materials employed in boiling and bleaching, less wear to the blades of the cylinders and plates, less waste in the process of opening the threads, and finally the various manipulations of the pulp before its transformation into paper will be easier and surer.

When one of the cases is full, the work-woman takes its contents to the reviewing table, made of a metallic cloth of iron wire, and examines the rags to see whether they all belong to the same number.

The superintendent of the cutting-room (called in France mistress or picker of the rags) should attentively examine this last operation, and address comments to the women upon the style in which each has done her work.

Another plan is to have all the women bring the same number to the reviewing table at once, so as only to make one lot, which is then taken to the store-room for cut rags.

It seems well to employ this method for the rarer numbers. For the common sorts this is a bad plan. It hurries the women, and prevents them from making a thorough review and ascertaining if they may not have allowed some buttons, hooks, &c., to escape their attention.

Before being carried to the store-room the rags should be weighed, and the result entered upon the foreman's list for the day.

This is the only way to ascertain correctly the waste caused by the presence of an excess of moisture, or impurities of every description in the rags, or by threads detached in cutting and found afterwards among the sweepings.

To diminish the expense of manual labor, or when working women are scarce, special machines are used called rag-cutters. Their work, however, is always defective, and should not be employed in the manufacture of fine paper.

It would be better to have the buttons, hooks, seams, and hems taken off by the women who cut the rags into bands of two to four inches broad, and to employ men to recut them transversely; their greater muscular strength allowing them to cut through large bunches at one stroke.

Cutting machines are of the greatest use in severing large ropes. When this material is present only by accident, or in limited quantities, this work is done with the axe.

We shall return to the subject of the cutting machines when treating of the working stock of a paper-mill.

The operation of cutting by hand, we cannot too often repeat, is indispensable for a mill making fine papers. This work requires a special and constant superintendence, both by the foreman and the director of the mill, if he wishes to preserve the superiority of his paper.

§ 2. Dusting.

The operation of dusting consists in passing the cut rags through a cylindrical or conical drum having a rotary movement, the covering being of wire cloth, the threads of which are about one-fourth of an inch apart. The rags enter at one end, and are dragged out at the other, either by spokes arranged spirally upon the axle, or by iron points about six inches in length placed also spirally on in the inner surface of the drum.

By this double motion of rotation and transmission, the rags are dusted as though with a brush, and the impurities escape between the wires of the cage.

Dusting is commonly not performed until just as the rags are about to be used, that is to say, before boiling. It would be a good plan, however, to pass them through the machine before depositing them in the store-room.

When the rags are very impure and coarse, or full of straw or hemp, such as pack-cloths and ropes, a more powerful dusting machine is used called a devil. The principle of its movements is the same as the former, only the friction is more energetic. There is, as it were, a disintegration of the fibres which renders them more susceptible to the action of the lye.

The waste occasioned by the dusting machine varies with the fineness and pureness of the rags. We should also add according to the manner in which the cutting has been done. The use of badly sharpened knives tears the rags instead of cutting them clearly. This results in a loss from ravelling, which it is important to avoid.

The mean waste is:—

1.5	per cent. for	clean white rags;
2.5 to 3.6	" "	hems and seams;
4 to 5	" "	rags containing straw.

The waste of rags from cutting, overhauling, dusting, and the moisture they contain, may be estimated as follows:—

Whites, fine and half fine	6	to	9	per	cent.
" coarse	10	"	15	"	"
Cottons, white	6	"	10	"	"
" colored	10	"	13	"	"
Pack-cloths, and coarse threads containing straw	15	"	20	"	"
Ropes not of hemp	16	"	18	"	"
Hempen ropes containing much straw	18	"	22	"	"

All things equal, it is very evident that old rags produce more waste than new and unbleached ones.

§ 3. Washing and Boiling.

In some paper-mills, the rags are washed with water before going to the boiling apparatus. By this washing they are cleansed from a part of the dirt, and nearly all the gravel which may have escaped the duster.

For this purpose a washing drum is used, similar to the duster, immersed in water, or, still better, a large wooden cylinder furnished with 18 or 20 blades or paddles also of wood.

The water coming in at the lower part of the tub with considerable velocity, keeps the whole mass of liquid in agitation, so as to hold the rags constantly suspended in it, and takes the place of stirring by hand. The water charged with impurities runs off above through a strainer of wire gauze, preventing the passage of fibres which otherwise the current of water might carry off.

This simple and cheap operation very much facilitates the boiling, and also economizes part of the alkaline substances employed.

The object of boiling is not merely to cleanse the rags of any fatty matter they might contain, but also to decompose a particular substance, which may be called vegetable gluten, and which renders the fibres too stiff to be readily made into paper.

Formerly, boiling was done over a naked fire in stationary caldrons, but this method has been abandoned since the invention of steam rotating boilers.

This apparatus consists in a kind of caldron either spherical or cylindrical, and has a continuous rotatory motion imparted to it by a pinion or band-wheel. It may contain, according to its size, from a ton to a ton and a half of rags. These are introduced through a manhole, which is then hermetically sealed.

The alkaline matters employed are lime and soda; more rarely potash, the price of which is higher, at least in France. The action of these last two being exactly the same, the choice depends entirely upon their commercial value.

The amount of alkali contained in the sodas and potashes of commerce is very variable, and it is necessary that the manufacturer should determine the quality of these materials at each delivery.

Lime should be bought in the stone, as the powder absorbs more or less carbonic acid from the atmosphere, and in consequence is entirely inert in the process of boiling.

Some manufacturers make their own lime in a kiln of several bushels in capacity, and this example should be followed in localities where this material is badly prepared.

The quantity of the alkali necessary for a thorough boiling depends upon the cleanliness and nature of the rags, and upon the alkalimetrical degree of the agent employed.

Lime, as being the cheapest material, is generally used by the manufacturers, though a few prefer soda, while others make a mixture of both.

In mills which still make use of the stationary boiler, we advise the employment of soda, which, combining with the fatty substances, produces a soluble compound easily carried off by washing, whereas lime forms an insoluble calcareous soap, which cakes upon the rags.

With the rotating apparatus, as the materials are kept constantly agitated, boiling with lime is almost as effective as if soda were used altogether or in part.

If a mixture is made of soda and lime, M. Planche[1] recommends the following preparation:—

To 500 parts of moderately soiled rags, using carbonate of soda at 80° (Fr. alkalimeter) take 6 parts of soda and 3 parts of unslacked lime. Dissolve the lime by sprinkling it with a little water and then mix with the soda. Boil the whole three or four hours in 60, or, still better, 100 parts of water.

By boiling there is formed a precipitate of the carbonate of lime, and the carbonate of soda becomes caustic soda, which increases its action on the matter contained in the rags.

Too weak a lye leaves behind a part of the substances it is proposed to eliminate; if too strong, it injures the tenacity of the fibres and the eventual waste is greater. It is better, however, to have it too strong than too weak.

There are two schools among manufacturers, in regard to the method of boiling. One prefers a low pressure of steam and a long duration of the process; the other admits that a high pressure and rapidity of operation offer great advantages.

We, ourselves, think it would be more correct to say that steam at a high pressure will allow the amount of alkali employed to be diminished. Indeed, the organic

[1] "De l'Industrié du papier."

matters contained in rags are decomposed the more readily as the temperature is raised; now every one knows that the temperature of steam increases with the pressure.

	Centigrade.	Fahrenheit.
1 atmosphere	100°	212°
2 "	121°	249.8°
3 "	135°	275°
4 "	145°	293°
5 "	153°	307.4°

We ought to add that for coarse and hard rags, it is well to use a high pressure and to continue the boiling for a long time; for clean and fine rags, a moderate pressure does less harm to the fibres.

A good plan for coarse and dirty rags is to boil them a second time. At first only half the lye is poured in, then at the end of six hours, and after a thorough washing, which carries off the greater part of the coloring matter, the other half of the soda or lime is added.

The rags thus prepared are softer and cleaner after the boiling is completed; their disintegration is more rapid and the bleaching easier.

The proportion of alkali required in boiling 100 parts of rags varies from 0.6 part to 5 and 6 parts of soda and from 2 to 10 and 12 parts of unslacked lime.

The quantity of lime varies according to its composition, and for the soda, its alkaline value determines the quantity to be employed for each kind of rag.

Any excess of alkali may be recognized if after the boiling litmus paper reddened by an acid is turned blue.

In former times rotting took the place of the boiling process. The rags, wet and heaped together, were allowed to remain for a longer or a shorter interval, during which a fermentation was set up which was manifested by the increased temperature of the mass and the development of a cryptogamic vegetation. The rags assumed a peculiar color, reminding one of the dregs of wine.

This method, unprofitable in every light, occasioned great waste, and could only be employed where paper was made by hand, and the daily consumption small.

M. L. Piette[1] has made some experiments which allow us to appreciate the superiority of the boiling process over that of rotting or fermentation.

The experiments were conducted by the two methods concurrently with a thousand kilogrammes of rags each.

[1] Manuel du fabricant de papier.

FERMENTED RAGS.

Denomination of the rags.	Weight of the crude rags.		Loss by cutting and dusting.		Remaining.		Duration of fermentation.	Weight of the material washed and dried.		Loss by fermentation.	
	French kilog.	English lbs.	Fren'h kilog.	English lbs.	Fren'h kilog.	English lbs.	Days.	Fren'h kilog.	English lbs.	Fren'h kilog.	English lbs.
Whites, fine	1000	2204.73	60	132.28	940	2072.44	6	720	1587.40	220	485.03
Whites, half fine	1000	2204.73	80	176.37	920	2028.35	12	660	1455.12	240	521.75
Grays, coarse	1000	2204.73	100	220.47	900	1984.26	24	400	881.89	500	1102.36
Colored, fine	1000	2204.73	60	132.28	940	2072.44	8	580	1278.73	360	793.70
Colored, coarse	1000	2204.73	80	176.37	920	2028.35	15	500	1102.36	420	903.93

BOILED RAGS.

Denomination of the rags.	Weight of the crude rags.		Loss from cutting and dusting.		Remaining.		Pressure, one atmosphere.	Weight of material dried and bleached.		Loss by boiling.		Differential gain over fermentation.	
	French kilog.	English lbs.	Fren'h kilog.	English lbs.	Fren'h kilog.	English lbs.	Hours.	Fren'h kilog.	English lbs.	Fren'h kilog.	English lbs.	Fren'h kilog.	English lbs.
Whites, fine .	1000	2204.73	60	132.28	940	2072.44	5	780	1719.68	160	352.75	60	132.28
Whites, ½ fine	1000	2204.73	80	176.37	920	2028.35	6	730	1609.45	190	418.89	70	154.33
Grays, coarse	1000	2204.73	100	220.47	900	1984.26	12	580	1278.73	320	705.51	180	396.84
Colored, fine .	1000	2204.73	60	132.28	940	2072.26	6	700	1543.31	240	529.12	120	264.56
Colored, coarse	1000	2204.73	80	176.37	920	2028.75	8	630	1388.98	290	639.36	130	286.61

This table allows us to draw the following conclusions:—

1st. The loss either from fermentation or from boiling varies according to the coarseness of the rags.

2d. By boiling we may obtain twelve times as great a product, in the same interval of time, supposing the work to be carried on by day only, and twenty-four times as great if it is kept up continuously.

3d. The comparative profit from the use of boiling instead of fermentation may amount to twenty per cent. of the weight of the rags.

According to experiments made in Germany, the advantage of the rotating boilers over those that are stationary, would be quite as great as that of boiling itself over fermentation.

Differential Results.

Boiling at 100° C. (212° Fah.) at the pressure of the atmosphere, it took:—

For 100 kilog. (220.04 lbs. avoird.) of strong gray rags
300 " (661.42 " ") of lime.
12 hours boiling.
640 kilog. (1410.92 lbs. avoird.) of coal.

Rotating boilers at 121° C. (251.8° F.):—

150 kilog. (330.69 lbs.) of lime.
4 hours boiling.
400 kilog. (881.89 lbs.) of coal.

Results.

Economy of lime 50 per cent.
" time 67 " "
" fuel 38 " "

To complete this experiment the boiling should have been done with soda, lime being very inferior in this case, as we have before had occasion to observe.

§ 4. Reduction to Half Stuff.

When the boiling process is finished, the rags are carried in boxes to the rag engines to be reduced to half stuff. These boxes are generally conveyed by means of a car running on an iron track. They are large enough to require but one or two for each lot.

This engine may be fed in two ways:—

1st. The foreman's assistants throw the whole contents of the boxes into the tank at once, and when the surface of the water reaches the level of the plate the foreman pushes the rags with a stirrer until they are caught by the cylinder. This should be raised a little, as some breakage might occur from too great a mass of rags passing under the roller at once, and, at any rate, the jarring would tend to wear out the machinery and generally obstruct the passage of the rags.

As soon as the whole mass of rags is suspended in the water, which rises to within a few inches of the upper edge of the tank, the workman lowers the cylinder, and the rags are subjected to a rapid friction, which very much facilitates the removal of dirt and other impurities. The water at once becomes muddy, and covered with a thick foam.

2d. The second plan requires that the tank should be two-thirds filled with water. The workman then takes the rags by handfuls, and thus gradually throws them into the tank. The quantity of rags presenting at one time being in this case diminished, there need be no fear of the accidents previously alluded to, and the cylinder should be at once lowered towards the plate.

The work is not quite so rapidly done as in the former instance, but less need be feared from the carelessness of workmen. It also gives us an opportunity of detecting any foreign bodies, such as stones, nails, buttons, etc., accidentally or maliciously mixed with the rags, and whose presence might disable the blades of the plate or cylinder.

The dirty water runs off by the strainers and washing drums; as soon as the water grows clean the foreman lowers the cylinder upon the plate so as completely to disintegrate the rags, which gradually lose their textile appearance, and take on, as it were, that of a very fine, long-fibred lint saturated with water. This substance is more or less white, according to the nature of the rags from which it is made.

The duration of the reduction varies according to the dimensions of the tank, the weight of the cylinder, the number of its revolutions per minute, the extent to which its blades and those of the plate are worn, the amount and purity of the water used in washing, the nature of the rags, and the skill of the workman who directs the operation.

In mills where the number of these engines is limited, the process of reduction has to be hastened, but it is always at the expense of the quality of the product. It takes from two to three hours for the work to be well done.

It is well to observe that if the pulp is to be bleached with chlorine gas, the reduction should be kept up longer than if liquid chlorine is to be used, in which case, if five hours can be given to the operation, the rags will be more thoroughly washed, and the pulp all the better.

M. Planche recommends, and we fully agree with him, that the engines should be arranged in two stories. The upper one, in which the preliminary washing is to take place, is furnished with strainers and washing-drums of coarser wire cloth, which allows a very rapid transmission of water. The lower cylinders receive the material, after the washing is nearly finished, and continue the reduction, thus rendering it more complete.

In a manufactory of fine papers, the increase of manual labor, and of the duration of the operation occasioned is more than compensated by the greater purity of the resulting product.

In localities where the water is impure and filtering expensive, these last-named engines might be alone supplied with clarified water.

During the entire process the workman should thoroughly stir the material and see that it be kept homogeneous by bringing it constantly to the surface, without which it runs great danger of being but imperfectly reduced.

An easy mechanical means of keeping up a continuous stirring is to let in the water at the lower part of the tank, so that through the velocity of its passage produced by pressure it may keep the contents constantly agitated.

When the reduction is complete the foreman raises the discharge plug, and the half stuff runs off, either into the drainage boxes, or directly into the bleaching cisterns, if liquid chlorine be employed.

Some manufacturers bleach in the rag engine itself; but this is a bad plan. The reducing process has to be suspended for a time, and this obliges us to have several engines. Moreover, the tanks are usually metallic, and will be more or less corroded by the chlorine and sulphuric acid which are used to disengage the bleaching agent. This remark applies still more to the blades of the cylinder and the plate which are not preserved as is the interior of the tank by a coat of paint. Before letting down the plug the workman throws a few buckets of water under the cylinder in order to carry off any of the half stuff remaining attached to the inclined planes. When the engine is completely raised, it is ready for the reduction of a new lot.

It is well to keep a daily register in the engine-rooms, in which the time of commencing and completing each operation may be set down. This register is important, especially for night work, when the superintendence is less regular than in the daytime.

In a well-regulated mill the water used in washing is collected in large stone cisterns, where the materials carried off are allowed to settle. The fibrous particles are then employed in the manufacture of boards and packing papers, and the residue, consisting of alkaline and fatty matters, may be made useful as manure.

Waste occasioned by washing, boiling, and reduction to half stuff:—

Whites, fine, half fine	7 to 10 per cent.
" coarse	9 " 13 " "
Cottons, white	7 " 9 " "
" colored	8 " 14 " "
Thirds and pack-cloths	18 " 26 " "
Ropes	20 " 25 " "
" tarred and containing much straw	20 " 35 " "

It will be readily understood that these figure can only be taken as approximate averages.

§ 5. Drainage.

After the reduction of the rags to half stuff, it is indispensable that the pulp should be subjected to a drainage, in order to render it more permeable to the chlorine gas, if that agent is to be used in bleaching.

The most simple means of effecting this is the natural drainage carried on in large, oblong, rectangular reservoirs of wood, stone, or cemented bricks, having a floor of wire cloth or porous bricks of peculiar make.

When a lot of the half stuff is ready, the foreman raises the discharge plug, as we have already said, and the pulp runs off through copper pipes to be conveyed to the reservoirs.

At the end of two or three days for soft cotton rags, five or six for those of linen, and eight or ten for harder kinds, the material loses the greater part of its water, and becomes spongy. The drainage may be considered sufficient when no water can be squeezed out of the pulp by pressing it between the fingers.

It is well to facilitate the drainage of the harder pulps by placing a layer of soft pulp at the bottom of the reservoirs, which thus serves, so to speak, as a filter at the same time that it sucks in the water from the layer above.

It being impossible to adopt this natural drainage in mills where space is wanting to set up a sufficient number of reservoirs, means have been sought to produce it artificially.

Three kinds of apparatus are employed:—

1st. Screw and hydraulic processes. By means of a square case, or, still better, a round tub, the sides of which are pierced with holes over their entire surface, and with a cover moving with the press and piston, cakes of compact half stuff are made containing the product of one operation of the engine.

This cake is afterwards torn into shreds with iron picks similar to those used in farming.

This system is attended with many inconveniences; the fibres become so adherent to each other, in consequence of the pressure, that unless the picking to pieces is very carefully managed, the interior parts are so compact as to be only imperfectly bleached.

2d. The Lamothe-Ferrand drainer consists of a simplified miniature paper-machine, with a fine wire gauze, on which the half stuff is made into a kind of moist board, and formed into rolls of different size. These rolls are then placed on end upon the bleaching cases.

This apparatus presents the same inconveniences as the hydraulic press, although in a less degree. Nevertheless it has rendered, and continues to render, great service in mills manufacturing the common kinds of paper.

For fine and superfine papers we recommend either the natural drainage or the use of the following machine.

3d. Turbine drainer acting by centrifugal force (Fr. essoreuse).

This apparatus, similar to that now so widely used for drying linen and draining sugar-loaves, produces a half stuff, which has the greatest analogy to that obtained by natural drainage. Aften ten or fifteen minutes' rotation the pulp becomes spongy, and may at once be carried to the bleachers.

The application of this machine to the work of a paper-mill is due to M. Rieder, of Rixheim.

§ 6. Bleaching.

Before the discovery of the discoloring chlorides and of chlorine gas, only choice rags could be employed for the manufacture of fine papers; at the present day, thanks to the use of this agent, the deepest colored cotton rags and the commonest and coarser, such as thirds, ropes, and pack-cloths, can be transformed into white paper.

There are two methods of bleaching; either with liquid chlorine, or with chlorine gas. Some manufacturers employ the two conjointly.

Liquid chlorine, the abbreviation for a solution of the hypochlorite of lime ($CaO,ClO+CaCl$) in water, is usually prepared in great wooden cisterns lined with lead or painted with a double coat of white lead. The chloride is ground up with two or three parts of water; this is allowed to rest for a moment, and then the supernatant liquid is decanted into the cistern. Where this has been repeated three or four times the soluble chlorinated portion will have been completely carried off. A residuum remains consisting of sand, carbonate of lime, &c., which may be thrown away.

The final concentration of the liquid is such that one kilogramme (220 lbs.) of chloride of lime will produce, according to its richness in chlorine, from eight to twelve litres (from 1.76 to 2.64 gallons) of the liquid.

To keep a mill constantly going there should be at least two cisterns, one which serves for the day's work, another which the workman prepares for the day following, and if there is room enough, the use of three in rotation would be preferable, allowing the liquid of the intermediate cistern to rest twenty-four hours.

The quantity of the chloride used varies according to the nature of the rags; 2 to 2.5 per cent. for white rags, while others, on the contrary, require 7, 8, or 10 per cent. For these last, chlorine gas is more economical, and therefore preferable.

Bleaching is performed in the rag engine itself, or in separate wooden bleaching vats, from five to eight metres (16.40 to 19.68 ft.) long, and from 2.50 metres (8.20 ft.)

broad, and 0.90 to 1.00 metre (2.95 to 3.28 ft.) deep, and able to contain from 300 to 600 kilog. (661.42 to 1322.84 lbs. avoird.) of half stuff.

When the bleaching vat is filled, the chlorine bath is added. Through the agitation produced by the movement of the cylinder, and by vigorous stirring, the hypochlorite is decomposed by the carbonic acid contained in the water, and pervading the atmosphere. The carbonate of lime is formed, and the chlorine passes into the condition of hydrochloric acid.

It is not exactly understood how the discoloration of the pulp is effected in this last chemical reaction; but it is certain that hydrogen in its nascent state produces the phenomenon of bleaching. The chlorine only acts by its transformation into hydrochloric acid.

When we consider the small amount of carbonic acid contained in the atmosphere, only from $\frac{4}{10000}$ to $\frac{6}{10000}$, we can understand the slowness of the bleaching operation.

To facilitate the disengagement of the chlorine, sulphuric acid is generally employed. The liberation of the gas is almost instantaneous, and a suffocating odor is diffused around the vat.

Instead of pouring in sulphuric acid of the ordinary strength, it is better to dilute it with ten to twenty times its own weight of water.

If the pulp is not to be used at once, it is returned to the draining reservoirs or chests.

To reduce the number of these chests, which ought not to be less than three, the half stuff is removed after twelve hours' rest to the vault where the pulps are kept. This store-room should be vaulted, paved, and cemented with great care, and should slope gradually towards a drain which will carry off all the water.

In order to avoid confusion, it is important that each lot should bear a label describing its quality.

Sometimes the pulps are bleached a second time to obtain a whiter product.

M. Planche recommends the following process, which he has employed for many years:—

The bleaching tub once filled, he allows the water to drain off, and be replaced by a bath of liquid chlorine. After producing its effect, the chlorinated liquid descends into a lower reservoir, and is succeeded by an acid bath (sulphuric acid). While the chemical action is going on, the chlorine water is carried up to its original reservoir, where a workman, especially designated for that duty, adds to it a quantity of fresh chlorides, so as to keep the strength of the liquid uniformly the same. The strength of the acidulated bath is renewed in the same manner. When this operation has been repeated two, three, or four times, the half stuff acquires a brilliant whiteness.

This method, though rational enough in principle, has the objection of being complicated. I would not recommend it in a mill where the pulps to be bleached are variable. It is difficult to secure a chlorine bath of the same strength at all times. The workman is allowed too much control of the process, as he has neither the instruments nor the instruction necessary to make an accurate estimate.

This process, modified in the following manner, is more practicable. A determined volume of chlorinated liquid is let into the tank, and after a certain interval the requisite quantity of the acid is added. When the chemical action has taken place, the greater part of the bath is allowed to run off, and considered as lost. A fresh supply of the chloride is let in, which manifests its chemical action at the expense of the small proportion of acid remaining. When the bleaching is completed this last bath is used, as a vehicle to effect the solution of the original amount of the powdered chloride.

The degree of concentration being the same, the reaction will naturally be more energetic as the volume employed is increased. It will then be sufficient to give the workman for each bath the amount of the chloride indicated on the foreman's list for the bleaching room.

After the second bath has run off the pulp must be freed by washing out the chlorine it contains, whose slow but continuous action would disintegrate the fibres, and end by affecting their strength.

If these washings are not carefully done it sometimes happens that the papers stored in warehouses exhale an odor of chlorine, and lose their whiteness little by little, until they become quite yellowish.

Some manufacturers pursue a different course. The half stuff is bleached to the required point, the contents of the vat are then let down into the drainage chests, and after from twelve to sixteen hours' delay are laid away in the stone vault. The bleaching continues, and the washing does not take place until the pulp reaches the beating or refining engine.

The product is whiter, but the loss of substance is greater by this method. When the washing is done in the bleaching apparatus, it is well to facilitate the operation by adding a small proportion of the hyposulphite of soda, known in paper-making as antichlorine.

By the addition of this substance there are formed sulphate of soda, chloride of sodium (common salt), and hydrochloric acid. It is, therefore, indispensable to continue the washing, in order to eliminate these new products, fortunately all very soluble.

The chloride of lime is generally bought already prepared. Nevertheless, in a large mill, it may be advantageous to make it ourselves. We give, further on, the method to be pursued in its preparation.

Chlorine gas being less expensive, and its action more energetic, and therefore better suited to the coarser and more strongly colored rags than the chloride of lime, most manufacturers employ it in profusion.

Chlorine gas is made by means, either of sulphuric or hydrochloric acid. The relative cost of these two acids determines which should be employed.

Bertholet, to whom we owe the application of this substance to bleaching stuffs and pulps, made use of the following proportions:—

0.370	parts of	peroxide of manganese,
1.000	"	common salt,
0.740	"	ordinary sulphuric acid of commerce,
0.740	"	water.

We now adopt:—

1	part	manganese,
½ to 2	parts	common salt,
2	"	sulphuric acid,
2	"	water.

In the preparation of this gas with hydrochloric acid, 1 part of manganese and 3 parts of the acid are alone used.

These figures are not absolute; they depend entirely upon the composition of the manganese and the strength of the acids.

Chlorine is generally prepared in especially adapted retorts, into which the manganese and the acid are conveyed by an S shaped tube. It is best to have the manganese in the lump and not in powder, as the action of the acid on the latter is more tardy, and agitation is necessary to effect a mixture of the two substances:

When sulphuric acid is used the acid must be first mixed with the water, and the manganese with the salt as much as possible. The acid is poured in by degrees; the gas is generated, and the whole is heated to 100° C. (212 Fahr.), requiring ten or fourteen hours for the operation.

The gas in escaping always carries with it a small proportion of hydrochloric acid, of which it is important to free it before conducting it into the bleaching chests or chambers, as the acid injures the toughness of the pulp-fibres.

Two means are adopted to attain this object:—

The first consists in leading the pipe which conveys the gas into a receiver containing a little water. The pipe only dips a few lines below the surface, in order that the height of the column of liquid may not exercise a sensible pressure in opposition to the escape of the gas. The bubbles of gas give up their particles of hydrochloric acid at the contact of the water which mechanically washes them away.

By the second method, a retort containing pieces of manganese is employed. These retain the hydrochloric acid, and liberate a proportionate amount of chlorine. After each operation, the resulting chloride of manganese is drawn off by a small stopcock, and when the manganese becomes exhausted it is replenished, by a supply of fresh material.

The purified gas is conveyed into the chambers by means of large leaden pipes. The chambers should be hermetically closed by pasting strips of paper along the door cracks.

The chambers are filled with half-stuff in different ways:—

If the Lamothe-Ferrand drainer is used, the rolls are first placed side by side, and then one above the other, so as to form two stories. The half stuff obtained by other methods is thrown in just as it is or in little blocks, without packing, so that the gas may be allowed to circulate through it more freely.

In some paper-mills it is placed on boards arranged in stories 0.60 metres (23.58 inches).

It should be observed, that boards with sawed edges are not to be used if it can be helped; the cells of the woody fibre are quickly attacked by the chlorine at the points where they are torn through, and peel off very easily, causing an impurity in the pulp, which should be avoided, when working in fine papers.

The proportion of chlorine employed varies according to the nature of the rags:—

For 100 parts of white rags there are usually taken,
15 parts of hydrochloric acid,
5 parts of manganese.
For commoner rags,
21 parts of acid,
20 parts of manganese.

We advise every manufacturer to have a small test box containing perhaps 20 kilog. (44.09 lbs. avoid.) of dry pulp, and to examine the effect of the chlorine, by gradually increasing its quantity.

The escape of chlorine may be surmised from its peculiar odor, and it is readily detected by holding a small uncorked vial of ammonia near the suspected leak. If the chlorine is escaping, white clouds of the chloride of ammonium will appear at once.

When the bleaching is thought to be accomplished, the doors are opened, and as soon as the workmen can bear the odor of chlorine mixed with air, the half stuff is carried off.

Some manufacturers bleach their stuffs with chlorine gas, and then with the liquid chlorine in order to give them a greater brilliancy. This also allows us to employ a smaller proportion of the gas, and lessens the danger of an excessive action upon the fibres.

When the half stuff leaves the bleaching chests, it is carried to the stone-vault, from which it is removed as needed.

Numerous attempts have been made to bleach by electricity. The various kinds of apparatus proposed are all based upon the following principle: By a current of electricity, water is decomposed into its constituent elements, oxygen and hydrogen. This latter substance, in its nascent state, serves as the bleaching agent. Thus far, the results of this mode of bleaching have been so uncertain that we need only mention it in order to record the suggestion.

The waste from bleaching varies:—

The fine rags from 1.5 to 3.5 per cent.

The coarse rags and thirds from 2.8 to 7.5 per cent.

The following extract on the subject of bleaching is made from the works of M. L. S. Le Normand.[1]

The rags which are used in paper making are bleached by the action of chlorine, in much the same way as cloths, with some modifications, however, as will be seen farther on. We borrow from the *Dictionnaire Technologique* the two articles furnished by the learned M. Robiquet on this subject, so important to the paper manufacturer.

[1] Nouveau manuel complet du fabricant de papier, ou de l'art de la papeterie.

"The Bleaching of Cloths."

"Ever since the art of making cloths has been known, the art of bleaching them has also been understood. It was universally known that by exposing raw flax and hemp to the simultaneous action of water and sunlight the coloring matter with which they are naturally invested could be made to disappear. In all ages attempts have been made to explain this singular phenomenon, but as long as the nature of light remains undiscovered, nothing but what is vague and uncertain can be said upon the subject.

"The bleaching of cloths may be effected, as I have just said, by the combined action of light and moisture alone; but then this requires a long time, which has been greatly shortened, by the employment of some other agents, and especially acids and alkalies. Long before the discovery of chlorine, cloths were perfectly well bleached.

"Flanders and Holland were the first and principal countries in which this art received its most important improvements. Since that time the process has been generally perfected, and now an equal amount of success is obtained everywhere.

"In bleaching cloths, there are some preliminary operations which belong to all processes alike. Cloths of the same grain and the same shade, should first be sorted, so that the changes which are to take place may do so for each in an equal interval of time. Otherwise some will be scarcely attacked, while others will be already too much so. A second operation is that which consists in freeing them from foreign substances with which they have been impregnated to facilitate weaving. This kind of sizing or dressing, with which the texture is covered during its manufacture, would offer an obstacle to the absorbing power of the threads, and the influence of external agents. This dressing, then, must first of all be destroyed, but destroyed by some means which will not be able to attack the vegetable fibre. This is usually done by a sort of well-managed fermentation; the operation requires great experience, and the following is the method to be employed.

"The cloth is first doubled into equal folds, then it is placed in the vat in layers, upon each of which, as they are arranged, a few buckets of tepid river water are thrown. If the cloths are but slightly charged with mucilage, a small proportion of bran or rye meal is added, to expedite the fermentation.[1] If otherwise, this addition is dispensed with. When the vat is full, it is covered over, and very often weights are placed upon the cloths, so that they may not be raised during the process of fermentation, which is developed in a few hours, and whose progress is the more rapid, as the prevailing temperature is raised. The establishment of fermentation may be recognized, by the scum which is seen to form, and especially the bubbles of gas which burst upon the surface of the liquid. When the fermentation is completed, this disengagement of gas ceases, and the scum disappears. It is at this stage that the cloths are to be removed and washed; this is usually at the end of twenty-four, thirty, or thirty-six hours, according to the rapidity of the fermentation, as also the fineness of the cloths. The exact moment to be seized, experience alone can teach. If the proper point is passed, there will be danger of losing the whole; a few moments will often

[1] M. Clément thinks it would be better to add molasses, in order not to use anything which might contribute to a putrid fermentation.

suffice for putrid fermentation to set in, and destroy the stuffs. It does not appear that any author has sought to determine what kind of fermentation is produced on this occasion, and how it acts upon the cloths. All that is known is, that the gas which is disengaged is inflammable, and that a certain quantity of acid is generated which afterwards disappears. Thus the same phenomena are observed in this case as those which are produced by the destruction of gluten in the preparation of starch. It is not therefore likely that this is an alcoholic fermentation, and that molasses would be of any use. The fermentation is not alone intended to destroy the dressing; it is likewise necessary that the pores of the cloth should be opened, that water should penetrate them somewhat, and that the foreign substances which are deposited in them should be attained and easily removed. However this may be, the cloths should be washed with the greatest care immediately after they have been subjected to maceration. In this manner a great deal of dirt, which differs essentially from the coloring matter, and which, not being soluble in the same agents, presents great obstacles to the bleaching, especially of fine muslins, lawns, and thread laces, is abstracted.

"The washing or cleansing is performed in different ways: two wooden rollers are often used, between which the cloth is made to pass; these rollers ought to be covered, and arranged over a current of water; the inferior roller is smooth, the upper one grooved; sometimes the grooves are far apart and irregular; generally a certain number of these rollers are placed one after the other. After the piece of cloth has passed through the first two, and has fallen into the water, it is taken up, passed between the next two, and so on.

"In many factories, they use a circular platform revolving on its axis, the circumference of which is sustained by rollers, in a manner similar to that used for the roof of a wind-mill. A workman places the cloths to be beaten on the platform; a crank adapted to a paddle-wheel causes the platform to turn slowly, and in such a way that all the pieces pass in regular succession under a certain number of beaters set in motion by the axle of the same wheel. The workman turns the cloths so as to present each surface to the beaters, and a current of water, kept up by the paddle-wheel, flows incessantly over the cloths, and carries off all heterogeneous and soluble substances.

"For some years, the preference seems to have been given to a washing-machine successfully used in England, and called dark-wheel; it is a kind of barrel or drum which is turned upon its axis by means of a crank, and having its interior divided by four partitions which intersect at right angles. Each of these partitions corresponds with an opening made in one of the ends. A pipe which communicates with a reservoir, and terminated by a stopcock, throws into the opposite end a stream of water which enters by a circular opening. Two pieces of cloth are thrown in by each of the four holes which correspond with the divisions; the machine is put in motion by almost any power, and the stopcock is then opened. At each revolution, the pieces of cloth fall from one partition to another, and a large part of the water they have absorbed is thrown out by the force of the great pressure which their fall occasions. When this machine is well managed, eight pieces of cloth can be perfectly beaten and cleansed in a quarter of an hour; but the best success will be obtained by giving it a mean velocity of twenty to twenty-two revolutions a minute. If the machine were more rapidly turned, the cloths would remain attached to the circumference where they would be thrown by the centrifugal force, would be kept always impregnated with the same water, and, consequently, would not be cleaned. In England, this machine has been substituted for all those we have mentioned, not only because it offers an economy in point of time, but also because it has not, like the others, the serious inconvenience of impoverishing the texture by the continual friction to which it is subjected by the other methods. The *dark wheel* is beginning to be used in France.

"It is where the cloths have been completely relieved of their dressing, and of everything which is foreign to them, that they are subjected to bleaching, to carry off the coloring materials.[1] It was thought that the successive use of chlorine and lyes would be sufficient for bleaching purposes; but experience has shown that nothing can take the place of the action of light, especially for linen cloths; and we have been obliged to return to it. The method of bleaching actually employed does not differ from the Dutch system except in the additional use of chlorine, which allows us to greatly accelerate the general progress of the operation. Thus, in bleaching cloths, they are generally subjected to the alternate action of lyes, sunlight, chlorine, and acids. These processes are very numerous, because each one of them is repeated several times.

"Chlorine and sunlight appear to act in the same gene-

[1] According to M. Welter, the difference between washing and bleaching cannot be too much insisted on. They are two entirely different things, and the first is generally much more difficult than the latter. There are even certain cloths, and especially those of Flanders, which only need to be cleansed; so that there is no necessity for the use of chlorine in bleaching them.

ral way, but probably by different means; chlorine does not limit its action, as was supposed, to changing the nature of the coloring matter, but in abstracting its hydrogen it combines with it; and the employment of alkalies is useful to dissolve not only that part of the coloring matter which has undergone the action of the chlorine, but also the chlorine itself which may have become fixed. As to light, all that is known of its action, is that it *predisposes* the coloring matters to combine with oxygen, and that this combination is singularly favored by keeping the cloth wet.

"It is possible, as some authors pretend, that light only acts in this case as might a high temperature, which would determine such a reaction among the elements, that new compounds would result possessing different qualities. Now it is well known that nothing favors chemical reaction so much as the conjoined effects of heat and moisture. It is quite commonly believed that the coloring matter in becoming oxygenated, is converted into a true acid, and that it is especially to carry off this acid that alkalies are necessary. As to the degree of usefulness which acids attain in bleaching, experience will not allow us to admit a doubt, and it seems well proved that their principal function is to carry off the calcareous carbonate produced by the action of the alkali on the salts contained in the water, and deposited upon the fibres of the cloth; to remove that portion of the alkali which may have become fixed in the tissue, and in addition to dissolve certain metallic oxides, and especially that of iron, which is found to form a part of the vegetable material and which soils it."

We will not go further in this quotation of M. Robiquet's article on the *Bleaching of Cloths;* all that follows is, without doubt, very useful for cloths, but would be superflous in treating of rags. We should not even have introduced here the extract which has just been read, if in his article on bleaching paper pulps, the same author had not referred to his article on the *Bleaching of Cloths.* The extract which follows is also borrowed from the *Dictionnaire Technologique*, and belongs to the same author, M. Robiquet.

"*The Bleaching of Paper Pulp.*—It is sufficient to know what kind of material is used in making paper, to understand that the method of bleaching by chlorine may be adapted to it with great advantage. Out of the enormous quantity of rags employed in this manufacture, there is only a very small portion which can immediately furnish white paper; all the rest, by following the old method, can only serve for the manufacture of papers of inferior quality, unless bleaching is practised, as it is now in a great number of paper-mills. This innovation, generally adopted in England, is much less widely employed in France, and this is owing to that sort of inertia which is so injurious to the progress of the arts, and perhaps also to a want of instruction. Nevertheless we see the difficulties being daily removed; and now that the manufacturers of chemical materials can reduce the chloride of lime to a very moderate price, everything leads us to think that we shall not leave our neighbors the sole possession of this very important improvement. Let us hope that before long we shall not be tributary to the foreign market for the papers of superior quality with which we still continue to be furnished.

"Loisel is one of those who has busied himself with great success in this kind of research. He has set before us, in an article which may be found incorporated in vol. 39 of the *Annales de Chimie*, all the principal results, which he has obtained in this respect. We see that the same reasons which led to the rejection of pure chlorine in the bleaching establishments for cloths and threads, have equally opposed themselves to its use in the bleaching of rags. Thus at a time when it was thought that a small quantity of alkali injured the bleaching qualities of chlorine, Loisel proposed to receive oxygenated muriatic acid into a solution of one hundred kilogrammes (220.47 lbs. avoird.) of potassa in one hundred litres (22.01 gallons) of water. It is with this liquid that he was enabled to give the rags the most brilliant whiteness; but he observed, as we have already done in regard to cloths, that the first immersions only acted superficially, and, to avoid repeating them a great number of times, it was better not to operate upon the pulp as it is ready to be worked up into paper, for at that time it is too coherent and compact to allow itself to be easily permeated, but upon the rags as simply reduced to half stuff in a preliminary engine, which suffices to open the fibres and destroy the texture.

"For motives of economy, a simple solution of chloride of lime has been substituted for this bleaching fluid proposed by Loisel; and we believe that we need not here repeat that the proportion of the chloride must be modified according to the quality of the rags upon which the action is to take place. Experience alone can guide us on this subject. It is, however, to be supposed that the necessary preliminary precaution of sorting the different kinds of rags, and bleaching those of the same quality together has been observed. I shall say nothing here of the choice which should be made, according to the kind of paper that we wish to manufacture, as I am only concerning myself now with what relates to bleaching. We have seen in the article on the bleaching of cloth, which precedes this, that the employment of chlorine did not allow

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us to dispense with the use of lyes and the immersions in the acid baths. It is certain that the same thing ought to be true in regard to rags, and that it is essential to proceed in the same manner. Nevertheless in those manufactures for which the rotting method is still in use, it is possible, by prudently combining this process with that of bleaching, to do away with the greater part of these successive immersions, because in this case the coloring matter undergoes a commencement of decomposition, which renders it much more easy to eliminate. A single boiling in lye, two baths of the chloride, and one of acidulated water,[1] generally are sufficient to bleach rags and even ropes.

"The advantages of bleaching are too evident to need setting forth: it cannot be pretended that it occasions great cost, on the contrary, it would be easy to show that it is economical if it were only by furnishing means of making a much larger quantity of fine papers with the same sort of rags and in a much less time.

"I will finish this article by inviting paper manufacturers to give this subject more study than they have hitherto done, and by assuring them that they will find themselves amply compensated for their trouble."

§ 7. Composition of the Pulp.

The composition of the pulp, or the relative proportion of each grade, the combination of which is to supply the refining or beating engine, is one of the most delicate operations of paper-making. It particularly concerns the superintendent of the mill, who alone can and ought to decide in the matter.

[1] Loisel directs us to employ three kilogrammes (6.61 lbs. avoird.) of sulphuric acid at 50° to two hundred litres (44.02 galls.) of water.

Papers are usually made upon orders for a certain pattern, and it is important to impart to them the qualities required, although it must be admitted that they are not always compatible. It is for the manufacturer to appreciate the practical value of these conditions, and to then regulate the general work of the mill accordingly.

Taking a certain theoretical composition for his pulp, he must see whether the price to which the paper will come is not too high.

The superintendent ought, therefore, to have in his mind, or near at hand, everything necessary for his information; the cost of the raw materials, and the expense of cutting, boiling, bleaching, sizing, and coloring. He should also see whether the supply will allow him to employ a certain grade in preference to another.

When these various points have been settled, he must foresee the difficulties that may be met with in making the paper by machinery. If the paper is to be glazed or satined, will such and such a material not be apt to introduce too many lumps and gravels into the pulp, and will not this result in wearing out the zincs and felts too rapidly?

It is in the matter of the composition of pulps that the knowledge of the manufacturer is displayed. Before settling the question he must indeed have gone over all those involved in the art of paper-making. It generally requires but a few minutes' reflection for one who thoroughly understands the capabilities of his mill.

We will try and give some general ideas on this subject.

1st. White linen and cotton rags should mainly enter into the composition of white papers.

2d. Foreign paper requires new wiry materials, giving it a crackle and great toughness. For the superior qualities linen is used; for the others fine thirds and untarred ropes, well boiled and bleached.

3d. Fine demy post also requires the use of rags but little worn and white cottons; for the inferior kinds, clean hems and seams, fine thirds, and bleached cotton checks.

4th. The more elegant printing papers particularly demand well-worn white rags, and clean white cottons, and sometimes a slight addition of unworn material to give them more firmness.

5th. The common printing papers are made of coarse thirds, ropes, and especially colored cottons.

6th. Papers for engraving need a larger proportion of cotton to render them softer and more *sensitive*, as it is called among engravers. They will also bear a larger proportion of kaolin; but this substance should not be made use of till it has been thoroughly cleansed of the silicious particles it almost always contains.

7th. For colored blotting papers clean cotton checks, either red or blue, are used, without boiling or bleaching. The coloring matter of the rags is sufficient to dye the pulp. Although the use of this paper is limited, it is well to make it up at the end of each year from the rags reserved for that purpose.

8th. For common wrapping papers rags of the coarsest kinds are employed, pack-cloths, tarred ropes, the wastings from the dusting engines, etc. The fine qualities need a certain amount of boiling and partial bleaching, while for the others, the rags are not subjected to any chemical preparation whatever.

At the present day there enters also a variable proportion of mineral substances into the composition of almost all pulps, such as kaolin, sulphate of lime, sulphate of baryta, etc.

We shall have a few words to say on this subject in the chapters on sizing and coloring matters.

§ 8. Refining or Beating.

The foreman of the refining room ought to pay attention to see that each lot of pulp contains the grades required by his working list for the day, and a sufficient quantity for the number of lots of stuff he is ordered to prepare. The assistants bring in the fixed amount of pulp to be beaten and throw it into the tank.

The first part of the refining process is accompanied by washing, either by means of strainers or washing drums, or by both these arrangements conjointly.

If the pulp contains traces of chlorine, it is well to facilitate the departure of this substance by the use of the antichlorine, which we have already mentioned.

When the pulp has arrived at such a degree of tenuity that it may be in danger of passing between the wires of the strainer, this is closed, and the washing ceases. If a washing drum is used it is raised to prevent it from operating.

The workman, having raised the water faucet, gradually lowers the cylinder upon the plate, and stirs vigorously. Little by little, a homogeneous mass is obtained, having entirely lost its filamentous appearance which up to this time it had preserved.

After a little experience the fineness of the pulp may be appreciated by the touch. It is well, however, to ascertain this fact more exactly by what is called the proof. For this purpose a few grains of pulp are diluted with a large quantity of water, in a cylindrical vessel made of copper, zinc, or gutta percha; and, on pouring this off, the fibres of the pulp will take a direction parallel to that of the current of water, at the point where it falls over, and thus allow us to ascertain their length.

There will remain quite a quantity of little white points or lumps, which have escaped the action of the cylinder. To make these disappear, the foreman raises the cylinder, so that the extremity of its blades approaches those of the plate as nearly as possible without touching. This is called softening. The lumps disappear, after having been thus triturated in their passage under the cylinder for fifteen or twenty minutes.

The operation of refining must be well managed; and it should only be intrusted to a skilful and intelligent workman, as the beauty of the paper depends upon it.

When the beating is three-quarters through, the sizing and coloring materials are thrown into the vat; and, while the pulp is finishing, the mixture takes place. It is well, however, to assist it by stirring.

When the lot is finished the foreman lifts the plug, and the pulp runs off, through large copper pipes, into the supply vat of the paper machine.

The rinsing finished, the plug is replaced, and a new operation may be commenced.

The duration of the beating, like that of the reduction to half-stuff, varies according to the nature of the pulp, the capacity of the vat, the weight of the cylinder, the velocity of its rotations, the degree to which its blades and those of the plate are worn, the supply of water for washing, the cleanness and fineness of the wire-cloth of the strainers and washing drums, and, lastly, according to the skill of the foreman.

Too limited a supply of beating engines obliges many manufacturers to reduce the duration of this process. This want of working stock injures the quality of the paper, which gives evidence of too hasty work. From three hours and a half to four hours are required on an average. If five hours can be given to it, the pulp is softer and more easily worked on the machine.

We shall return to the dimensions and mechanism of the rag engines while treating the general subject of the working stock of a paper-mill.

Refining is also accomplished in particular machines, called centrifugal refiners.

These are not well known in France, but in America they have rendered great service. As is always the case at the appearance of a new machine, general opinion is very much divided.

§ 9. Sizing.

Before the invention of paper machines, the leaves were sized with gelatine or animal size, a process which is still followed in paper-making by hand. This method is tedious, and at all times unsuited to the manufacture of continuous paper.

The first attempts at pulp-sizing, or sizing in the beating engine, go back to the beginning of this century.

M. Braconnot, in analyzing German papers sized in the pulp, was led to the preparation of vegetable size, which he obtained through the precipitation of a mixture of an alumino-resinous soap and starch, by means of alum.

M. d'Arcet, after several experiments, following the instructions of M. Braconnot, originally adopted the following proportions for 100 parts of dry pulp:—

12.0	parts of	starch,
1.0	"	resin, dissolved in
0.5	"	carbonate of soda,
315.0	"	water.

He first boiled the resinous soap in water, and then added the starch previously dissolved in water.

The proportion of alum, made use of to precipitate the resin was such, that the test-paper would no longer indicate the presence of an alkali in the pulp. As the paper, however, lacked the firmness which was imparted to it by gelatine, M. d'Arcet modified the quantities to be employed as follows:—

100	parts of	dry pulp,
4	"	starch,
8	"	resinous soap,
8	"	alum.

The resinous soap is obtained from—

4.80	parts of	powdered resin,
2.22	"	crystals of soda, at 80° (Fr. alkalimeter).
100.00	"	water.

The gelatine is first dissolved in hot water. Theoretically speaking, we should only need 2.45 parts of alum to precipitate the resin; but the waters, which are almost always calcareous, neutralize a part of it.

When the alum is poured in sulphate of soda is formed, and the molecules of resin adhere with great tenacity to the fibres of the pulp.

At the present day, resinous size is made thus:—

Soda at 80° (alkalimeter) is dissolved in hot water, and is rendered caustic by the addition of a little lime, which takes away the carbonic acid from the carbonated part of the salt. It may be readily understood from this, that the proportion of lime ought to vary according to the composition of the soda employed.

The liquid is shaken, and after settling is decanted. The part remaining at the bottom of the vessel is then washed to carry off the last remaining traces of soda. This alkaline solution is then poured into a great wooden tub heated by steam. By degrees the powdered resin is thrown in, and after continued stirring the solution is effected. The operation lasts from two to three hours. The product is then made to run off into a lower receiver. On cooling, this resinous soap takes a more or less brown appearance, according to the resin employed.

To make the actual size, a certain quantity of this resinous soap is thrown into a tub containing water heated by steam; the starch previously mixed with a small quantity of lukewarm water is then poured into the mixture.

In some paper-mills the starch and kaolin are thrown in alternately, in small portions, and constantly stirred to obtain a perfectly homogeneous mixture.

When the tub is full it is allowed to cool, and the preparation then has the appearance of a slightly yellow size, with a more or less stony feel, according to the amount of kaolin which has been added.

There are generally two or four tubs; two are used for the day's work, and the other two are filled for the day following.

A determined quantity of this size is poured into each lot of pulp which is indicated upon the day's working list of the foreman of the beating engines.

Some manufacturers throw the powdered alum directly into the engine. It is much better to dissolve it at a temperature from 60° or 70° C. (140° to 158° Fahr.) and to draw it off as required through a felt which retains all impurities. As in the case of the size, volumes are used instead of weights, which amounts to the same thing, if we know the strength of the liquid.

Generally equal quantities of alum and lime are taken. Sometimes, the proportion of alum is increased if the water is calcareous, or if it is desired to give greater firmness to the paper.

The quantities employed are very various. M. Planche recommends—

16 parts of soda,
8 " lime

to dissolve—

100 parts of resin,
210 " water.

The soda must be in excess to make sure that the resin is dissolved.

He admitted that one part of soda at 80° of the alkalimeter dissolves six parts of resin, and that one part of soda rendered caustic by 0.5 part of lime will dissolve ten parts of that substance.

When alum is found to be injurious to certain colors, sulphate of zinc in the proportion of one-third the amount of alum is employed.

The composition used by M. Piette is as follows:—

30 parts of soda at 80° (Fr. alkalimeter),
2 " quick lime,
for 150 parts of resin.

To size 100 kilog. (220.47 lbs. avoird.) of paper 4 to 6 kilog. (8.81 to 13.22 lbs.) of resin, and as much alum will be required.

M. Payen gives the following proportion in his industrial chemistry:—

75 parts of crystallized soda,
12.05 " lime,
375 " water.

Then are added—

150 parts of resin,
150 " water resulting from washing and boiling by steam.

Having thus obtained the resinous soap, he takes one-tenth, or say—

75 parts of resinous soap,
500 " water containing
20 " starch.

For 100 kilog. (220.47 lbs. avoird.) of paper, 75 litres (19.80 gals.) of size, and 4 kilog. (8.81 lbs.) of alum are employed.

In some instances the mixed size is returned to—

2 parts of gelatine,
4 " starch,
2 " resin,
2 " kaolin.

In certain particular cases, and for common papers, the pulp can be very economically sized by throwing into the rag engine perfectly pulverized resin. The resinous particles adhere to the fibres of the pulp, and render the paper impermeable. Although this method should not be followed as a regular thing, it may sometimes offer advantages, and this has induced us to mention it.

The preparation of sizing is one of the operations of which manufacturers make a mystery, each one imagining that the proportions he employs are very preferable to those made use of by his colleagues. But we repeat it, these proportions should vary according to the nature of the rags and the quality of the paper.

The proportion of kaolin is very variable, according to the nature of the papers and the composition of the pulps. All things equal, hard rags retain a larger quantity than the soft. In papers of good quality, we have found from 10 to 18 per cent. and more. Certain manufacturers go as high as 28 to 35 per cent., but the paper then loses its tenacity. It retains a certain amount of stiffness, owing to the starch; but yields to the least effort, when once rumpled.

Kaolin, introduced into papers without size for printing, undergoes a considerable waste, which may reach from 50 to 60 per cent. In sized papers, the result of a great many experiments shows that 30 per cent. may be considered as the mean, when at least the proportions employed do not surpass the ordinary limits.

Thus for 100 parts of dry pulp for printing or writing paper we may take as a basis:—

30 to 50 parts of kaolin,
20 to 30 " starch,
10 to 12 " resin,
And as much alum.

There are different qualities of kaolin; the finest and whitest ought therefore to be used for fine papers. The kaolin of commerce contains from ten to fifteen per cent. of water; it is well therefore from time to time to ascertain its degree of moisture.

§ 10. Coloring Matters.

Whatever care may have been taken in bleaching, the pulps always retain a slight yellow tint which it is essential to remove, if we wish to obtain for the paper a more agreeable appearance.

The addition of a few grammes of blue and red takes off the unfinished look. The use of blue alone would produce a greenish tone which the pink serves to correct.

It is difficult, not to say impossible, to indicate by weight the exact amount of coloring matters to be used for 100 kilog. of paper.

This varies according to the nature of the rags which have produced the pulp, the pureness of the water, and the attention paid to washing, as slight traces of chlorine will annihilate a part of the effect of the materials employed; and finally according to the quality of the paper which it is proposed to make.

The safest way, is to operate experimentally, and to try various mixtures until a sufficient approximation to the desired color is obtained.

A practical appreciation of this is soon, however, acquired if one has an eye for colors.

The blue, most universally employed for white paper at the present day, is artificial ultramarine, known in France under the name of "bleu Guimet."

Although this coloring matter is bought ready made, we think it will be useful to enter into some details in regard to its various methods of manufacture.

1st. Method followed at Nuremberg:—

Heat in a reverberatory furnace—

100 parts of sulphate of soda,
33 " powdered wood charcoal,
10 " slacked lime.

The sulphide of sodium obtained is run into metallic moulds.

By dissolving it in water, the particles of carbon not decomposed are precipitated; the decanted liquid is treated with sulphur and carried to the boiling point to transform the monosulphide into a polysulphide.

This polysulphide is then evaporated in an iron caldron to a syrupy consistence, and a mixture made of—

0.50 kilog. (1.339 lbs. troy) of this polysulphide,
1.25 kilog. (3.348 lbs. troy) of clay well-washed and free from sand,
0.125 gramme (1.93 grs. troy) of sulphate of peroxide of iron free from copper.

A sulphate of iron is formed, and the product takes on a green tinge.

After having evaporated to dryness the whole is pulverized.

This powder, submitted to a brisk roasting, assumes different tints in succession, brown, red, green, and lastly blue.

On the management of this operation depends all the success; if heated too much the ultramarine is decomposed; if not enough, a part of the material does not take on the desired blue color.

This powder, treated with water to remove the soluble parts, is again roasted, and frequently stirred to render the blue color entirely homogeneous.

2. *Brunner's Method.*—The following mixture is calcined at a low red heat in a covered crucible:—

70	parts of	finely-powdered sand,
240	"	burnt alum (anhydrous),
48	"	powdered charcoal,
144	"	sulphur,
240	"	anhydrous carbonate of soda.

The mass when cooled is treated with water, the residuum dried and thoroughly mixed with its own weight of sulphur and one and a half parts of carbonate of soda.

The mixture is again calcined, and treated with water. The residuum, well washed and dried, is sifted through very fine muslin.

What has passed through the sieve is spread upon an iron plate, over a bed of slowly-burning sulphur. This operation is repeated until the color is quite bright.

To color the pulp with ultramarine, it is made into a thick paste, and stirred; water is then added. Before pouring this into the engine, it is filtered through flannel, which retains the coarser particles resembling grains of sand, and which produce so many spots in the paper.

If the pulp is a little acid from the addition of rather a strong solution of alum, a few crystals of soda are added before pouring in the blue. Acids decompose ultramarine.

Prussian blue (ferrocyanide of iron, $3FeCy,+2Fe_2Cy_3$). This coloring matter is employed for common papers.

The formation of this material, whatever process may be adopted, depends upon a precipitation of a salt of the peroxide of iron by the yellow prussiate of potash (ferrocyanide of potassium $2KCy,FeCy + 3HO$).[1]

To prepare it take—

6 parts of sulphate of iron (sulphate of the sesquioxide $Fe_2O_3,3SO_3$) dissolved in
15 parts of water.

In another vessel dissolve—

6 parts of yellow prussiate in
15 " water.

After mixing these two solutions add—

20 parts of hydrochloric acid.

Finally add a solution of chloride of lime until a handsome blue precipitate is obtained. This precipitate is washed with pure water several times.

[1] The chemical equation for the formation of this salt is $3(2KCy, FeCy)+2(Fe_2O_3 3SO_3)+Aq = 3FeCy,2Fe_2Cy_3 + 6(KO,SO_3) + Aq$. (Tr.)

If Prussian blue is bought in the calcined condition, after having reduced it to a fine sifted powder, add for—

3 parts of the blue,
2 " hydrochloric acid.

It is then washed with pure water several times, and the water drawn off by a siphon.

Pink Red.

The materials most used are cochineal, Pernambuco (Brazil) wood, and carthamine (saffron, dyer's saffron).

The Red Shade.—There are several methods for the manufacture of the carmine of cochineal, which is used for fine papers.

First process.—Boil for half an hour—

1,000 grammes (2.679 lbs. troy) of crude cochineal,
16 " (247 grs. troy) of soda (alicante),
39,000 " (77,791 lbs. troy) of water.

Take the vessel from the fire, and add—

50 grammes (772 grs.) of pure alum,
10 " (154 grs.) of cream of tartar (bitartrate of potassa).

The mixture, when stirred, passes from violet to pink, and finally to a bright red.

After the liquid is decanted, four whites of eggs well beaten are to be added; and if the carmine does not float in flakes it should be heated. The decanted matter is thrown upon a cloth, and dried at from 30 to 35 degrees (86° to 95° Fahr.).

50 grammes (772 grs.) of carmine are thus obtained. The decanted liquid is then brought to this boiling point, and four other whites of eggs beaten and thrown in. 25 grammes of carmine are thus obtained, not quite so handsome as the other, and a little more granulated.

The residuum of the cochineal, after its carmine is extracted, serves to prepare carmine lakes, which can be used for second-class paper.

It is sufficient to throw into a decoction of this residuum, a solution of alum and some grammes of chloride of tin.

The alumina of the liquid is precipitated by a solution of the supercarbonate of soda (bicarbonate of soda $NaO, 2CO_2$).

The decoction, left to itself for some time, enters into fermentation, and produces a scarlet matter which is converted into a jelly with the alumina.

Second process:—

1000 grammes (2.679 lbs. troy) of crude cochineal,
20 litres (4.40 gals.) of water rendered alkaline.

This liquid should be decanted, and renewed three times so as to have 60 litres (13.20 gals.).

Precipitate with—

830 grammes (2.223 lbs. troy) of crystallized bichloride of tin. The product is filtered, washed, and decanted.

Pernambuco Wood (*Brazil Wood*, *Cæsalpina Echinata*).

It should be bought in block, because it not unfrequently happens that chips are sold which have been used before; if it is of a good quality, its specific gravity being greater than that of water, it ought not to float.

Process.—First wash the material with eight or ten times its weight of water at 35° to 45° (95° to 113°F.) This water is drained off, and a new bath prepared of—

1 part of the wood,
10 parts of water.

After boiling two hours, filter, and add to the filtrate—

0.25 parts of salt of tin (protochloride of tin).

By rest the coloring matter is precipitated. The water is drained off, and the washing continued until the liquid is no longer acid.

By this first boiling, a beautiful red coloring matter is obtained.

After pouring into the caldron a new quantity of water, rendered alkaline by 2 parts of soda to the 100 of water, boil again, and the coloring matter is once more precipitated with salt of tin.

By this operation an orange-brown color is obtained.

As the pink color is less brilliant if the pulp contains calcareous salts, it is important to precipitate them by a corresponding proportion of oxalic acid.

Carthamine gives the handsomest pink, but unfortunately it is not durable; it answers, however, very well for certain satined papers, intended for making artificial flowers.

On 1 part of washed and dried carthamine pour 10 parts of water, rendered alkaline by 1 part of crystals of soda. The filtered liquor is precipitated with acetic or citric acid until it becomes acid.

Let it rest, and then decant.

The violet is obtained by a decoction of Campeachy wood (logwood).[1] Its preparation is analogous to the process we have just given for Pernambuco (Brazil) wood.

Yellow.

This color is obtained by the double decomposition of

[1] The coloring matter of logwood is *hæmatoxyline*, that of Brazil wood, braziline.—Tr.

bichromate of potassa and subacetate of lead. A precipitate of the chromate of lead of a bright yellow is formed.

1000 parts of subacetate of lead,
180 " " bichromate of potassa or red chromate.

By varying these proportions the color takes an orange or a bright yellow tint.

By forcing the chromate the tint becomes orange; by forcing the acetate the tint becomes yellow.

Buff.

Dissolve
1 part of sulphate of iron,
8 parts of water.

Add a solution formed of
1 part of chloride of lime,
10 parts of water.

After stirring, soda is added to render the product alkaline.

The liquid is afterwards decanted from the deposit which is washed.

Sometimes it is sufficient to throw into the rag engine,

For light buff:—

5 parts of sulphate of iron,
3 " " salt of soda, or
2 " " chloride of lime.

For dark buff:—

16 parts of sulphate of iron,
9 " " salt of soda, or
6 " " chloride of lime.

Soda tarnishes the papers less than lime.

Green.

Green is obtained from a mixture of blue and yellow. The relative proportions of these two substances determine the shade.

Ultramarine is used for fine, and Prussian blue for common papers.

A very handsome green could also be produced by a salt of arsenic; but this coloring matter being poisonous, its use should be proscribed so far as its application to paper-making.[1]

Brown.

Brown colors are obtained from the employment of umbers, ochres, etc.

The chloride of manganese resulting from the preparation of chlorine gas may be put to use. After being saturated with carbonate of soda it is filtered. The product takes a brown tint by the addition of chloride of lime.

Dark Gray.

Grays are obtained by pouring lampblack into the rag engine after it is cleansed from grease by a warm dilute solution of soda or potassa. The material is then washed until all traces of the alkali have disappeared.

By increasing the proportion of this substance, the pulp becomes darker.

[1] The salt of arsenic referred to is probably a double compound of the arsenite and acetate of copper, known commonly as Schweinfurth's green or Vienna green. It is as poisonous as white arsenic. There is also an arsenite of copper (CuO,AsO_3), called Scheele's green.—Tr.

This color may be also obtained from the gallate of iron by boiling

1 pint of nutgalls (gallic acid C_7HO_3+2HO),
2 parts of sulphite of iron (green vitriol),
10 " " water.

Filtration will retain the insoluble products of the nutgalls and the sulphide of iron.

(The following extract on this important matter of coloring is from the work of M. L. S. Le Normand, from whom we have already quoted on the subject of bleaching.—Tr.)

Colored Papers.

However well the pulp may have been bleached to the highest point that chlorine can carry the operation, however fair the quality of the rags from which it is produced, notwithstanding all the care that may have been exercised in its fabrication, the resulting paper presents a slight yellow tinge, which would not escape the most inexperienced eye. The dead white which this paper presents to the sight is unpleasant when compared with that to which there is given a slight blue tint which takes off the glare.

Thus after being bleached, fine washing, although very white, undergoes a slight *blueing*, which gives it a more brilliant appearance and renders it more pleasing to the eye. These two operations, which are analogous, have given to that beautiful paper of a faint blue shade the name of azured paper, and the operation by which this is obtained is called *blueing.*

In paper-mills also different colored papers are manufactured, not after the manner of the illuminators, who merely color the two surfaces with the same shade by means of a sponge or of a large brush, which being foreign to paper-making will not concern us, but by employing pulps colored in the vat or the engine, which furnish papers dyed the same color throughout their substance.

There are then two distinct and separate manners by which these two results are obtained, which we shall describe the one after the other in two distinct and separate paragraphs.

1*st.* *Blueing.*

Formerly the only process known for blueing paper was the employment of Prussian blue, or of indigo precipitated from its sulphate[1] by lime; but Prussian blue is too difficult of management to obtain a uniform shade, besides this color is not durable. A leaf exposed for some time to the light soon loses its tint, and the paper appears mottled.

Indigo extracted from its sulphate gave a more substantial azure, less difficult to manage, and more durable; but this substance was superseded by oxide of cobalt (smalt, azure or cobalt blue), as soon as handsome English papers blued with this material were seen. This oxide gives a more brilliant and especially a more durable blue than any other material yet employed.

The English papers presented a great defect; the *right* side of the sheet was of a very beautiful shade, whereas the *opposite* side was deprived of it. This defect proceeded from the fact that the English had not learned how to use this dye. They threw it into the vat which

[1] Indigo blue dissolved in fuming sulphuric acid forms a chemical compound known as sulphindigotic acid; no other liquid will dissolve it.—Tr.

was constantly stirred. This blue is very heavy, its specific gravity is very much greater than that of paper-pulp, so that when the *vatman* has filled his mould and shaken it as usual, the blue falls to the lower surface, and the superior surface is deprived of it.

M. Mérimée has indicated the means of employing this material, and, at the same time, avoiding the difficulties which were experienced by the English.

"*Cobalt blue* is mixed with starch, and thus closely incorporated with that substance it becomes lighter, and no longer falls to the reverse side of the sheet."

This is the process followed by M. Canson to manufacture the paper thus blued, which he presented for examination to the Société d'Encouragement. The instructions of the commissioners were communicated to M. Canson in 1815, and it was not until several years after that he displayed his papers blued on both faces with cobalt blue.

We would have given the process of the manufacture of this blue, which is not a secret, if it could be of any service in the paper-mill; but this operation can only be conducted with advantage in establishments solely designed for this work.[1] Cobalt blue is abundantly found in the market already prepared; there are several qualities of it, and the paper-maker should choose the best, which is also the most finely pulverized. It is known in France under the name of *azur des quatre feux* (azure of the four fires). Those who wish to understand its

[1] The following is the general principle of preparation for this substance. The cobalt ores are converted into oxide of cobalt in a reverberatory furnace. The oxide is fused in clay crucibles with sand and carbonate of potassa, producing a deep blue colored glass. This is poured into cold water to render it brittle, and then reduced to an impalpable powder, which is the coloring matter to be used.—Tr.

manufacture can consult Thénard's *Traité de Chimie*, vol. 2, p. 494, edition of 1824.

There have been sent from Paris to the paper manufacturers, for about two years past, small samples of a powder designated by the name of azure, of a very beautiful shade bordering on lilac, which has appeared to us to be artificial ultramarine weakened with starch. It is employed in the same manner as cobalt blue.

Of Papers Colored in the Pulp.

There are two ways of manufacturing papers colored in the pulp, which we will describe separately.

1st. *For blue papers.*—In sorting, all the blue rags of whatever nature, whether fine or coarse, are set aside; these are afterwards separated into lots, as would be done with the whites. The finest are kept for handsome papers, and the rest for the commoner kinds.

These rags undergo the same treatment as those intended for white paper, and it will be readily seen that in using the pulp there will be produced a white paper varying in shade, according to the depth of the color of the rags. If the tint is too deep, more or less white pulp is added to it in the rag-engine, which is then allowed to work until the mixture is complete and the color uniform.

2d. *For the red*, called *rose paper.*—All the red rags, whether linen or cotton, dyed with Turkey red (madder alizarine), are set apart; they are treated like the blue, and a red pulp is obtained which gives a very pretty rose color to the paper.

Papers are also made of every color, by dyeing the pulp in the rag-engine. They are stained with either vegetable or mineral colors. As these last are the most brilliant and firmest, we shall limit ourselves to the receipts for their production, and shall only mention the vegetable substances from which the dyes may be prepared.

It is sufficient to be acquainted with the process for obtaining the three primitive colors, *blue*, *yellow*, and *red*, to procure all the others to which *black* is added to procure the various shades.

Blue.—We have mentioned the oxide of cobalt. It will be sufficient to choose a very deeply-colored quality, and the desired shade may be easily arrived at.

Yellow.—(The coloring matter here recommended is the yellow chromate of lead, the preparation of which has already been fully described in the text.—Tr.)

Red.—The *tritoxide of iron*, from which *Russian red* is made, gives substantial colors, which, however, border on brown; nevertheless, when it is prepared with care and well washed, the shade is not disagreeable, and closely approximates pure red.

Vermilion, known under the name of *Chinese vermilion*, and brought to great perfection in Paris, furnishes a very beautiful red.

Vegetable substances ought not to be employed in paper-making to dye the pulp, except in cases where the coloring matters furnished by the mineral substances we have spoken of would not give pure shades, or when such could not be obtained by their aid. It must not be forgotten that vegetable colors are unstable, that air and light decompose them easily, and that sufficient solidity could not be given to those serving to dye the pulps employed for making paper used to cover pamphlets or books bound in boards. We shall confine ourselves to the description of the processes to be employed to procure the most brilliant *reds*, *black* which would be difficult to obtain pure through the agency of mineral substances, and the very deep and beautiful *indigo blue*, which may take the place of the more costly *oxide of cobalt.*

Red.—Several American woods afford a red coloring matter. They are distinguished by the generic name of *Brazil wood;* that of Pernambuco is the most esteemed, but is very rare; Linnæus designates it by the name *Cæsalpina Crista.*

Boiling water extracts all the coloring matter from Brazil woods. The decoction of *Pernambuco* wood is of a very beautiful red; that of the other woods which are substituted for it is of a yellow approaching more or less to fawn color, which for a long time, to the despair of the dyers, resisted every investigation of the chemists who devote themselves to this important branch of our national industry. A German chemist has solved the problem.

In No. 209 (Nov. 1821) of the *Bulletin de la Société d'Encouragement pour l'Industrie nationale* may be found a simple and easy method of eliminating the tawny color from the baths of the inferior qualities of Brazil woods, such as those of *St. Martha*, *Aniola*, *Nicaragua*, *Siam*, *Japan*, etc., and to substitute them with assured success for true *Pernambuco* wood.

This is the manner in which M. Dingler, the author of this method, advises us to proceed:—

"The wood having been rasped or scraped as usual, all the coloring matter is extracted from it, either by boiling or by the action of steam. The decoction thus obtained is evaporated until, for instance, there only remain for two parts of wood, six or seven parts of liquid. This liquid is cooled, and from twelve to eighteen hours afterwards one part of skimmed milk is poured in.

"After being well stirred, this mixture is boiled for several minutes, and then passed through a very fine piece of flannel. The tawny pigment remains upon the strainer with the caseous matter to which it attaches itself, while the red coloring matter passes through in a state of great purity, and without suffering the slightest diminution.

"If it is desired to use this liquid as a red dye, it is diluted with a sufficient quantity of pure water, and then employed for coloring. A solution of salt of tin or sulphate of alumina thrown in small quantities into the bath, enlivens this red in an astonishing manner."

Madder red.—As soon as I had heard of this process of M. Dingler, which I had put in practice and which succeeded with me perfectly, I conceived that it might be applied to the pigment of madder, which it is well known is always impregnated with a fawn color injurious to the pureness of the red this substance is capable of furnishing. I spoke of it to the late Vitalis whose work was in press; he told me that the same idea had occurred to him, and showed me in the proofs which he had retained that he had noted it without trying the experiment. I did try it, succeeded entirely, and showed him the result. This madder red is very permanent.

Indigo blue.—The pulps might be dyed directly with indigo reduced to a fine powder, by the action of a mill, as is done in dyeing houses; but it is not carried to a sufficient degree of comminution to be economically or successfully employed. For this purpose a sulphate of this substance should be formed, and when perfectly dissolved, the sulphuric acid is removed by lime. The following is the best process known at present.

It consists in pouring gradually four parts of very concentrated (fuming) sulphuric acid upon one part of finely-powdered indigo, and dissolving the powder in the acid, so as to form a kind of paste perfectly homogeneous. This is heated for some hours in a glass vessel, over either a sand or water-bath, at a temperature of 25 to 30 degrees Reaumur (88.25° to 99.50° F.). It is then allowed to become perfectly cool.

When the mass is cool, eight parts of water in which four parts of quicklime have been dissolved are gradually poured upon it. The water is poured on in small quantities, to prevent the glass from being broken by the great heat which is evolved, and in order not to cause too violent an effervescence. This is stirred all the while, and then allowed to rest 24 hours. Sulphate of lime is formed and precipitated, and the supernatant liquid contains the pure indigo in a state of extremely minute subdivision; this liquid is decanted and used for dyeing. It can be diluted with water until it reaches the desired shade of blue.

Black.—The pulp is very seldom dyed black; but by weakening pure black, that is, by diluting it with more or less water, different shades of gray are obtained, which added to colors darkens them so as to enable us to produce any given shade.

The illuminators mix lampblack freed from its greasy or oily particles by repeated washing in a solution of caustic soda or potassa, until the black is precipitated. The alkali forms a soap by taking up the greasy matters. The whole is washed with pure water until the water runs off clear, and then is allowed to rest. The liquid is decanted, and the black thus purified is mixed with the sizing in the vat or the rag-engine.

By mingling the colors called *primitive*, two by two, three by three, or four by four, and in different proportions, in the same manner as the painter mixes them upon his pallet, we obtain all the colors and all the shades that nature furnishes.

The mixture of *blue* and *red* produces purple, violet, lilac, pansy, amaranth, prune, dove-color, mauve, peach-blossom, carnation pink, and a great number of other shades, which depend upon the relative proportion of the two colors, the preponderance of the blue over the red or the red over the blue, and lastly on some peculiar condition of the operation.

Blue and *yellow* mixed give green. There are few colors of which there are so many various shades as green. The principal ones are sap green, pea green, grass green, meadow green, laurel green, leaf green, sea green, parrot green, cabbage green, apple green, nut green, bottle green, duck green, etc.

It may be readily anticipated that greens are so entirely dependent upon their base of blue, that this needs to be proportional to the intensity of the green to be produced, and thus it will require a deep blue for duck green; a sky blue for parrot green; a light blue for apple and sea green, and a still lighter blue for sap green.

Blue, *gray*, and *yellow*, when mixed, produce *olive*.

The shades of olive are greenish or yellowish-grays; they require, therefore, that the gray which forms their base should incline more or less towards blue. The colors must be mixed in suitable proportions as the eye and experience may direct.

We distinguish two principal shades of olive, viz., *green olive* and *brown* or *rotten olive* These two are of entirely different tints.

Mixture of *red* and *yellow*. The colors resulting from this combination are very numerous. However, the tone of these shades depends upon the nature of the red or yellow, which enters into the formation of the color. The principal color thus produced is *orange;* but there are numberless others depending upon the proportions of red or yellow employed. Such are *fawn*, *flame*, *pomegranate*, *nasturtium*, *orange*, *jonquil*, *gold*, *buff*, *light coffee*, and *chocolate*, *cinnamon*, *tobacco*, *chestnut*, *marigold*, *coquelicot*, and *brick* colors, etc.

Black, or rather *gray*, only serves to darken certain colors, as we have exemplified in the case of olives. The workman, if somewhat intelligent, will easily judge when he needs gray to darken a color, in order to attain the shade which he is required to produce.

To employ these colors we may pour the colored bath into the vat with a solution of alum; nevertheless it will be better, when the pulp has been sufficiently worked in the rag-engine, to close the entrance and exit of the water, and then turn into it the coloring bath with the required proportion of alum. In a short time the pulp becomes uniformly dyed by the action of the cylinder, which facilitates the union of the finely-divided particles of the pulp with those of the coloring matter.

The colors we have just gone over may be considered in the light of fine materials, only to be used in the preparation of handsome papers made from choice pulp. The preparation of coloring matters gives considerable trouble and requires a degree of care which would not be repaid in the manufacture of common paper. For the coarsest of these, used for packing common substances, but which it is still desirable to color, other processes are employed. To accomplish this, yellow, red, or brown ochres are used. They should be previously soaked some time in water, and then carefully washed to remove the sand and other refuse matters, and leave the finer parts for use. This process is too well understood for us to stop to describe it.

The custom is still retained at the sugar refinery of Bordeaux, and perhaps elsewhere, of coloring the paper employed to wrap the sugar loaves of a dark blue. So far this dye has been made of prepared archil.[1] A decoction of Campeachy or logwood has for some years been substituted which has the property of assuming a violet color on the addition of alum. But in order to imitate the reddish blue of the archil a solution of Brazil wood is combined with it. This process is as follows:—

Boil for one hour ten parts of logwood, powdered or in chips, and add a half pound of Brazil wood, also in powder or in chips; boil for half an hour after having thrown in half a pound of powdered verdigris (basic acetate of copper $CuO,A+HO$). Stir well, and finally mix with it half a pound of powdered alum. When the solution is completed the dye is ready for use. It is then thrown into the vat, well stirred, and the paper-making may be begun at once.

We think it right to repeat and insist on what we have already said upon the subject of Prussian blue. Manufacturers should renounce its use, either for blueing or dyeing their papers. This substance should not be allowed in the mill, it is not permanent; the atmosphere turns it gray, though so brilliant when fresh, and the feeblest alkali will discolor it instantaneously.

[1] Several species of lichen, growing in England and France, containing coloring principles called orcine and erythrine, which take a handsome purple color when acted on by ammonia. For this purpose the lichens are allowed to putrefy in urine, and are then made into a paste of a red or violet color. When lime is added this color becomes blue. This substance is then called litmus, and is commonly used for test paper, as it is again reduced by acids.—TR.

We will not finish these remarks without saying to manufacturers that they ought never to make papers dyed in the pulp during winter. This was pointed out to us by M. Canson when we visited his beautiful paper-mill at Vidalon-les-Annonay, in the month of September, 1828. He was then manufacturing paper dyed in the pulp; one of his relations, who was accompanying me, asked him why he did not reserve this work for winter, saying that summer had always appeared to him most favorable for white paper. "That is true," answered he, "but I have found by experience that in winter the colors are very much weaker."

§ 11. The Work of the Paper-Machine.

The pulp, on leaving the refining or beating cylinders, is conveyed into the great reservoirs placed at the head of the paper-machine.

When the workman wishes to set the machine in operation, he opens the pulp and water faucets at the same time, to make the mean density of the mixture correspond with the proposed thickness of the paper.

In passing the sand boxes, the heaviest particles sink to the bottom, and are arrested in their progress by the inclined blade; the lighter ones are conveyed to the strainers, or knotters, which hold back almost all the lumps or knots which have escaped the softening process.[1]

[1] Mr. Richard Herring, in his work on Paper and Paper-making, observes, that he has found from repeated examinations of these lumps retained upon the knotter, that they consist to a great extent of India-rubber, proceeding from the bits of ornamental braid, etc., from which the rags have not been entirely freed.—Tr.

The purified pulp is finally poured out upon the wire cloth, which we call the table of manufacture.

This endless web has a double forward and oscillating motion; the last communicated by an eccentric.

As the web advances, the drainage is effected; the pulpclots, after passing the suction boxes, acquire sufficient consistence to undergo the action of the first wet press roller.

At this time the sheet (it may be now properly so named) leaves the wire gauze, and is carried off by continuous felts under the other wet press and drying cylinders, which bring it into the condition of perfectly dry paper. On leaving the last drying roller, the sheet is generally cut lengthways into parallel bands by circular cutters, and rolled off upon reels.

The paper is then cut, at stated intervals, into a series of superimposed bands, which correspond in length to the breadth of the reel. These are cut transversely, by means of especial blades, according to the required form.

When the working of a paper machine is first examined, it seems as if the operation was self-conducting, and would require no care. But as we gradually become familiar with the different apparatus which compose this machine, this confidence disappears, and we become aware that continual attention and great skill are required on the part of the workman, in order successfully to accomplish this most important part of the manufacture.

The first condition to be fulfilled is to make the paper correspond in weight to that indicated on the foreman's list. To accomplish this, the workman takes a piece of the paper, as it leaves the last drying cylinder, and cutting it into the required form, weighs it. If the weight is too great, he closes the pulp faucet a little, and if the paper is not heavy enough, he either shuts off the additional water somewhat, or lets in a greater amount of pulp. He does one or the other, as the rapidity of motion of the machine may require.

If the paper is crushed under the first wet press, there are several means of remedying it. Less water is added to the pulp, and the rate of motion of the machine is changed. If these means are insufficient, we examine whether it will be most advantageous to modify the composition of the pulp, or to replace the wire cloth by one of a lower number.

In some instances it will be well to try heating the pulp, which facilitates its drainage.

After first diminishing the pressure of the rollers, it should also be ascertained whether this crushing does not proceed from some derangement in the working of the air-pumps, and their velocity may be increased.

The slits of the knotter should be made to correspond in their size with the kind of paper to be made. If the pulp passes with difficulty, this may proceed from incomplete beating or softening. The knots obstruct the slits, and it becomes necessary to clean them frequently, either with the brush or the rake. When this engorgement is complete, it is sometimes indispensable that the machine should be stopped in order to clear the knotter.

The workman should watch carefully to see that the felts are kept tense, and that the web of paper be not too much stretched in passing over the drying cylinders, as this might occasion a break in the paper, or, at any rate, diminish its strength by the excessive tension which the filaments would undergo.

Pulp, containing too great a proportion of crude material or rags but little worn, is hard to drain; the paper creases, and is more or less transparent. It is proper in this case to augment the amount of well worn cottons and linens.

The essential condition of success with the machine is that all the rollers should be exactly parallel with each other, so that the paper may be drawn uniformly throughout its whole length, and not wrinkle.

This is still more important when a new wire cloth is to be put on the machine, as it may be ruined in a few hours by a lack of attention on the part of the workman.

If the first drying cylinders are too hot, the paper is too quickly dried, and shrinks and wrinkles the more; whereas a graduated drying will give a finer grain and smoother paper, which is more easily finished.

Before each operation of the machine, the workman should always work it empty for a little while, in order to see that all the parts are in order. He should also frequently examine the spindles of the rollers, and see that they do not become heated.

In some few mills the paper is satined as it leaves the machine. The apparatus employed up to the present time to attain this object, which would be very economical, have not, however, worked well enough for us to recommend their use. We shall say a few words in regard to these machines in treating the general subject of the stock of a paper-mill.

§ 12. Finishing.

The finish to be given to the paper varies according to its quality, or the uses for which it is intended.

The common wrapping, writing, and printing papers, on leaving the reel of the machine, are cut into form; slightly looked over to remove the few torn sheets which the piles might contain; pressed once or twice, and then put up into reams and packages.

Fine papers undergo a series of operations, such as reviewing, sorting, satining, and glazing, before leaving the mill.

The women employed in this work of reviewing carefully examine the paper on both sides, and remove impurities, such as gravel, shreds, lumps, or knots, with an eraser, and with India-rubber the spots that may be expected to disappear.

This work requires practised hands; for, by using an eraser carelessly, they run great risk of piercing the paper, or at least destroying the effect of the size in that spot. This defect should be always avoided, especially in writing paper.

It is therefore necessary to watch attentively the refining and straining of the pulp, to diminish as much as possible the occurrence of knots in the paper.

Generally four or five lots are made in reviewing the sheets:—

1st. Good sheets.

2d. Those slightly knotted and wrinkled.

3d. Those torn at one end, but available for a smaller size.

4th. Waste sheets.

The foreman of the finishing room should see that the work is done properly, and should ascertain the causes of waste, whether proceeding from the manufacture or from the woman's work.

After this review, the papers undergo the operation of satining, which has for its object to render the surfaces soft and smooth to the touch.

The oldest and most commonly used apparatus is the smoothing or rolling press, consisting of two polished cast iron cylinders, between which a series of superimposed plates are passed, containing between them the leaves of paper.

These plates are of steel, copper, or zinc; this last named metal being preferred from motives of economy, although it is open to the objection of somewhat blackening the paper.

In some mills they still smooth the paper by means of polished boards, such as are used by printers to remove the depressions made by the type during the process of printing.

In passing between the rollers, the paper undergoes a strong pressure, the grain is crushed, and the surface, from being ridged, becomes smooth.

It will be readily seen that it is important that the paper should not contain grains of sand or knots which would mark the zinc, and render them very soon unfit for service. They then have to be smoothed again to give them back their original polish.

The finish depends upon the number of times the packages pass under the rollers. For ordinary papers from two to four times are sufficient.

When it is desired to glaze the papers after having rolled them four times, they are placed between fresh zincs, or the same in the inverse order, and the rolling operation is repeated.

If, at the time of the first passage under the rollers the pressure is too strong, the filaments will be crushed and lose a great part of their resisting power.

For the more elegant papers, it is therefore important to have a medium pressure, and even to let the papers remain piled up for 24 hours before subjecting them to the rolling press a second time.

By repeating this operation two, three, and four times, a superior product is obtained.

In packing the paper, the leaves should be placed evenly over each other, or else marks will be visible on the side of the sheets indicating an unequal pressure.

In order to avoid this almost inevitable defect, it is indispensable to recut all fine papers, notwithstanding the waste thus occasioned.

The thickness of the packages varies according to the thickness of the paper and the zincs and the distance apart of the rollers.

The package contains from 20 to 35 sheets, and consequently from 21 to 36 plates of zinc.

Satining brings out the defects of badly prepared size. The grains of resin remaining undissolved by the alkali, are crushed and appear as transparent yellow spots when the leaf is held up to the light.

The work of a satining apparatus requires quite a large number of hands; three or four gangs of three persons besides one or two workmen to present the packages. One will be sufficient, if the rollers work in both directions so as to return the package when reversed.

Generally, a child places and removes the sheets of paper, and a workman lays on the zinc plate. Sometimes this work is confided to a woman, but a man is indispensable for the larger sizes.

Calenders, or three cylindrical presses, are also used to satin the leaves, the middle one being of paper and the other two of metal. This apparatus is absolutely necessary to soften paper in rolls. The paper is wound upon rollers placed at the head of the callender, and passes first between the upper and middle cylinder, and then between the middle and lower ones.

This smoothing in rolls, especially when the paper is very wide, presents some difficulties. It is necessary that there should be a uniform pressure upon every point of contact, otherwise the paper will be creased and a considerable loss ensue.

This accident is less to be apprehended when the paper is smoothed in separate sheets.

In that case, three hands are necessary to attend to the work of a callender. The first engages the leaf between the two upper cylinders; the second returns it between the middle and the lower; and the third receives the sheet.

The calendered paper preserves its whiteness, which is somewhat impaired by zinc. All things being equal, the plates are better for thin papers.

It is difficult to calender more than 40 to 60 reams, whereas over 100 may be furnished by means of the first mentioned machine.

In some paper-mills, different designs are impressed upon the paper bearing the generic name of watermarks. Sometimes a series of parallel or cross lines, very much in demand at the present day for letter papers, are considered sufficient.

This marking is generally done in the stationers' shops or in special factories, established in the great centres of population.

These impressions are obtained by means of boards prepared for this purpose or by metallic plates bearing a design reproduced in relief by electrotyping.

There is another kind of watermark obtained during the manufacture of the paper itself, but as this subject belongs under the head of hand manufacture, we shall reserve it for a future chapter.

The softening or glazing terminated, there remains the operation of counting and putting up into reams.

The ream is composed of 500 sheets, or 20 quires of 25 sheets each.[1] Some manufacturers compose their reams of 18 quires of No. 1 paper, and 2 quires of No. 2, one on top and the other at the bottom.

The leaves are counted by special women hands who acquire a very great skill.

The quires after being arranged in reams, with the backs placed alternately for folded papers, are put under the press at night, and the next day are ready to be packed.

Packages are usually composed of two reams for thin papers.

It is well to weigh each ream before packing; a label is pasted on indicating the quantity, and bearing the name and address of the consignee, etc.

A careful manufacturer should see that the packing is always done with care, and even with elegance, in the case of choice papers. One cannot be too well convinced of the great principle that merchandise must be well dressed.

[1] In the United States the ream consists uniformly of 20 quires of 24 sheets each.—TR.

CHAPTER IV.

MANUFACTURE OF PAPER FROM THE VAT OR BY HAND.

To render more comprehensible what follows upon the subject of hand-manufacture, we shall first enter into some details in regard to the apparatus employed.

The principal instrument used in making the paper is called the *mould.* It is a square wooden frame, covered with metallic gauze of *laid* or *woven* wire, the whole surmounted with a *deckle* or empty frame. Figures 1, 2, 3, Pl. V., represent a vertical and horizontal plan of the mould.

a. Frame of the mould.

b. Wire cloth.

c. Deckle.

The wire cloth is sustained by a number of cross pieces, parallel with the short sides of the mould frame; they are called—

d. Ribs.

Making the moulds and fitting the deckles require great skill on the part of the workman charged with that business.

Any defect in contact between the wire cloth and the inner border of the deckle would prevent the deckle from *cutting*, to use an expression of the art, that is to say, the pulp, escaping through these fissures, would give a ragged edge to the sheet of paper. On the contrary, when the deckle fits closely, the edge of the paper is clean cut.

The size of the deckle will regulate that of the paper.

To work continuously two moulds are required, and the deckle should fit them both accurately.

The frame of the mould and deckle should be made of oak, prepared in a particular manner to prevent it from warping through the alternate moisture and dryness to which it is exposed.

This wood is cut into thin boards without knots or flaws, submitted to the action of boiling water and then dried. This is repeated several times before the wood is considered properly fitted for use. The ribs are of pine.

These different parts taken together are called the *stock* of the mould.

If the wire cloth is *laid* this is done by the maker of the mould.

Le Normand, in the *Technological Dictionary*, thus describes this operation:—

"The workman takes the stocks when finished, and bores on the upper surface of one of the long sides of the mould, above the tenon of each rib, as many holes as there are ribs.

"He then places a pin in each hole carrying two threads of fine brass wire each wound upon a separate spool. These are the *cross wires*.

"After having laid out the wire intended to compose the cloth, the workman proceeds to its manufacture.

"He lays the wire, by means of an instrument adapted to that purpose, and of which the simplest form is a metallic plate, on the surface of which are driven two rows of well-polished iron pins in the shape of a quincunx, giving a series of cylinders having all their surfaces on each side in a straight line, representing two parallel straight lines, with a distance between them equal to the size of the wire.[1]

"He first cuts the wire into suitable and equal lengths, that is the external distance between the short sides of the mould.

"The workman then places the stock in front of him in an inclined position.

"He passes one of the laid wires through the space between the two cross wires which he separates, and carries it from one end of the frame to the other. He fastens the thread by means of the cross wires, passing it around one from within out, and around the other from without in. He continues thus to fasten each of the wires, laying one after another, and by this means manufactures a true cloth in the same manner as a weaver. Thus, if we consider the cross wires as the warp and laid wire as the weft, we shall be convinced that these two are interlaced in the same manner as cloth, with the single difference that the meshes of the warp are about twenty-seven millimetres (1.06 in.) apart.

"When he has filled the whole bottom of the mould, he binds the cloth to the ribs with very fine wire, by passing it through the holes bored at the edges of the ribs from eighteen to twenty-seven millimetres (from 0.67 to 1.06 in.) apart wrapping them round and above the laid wire at this place.

"He then fastens the edges of the wire cloth to the stock by means of very thin and narrow brass bands, which he nails upon the frame with small brass nails. These bands serve not only to secure the free ends of the

[1] This operation is more simply accomplished by giving the wire a turn, and using two fingers of the left hand to stretch it. Under the influence of this double movement the wire becomes perfectly straight.

laid and cross wires, but also to retain the pins which hold the cross wires at their extremities, and strengthen the joining of the corners of the mould."

For moulds of woven wire, the maker buys the wire gauze ready made; cuts it of a suitable size and fastens it to the mould in the same manner as we have described for that of laid wire.

The size of the laid wire depends upon the quality of the pulp and upon the operation of the exchange, as we shall see further on. All things equal, short-grained pulp requires the finest meshes. On the other hand, the coarser the laid wire cloth the more rapid will be the work.

The vessel containing the pulp ready for making the paper is called the *vat.* It may be either of copper, wood, or mason work. Formerly most vats were of copper and heated by a small furnace called in French *pistolet*, pistol.

When a steam heater is available it is simpler and more economical to conduct the steam-pipe directly into the vat, and to heat the contents at intervals by opening the stopcock. The mean temperature ought to be from 25° to 35° C. (from 77° to 95° Fahr.) and ought never to exceed 40° C. (104° F.).

We give fig. 1 to 11, pl. IV., the arrangement of two wooden vats furnished with all their accessories. (See the explanation of the plates at the end of the manual.)

The name of *post* is applied to a variable number of woollen felts a little larger than the leaves of the paper to be manufactured. The post contains 6, 7, or 8 quires of 26 pages each, that is to say, 6 times 26, 7 times 26, or 8 times 26. In other words

1 post of	6 quires	contains	157	felts and	156	sheets of paper
" "	" 7	"	183	" "	182	" " "
" "	" 8	"	209	" "	208	" " "

The felts should possess particular qualities which Desmarest thus describes in his *Traité de l'Art de Fabriquer le Papier.*

"The felts have two surfaces furnished with different naps. That side which has the longest nap is applied to the couched leaves, and on the side with the shortest the fresh leaves are laid.

"If this arrangement of the felts were changed, and the leaves laid upon the surface covered with a long nap, not only would they not apply themselves accurately to the felt, but the long stiff hairs would pierce the paper or cause *depressions*, which would injure the texture.

"On the contrary, the leaves fit themselves evenly to the side with a short nap, which absorbs the surplus water, and gives them a sufficient consistency for the time being.

"It is also from this side that the layman detaches the leaves, after the post has passed through the press, and after he has raised the felts which covered them with their rough side, so that the different character of these surfaces is an assistance as well to the layman as to the coucher.

"The stuff of which the felts are made requires great attention on the part of the paper-maker, and much care and knowledge of the art of paper-making on the part of the manufacturer who prepares them.

"They should be firm enough to be spread evenly upon the leaves without wrinkling or needing to be displaced. Besides this, they should be supple enough to adapt themselves to the work of the coucher, who applies the mould successively from one border of the felt to the other upon every intermediate point.

"As the felts have to resist the reiterated efforts of the coucher and the press, it appears necessary that the warp of these stuffs should be very strong, and consequently of combed and well-twisted wool.[1]

"On the other hand, as they should be clean and quickly absorb and give up again a certain amount of water, their weft should be of carded wool loosely spun and woven in about the same manner as light cloths. It results from this that the weft abundantly fills the stuff and covers the warp in such a way that the texture is not marked upon the paper, which would injure its grain by the irregular impression of an uncovered warp and weft, as is often observed in manufactories where felts not woven upon these principles are used, and which does not denote much talent on the part of the paper manufacturer.

"If the stuff were too closely woven, like ordinary cloths, or even the finest kinds, it would not absorb the water enough to enable the leaves to adhere, and assume a certain consistency. It is for this reason that Carcassonne cloths are very well adapted to this purpose, and that those of Louviers, of which the texture is very close, would not take the leaves of paper couched upon them in experiments several times repeated, because the water could not sufficiently penetrate them.

"It is very essential that the warp of the stuff, intended to be made into felts, should be strong and tough, so that they may be of good service, and wear well."

[1] "We are authorized in supposing that the first felts employed in paper-making," says Desmarest, "were not textures woven upon a loom, and consisting of a warp and weft, but a felted woollen material similar to that used for making hats. It was afterwards found that these felts could be advantageously replaced by woven fabrics, but their ancient denomination has been retained."—Tr.

To realize these conditions the surface of the felt, upon which the mould is applied in couching, is shorn.

For the manufacture of fine note and bank-note paper, flannels are advantageously employed.

The general principle is that the wool of the felts should be proportionately fine as we wish to give the paper a finer grain and more homogeneous texture.

The aggregate of leaves of paper in a post raised from the felts is called a white post.

Formerly the pulp was triturated by means of mallets, and as late as the year 1861 the stamp-office required that these primitive engines should be used. On according the last contract for stamped paper, the office authorized the preparation of pulp by the cylindrical engine, now universally used. Nevertheless, some of the paper mills of Puy-de-Dôme still possess a few of these mallet engines.

§ 1. Manufacture of Paper by Hand.

Paper-making from the vat, or by hand, requires the labor of three workmen for each vat.

1st. The vatman.

2d. The coucher.

3d. The layman.

The first, by dipping the mould into the vat, makes the sheet; the second stretches or couches it upon the felt; the third, when the post has been pressed, successively detaches each damp leaf interposed between the felts.

We are about to examine these different manipulations in their natural order.

The workman, holding the mould in both hands by the two short sides, dips it into the pulp at an inclination of about 60 to 70 degrees, and raises it horizontally, after having taken up enough of the pulp to obtain the required thickness of the paper he intends to make.

By means of a double oscillating motion, called balancing, he distributes the pulp, as uniformly as possible, over the entire surface of the mould. Gradually the water drains through the wires or the meshes of the wire gauze; the pulp solidifies, and assumes a peculiar shiny look, which indicates to the workman that the leaf is made.

The workman then lays the mould upon the plank; takes off the deckle which he places at his right upon the bridge, and then hands the mould to the coucher. This workman raises it, and places it upon a small, curved, wooden stay in such a position that its inclination will favor the drainage of the water.

The vatman then applies his deckle to the second mould, and makes another sheet. In the mean time, the coucher seizes the mould with his left hand by the short side nearest him, and grasping it again by the upper long side which, by turning the mould, is on his right, he applies it to the felt making it describe the quarter of a circle.

When this is completed, the coucher rises, and slides the empty mould along the bridge.

It is after this operation that the vatman shoves forward the second mould deprived of its deckle, which the coucher places upon the curved stay to drain. This workman then takes a felt from the bench on his right, and applies it accurately to the leaf which he has just couched.

The operation we have just described continues until the post is completed, that is, until the coucher has exhausted all the felts of which it is composed.

The number of the felts in a post is variable; in the older mills it was composed of eight quires, that is to say, 209 felts containing $26 \times 8 = 208$ leaves of paper.

The two workmen should regulate their work so that the manipulations of each may coincide.

The rapidity of operation, however, depends upon the nature of the pulp and of the wire cloth of the mould.

There are two methods of couching: the French and the Swiss. In the first the coucher applies the mould vertically upon the felt and then reverses it.

In the second, the mould has been rotated 180 degrees, so that it occupies an almost reverse horizontal position; the coucher first leans it on the long side, and then making it describe an arc of 90 degrees, he couches every part of the leaf upon the felt successively.

This last method is more rapid than the first, but requires more skill on the part of the workman to couch the leaves evenly one upon the other.

It should, however, be adopted exclusively in working with pulp not readily drained, as the weight of the pulp causes it to gravitate towards the lower edge, and more or less destroy the homogeneous character given the sheet by the vatman.

It is important that the coucher should not allow any drops of water to fall upon the pages in raising the mould, which would produce so many spots impossible afterwards to remove.

On beginning a post, it is prudent to place several felts, one upon the other, so as to make a softer bed for couching the first leaves. Without this precaution, shreds of pulp remain attached to the mould, and produce breaks in the paper.

Couching by the long side of the mould offers the double advantage of accelerating the work and facilitating the extraction of the pulp from between the laid wires, as each interval will develop the outline of the surface generated by the motion of the coucher.

Another cause of waste, proceeding from couching, are bubbles, that is to say, blemishes upon the leaf, produced by the interposition of a volume of air between the felt and the leaf which, escaping when the next leaf is couched, manifests its departure by a depression in the sheet of paper bearing more or less resemblance to a bottle; hence, they are called in France, "bouteilles."

New felts are soft, and taking less hold of the surface of the leaf are liable to this kind of accident, which also occurs when the felt is badly stretched.

When the post is completed, the three workmen unite to carry and place it under the press; the central portion being generally more elevated than the edges, the difference in thickness is made up by bits of wood in the shape of an elongated triangular prism.

The workman then places a strong oak beam, from 15 to 20 centimetres (4.89 to 7.86 inches) thick, upon which the force of the press is exercised.

It is preferable to employ, instead of the hand-press of the older mills, an hydraulic press, the force-pump of which should be of sufficient diameter to accelerate the operation of pressing. In this case it would be well to place a strong oak plank under the lid of the press, as the elasticity of the wood renders the pressure more uniform.

The requisite degree of pressure attained, the workman brushes off the drops of water that ooze out along the felts, and which would be absorbed by them and thence by the leaves of paper when the pressure is taken off.

When the post is carried away, the work of the third hand begins, while the other workmen are filling the vat with a quantity of pulp proportioned to the weight of the preceding post.

The layman successively detaches the moist sheets, placing them one upon the other, and throws back the felts upon the bench to the right of the coucher.

The operation of raising the leaves is accomplished in two ways: either upon an inclined or horizontal plane. In the first method, generally employed in France, benches are used with an inclination of about 50 to 60 degrees.

The layman is generally assisted by an apprentice whose duty is to remove the felt, while the workman lays his leaf upon the preceding one.

This assistant may be dispensed with when the work is done upon an inclined plane; but is necessary when the direction is horizontal. He holds a sort of flat rule, over which the layman throws the leaf as soon as detached from the felt, still holding it with both hands by the two corners of the short side nearest him. The leaf, thus supported by the four corners is placed without difficulty upon the preceding one.

Without the aid of the assistant, the leaf, still very moist, would adhere too readily, and it would be difficult to avoid the presence of folds.

When the leaf is adjusted, the assistant withdraws the rule, removes the felt, and the operation is repeated.

If the post has been but slightly pressed, it is difficult to raise the leaves, the pulp has little consistency, and breaks, the corners tear off, and the result is the loss of a great number of sheets. If, on the other hand, the pressure has been too great, the leaves adhere too firmly to the felts and carry away some fibres of wool. It is the duty of the layman, therefore, to observe whether the pressure is sufficient, too slight, or too great.

When all the leaves are detached, the layman takes several felts to cover this first post of paper, and pats it forcibly with both hands to make it into a sort of compact cake less liable to be torn in handling.

After several days' work, the felts become greasy, and on being detached from the leaves, give rise to a peculiar creak. It is indispensable to wash them with brown soap in order to give them back their softness and absorbing qualities, so as to facilitate the operations of couching and separating the leaves.

There also accumulates around the sides of the vat, after a certain length of time, a peculiar kind of grease which, if mixed with the pulp, would produce spots upon the paper.

It is proper to clean the vats at least once a month, and even every fortnight. This cleaning should take place on Saturday, at the close of the day's work. The pulp is used up as far as possible by making a last post of paper somewhat thinner than the others. The pulp is then removed with great care, without touching the substances at the bottom of the vat, which are most impregnated with this grease.

By means of a brush the internal surface of the vat is perfectly cleansed, and, after repeated rinsing, the pulp which had been removed is replaced.

The greasy pulp may serve for manufacturing the common kinds of paper.

In some mills the posts of paper, after having been subjected to a slight pressure, are carried to the drying room. But if we desire to obtain a superior quality of paper, it is essential to lift and exchange the leaves.

Lifting consists in detaching one, two, or several leaves together, and forming new posts before hanging them up to dry.

In the exchange, the leaves are lifted one by one, and replaced one above the other in a different order from that which they at first occupied. The person charged with this work takes alternately a leaf from two posts placed beside him and makes of them a new one, in such a way that the middle leaves are at the outside, and *vice versâ*.

The grain of the paper is softened, the pulp acquires a greater degree of firmness, and assumes the velvety feel which characterizes the Dutch papers where the exchange is universally practised.

After four or five such operations, alternating with pressure growing stronger as the paper gains consistency, the leaves are carried to the drying-room.

These posts of paper being thicker in the middle than at the edges, the irregularity is compensated by bands of felt at the moment of subjecting them to the action of the press.

It is very important to moderate the pressure, especially at the commencement of the exchange, for it might happen that the leaves should become as it were welded to each other; and if laid paper is being made, the watermark of the wires might in part disappear. The Dutch therefore, consistent in their methods of manufacture, adopt coarser laid wires.

The exchange requiring great lightness of hand, it is preferable to employ women in this work, which we consider indispensable, for fine drawing-paper and certain kinds of register paper, which are not to be satined at all.

The paper is hung in spurs of four or five leaves, which are placed upon the ropes or tribbles by means of poles.

Paper not exchanged, when dried in warm weather, shrinks, and acquires a hardness which nothing will remove.

Moreover, the material when too soft yields to its own weight, lengthens out and forms a wrinkle on the back of the leaf, a defect which, it must be admitted, is found in almost all French paper. This imperfection is less evident when the paper is delivered folded; but if it is sold unfolded, which is necessary for printing paper, there result a great number of broken sheets.

In France, the drying-rooms are perched upon the top of the house. In Holland less elevated, and cooler stories are preferred, in order to prolong the drying.

Some manufacturers go so far as to hang the paper in spurs of seven or eight leaves in order to economize space in the drying-room. This method is bad under every aspect. The leaves on the outside dry more quickly than the under ones. The air circulates badly, and the drying is not homogeneous and uniform.

The nature of the tribbles has a great influence upon the cleanliness of the paper. Hempen ropes ought to be rejected, as they stain the back of the sheet yellow. Those of aloes and of the fibres of several kinds of cane are advantageously employed.

In France, the diameter of the tribbles is generally too small. With large ropes, the air circulates better, and the back of the sheet, being more rounded, is not so apt to crease.

As soon as the paper is dry, which fact is recognized by the peculiar rustling produced among the leaves when they are agitated by the hand, follows the operation of sizing.

The duration of the drying depends upon the season, the situation of the drying-room, the diameter of the tribbles, the number of leaves in a spur, the operation of exchange, the thickness of the paper, and the pulp used in making it.

To be kept continuously at work, a well-organized mill ought to be furnished with drying-rooms warmed by hot-air furnaces, so as to be able to dry and size the paper at all seasons.

§ 2. Sizing.

To render the hand-made paper impermeable, or fitted to receive writing, it is dipped in a warm solution of gelatine raised to a temperature of from 20° to 35° C. (68° to 95° Fahr.). This constitutes animal sizing.

This size is prepared by dissolving through long boiling, tablets of the dry gelatine of commerce, previously swollen by immersion in cold water.

It is nevertheless an advantage, in some countries, for the paper manufacturer to prepare his own size by means of the refuse of hides, cartilages, ears, hoofs, tendons, etc., bought from tanners or the shambles.

This refuse animal matter is dipped in milk of lime, which preserves it from putrefaction, and after drying in the open air is sold under the name of *scrolls*.

Notwithstanding the use of lime, if the desiccation has not been well attended to, it happens that this size undergoes a certain kind of fermentation which deprives it of a part of its adhesive qualities. This defect is recognized by the ammoniacal odor generated while the material is boiling.

Size obtained from young animals, such as lambs, calves, etc., is easily prepared, and of a white color; whereas that produced by the hides of oxen, cows, etc., is darker, but stronger, and tougher, and gives more firmness and resonance to the paper.

To obtain the solution of the gelatine contained in the scrolls, these last are placed in a copper boiler, surrounded by mason work, and usually heated by a naked fire.

It is well first to wash the scrolls in order to remove the various impurities which they contain.

The duration of the boiling varies according to the nature of the materials. For those obtained from oxen, from twelve to sixteen hours at least are required.

The scrolls should not touch the bottom of the vessel; as the parts in contact with the metal become too greatly heated, and produce a brown discoloration of the solution. To remedy this evil, in some mills a bed of straw is laid at the bottom of the caldron. But though the nature of the evil is changed, the effect remains much the same, as the straw gives up its own yellow coloring matter.

When fine paper is to be made, it is advantageous to employ wicker, or, still better, copper baskets, holding from 100 to 150 kilog. (220.47 to 330.69 lbs. avoird.) of size, which may be let down into the caldron by means of a pulley.

During the first hours of boiling, fatty matters appear upon the surface which are skimmed off. To facilitate this operation, they are sprinkled with lime, so as to form a calcareous soap.

When it is thought that the solution is sufficiently concentrated, the liquid is run off into a lower vessel, and the caldron again filled with water. By again boiling, a second weaker solution is obtained, and is generally mixed with the first.

Another method is to let into the boiler a quantity of water proportioned to the volume of the solution drawn off by the stopcock, so that the level of the liquid will remain invariable. The boiling is continued, and the fire is removed when it is judged by the amount drawn off that the scrolls have been deprived of all their soluble principles. This, however, may be easily ascertained by withdrawing some of the animal matter from the basket.

The solution thus obtained is never clear; it contains suspended in it different substances of which it is to be freed. This constitutes the operation of clarifying the size.

A small quantity of powdered lime is added, and, after being stirred, the liquid is allowed to rest. If the impurities have not completely settled to the bottom, a half a hundredth part of sulphuric acid is added. An insoluble sulphate of lime is formed at once, and its precipitation clarifies the solution.

The liquid is decanted and filtered through several folds of felt which retain any remaining impurities. This solution contains a mixture of gelatine and chondrine, two substances differing very greatly in their properties. The latter being an obstacle in sizing, it is indispensable to illuminate it. Very fortunately this material is completely precipitated by a concentrated solution of alum. Sulphate of alumina, and sulphate of iron produce the same effect.

The size, when again filtered, is ready for use; if it is too concentrated it is diluted with warm water. The temperature and the strength of the size both vary according to the nature of the paper and the condition of the atmosphere. Papers manufactured from hard rags, not fermented, require a thin size with a high temperature. The reverse is the case with those made from soft rags. All things equal, it is important that the strength should be greater in summer than in winter.

The papers are dipped in a copper caldron of about one metre (3.28 feet) in diameter by 0.50 to 0.70 metre (1.64 to 2.24 feet) in depth. These dimensions are not fixed; they will depend, as may be readily seen, upon the size of the paper.

To keep up an even temperature, the caldron is heated by a small furnace. It would be much preferable to adopt the heat of a water-bath or steam, by means of a worm or a caldron with double sides.

The workman employed in the operation of sizing dips a package containing from 100 to 150 leaves at a time, separating them like a fan, and manipulates them so that every part of the leaves shall be uniformly saturated. This requires a certain amount of skill.

He then carries the package to the immovable stand of a hand-press near the sizing tub.

He then lays a series of packages one above the other, and when they have attained a height of 0.50 metre (1.64 feet) he places a plank upon them, and presses them in order to drive out the excess of size, which flows back into the tub placed below it.

The degree of pressure should vary according to the nature of the paper; so that, in all cases, the leaves may be readily removed singly and without tearing.

The moist-sized paper must then be carried to the drying-room, and hung upon the tribbles in spurs of two, three, or four sheets.

Careful manufacturers exchange the paper when sized before carrying it to the drying-rooms. The drying is benefited by this, and the leaves acquire more strength and firmness.

M. Payen, in his *Chimie Industrielle*, gives the following theory of gelatine sizing:—

"In order that paper may be well sized, it must be properly dried. This should be done gradually and slowly, without, however, being carried so far as to allow the spontaneous decomposition of the gelatine to take place.

"This accident sometimes occurs in summer, especially in damp and stormy weather; the size then liquefies, loses its adhesive qualities, and the operation miscarries. If the drying is too rapid, the size remains disseminated through the entire substance of the paper; but if the process is carried on with proper slowness, the moisture contained in the paper gradually finds its way to the surface, and carries with it the gelatine, which forms a superficial and impermeable coating.

"The drying is moderated by means of ordinary window blinds, the openings of which may be regulated at will. It will be understood that by drying slowly the gelatinous solution is allowed to come to the surface as fast as the evaporation of the water takes place, and that therefore the greater part of the gelatine is concentrated at the surface, and renders the paper impermeable, whereas if dried too quickly this material would remain disseminated throughout its entire substance.

"It is easily ascertained whether the paper is sized on the surface only, by scratching it, and then drawing an ink mark over the denuded part. The paper sized with gelatine will absorb the liquid, whereas the ink will remain unaffected by machine-made paper sized with resin through the entire thickness."

This explanation is entirely confirmed by the practice of dampening the paper when too quickly dried, and appearing to be imperfectly sized. Such paper placed between wet leaves becomes moist, and by again passing through the drying-room, the size disseminated throughout the substance of the leaves comes out on the surface as the water evaporates, and the paper becomes impermeable without any additional gelatine.

This process gives the paper firmness, and some manufacturers were formerly in the habit of always employing it for certain kinds of paper, finding in the excellence of the result a sufficient compensation for the cost of the double manipulation.

The character of the water has a marked effect upon sizing, as direct experiments made by M. Mongolfier, prove beyond a doubt.

It is therefore essential that the water which is to be used in the different manipulations of the pulp should be clarified with much care. If the water is very highly charged with calcareous matters, it is well to precipitate these substances with carbonate of soda or even alum.

The proportion of these reagents ought, of course, t vary according to the composition of the water.

Certain well waters containing a great quantity of selenite (sulphate of lime, CaO,SO_3+2HO) absorb 1.83 grammes (28.25 grs. troy) of pure dry carbonate of soda, before being enabled to dissolve soap.

River waters require from ten to thirty grammes (159.42 to 463.25 grs. troy) of alum to the hectolitre (22.01 gallons) of liquid to effect this precipitate. This fact explains the superiority of the papers produced by some mills situated upon streams with granite beds yielding them no calcareous elements.

When certain kinds of drawing paper are not sufficiently sized, we advise the use of the following mixture, very much employed in the offices of civil engineers and architects. Its composition is simple and its preparation easy.

Dissolve in one litre (1.76 pints) of water

122 grammes (1583.96 grs. troy) Flemish glue,

122 " (1583.96 grs. troy) white soap.

After dissolving add—

62 grammes (0.126 lb.) of powdered alum.

This size is applied cold with a sponge or fine brush.

§ 3. Finishing.

The closing preparation of hand-made paper is the same as that before described in the case of paper made by machinery.

On leaving the drying-rooms, the paper is piled up and subjected to repeated pressures in order to remove in part the trace of the fold on the back. A series of packages is made up, between each of which packages is placed a wooden board of the same size as the paper, in order that the action of the press may be more uniform and better economized.

Such papers as are not to be rolled require a more energetic pressure. It is also well not to pile them up when they are too dry, as the last traces of moisture greatly facilitate the work.

The nature of the wood from which the boards are made is not a matter of indifference: wood without knots is required; and very dry walnut answers the purpose quite well.

Sometimes these boards are covered over with polished pasteboard, or the latter is used alone.

Whatever may be the nature of the hard substances placed between the packages (200 to 500 leaves), it is very essential that the pressure should be quite gradual in the beginning, otherwise the leaves crease, or the grain is unequally crushed, and never gives that uniform dead surface which is characteristic of the products of the best paper-mills.

Before being put up into reams and packed, the pressure of an hydraulic press would much increase the lustre of the paper.

The principal defects which are found in paper made by hand, are knots, lumps, shreds, drops of water, bubbles, folds, torn edges, ragged edges, spots of size, holes, and tears.

When the paper is put up in reams, it should be perfectly dry, and laid in a dry and well-ventilated place, otherwise, by the action of moisture, it would soon sour.

§ 4. Manufacture of Bank Note Paper and Watermarked Paper in general.

The paper of bank notes, when held to the light, generally presents inscriptions or designs which, in the art, are called watermarks.

There are several kinds of watermarks. The most simple are obtained by sewing to the laid or wove wires of the mould fine brass wire twisted according to the outlines of the design, or, still better, a thin copper leaf cut out with a puncher or graver.

The increase of thickness in this place, and the raised wire preventing the pulp from draining, produces a reverse effect upon the paper, the design of which is seen lighter than the rest of the leaf.

This kind of watermark is adopted for French stamped paper. The design is, at present, an eagle surrounded by two concentric ovals, between which is inscribed "*Timbre Imperial*," and the year in which the paper is made.

This simple watermark, easily imitated by pressure, is insufficient for bank notes and paper money, properly so-called.

In this case the following devices are resorted to, first, the use of a dark watermark with light letters obtained by depressing the wire cloth itself, in such a manner as to produce a sort of rectangular cavity in which a greater quantity of pulp may be deposited, and then sewing the letters to the bottom of this depression. Second, shaded watermarks, the richest of all, allow us to obtain, by a sort of moulding process, every variety of relief, of whatever nature.

We give, in Pl. V., different specimens of watermark:—

1st, Fig. 10 to 14, light watermark.
2d, " 15 and 16, light watermark on dark ground.
3d, " 18, shaded watermark.

The principle of depressing the face of wire cloth or the preparation of watermarks, is that every part of the surface should be readily stripped from the paper in order to render possible the operation of couching.

The manufacture of watermarked paper requires especial care. The workman must manage to produce a leaf of exactly uniform thickness throughout its whole extent. This is necessary to secure a clear impression. The coucher should see that this impression is sufficiently distinct, and notify the foreman at once, when a letter or any other part has become detached or unsewed.

Moulding the wire cloth, for shaded watermarks, requires the skill both of a moulder and an engraver.

As paper money is to undergo constant rumpling, the manufacturer should exclusively employ linen or brown Holland rags, well boiled and slightly bleached in order to remove the gummy, fatty, and other matters which would render the paper too transparent, but these operations need to be carried on with great care in order not to impair the strength of the fibres.

In order to soften the grain and remove the marks of the felts or flannels, the exchange must be resorted to, and the first drying should take place between sheets of bibulous paper. When once the greater part of the water has been drained off, the paper may without danger be carried to the drying-rooms.

The preparation of the size is one of the most important operations; for if it is badly made, the paper will be soft, instead of presenting its characteristic firmness and metallic resonance.

Although we have paid especial attention to the manufacture of the material of bank notes, paper money, etc., our reserve in not entering further into the different processes adopted and practised by the banks for the manufacture of their bills will be readily appreciated.

§ 5. Comparison between Machine and Hand-made Papers.

The papers made by one or the other method of manufacture having each a special application, it will be sufficient for us to indicate these in order to set forth the respective advantages of both kinds.

Machine-made paper abundantly produced, and quickly delivered, is indispensable at the present day for common printing and writing papers, and those for wrapping, packing, etc.; in other words for all paper the uses of which are ephemeral and limited.

One of the great advantages of a machine, is that it enables us to make the paper, size, dry, and deliver it within twenty-four hours.

Hand-made papers, on the contrary, require long-continued and expensive labor, and, in consequence, cannot be delivered in less than the second month after the order is received.

For each size of paper, a separate pair of moulds has to be made.

This kind of paper is particularly adapted for important documents, whether printed or written, as it is composed of strong filamentous substances exclusively.

As the addition of mineral matters in making paper by machinery increases every day, the paper becomes brittle, and the use of chemical reagents in too large proportions impairs the resisting power of the fibres to such an extent, that there merely remains a material without consistency, and receiving only an appearance of strength from the increased proportion of starch used in preparing the size.

The cost of labor required by hand-made papers constitutes one of the principal elements of the entire expense of a mill; the manufacturer, therefore, works up only linen, slightly boiled and unbleached, so as to give the paper all possible strength and suppleness.

In manufacturing by the machine the paper undergoes constant traction, and especially between the last wet press and the first drying cylinder. This tension deranges the interlacing of the fibres, and is sometimes so great that the sheet is broken.

In manufacturing by hand the fibres retain the original order of their arrangement, the texture is more supple, and, when rendered impermeable by varnishing both sides with gelatine, the paper acquires a peculiar resonance.

To these advantages we may add another no less important for certain kinds of paper. We allude to the watermarks.

The paper being made leaf by leaf upon the same or perfectly similar moulds, it is evident that the watermark will invariably occupy the same position in each sheet.

As the guaranty of the watermark is beyond dispute, we can appreciate the reasons of the French government, notwithstanding all that has been said, in maintaining the method of manufacture by hand for stamped paper. More especially, then, do we admit the necessity of employing papers made by hand upon watermark moulds for bank notes, paper money, etc.

It is also impossible to exercise strict control over the amount of paper made by machinery, whereas by the other system we easily regulate the entire number of pages to be manufactured in a day. Nothing can be more simple than, for example, to fix the product of each vat at 2,000, 2,200, or 3,000 leaves for every ten hours of actual work.

To recapitulate, then, the machine-made papers are suited to the current uses of writing and printing materials, etc.; and their consumption considerably increases every year.

Hand-made papers are reserved for printing works destined to be transmitted to posterity, stamped papers, or those which are required to be taxed, paper money in general, and drawing paper, which, up to the present time, the machine has only been able to imitate very imperfectly. We think, therefore, for the above reasons, that these two methods of manufacture will always have a legitimate and distinct existence.

§ 6. Classification of Paper.

The different kinds of paper which it may be necessary to make are embraced in the following classification, perhaps seemingly puerile, but which allows us to discern at a glance the aggregate of the qualities resulting from the composition of the papers or the uses to which they are adapted:—

White papers.
Colored papers.
Double colored papers.
Papers sized with resin or vegetable size.
Papers sized with gelatine or animal size.
Papers sized with a mixture of animal or vegetable size.
Papers half sized.
Papers unsized.
Wove papers.
Laid papers.
Papers watermarked by compression.
Papers watermarked in the pulp.
Unpolished paper.
Rolled or satined paper.
Glazed paper.
Writing paper.
Printing paper.
Engraving paper.
Tissue paper for artificial flowers.
Tissue paper unsized.
Tissue paper for tracing.
Register paper.
Drawing paper.
Parchment paper.

Bibulous paper.
Silk or silver paper.
Berzelius or filtering paper.
Cigarette paper.
Brown paper.
Wrapping paper.
Packing paper.
Blotting paper.
Leather paper.
Tarred paper.
Paper made of straw.
Paper made of wood, etc. etc.

Papers also receive different names according to their sizes.

CHAPTER V.

FURTHER REMARKS ON SIZING.

[The importance of sizing, as a part of the processes for the manufacture of paper, induces the translator to believe that the following chapter, by M. L. S. Le Normand,[1] will be of interest and value to the American manufacturer.]

If paper were sent into the market in the stage of preparation to which it attains before sizing; if we were satisfied with first drying and then forcibly pressing it, the material would be soft, with scarcely any consistency, and could only possess a very limited usefulness. Ink, if deposited upon one of its surfaces, would pass through the pores of the paper and appear at once upon the opposite side. Printer's ink would scarcely adhere to it.

At the time when the very first sheets of paper were made, this inconvenience was recognized, and means were sought to remedy it. The sizing used for many other objects was the only kind then known, and its application to this new product was therefore attempted.

Two methods presented themselves for attaining this object. One was to mix the size with the rag pulp, which would carry this material, so necessary to the solidity of the manufacture, into the substance of the paper itself; the other was to cover over the surfaces of each leaf with a preparation of the same material. It seems that the first method was not even tried, and that

[1] "Nouveau Manuel Complet du Fabricant de Papiers, ou de l'Art de la Papeterie."

it was feared, lest by introducing this mucilaginous substance into the pulp, it would impair the regularity of surface so important to the paper. The most ancient authors make no mention of such an attempt, which certainly would have led them to the improvements recently introduced into the art we are studying, as we shall see further on. It must not be lost sight of that our plan consists in describing first the old methods of preparing paper, and afterwards ending off with the new processes, by showing all the improvements which have been made in this important art.

The second of the above-mentioned methods was at first alone practised; it consists in using glue or gelatine, into a solution of which the paper is dipped, so that it becomes glazed on both sides, and acquires the properties which it before lacked. This operation, which is called sizing, requires us to enter into minute details in order fully to understand the various manipulations.

§ 1. Of the Sizing-Room.

In a paper-mill, the sizing-room is an apartment set aside for the operation of sizing alone. It contains apparatus, which we shall now describe in turn.

1st. A furnace of mason work built against one side of the room, and furnished with a copper caldron, five feet in diameter by three in depth. It is in this caldron that the size is made, or the gelatine extracted from the substances which contain it, and of which we shall speak further on.

2d. An ozier basket, surrounded by an iron casing, which gives it sufficient solidity to allow it to be elevated or depressed at will, as the operation may require, and supported by two iron chains, fastened by their four extremities to the iron cross-bars of the casing. The chains are united in their middle by a rope, the other extremity of which is wound round the axle of a wheel, firmly fixed upon the upper floor.

This axle is horizontal, ten inches in diameter, and revolves upon iron spindles. Around it, as we have said, the rope sustaining the basket is wound, after passing through a hole in the mantle of the furnace. In order to facilitate the management of the basket, which is rendered very heavy by its iron casing and the matters containing the gelatine, a wheel, fifty inches in diameter, revolves at the other extremity of the axle, around which is wound a second rope, descending to the side of the furnace and there fastened to a strong iron hook, to sustain the basket at the desired height. Those who have a slight notion of mechanics will at once perceive the advantage which this wheel, with a diameter which may be increased at will, presents in diminishing the amount of force required. With the proportions we have indicated, the amount of power required will be only equal to a quarter of the weight of the basket when full, the size of the basket being four and a half feet in diameter by two in depth, so as to allow it easily to be contained in the caldron.

Into this basket, which is not used in all paper-mills, are thrown the substances containing gelatine. The advantage of this arrangement is, that the materials called scrolls, the boiling of which furnishes the glue, can be withdrawn at pleasure from the caldron, thus preventing them from mixing with and making the decoction turbid, which it is important to keep clear and limpid, and enabling us to ascertain whether they are sufficiently boiled, or, in other words, have furnished all the gelatine they are capable of affording.

3d. By the side of this furnace and against the wall is placed a copper, or simply a wooden chest 2 metres (6.56 ft.) long, by 1 metre (3.28 ft.) wide, and 20 centimetres (7.86 inches) deep. This chest is solidly fastened and hooked with iron, and rests upon three wooden cross-pieces. On the side nearest the furnace is placed a square frame, sustaining a piece of blanket or woollen cloth, for filtering the gelatine. The blanket is fastened to the frame by small iron hooks, and supported from below by a few slack cords.

4th. Several presses may be seen in this room, which present nothing remarkable except in their arrangement, which will be explained in describing the operation of sizing.

5th. And lastly a copper vessel called a sizing tub, in which the operation of sizing is effected. This vessel is 1 metre (3.28 ft.) in diameter, and 541 millimetres (21.28 inches) deep. It is mounted upon an iron tripod 8 inches high, under which is placed a small coal furnace to keep the gelatine at a proper temperature during the process of sizing.

The tub is placed near the press, so that the size in running off from the saturated paper may return to it and not be wasted in the passage.

Several copper basins, each having two handles, are also found in the sizing-room. They are for general use in manipulating.

§ 2. Method of Extracting Gelatine.

"Gelatine," says Thenard, "never enters into the composition of the fluid parts of animals, but all their soft and solid parts contain the substances suitable for its formation. In this condition it is found in the muscular fibre, skin, ligaments, cartilages, tendons, and aponeuroses; the membranes contain a large proportion of gelatine, and it constitutes about half the weight of bones.

"Gelatine is heavier than water, without taste or smell, colorless, and without reaction upon litmus paper or syrup of violets; it is, therefore, neither acid nor alkaline.

"Decomposed by fire, gelatine again offers us the same phenomena as these substances, but is easily distinguished from them by certain of its properties.

"This material is very soluble in boiling water, but very sparingly so in cold. When two parts and a half are dissolved in a hundred parts of water, the liquid congeals on cooling. The jelly sours in a few days, especially in summer; it then liquefies, and before long takes on all the phenomena of putrid fermentation.

"Gelatine or glue is generally prepared for the uses of commerce from parings of hides, parchment and gloves, and from the hoofs and ears of oxen, horses, sheep, and calves.

"These substances, after being cleaned and relieved of their fat and hair, are boiled in a large quantity of water for a long time, care being taken to remove the skum as fast as it appears, and its formation being even occasionally hastened by the addition of alum or lime. After this the liquid is passed through a sieve, allowed to rest, and finally decanted, skimmed again, and run into wet uncovered moulds, when it assumes the form of flat plates. When these plates are perfectly cool, which they generally are at the end of twenty-four hours, they are taken away, cut into tablets, and the operation is terminated by placing them on coarse nets in some warm and well-ventilated place.

"Gelatine is not extracted in this manner from bones. As these contain much phosphate of lime, they should first be brought into contact with liquid hydrochloric acid, which is renewed if necessary at the end of eight days. By this means they are deprived of all their saline matters and become elastic, semi-transparent, and flexible. If they are then treated with boiling water, they become almost immediately converted into glue. Four hours' boiling will be sufficient, and the remainder of the operation is performed in the manner indicated above.

"All size is more or less transparent. Some sorts are of a blackish and some of a reddish-brown, while others are of a slightly yellow-white. The most transparent and least colored are the purest, and these kinds are employed by the paper-maker. Glue extracted from bones by the process we have just described, and which M. D'Arcet has made upon a large scale, is much superior to all other, and is even as handsome as the best isinglass."

This is the process employed by M. D'Arcet, as described in the patent taken out by him, January 14, 1814, and which expired on the same day, 1829.

"It is well known that by boiling powdered bones in water, twelve or fourteen per cent. of gelatine may be extracted, and that this method has already been proposed and employed on a large scale for making glue and bone soup; but it is also well known that bones contain nearly fifty per cent. of animal matter; whence it follows that by the known method about thirty-five hundredths of a hundred kilogrammes of bones are lost. These thirty-five hundredths of dry gelatine are very sparingly soluble in water, and the residuum which contains them is abandoned as useless, or sold only for manure.

"My process has nothing in common with that of which I have just spoken; it consists in converting into glue the thirty-five hundredths of cartilage which are lost by the known method.

"I operate upon fresh bones, or upon the residuum of bones, after they have been treated with boiling water only.

"If the bones are fresh, I begin by breaking them up to extract the gelatine they may yield by simple boiling in water; unless, indeed, I should find it more economical to lose the gelatine, which might be obtained by this process.

"I then put a hundred kilogrammes (220.47 lbs. avoir.) to soak in deal tanks or reservoirs, lined with lead, with four hundred kilogrammes (881.88 lbs.) of muriatic acid, diluted with water till it marks six degrees of the hydrometer. The whole is stirred once a day, and when the bones are well softened, I wash them with running water; pass them through the press, and wash them again carefully. The cartilage thus obtained may be at once converted into glue, or desiccated at the drying stove. To convert this material into jelly, it will be sufficient to dissolve it in boiling water, or in the solution of gelatine already obtained, by treating the bones with boiling water, and thus to bring the solution to the requisite degree of concentration. This solution of gelatine stiffens on cooling. To be considered of first quality in commerce, it should contain for every hundred and ten kilogrammes (242.51 lbs. avoir.) of dry gelatine, eighty-six kilogrammes (189.59 lbs.) of water.

"If the cartilage should be somewhat difficult to dissolve in boiling water, it is because the washing has been carried too far. It would then be necessary to add to the water a few drops of hydrochloric or sulphuric acid, or simply of vinegar, in order to render the solution of the cartilage very prompt and complete. When the operation is well managed there should remain no residuum.

"To convert this jelly into glue, we have but to reduce the solution to such a degree of concentration that it shall contain twenty-five kilogrammes (55.10 lbs. avoir.) of dry glue, and seventy-five kilogrammes (165.35 lbs.) of water, to one hundred kilogrammes (220.47 lbs.) of the solution. It is then run into moulds and cut into tablets, as described in *the art of making glue.*

"The washed and pressed cartilage may be desiccated by exposing it to the air, or by employing a drying stove. In this condition it remains unchanged by the action of the atmosphere; may be kept for a long time, and sent to great distances. This substance represents an equal weight of glue, and to convert it into jelly, it will suffice to put it to soak for one night, and then treat it with boiling water, as we have before mentioned.

"The cartilage, when strongly pressed, takes up very little room; is easily transported; sells remarkably well; and takes the place of the raw materials commonly employed in glue manufactories.

"The advantages presented by this process are very considerable. 1st. Hydrochloric acid is utilized, which, for want of use, has little or no commercial value, and of which immense quantities are wasted every day. The same is true in regard to bones, from which only a poor profit has as yet been derived.

"2d. From a quintal of bones we can obtain five hundred pounds of good jelly, or about fifty pounds of dry glue, reduced to tablets; whereas, by the process employed thus far, a quintal of bones only yields, with great trouble and expense in fuel, one hundred and forty pounds of jelly, or from fourteen to fifteen of dry glue.

"The jelly, prepared by this means, has the great advantage of remaining fresh for a long time; it contains a slight excess of acid and a little oil, which guard it against the rapid changes, generally undergone by animal size, and which are the cause of such large annual losses in the manufactories.

"Bone size is, besides this, entirely inodorous, and, being almost colorless itself, does not impair the shade of the dye-stuffs with which it is mixed, but allows them to retain all their brilliancy, even giving them a softer tone, which I believe to be due to the small proportion of oil combined with the sizing.

"To conclude, I will add that this size, if carefully prepared, may, in many instances, take the place of isinglass, which we are obliged to import from abroad, and sell at a very high rate."

Our desire to see all possible improvements introduced into the paper-mills of this country, has induced us to give the foregoing literal transcript of the patent taken out by M. D'Arcet; we now lay before the reader the actual processes employed in mills worked upon the old system, in order to obtain size for their own use.

We have already mentioned the substances from which gelatine is extracted, and, with Thénard, have called attention to the fact that the glue we obtain is of different colors and different quality, in accordance with that of the raw material employed. The paper-maker desires to obtain the whitest possible size for his superfine papers; he therefore employs for this purpose the skins of small animals, such as hares, rabbits, or eels, and the parings of leather-dressers and parchment-makers. For common papers he uses sheep's feet, the ears and cartilages of calves, and such leather parings as are furnished by the tanner. Lastly, for the coarsest kinds, the feet and ears of oxen, and the cartilages of old animals are employed.

Paper-makers take care to sort all these parings, which they classify according to their qualities, especially rejecting any rotten pieces of leather, which might infect the size while boiling, and separating the lime as far as possible. After this sorting, they place all these pieces, cutting them up still more finely if they think necessary, in the basket we have described as hanging over the caldron. The basket is let down by means of the wheel and the caldron filled with water. The fire is then lit and the material slowly boiled, until it has evidently yielded all the gelatine it can. The fire should be carefully managed; at first it should be quick and then slackened. The liquid must be skimmed and the boiling kept up equably, as a good housewife would do in preparing soup. The time which the boiling should last cannot be fixed, as it depends upon too many extremely variable circumstances.

The process completed, the basket is raised and fixed over the caldron to drain; the fire is extinguished, and the liquid left for some time to itself. The decoction is drawn off from the caldron by means of a faucet while still quite warm. The workman receives the liquid in small copper basins and carries it to the strainer, which he has already prepared over the chest, in order to filter it. It would be well to leave the filtrate for some time in the tank in which it is received, in order to allow it to settle and become clear; but the prejudice of manufacturers is against this practice, which, however, as Desmarest observes, is adopted in Holland.

Before being applied to the paper, the size is again filtered as it is poured into the tub, in which the operation of sizing we are about to describe is performed.

It will be useful here to answer a question often asked us, and to which we have always given the answer we now repeat. Why, it is said, does the paper-maker occupy himself in preparing size? is not his art sufficiently complicated? does it not require enough minute attention, without his being obliged to add to it a branch of industry, presenting in itself many difficulties, that of the manufacture of glue? Would it not be better to buy his size ready made? Does not his interest point out this course?

It would be perhaps possible to mention some very rare cases, in which economy would direct the paper-maker to buy his size already prepared, instead of making it himself; but in general two very powerful reasons prevent him from so doing. We have indicated the materials used in preparing the different kinds of size, suited each to different qualities of paper; he might readily be deceived in regard to these materials. The paper-maker can only obtain size in the form of tablets, adopted to facilitate its transportation; but to reduce the gelatine of the tablets, the manufacturer has already been obliged to use a great amount of fuel in evaporating the excess of water, and a long and laborious operation has been gone through with to bring these tablets to the degree of dryness requisite to prevent them from undergoing a change during transportation, or while in store. All these various manipulations require an outlay, which has to be returned with some profit to the glue manufacturer. Now the paper-maker has no need that his size should be reduced to tablets. As soon as his liquid is sufficiently impregnated with gelatine he uses it, and thus, by making his own size, economizes all the costs, which the labor of reducing it to tablets would require. In addition to this, also, he is enabled to use whatever raw materials he thinks best.

§ 3. Operation of Sizing.

In the first paragraph of this chapter we said that a caldron or tub, in which the operation of sizing takes place, is situated near the press, so that the size, which runs off from the handful of leaves, just dipped by the workman in the tub, and laid on the stand of the press, may not be lost, but fall back into the same vessel. We added that we should here describe this stand, so that the reader might obtain a clearer notion of the manner in which the drainage from the press is effected.

The upper surface of the press-stand, which is constructed with a view to great solidity, is raised thirty inches above the floor, and is thirty-six inches long by twenty-four inches broad between the uprights. This stand is surmounted by a frame two inches broad on all sides, and a good inch in thickness. The frame is strongly fixed upon the stand by screw bolts, the heads of which are buried in the frame above, and fastened by a nut under the table. In place of these bolts, strong wood screws may be used, having their conical heads likewise buried in the frame, which should fit the upper surface of the table so accurately that water may not be able to pass between them. It will be seen that by this arrangement the press stand presents a regular hollow eighteen inches broad by thirty long.

In the left hand corner of the press-stand, and eighteen lines below the lower surface of the frame, a hole is pierced, slanting upwards, and opening in front of the inner border of the frame, into which is fitted a copper pipe, projecting far enough beyond to pour the excess of fluid continually into the tub. This pipe should be well cemented to the edge of the hole, so that no liquid may be able to run off by any other outlet.

The workman generally stands at the tub, with the press at his right hand, and on his left a bench supporting the leaves, just as they have been carried from the drying-room after the stiffness has been taken out. The tub is then filled with tepid size, and the furnace placed under it. A quantity of alum is thrown in, varying according to time and circumstances, as we shall explain in the general remarks at the end of this chapter. The alum is dissolved in hot water, and well stirred to mix it with the gelatine. The alum prevents the size from decomposing, and preserves it for a considerable time. Some manufacturers add white vitriol (sulphate of zinc).

The workman places by his side three or four wooden instruments, called pallets, by means of which he manages the leaves of paper in the manipulations of sizing. These pallets are pieces of wood, flat upon one face, rounded on the other, and slightly conical at the two extremities. The shape of this instrument may be readily imagined by considering it as formed of a cylinder, three or four inches in diameter by twenty-two in length, terminated at each end by a blunt elongated cone, then cut in two by a plain parallel to its axis, and by this division forming two pallets.

Standing in front of the tub, the workman takes a handful of paper in his left hand, and supports it from beneath by one of these pallets; he seizes the leaves on the opposite side with his right hand, and takes care to separate them with the fingers of that hand, in order that the size may the more readily penetrate between them; he submerges that entire end of the paper by

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dipping his hand into the size; he then lifts the bunch with his left hand, and holds it above the tub to drip, which brings the leaves together. The end held in the right hand is allowed to rest upon a second pallet, which generally floats upon the size, while with a third he seizes it above, so as to catch it between the two, and lets go the other end, which he held in the left hand. He again separates the leaves with his fingers as before, and plunges his left hand into the size with this end. The bunch of leaves is held suspended for some time to allow the size to run off and the pages to adhere; and the workman, after having raised the lower end with his left hand, carries the lot with both hands to the hollow surface of the press-stand.

This operation is continued until ten or twelve handfuls have been sized. A turn is then given to the press, which causes the size to penetrate the substance of the paper, and the excess of the liquid flows back into the tub by the pipe we have already mentioned. This operation requires considerable care; for, if the paper is pressed too hard, an excessive amount of gelatine is thereby expelled, and the interior of the handfuls of leaves would remain unsized. From exact experiments it has been estimated that a quantity of unsized paper, weighing eighty-six pounds, absorbs, in sizing six pounds of dry gelatine.

§ 4. Drying after Sizing, the Dutch Method preferable to the French.

We have observed that, when the process of sizing is completed, the workman presses the entire mass of paper, gently and slowly, not carrying the operation too far, so that the size may have time to become fixed in the substance of the leaves. The paper is only left long enough under the press to insure a uniform penetration of the size, without allowing it to dry, as, in that case, there would be danger of the leaves becoming so tightly glued together, as to be no longer separable.

When the moment of taking off the pressure has arrived, the paper, still wet, is delivered to women who separate it sheet by sheet, and thus hang it upon the tribbles, or ropes, in the drying-room, by means of T shaped lifters, beginning from above. These lifters, with handles varying in length with the height of the tribbles, are employed to avoid the necessity of mounting upon trestles. The entire length of one line is covered with leaves before beginning upon the next.

There are a great many mills, in which, instead of using lifters with poles of various lengths, so as to work from the ground, after the manner of the Dutch, they still employ benches, or trestles, of different heights, to hold the trays, on which the paper is brought to the drying-room, as well as to enable the women to reach the tribbles. The Dutch method, however, is preferable, as being more economical and less dangerous.

In France, we have the defect of hanging the leaves on the lines, one by one, while still warm. The paper dries very rapidly, and loses by this ill-advised evaporation a great part of the size, which had penetrated its interior and covered its surfaces. The openings into the drying-room are not so arranged as to be closed hermetically, the external temperature easily pervades the room, the desiccation goes on too rapidly, and the paper assumes that granulated appearance, which it was the object of this process to remove.

It has been thought that this defect might be remedied by sizing early in the morning, and hanging the paper to dry at once. This method, however, is only palliative, as is judiciously observed by Desmarest. The heat of the day comes on before the operation is finished, and the drying has the same bad results as before. A thunder storm, supervening during the process, increases the difficulty, and, as is well known, often sours the size, so as entirely to prevent its action, or allow it to be only imperfectly produced. By adopting the Dutch method of drying, nothing is to be feared from extreme heat.

The Dutch have a great advantage over us in the processes they employ for the preparation of paper after sizing. They have had the good sense to introduce the operation known as the exchange, which is performed on the paper as it leaves the sizing-room. They operate as follows:—

"When the paper has remained long enough under the press, the workman carries it away, in portions of one or two handfuls, and distributes it along the table; he then begins with the nearest lot and exchanges the leaves one by one, lifting them by the corner, so as to form a new pile which differs from the first, only in that the surfaces, which before touched and had been pressed against each other, are made to correspond with the surfaces of other leaves. By thus mixing the leaves in a new distribution each surface is detached from those of the contiguous leaves, to which it adhered, and applied to others, against which it is again pressed. It is of little consequence whether the paper is still warm or not, so long as it is wet. Care must be taken, however, to see that the leaves are not replaced under the press, after the exchange, until the paper is cool; for if still warm, the size would be fluid and liable to be expelled from the leaves by the action of the press, or to extravasate unequally upon the surface, thus producing irregularities and destroying the advantage of the exchange.

"It is better," adds Desmarest, who furnishes us with these judicious observations, "that the paper, while still warmed by the size, should acquire a certain amount of consistency during the exchange. The size should also become firm, while the material is cooling, so that the result of this operation may be perfected under the press, which terminates it by giving to the paper a dead polish, very suitable for writing or drawing purposes.

"From these considerations, it seems to me," continues our author, "that the advantages presented by the exchange after sizing, render the operation of great importance. In Holland, it is performed upon every kind of paper. The second exchange deserves to be the more carefully attended to, as its effect remains invariably impressed upon the paper, and is not disturbed by any subsequent operation.

"I ought to say," Desmarest remarks, "that in France, where they do not seem to pay so much attention to softening the face of the paper, it is at the time when the women throw the sized leaves upon the lifting poles that I have noticed the greatest amount of roughness. The leaves are separated with difficulty, owing to the adhesion produced by drying. It can be seen, by taking a position opposite to the light, that the paper bristles with an infinite number of little hairs, which the adhesion, and the sudden effort at separating the leaves, has produced over the whole extent of their surface. Afterwards, when dried quickly and thoroughly, the paper retains the same inequalities which are only imperfectly removed by the finishing press; for when the leaves are subjected to its operation, they have become so stiff and hard that these fibrillæ can no longer re-enter their substance. The Dutch, on the contrary, gather their leaves before they are so dry, and while they are still susceptible to the action of the finishing press, which imparts to them that beautiful lustre so much esteemed throughout all Europe."

§5. Some Important Observations upon Sizing.

The learned and judicious observer, Desmarest, has pursued the subject of paper-making with so much care, both in France and in Holland, that it is impossible to say anything more to the point than what he has given in his work on the art of making paper. We shall, therefore, quote again from this author.

"In French mills, when the paper is about to be sized, it is gathered from the tribbles without much care as to the stage of dryness it has arrived at; and yet most manufacturers know by experience that the sheets, when too dry, take the sizing less readily, and that this material penetrates them more freely and is distributed more uniformly, when they still retain a small amount of moisture; but the construction of the drying-rooms, as we have already observed, not allowing them to take advantage of this observation, they make no practical use of it.

"Another disadvantage of paper too rapidly dried, is that, in this condition, it forms a kind of hard board, which cannot be made soft enough to absorb the requisite amount of size. It is not surprising, therefore, that in dipping such paper into the size, it should only penetrate the leaves with difficulty and very unequally.

"In the Dutch mills this does not occur. There, the leaves are first gathered from the drying-room, the stiffness taken out of them, and their adhesion greatly destroyed by opening the spurs. The workman, who attends to the sizing, then distributes them into handfuls, ready to be dipped into the sizing-tub. It seems that in this division the object is to remove any obstacle to the absorption of size; for the paper of fermented pulp takes the size with great difficulty, even when the leaves are exposed to its action almost one by one. This difficulty is so great that, if bunches of many leaves, strongly adherent, as they are with us, and manufactured of fermented pulp, were plunged into the tub, it would be impossible to make the size penetrate them.

"Besides these precautions, care is taken to join with each handful two sheets of brown paper, of the same form as the paper to be sized. This brown paper, which is firm, solid, and already sized, serves to support the handful of leaves on each side.

"The Dutch have nothing peculiar in their method of preparing size, but they differ from us in that they strain it after boiling, as soon as the scrolls and other coarse materials have settled to the bottom of the caldron, in which the decoction has taken place. They set it to cool in a wooden tub, or copper basin, of some size but not deep. While the size is cooling, it gradually deposits on the bottom of the vessel a sediment, consisting of materials which would be prejudicial to its transparency and give the paper a yellowish tint. When the size is to be used, it is poured into a caldron and heated over to the required degree. This practice is entirely opposed to the ideas of most French manufacturers, who pretend that by heating over the size we weaken it to such an extent as to render it no longer serviceable. The result of this prejudice is that in our mills the size is rarely strained, is allowed to remain on the scrolls, and is generally used while still charged with foreign matters which sensibly tarnish the whiteness of our most delicate papers. The success of the opposite plan pursued by the Dutch, proves that we might allow the size to attain all its transparency by well watched and very gradual cooling, without running any great risk of weakening it."

We do not wish to change anything in this last observation of Desmarest's, but we ought to add that at the time we were visiting different paper mills, with a view of introducing among them the improvements we thought most commonly in use, we found this prejudice almost universally prevalent. We wished to assure ourselves whether it had any foundation in fact, and therefore took two litres (1.76 quart) of freshly made size, perfectly clear and heated to the proper point. With this preparation we sized a sheet of paper, and allowed the rest of the liquid to cool for twenty-four hours. At the end of this time we warmed over the solution to the required degree, dipped into it a second sheet of paper, and so repeated the operation twelve times, allowing twenty-four hours to intervene between each experiment, in order to permit the size to become thoroughly cooled each time. We had taken care to number the results of this series of experiments, and it was ascertained that the twelfth leaf was as well sized as the first, and that the size had, therefore, undergone no deterioration.

We wished to ascertain from the residuum whether the size would alter, and, if so, what might be the cause of the change. We therefore warmed the solution over several times, after having allowed it to cool. As long as we did not raise the temperature above 16° Reaumur, or 20° Cent. (68° Fahr.), that at which common paper is sized, the solution did not change; but when the heat had reached 60° (140° Fahr.) it began to deteriorate, especially if warmed rapidly. By this means I convinced the manufacturers, that with some precautions we can, and ought, to imitate the Dutch.

Desmarest continues thus: "In Holland the workman takes the leaves of paper by handfuls and plunges them into a tub filled with warm and clarified size, separating them, as we have already seen, in order to facilitate the introduction of the liquid to all their surfaces; indeed, to this object tend all the little manipulations the workman performs during the process of dipping.

"It is necessary that the brown paper should hold the leaves in position, as the workman turns and returns the bunch in every direction; for during these motions, the outside sheets no longer adhering to the inner ones, would float loosely in the liquid, thus occasioning breaks. This precaution was suggested by the long stay the Dutch paper is obliged to make in the tub before it absorbs enough of the fluid.

"It is not, however, on account of any danger of the paper becoming too soft through the action of the size; for it always preserves enough firmness for transportation, after having absorbed the requisite amount of this material; nor did I ever notice that a single sheet was broken during the sizing, and still less, therefore, should we look for this accident in bunches of several leaves. These mishaps, which are common enough with us where fermented pulp is used, show that it is to the nature and composition of this material that these differences are due.

"When the bunches of leaves are sufficiently sized, they are withdrawn from the tub accompanied by the brown papers, which follow them under the press. The quantity of liquid, which of itself dripped from the paper when lifted up after sizing, was much less abundant than what now drains from these masses of rotten and spungy pulp.

"When the paper is put under the press, it is first acted on gently and then with more or less force, according to the strength and capacity of the material. The different shades of these conditions may be conjectured from the time it has taken the paper to become saturated with size; the longer it has required, the more strongly should it be pressed, in order to force the sizing principle into the substance uniformly, and at the same time to expel the surplus fluid.

"Although the Dutch paper absorbs size with difficulty, it is enabled to take up enough by the long stay it makes in the tub. Its capacity in this respect, however, is very much less than that of our paper; but it holds on so tenaciously to what it does contain, that the smaller amount of size is sufficient. This kind of paper gives up very little liquid under pressure, and it may be remarked also, that after it is once swollen with size, through its own elasticity, the paper loses very little of its volume either under the press, or while drying. The reverse is true of the paper made from fermented pulp, which after swelling with the liquid, loses much in thickness while passing through the press and the drying room.

"The Dutch paper is allowed to remain at least a quarter of an hour under the press, after which it is taken away in packages, of which the sheets of brown paper always serve to determine the thickness, and these are arranged in piles around the table, intended for the process of exchange, in order that the workmen engaged in this operation may be enabled to divide their labor."

The reader who might visit most of the French paper-mills after having thought over what has just been said, would be exceedingly surprised at seeing that our manufacturers have paid no attention to the exact and luminous descriptions given by Desmarest, that learned and indefatigable man, who for so long a time studied the processes employed to perfect the manufacture of paper among the ingenious people of Holland.

For about a half a century his observations and minute details have been before the public. His work on the art of paper-making is considerably known, and was printed in 1788. We have ourselves, in the numerous manufactories we have visited, evinced our surprise that, especially in the operation of sizing, which is one of the most difficult and important ones of paper-making, they have not adopted the Dutch method, which is very sure and economical. We have always found indifference and unchangeable attachment to their old routine, which will not allow them to try the few simple experiments necessary to convince them at once.

The English, our rivals in the arts, have not been so obstinate; a young Swiss manufacturer, who made quite a long journey in England in 1831, and there visited a large number of paper-mills as an enlightened observer, told me that the Dutch processes, which he understood thoroughly from having visited their manufactories, were everywhere adopted throughout Great Britain. He had found the English very much superior to the French paper, and said that he was about to return home after having travelled two years, to introduce into his own paper-mill all the improvements he had observed in his frequent excursions.

Let us continue to follow the remarks of Desmarest upon this subject, which are too important not to be placed before the reader.

When the paper has been sized, exchanged, and left four or five hours under the press, it is withdrawn and carried to the drying-room. There it is distributed along the tribbles, in spurs of two, three, or five sheets according to their size; the smaller kinds by fives and the larger by twos only. This hanging is accomplished with the greatest ease by means of lifting poles, long enough to enable the women to reach the different tiers of ropes, as we have already pointed out. In this state the paper does very well and does not suffer any sensible waste; because the leaves mutually protect each other from drying too suddenly. As the size has already solidified and become fixed on the surface of the paper during the entire operation of exchange, the insensible and gradual progress of the drying process only renders perfect the good results already obtained.

The Dutch, by the exchange after sizing, and by hanging their paper in spurs, avoid the more laborious and hazardous method of the French.

Although French paper is in general very flabby, especially after leaving the sizing-tub, still the result of our system is that we are obliged to separate each leaf of the handful, at that stage of the operation, and thus to hang them singly; otherwise we should only obtain, after drying, a kind of board, or an aggregation of leaves stuck tightly together, instead of thin and delicate sheets.

"In Holland the facility of manipulation, even after sizing, enables the exchange to be introduced, which, as far as separating the leaves is concerned, resembles somewhat our system of drying them one by one, but which is very far from causing the same inconvenience, either in its effects, or in the method of execution. In the first place the manipulations of the exchange after sizing are less laborious, and require fewer hands, than those of the corresponding operation in France. Three men in

Holland can do the work which four could not accomplish in our own country. Less time is needed to exchange the sized paper, to press it, and finally to hang it to dry in spurs, than merely to hang the same amount in France, after having separated the leaves in their flabby and adherent condition.

"Thus, by following the Dutch system, we obtain, not merely the good results of the exchange, but also an economy of labor. All our manipulations after sizing are those of absolute necessity, and none of them have in view the improvement of the product. We hurry on the work without thinking that the paper is deteriorated by imperfectly performed operations.

"We have seen how the rapid separation of the freshly sized leaves raises a hairy coat on their surfaces, and how much coarser the paper is thus rendered in French mills. We also remarked, that these irregularities, when afterwards too rapidly dried, remained fixed in this state. It is not, therefore, astonishing that the product of all these ill-advised operations is stiff, dry, and without softness of grain, instead of the firm and supple material, with an even and polished face, which might have been obtained, as the result of the processes we have described.

"If we add the breaks and other defects, which are produced by hanging the paper in the drying-room, leaf by leaf, after sizing, notwithstanding the great dexterity of our workwomen, we shall be more surprised still at the advantage which the Dutch have obtained from the exchange. Besides the leaves, entirely broken and thrown away, how many we see with edges ragged, or torn off by the continual effort which is necessary in this long and laborious process of separation.

"It is true, that it is to the nature of their unfermented pulp that the Dutch owe their advantage in abandoning our method of drying leaf by leaf; because their paper adapts itself to all the manipulations which are required by the process they have so happily substituted for our method of drying; whereas with our rotten pulp we are unable to adopt their system without inconvenience, although our paper stands so much in need of it."

From all we have said of sizing, it will be seen that it is one of the most difficult and uncertain operations of paper-making. We are frequently obliged to begin anew, either by the season, the adverse hygrometrical condition of the atmosphere, or the temperature of the size itself. If the size is too hot it injures the paper; if too cold it will not permeate it; if too thick it attaches itself only to the surfaces and runs off when the paper is dry; and lastly, if too thin the sizing will be insufficient. The atmosphere also takes a most important part in the process, as will be seen by the following excellent article on the sizing of paper by MM. D'Arcet and Merimée, which we transcribe literally. It will throw much light on this important subject.

§ 6. Appendix upon Sizing.

The "Société d'Encouragement," of Paris, commissioned MM. D'Arcet and Merimée, in 1813, to investigate the means of improving the sizing of paper. These learned men, after having gone over a great many mills and collected a great many facts, published instructions upon this subject, which they had drawn up in 1815, and already communicated, in manuscript, to a number of manufacturers. These instructions upon the theory of sizing are incorporated in the 26th vol. of the transactions of this society, page 439.

"Hemp, flax, and all other vegetable, fibrous substances, of which paper may be made, contain, in larger or smaller quantities, a kind of gluten,[1] which, if the proportion is sufficient, may take the place of size and render the paper impermeable to ink.

"This matter is so abundant in raw hemp and flax, that paper made of tow is transparent and naturally sized. So tenacious is this substance, that the repeated action of lyes does not entirely remove it, so that there still remains a certain proportion of it in old linen, and nothing but putrid fermentation will entirely destroy it.

"In Holland and England rags are not fermented, but in France this kind of maceration is employed; not only in small mills, when their inadequate means of trituration render it necessary, but even in those where the rags are reduced by means of engines.

"This is the principal cause to which we must attribute our neighbor's superiority in the matter of sizing. Their unfermented pulp still contains a certain proportion of gluten, and produces paper rendered impermeable by a comparatively weak size; whereas a much stronger solution is insufficient for our papers manufactured from rotten pulp.

"Drying too rapidly after sizing is another one of the circumstances, which are opposed to the success of the operation. The Dutch sheds are much better arranged than ours to resist the effects of the drying winds of summer.

"To these preliminary ideas we will add an account

[1] "We believe we may use the word gluten," say these authors, "although the material we refer to does not resemble the gluten of flour; but like it this substance partakes of the nature of animal matter, as ammonia is disengaged from the rags during fermentation."

of several facts, a knowledge of which it seems to us may throw some light upon the theory of sizing.

"Size alone, when sufficiently concentrated to render the paper transparent, does not render it impermeable to ink. In order that it shall produce this effect, it is necessary to combine it with a certain amount of alum.

"When alum is mixed with a solution of glue, the liquid thickens and appears to coagulate to such an extent, that it can with difficulty be stirred, but liquefies again on the addition of water. In trying the experiment with warm size, the solution will have to be more concentrated in order that coagulation may take place.

"If size mixed with alum is left on the fire, a pellicle appears on the surface which grows thicker and thicker, and after being removed is succeeded by another, and so on till the whole mass of size may be converted into pellicles.

"These pellicles do not liquefy at the simple heat of the water-bath, at which gelatinized size melts. It is necessary to employ a higher temperature, and this skum is, therefore, in our mills thrown back into the caldron with the raw materials after the alum is added.

"If a sheet of paper impregnated with alum is dipped into a solution of size, not yet mixed with that material, it becomes coated with coagulated size, which crumbles under the fingers and no longer retains its adhesiveness.

"Alum, therefore, diminishes the solubility of size. The action of the atmosphere appears also to be a necessary condition of this effect; for if, instead of a single aluminated leaf a number of them are dipped, the coagulation only takes place on the exterior leaves, and not at all upon those in the centre of the bunch.

"The action of the atmosphere is observable under other circumstances.

"We exposed size mixed with alum to a temperature of five or six degrees (41° to 43° Fahrenheit) for one night, and the next morning melted it. There separated from it a watery fluid, which gave an abundant precipitate with an infusion of nutgalls. The remaining mass was spongy, and crumbled under the finger without adhering. We tried, without success, to melt this residuum, which resembled softened horn. Nevertheless, by the addition of water, and the assistance of vigorous boiling, we were able to dissolve it; but this size, which, before being congealed, was perfectly clear, contained a considerable amount of coagulated gelatine, rendering it very turbid.

"We dried, by slow evaporation, some clarified size, mixed with alum; we then melted it, after taking the precaution to soften it in boiling water, when a part still remained undissolved, even after thorough boiling.

"Finally, when the persulphate of iron ($Fe_2O_3,3SO_3$) is mixed with gelatine, the gelatine coagulates at once to such an extent that it will not redissolve on the addition of water. The same effect does not follow the use of the green sulphate (green vitriol Fe,OSO_3). The oxygen of the persulphate is probably the cause of the coagulation.[1]

"The impermeability, which size mixed with alum imparts to paper, may, in part, be attributed to the action of the atmosphere; and this explains why paper is not so well sized when dried rapidly, and how this accident is remedied by dampening the leaves, that is to

[1] When brown paper, so colored by the oxide of iron (hydrated sesquioxide, $Fe_2O_3,3HO$), is sized, a quarter of the amount of gelatine used for white paper will be sufficient if, instead of alum, sulphate of iron is added.

say, by restoring its moisture to the paper, and again exposing it to the air.[1]

"As we have said, it is indispensable to macerate the rags in small mills, where only mallets can be used to triturate them. This process is moreover necessary in the case of paper intended for copper-plate engraving; but can it not be so conducted that we may reap the benefits without incurring the disadvantages?

"Let us first examine what occurs in the putrid fermentation to which the rags are subjected.

"The first change observed in the rags, after they have been for some time in the fermenting vat, is the disengagement of a material resembling mucus, so sparingly soluble in water that it is not removed in triturating the rags, and is even found in the vat at the time of manufacturing the paper. Pulp, produced by rags thus prepared, retains water, so that the paper made of this material shrinks very much in drying, and in consequence has neither the weight nor the size which it should have.

"This mucosity is more abundant in proportion as the rags are coarser, as they have been less thoroughly washed before rotting, and as the air of the fermenting vessel is more stagnant. This substance decomposes, as the putrefaction advances, and gives rise to a kind of white mildew, similar to that which is seen on manure; and by that time a considerable portion of the rag fibres have been reduced to mould.

"In regard to the quantity of water which this mucous substance in the pulp will retain, the paper resembles that made from tow, containing a great deal of gluten. It

[1] The operation of dampening consists in placing between wet felts two, three, or four spurs of paper gathered from the tribbles, and found to have dried too quickly. They are afterwards subjected to slight pressure, and then hung to dry over again.

would seem, therefore, that such paper ought to be already partially sized, but this is not so; a weak size will not be sufficient to render it impermeable, and if a stronger solution is used, it will have great difficulty in penetrating the interior of the leaves.

"Fermentation facilitates trituration by destroying the glutinous materials which unite the rag-fibres; but the filaments of straw, broom, and bamboo are much more firmly glued together, and their union forms a much less yielding tissue, and yet, when they have been for some time exposed to the action of lime, they divide themselves into very fine shreds, and there is no difficulty in reducing them to as delicate a pulp as that made from rags.

"It seems to us, therefore, beyond a doubt that lime in suitable proportions would produce the same effect on the rags without entirely destroying their gluten; because in the treatment to which straw is subjected, in order to convert it into paper, neither the lime which softens, nor the acids which bleach it, carry away the whole amount of its gluten. On the contrary, so much of it remains that it takes but a weak size to make the paper perfectly impermeable.

"Lime, it is well known, has been employed at all times in our paper-mills, and in some of them is so at the present day, not, however, to macerate the rags, but on the contrary to arrest the effects of maceration. When some circumstance has given rise to long delay the rags are taken out of the fermenting vessel, where they would not remain long, without turning into mould, and dipped into a milk of lime. The material, when thus prepared, can be kept indefinitely. The same means are also employed to preserve the pulp, while in the condition of half-stuff.

The Size and its Preparation.

"Numerous experiments have shown, that, with the best size, paper cannot always be rendered impermeable, even when the operation is perfectly well conducted. It is none the less necessary to pay the greatest attention to the choice of materials, from which the size is manufactured, as well as to the method of preparation, which fortunately has made great progress, since an easy process has been discovered for obtaining very pure gelatine from bones, by means of acids. This art has now arrived at such a state of perfection, that every paper-maker, who is willing to take the proper amount of care, can always obtain size uniting the two most desirable qualities, namely, whiteness and tenacity.[1]

"Generally speaking, the skins of young animals produce the whitest size and dissolve most readily. Nevertheless we have obtained very white size from pieces of ox hide, and all were found completely melted by the time the water reached the boiling point. To be sure, these hides had remained a long time in lime, but we may conclude from the experiment that the preparation of the raw materials, before boiling them, has an influence upon the whiteness of the size.

"Saddle-maker's size is esteemed more than any other for the preparation of paper, but it has the objection of being the most highly colored. This no doubt proceeds from the bits of tanned leather, always found mixed with the Hungary leather, of which the parings of harnesses, &c., used in making this size consists.

"Without this mixture, it would be impossible to see any reason why this article should be any darker than that obtained from tanners or leather dressers.

[1] This process is described in the second section of this chapter.

"It is, therefore, to be presumed that we should obtain a less highly colored solution, if attention were paid to removing all the scraps of tanned leather, and if the scrolls were saturated, for some days, with milk of lime.

"It is by leaving the parings of hide in contact with lime for a few days, that they are preserved from putrefaction, to which they are exposed before their complete desiccation. By means of this preparation, they can be dried before any decomposition takes place, and afterwards kept indefinitely; but if, when they are withdrawn from the lime, they are allowed to remain heaped together too long, or if they are spread in too thick layers in the drying-room, they may still ferment and putrefy.

"Scrolls, which have putrefied before drying, are called heated, and may be recognized by the gray color they present under the light coating of lime, which covers their surface.

"When they are boiled, they exhale an ammoniacal odor, which partially disappears on the addition of alum. Often, however, when no disagreeable odor is manifest while boiling, ammonia is none the less present in a state of combination. This substance is liberated by the addition of a little lime, which also serves to disengage the putrid ferment contained in the size.

"There are several methods of preparing size in our paper-mills. In some of them it is considered sufficient to put the raw materials into a caldron, containing a suitable proportion of boiling water, and to cook them thus until all the gelatine is extracted. The boiling is kept up from twelve to fifteen hours, for three hundred pounds of ox-hide parings.

"It is evident that the strength of the size is proportional to the quantity of raw material employed.

"In other mills a smaller amount of water is, at first, added, and when the decoction is concentrated enough, the liquid is drawn off and replaced by another smaller amount of water. In this manner, three or four solutions are obtained, which are either mixed together or preserved separately.

"This method is undoubtedly preferable; because, the bits of hide being unequally soluble, the first portion of gelatine extracted deteriorates by remaining in the caldron until the rest has been melted. Besides this, the quality of the materials may be better ascertained from the amount of size they have furnished.

"Whatever method may be adopted, it is important that the scrolls should not touch the bottom of the caldron, as, in that case, they would be burnt, and give the size a darker color.

"Some manufacturers cover the bottoms of their caldrons with beds of straw, and in this manner no doubt prevent the scrolls from adhering; but in their desire to avoid this evil they fall into another.

"Straw contains a deep yellow coloring matter, the extraction of which is facilitated by the lime of the raw materials that has not yet lost its alkalinity by exposure to the air, so that when the straw is withdrawn, on emptying the caldron, it is found brown like that of manure.

"In the Dutch paper-mills the raw materials are held in a wicker basket, which is let down into the caldron and withdrawn by means of a pulley, when the size is to be removed. This apparatus is very simple, and allows us to ascertain whether there still remains any gelatine undissolved.

"With whatever care size is extracted, the decoction will never be clear; it holds in suspension a great quantity of undissolved gelatinous matter, which would not be precipitated, even after long rest, with the fluidity of the size constantly maintained; but if by any means an abundant precipitate can be determined, the particles of suspended matter will be carried with it and the size will then become perfectly clear.

"This clarification may be accomplished in several ways.

"1st. When the size has been strained through the basket a small amount of quicklime is added—about half a pound to forty buckets of size. The lime is first wet with water and then stirred in so as to mix it thoroughly with the liquid. The lime soon precipitates, and carries with it part of the matters which clouded the transparency of the decoction. The size is then drawn off and a concentrated solution of alum gradually added and stirred in gently till the mixture is complete; the alum is decomposed by the lime and occasions considerable thickenening, as it were a coagulation, of the size; the stirring is continued and the whole mass soon resembles curdled sauce; the precipitate falls to the bottom of the vessel, and the liquid becomes transparent. It now only remains to draw off the solution through a siphon and add the proper proportion of alum.

"If this operation has been well conducted, there should no longer remain any lime in the size; this is ascertained by test paper; if any should be present, it must be precipitated by a few drops of sulphuric acid.

"If too much alum has been used in clarifying the size so as to exceed the point of saturation, the solution would remain turbid; in this case in order to remove it, it may be precipitated with lime. This is very easily done, but the precipitate will involve a loss of gelatine and the size be proportionately weakened.

"The gelatinous precipitate formed in clarifying should not be thrown away; it could not indeed be re-dissolved, but if mixed with the coarser kinds of pulp at the time when their trituration is completed, the paper made from this pulp will by this addition be somewhat sized.

"2d. Size may also be clarified by mucilage of marsh-mallow roots. These roots are reduced to paste after being well washed, and that substance mixed with the size; the alum being added immediately after, the mucilage coagulates and carries down with it all the matters which obscured the transparency of the size. There is no danger of using too much alum.

"The following method will undoubtedly be preferred because it requires no mixtures nor any particular attention, and is self-operating by means of a very simple filtering apparatus.

"We know that when size is filtered through paper, it passes perfectly clear, but the paper soon becomes choked up and the filtration is arrested, even if we succeed in keeping the size fluid. The inevitable effect of the obstruction of the filters may be remedied by the following apparatus. It is composed of a square box from twelve to fifteen inches high. The size enters at the bottom, passes through several felts and issues through a stopcock placed at the upper part of the box.

"The felts are sustained by frames fitted to the inside of the box, so that nothing can pass over their edges, and the box itself is lined with felt.

"It is true that this filter will soon be choked up, but it only takes a moment to open the box, remove the felts, and put others in their place. In a similar apparatus, which we had made and which has been in use for several years, the felts are only removed once in five or six days. There are only four felts, and yet the size is found to be sufficiently clear; in which opinion, however, we do not concur, and believe that it would be better to use ten or twelve. If this were done, the obstruction of the apparatus would not take place any sooner, and the size would be made as clear as though filtered through paper.

"If the caldron were placed on the story above the filter the passage of the liquid through it would be hastened by the weight of the column of size.

"Alum is added at the time of drawing off the solution, but it is never exactly understood in what proportion. The weight of the dry materials of the size is taken as the basis, but experience shows that there is considerable variation in the product of these substances.

"We believe that by means of a hydrometer made for the purpose, the degree of concentration of the size might be ascertained, and the proportion of alum to be used thus more surely regulated.

"In several mills soap is mixed with the size. This mixture must be accomplished before the addition of the alum, as the soap would be at once decomposed if turned into the aluminated solution. We have several times had occasion to witness the good effects of this combination, and we have found that it rendered the sizing less dependent on the duration of the drying, and contributed to make the paper more impermeable.

"The liquid, which Ackerman used to render stuffs impermeable, is a mixture of soap, size, and alum. We shall give the receipt for this preparation at the end of these instructions.

"The size used for paper, made of unfermented pulp, is always weaker than that intended for fermented pulp. Still further, if the pulp is very fresh, paper may be perfectly sized with so weak a solution, that after the operation it will appear to have produced no effect. The paper will become impermeable if before hanging to dry it is allowed to remain for several days in contact with the moist size; but in order that this sweating should produce the desired effect, it is necessary that neither the size nor the pulp of the paper should contain any germ of putrid ferment.

"M. Montgolfier has confirmed by experiments made with the greatest care, what we had anticipated of the effect of size kept moist in the paper for a long time before drying. He kept for twenty days, without drying, some paper made from unfermented pulp, dipped in much weaker size than he was in the habit of using, and the paper, which did not at first appear sized, became progressively more impermeable.

"The package of paper, well wrapped in felts, was opened each day, and a leaf taken out and dried.

"That which was taken out immediately after the operation, while the size was still warm, did not appear sized; that of the next day but slightly so. Each day the paper was sensibly improved until the twelfth, at which time the leaf was spread upon a tub of water, and found to have become perfectly impermeable.

"The trial was continued till the twentieth day with the same success, when all the paper was dried for fear of spoiling.

"During this time the paper had been exchanged, and pressed three or four times, the thermometer indicating 12 to 15° C. (53.6 to 59 Fahr.).

"We desired that this experiment should be tried comparatively with paper made of fermented and unfermented pulp. This latter kind gave exactly the inverse result, and, when dried at once, appeared sized, but was not impermeable. The next day it was found less sized, and on the fifth seemed to have lost every particle of sizing.

"We were not surprised at this effect. We had anticipated that fermented pulp, however well-washed, would still retain a little putrid ferment, which would affect the composition of the size; but what we were far from expecting was, that the character of the water should entirely change the result.

"The experiment we have just cited was performed at Annonay, and M. Montgolfier wished to repeat it at his paper-mill at Voiron. The pulp, from which the paper had been made, was very fresh; the size remarkably pure and clarified with much care, and yet, at the end of a few days, the paper exhaled an offensive odor, and was not at all sized. M. Montgolfier repeated the experiment, and remained convinced that this unexpected result was due to the qualities of the water.

"We are, like him, persuaded that the putrid fermentation which is developed should be attributed to the decomposition of the sulphate of lime contained in the water, but at the same time we believe that whatever may be the defect it may be remedied.

"Eleven specimens of well water, containing selenite (sulphate of lime), examined by M. D'Arcet, required on an average 1.298 grammes (20.051 grs. troy) of pure dry subcarbonate of soda (carbonate of soda, $NaO,CO_2 + 10HO$) to saturate one litre (1.76 pt.) to the point of perfectly dissolving soap. The worst specimen absorbed 1.83 grammes (28.25 grs.) of pure, dry subcarbonate of soda.

"River water may be clarified by employing 25 grammes (386 grs.) of alum to the hectolitre (22.01 gals.).

"Paper of fermented pulp cannot be well sized at one operation; it should be twice dipped, if it is desired to become perfectly impermeable. This double process would increase the expense of manufacture and impair the whiteness of the paper, so that we believe that it would be most economical to restore the gluten lost by fermentation. This means is adopted by the Chinese, who add to their paper pulp a sizing extracted from rice while cold,[1] and the infusion of a plant called Oreni, one of the Malvaceæ. The effect of this mucilage is to hold in suspension the starch extracted from the rice, and to keep the leaves from adhering to each other; for the Chinese couch their leaves one upon the other, without interposing felts, only placing thin bits of bamboo between them to enable them to be separated more readily. In this operation the paper is not sized. That which is destined for writing or colors, receives a further sizing, which is rather a saturation with alum; for the liquid in which the paper is dipped contains only one part of size to two of alum.[2]

"It is well known that alum forms insoluble precipitates with mucilaginous substances; at the same time the rice starch is converted by heat into a dressing.[3]

[1] "The rice is first wet and put into an unglazed earthenware pot. It is stirred and then placed in a cloth, while cold water is poured over it, carrying off the gummy matter. What remains on the filter is then treated in the same way and so on until no gelatine remains." (Kempfer, "Amoenitates Exoticae"). It is evident that in this operation not only the gummy part of the rice is carried off, but that the starch is detached by rubbing against the sides of the unglazed vessel.

[2] This is the process employed by the colorers which we shall give in full before the end of the chapter.

[3] The paper is sized leaf by leaf. Each sheet is attached to a piece of bamboo and dipped into the sizing fluid, which should be very warm.

These two results combined render the Chinese paper impermeable, by the aid of a sizing which would produce no effect upon ours.

"We endeavored to obtain the same result by adding starch to the fermented pulp, and the success was equal to our anticipations. We prepared a light size of potato starch, to which we added alum; this size being well mixed with the stuffs in the rag-engine, we poured in a solution of resinous soap, which produced a precipitate of resin, starch, and alumina. A very slight sizing rendered the paper made from this pulp perfectly impermeable.

"We had employed to the hundred pounds of dry pulp, two kilogrammes (4.41 lbs. avoird.) of starch, one kilogramme (2.20 lbs.) of saponified resin, with half a kilogramme (1.10 lbs.), each, of subcarbonate of soda and alum.

"During the operation of sizing, it is customary to try the strength of the size from time to time, by drying rapidly one of the sized leaves. For this purpose one of them is drawn out from a post of paper, but at whatever place a post is opened, the separation always takes place between two spurs and the leaf which is taken out is always the top of a spur. Observing this, we thought proper to have a leaf taken from the middle together with the top ones. After drying, we found that the centre leaves were less sized than the top ones, and this explained why on examining leaves made of the same pulp and sized at the same time, some of them are found more impervious than others.

"It is important, therefore, not to make the spurs too thick. Two leaves are enough for the stronger and five for the thinner. It need not be feared that the paper will shrivel on drying; this cannot occur if the exchange has been carefully attended to and the drying well conducted.

"The process of exchange which we derive from the Dutch, is not only intended to soften the grain of the paper and render its surface velvety, but is an absolutely indispensable operation, when unfermented pulps are employed. Whatever thickness is given to the spurs of paper, if they were hung after they had been pressed without felts, they would shrivel on drying and would be covered with wrinkles, which it would be impossible to remove. Paper made from tow furnishes us with a palpable proof of what we affirm. It contains gluten in so great a proportion, that it is necessary to dry it between two leaves of paper made of fermented pulp. Without this precaution, the leaves dried in the usual spurs would be as wrinkled as crape.

"In some of our mills an apparatus is used, invented in England, by means of which several reams of paper may be sized at once. It is composed of a chest, in which the leaves are placed vertically; the chest is then closed and the water withdrawn by means of a pump. The size introduced at the bottom rises slowly, and when the leaves are considered sufficiently penetrated with the material, a horizontal press is worked, which compresses the leaves and expels the superfluous size from the chest.

"Such an apparatus is useful, but too costly to be used in small mills, as paper may be perfectly well sized without it.

"It has been seen from what precedes, that the only difficulty is in sizing paper made from fermented pulp; but it has been also seen that maceration may be so managed as to facilitate trituration, without destroying so much of the glutinous material. In the second place, that where this substance has been destroyed, it may be replaced by a substitute, which renders the sizing less difficult.

"We think it scarcely necessary to add, that the fresher the pulp the warmer the size should be, and that the reverse holds good for paper of fermented pulp. In either case there is an advantage in heating the paper in a drying-stove before sizing."

Ackerman's Fluid for rendering Papers and Stuffs Impermeable.

The learned Vauquelin, who by his sudden death left an immense void in the useful arts based upon chemistry, made an analysis of a liquid, discovered by Ackerman, and employed by him to render every kind of stuff, of whatever nature, impermeable to water.

Vauquelin gives the following receipt for preparing this liquid:—

Dissolve soap and glue, or any other kind of gelatine, in water; add to this a solution of alum, which will decompose and form in the mixture a flaky precipitate of oil, alumina, and animal matter. Add weak sulphuric acid to redissolve a portion of the alum, render the precipitate light, and prevent it from falling. But alum, when united with oil and animal matter, does not entirely redissolve in sulphuric acid, and the oil, therefore, remains very opaque and neither rises nor sinks to the bottom. Of course too great a quantity of sulphuric acid must not be added. This operation has been modified by M. D'Arcet.

§ 7. THEORIES OF SIZING.

Two different opinions having been held in regard to the theory of sizing, and this subject being one of the highest importance, we think it our duty to give these two theories separately. We believe that from this comparison may result an improvement in one of the most extensive branches of our industry.

MM. D'Arcet and Merimée, as commissioners appointed by the "Société d'Encouragement" to investigate the subject of sizing, made a very enlightened report upon this important matter, which we have already given. The following is that of M. Payen:—

"The process of sizing, still most generally in use in our paper-mills, consists, as is well known, in dipping the leaves of paper into a solution of gelatine and alum.

"Since we have been enabled to manufacture and dry the paper at once, many researches have been made to discover means of carrying the same economy of labor into the operation of sizing. It has, however, been observed that paper, impregnated with an equal amount of the same gelatinous solution and then dried upon cylinders internally heated by steam, was not sized, that is to say, when ink marks were drawn on its surface, they would quickly penetrate the substance of the paper, and, spreading in every direction, form irregular and illegible characters. It was generally supposed that the sizing was impaired by heat, and inquiry was particularly directed towards the means of drying the sized paper at a lower temperature. The attempts in this direction were not successful, and as others are making, which will be also entirely useless, we believe it our duty to publish our observations upon what actually constitutes the sizing of paper according to the old process.

"When the leaves of sized paper are carried still damp to the drying-room, they are dried more or less gradually, according to the amount of moisture in the air, and the comparative elevation of temperature. The surface first undergoes the action of the atmosphere, and then, through the capillary attraction of the paper fibres, absorbs an additional quantity of the gelatinous solution. This liquid, when brought to the surface and evaporated, deposits its gelatine; again a fresh supply of the solution is drawn to the surface, deposits the gelatine it contains, and the same thing is repeated until the paper is dry. It will be readily seen that the greater part of the gelatine is thus brought to the surface of the paper, and that, rendered more insoluble by the action of the alum, it opposes the infiltration of the ink into the substance of the paper, or, in plain terms, prevents it from blotting. Thus, in fact, as soon as this superficial coating is removed, we find that we can no longer write without the addition of some new material. Pounce is the substance, as we all know, generally used to prevent the ink from spreading.

"It may be seen that the same phenomenon cannot take place, when this process of sizing is applied to paper made by machinery; for indeed in this case, the paper is carried under cylinders, heated to 60 or 70 degrees (140° to 158° Fahr.) and dried almost instantaneously. This temperature cannot decompose the gelatine, but this material becomes fixed throughout the substance of the paper, by the rapidity with which it is dried, and is therefore found at every point too small in quantity to prevent the infiltration of the ink; yet, if a sufficient amount of gelatine were used to attain this object, the paper would be very stiff and its sizing very costly. All attempts, therefore, at tub-sizing, or by continuous machinery intended for that purpose, would be fruitless.

"It is probable that both methods will be successful, if a process is followed, analogous to that, resulting so well in the hands of M. Canson, and which appears to consist in permeating the entire substance of the paper, with a material obtained by decomposing a resinous wax soap with alum, and adding starch."

§ 8. Sizing in the Pulp.

The improvements to be introduced into the French method of sizing, in order at least to equal that which is practised in Holland, had from 1806 excited the solicitude of the "Société d'Encouragement," which as early as that year offered a prize of three thousand francs. The essays received in this competition not having satisfied the conditions required, although the government had doubled the prize, and the reunion of Holland to France having given hopes that we might obtain an easy knowledge of the processes in use among our neighbors, induced the Society, upon the advice of its Committee on Chemical Arts, to withdraw the offer of this prize, and charge a special commission with the work of making the necessary researches for the attainment of this object.

MM. D'Arcet and Merimée were the commissioners appointed, and were for five years successfully engaged in this important labor. They obtained precious results not merely in regard to sizing after the paper is made, but also with reference to sizing in the pulp, that is to say, at the time of making the paper. It was in 1815 that M. Merimée made a report in the name of the commission, in which, after having set forth the advantages they had obtained, the commission proposed to keep its processes secret, and communicate them only to those manufacturers who might wish to try these processes, and who should engage themselves to communicate the result of their experiments to the Society. This proposition was accepted, and it was decided that these instructions should not be published in the transactions, until after our own manufacturers should have an opportunity of reaping the advantages of the new process, and the inventors should judge that it had been carried to perfection by practice.

The hopes of the Society were disappointed, and the interest it had taken in the advancement of our manufactures was not appreciated. Notwithstanding the engagements, taken by all, only three manufacturers fulfilled their promise. M. Eli Montgolfier acknowledged the receipt of the communication, and announced that he had tried the experiment and found the result satisfactory; but that the process seemed to him more expensive than the one he was accustomed to employ, and, therefore, would be difficult to adopt.

At the Exhibition of 1819 there appeared paper from the mills of MM. Odent and Grevenich, who had, each separately taken the same engagement as M. Eli Montgolfier, in receiving the instructions. The first was the only one who acknowledged the receipt, or rendered an account of his experiments. For some time the paper, furnished by him to the Administration of Lotteries was sized in the new way; but, as he only worked with fermented pulp, his paper was too soft, and the Administration obliged him to size with gelatine.

M. Canson, to whom the same process was communicated, endeavored to modify it, and took out a patent to insure himself a monopoly of the method he employs at his beautiful paper-mills at Vidalon les Annonay. This process is at the present day well known to all, and we will speak of it further on.

We should probably have been longer in being able to fix upon the substances suited to sizing in the pulp, had not chance thrown into the hands of M. Braconnot, in September, 1826, a leaf of paper made in the department of Vosges and sized in the pulp. This learned chemist analyzed this leaf, and from his analysis deduced the following process for forming a size to be mixed in the vat, in order to size the pulp, as soon as manufactured. This analysis is described in the 33d volume of the *Annales de Chimie et de Physique*, page 39.[1]

"To a hundred parts of dry pulp, properly diluted with water, add a boiling and perfectly homogeneous solution of 8 parts of flour, first mixed with a small amount of caustic potassa to render the solution more perfect. To this now add one part of white soap, previously dissolved in hot water. At the same time heat a half a part of galipot[2] with a sufficient quantity of a solution of potassa, rendered caustic by lime to dissolve this resin entirely, and after having mixed the whole, it only remains to pour in a solution of one part of alum."

The compound resulting from the intimate union of the above-named materials was applied by M. Braconnot to brown paper, in only thin coatings, and the paper was perfectly sized. "It seems," adds this learned man, "that in introducing fat and resinous matters into the pulp, the principal object is, as it were, to fix and agglutinate the size, in order to prevent it from being expelled by pressure."

This is then the discovery of the materials employed in sizing paper in the pulp, due to the power of science put in practice by so learned a man as M. Braconnot, to whom it will insure an undying reputation.

Several manufacturers tried this process without success; but doubtless they operated upon fermented pulp,

[1] See page 232 of this book.—Tr.

[2] Galipot is a very clear, yellowish-white pine resin of French origin. —Tr.

and the failure is only to be attributed to the persons themselves who made the attempt.

The same is true of the receipt of M. Canson. It answers very well in his mills, but was without success in those of a manufacturer I was visiting in the month of September, 1828, and with whom I should have made it succeed if I had been able to stay longer with him, or if the mill had been working during my sojourn in the city where it was situated.

It is important to understand in brief the work of the commission of the "Société d'Encouragement," a report of which is contained in their transactions.

The "Société d'Encouragement" had received about twenty-four years ago specimens of paper made in Germany, and sized, the one with resinous soap, the other with starch. They were but feebly sized, which was due to the fact that in German mills, as in ours, the rags are fermented. This long maceration, carried as far as putrid fermentation, deprives the rags of their gluten, and the pulp then requires a great quantity of starch; but in that case the leaves, on being withdrawn from the press, cannot be separated without peeling. The commissioners knew of these processes, and it occurred to them to unite the two. They believed that the addition of resinous soap would permit them to employ a larger proportion of starch, without thereby increasing the adhesiveness of the leaves. Taking the practice of the Chinese as a starting point, they were in the hopes of success. Experience confirmed their conjectures; but, as they were operating with fermented pulp, the paper, although impermeable, had not enough stiffness to make the sizing appear satisfactory. The commissioners thought that the process would not succeed completely with any but unfermented pulp. The following was their method of operating:—

When the trituration was complete, and the pulp had arrived at that point, when it only remained to add the blueing, they poured into the rag-engine two buckets of a size made of starch and alum. When the mixture was complete, they gradually added a solution of resinous soap, made with subcarbonate of soda instead of the caustic potassa, used by Braconnot. This soap was added in sufficient quantities to dissolve the alum. The action of the cylinder produced a great deal of foam, which disappeared on the addition of a tumblerful of oil.

With a view to giving greater stiffness to the paper, they added clarified animal size. The paper peeled somewhat, after being pressed without the felts; but this evil was remedied by pouring into the rag-engine a small amount of a solution of white soap, and the leaves could then be stripped off without peeling at all. Animal size did not seem to them to be necessary, nor is it employed by M. Canson, as will be seen hereafter.

It appears to us important to describe the manner in which the commissioners prepared their resinous soap. To a solution of subcarbonate of soda they added resin, until it refused to combine any farther. They at once dissolved this soap in hot water and poured it into a barrel; the uncombined resin precipitated, and the solution gelatinized on cooling. By this precaution they made themselves sure of using an exact mixture of alumina, resin, and starch, which they then precipitated around the molecules of the pulp, as equably as possible.

The commissioners think that it would be better to treat the pulp first with alum, and then to mix a little caustic soda with the water in which the starch is dissolved, on account of the property, recognized as belonging to caustic alkalies, of converting the starchy particles at once into size. The succeeding boiling renders the size still more fluid. The soap is now added and, when the materials are very intimately united, they are gradually poured upon the previously aluminated pulp until complete saturation is obtained, which is indicated by test paper. Lastly, a solution of white soap is poured into the vat, and if this should occasion bubbles during the motions of the vatman in forming the paper, they may be made to disappear by the addition of a little oil, or still better, of an oleaginous emulsion. Nut or poppy oil should be preferred on account of their drying qualities.

Although they succeeded in making size with wheat flour, yet the commissioners advise the use of rice flour, in imitation of the Chinese. The proportions should vary and be regulated by the quality of the pulp which may contain more or less gluten. Experiments on a small scale, which any intelligent manufacturer may make without difficulty, will establish the proportions to be employed.

In employing this process, we are not able to azure the paper with Prussian blue, as that substance is decomposed by the alkali of the soap. Cobalt blue should be used and dissolved with the starch when the size is prepared, as in this manner, being closely blended with the dressing, it is lighter, and does not fall to the lower surface of the leaf, as occurs in the case of English paper.

Moreover, cobalt blue, which is employed in Holland and in England, is a more brilliant and a faster color than Prussian blue.

M. D'Arcet, being at Cusset in the paper-mill of M. Bujon at the time of the publication of M. Braconnot's discovery, successfully repeated the experiment at that place; but not finding the paper sufficiently sized, concluded, after a comparative examination of the shade produced with iodine, that the proportion of starch required to be increased and advised the adoption of the following:—

100.00	parts of	dried pulp,
12.00	"	starch,
1.00	"	resin, dissolved in
0.50	"	subcarbonate of soda,
315.00	"	water.

The water was first boiled, and the soap, the resin, and the soda added. The boiling was continued until the combination of these materials was complete, and the starch, previously mixed with cold water poured in. The whole was then boiled until it became as transparent as very fluid, freshly-made soap.

This composition was poured warm into the rag-engine, and the action of the cylinder, in a very short time, produced an intimate union of the whole.

The pulp, which was made from fermented rags, was already alkaline before the addition was made, and after being thus mixed became very much more so. A solution of alum was added, until the presence of an alkali was no longer indicated by test-paper. After being carried to the vat, however, the pulp still indicated some trace of alkali, and it was therefore saturated by the addition of a little alum. This was repeated after the manufacture of each post of paper, so as to render the product slightly acid.

With a hundred kilogrammes (220.47 lbs. avoir.) of pulp thus prepared, five posts of paper were made, of which the sizing was at first slight, but became successively stronger, so that the last post was very well sized.

An examination of the water in the vat explained this progress in the strength of the size; for while the water which ran off from the paper was clear, that in the vat was milky, and iodine colored it a handsome blue, proving that it contained starch. Thus each time that the fresh supply of pulp was placed in the vat, the proportion of starch was augmented by that remaining in the water. This milky water was filtered, and very soon choked up the filtering paper, which was found to have become sized.

The illuminators are obliged to size their papers upon applying colors. We have already given this process, as well as the composition of Ackerman's solution, which was analyzed by M. Vauquelin.

M. D'Arcet modified the latter receipt, so as to give the following proportions:—

100 parts of dry pulp,
4 " Flemish glue,
8 " resinous soap,
8 " alum.

To obtain the exact proportions only 2.424 parts ought to be used. The glue is allowed to swell for twelve hours before the preparation of the sizing. The resinous soap was made with—

4 kilog. 800 grammes (10.57 lbs. avoir.) of pulverized resin,
2 kilog. 200 grammes (4.88 lbs. avoir.) of crystals of soda.
marking 800° of the alkalimeter.
100 litres (22.01 gals.) of water.

This was boiled until perfect combination was obtained, the size added, and when it was entirely dissolved, a warm solution of alum poured in containing 8 kilog. (17.63 lbs.) of that salt. Three-quarters of this size was poured into the vat upon the well-diluted pulp, and thoroughly stirred. A post of paper was made of this mixture, which, when rapidly dried, was estimated to be sized to an extent represented by $\frac{7}{8}$. The remainder of the size was then turned in, and a second post made, which was judged to be perfectly sized.

M. Bujon's account of this experiment transmitted to M. D'Arcet is thus expressed:—

"It is beyond doubt that this process presents great advantages; the manufacture of paper is perhaps less difficult even than when the pulp is unmixed.

"The paper is readily couched upon the felts and the vat only requires to be kept somewhat warm, so that at the time of raising the leaves, they may not have entirely lost their heat. The paper detaches itself from the felts without difficulty and occasions very few broken leaves. It dries somewhat more slowly upon the tribbles and perhaps has a little less resonance, than paper sized with starch; but on the whole this paper is better sized, admits of a higher finish, and bears a greater resemblance to the very best."

One of the motives which probably determines the preference given by M. Bujon to this composition, is that it may be poured into the vat at the time of making the paper, without requiring the mixture to be effected by means of the cylinder, and that it keeps a considerable time without spoiling.

It should be remarked that the operation was performed with fermented pulp, and that with the unfermented, the paper would have been better sized and required less of the mixture.

"For all this," adds M. Merimée, who makes the report, "though the results have appeared satisfactory to an experienced manufacturer, we only present them as a starting point to give direction to experiments, which cannot be too often repeated if we wish to arrive at perfection."

Manufacturers can choose between this last process and that by gelatine, which might be preferable in certain cases, especially when the manufacture of gelatine has been carried to such a degree of perfection. "It is for time," to use the words of our learned reporter, "to decide whether the advantages of this method of sizing in the pulp are such as they appear, and whether it should be resorted to in all cases."

§ 9. M. Canson's Method of Sizing in the Pulp.

This process is no longer a secret, but is in the hands of a great number of persons; nevertheless, as the inventor has taken out a patent which insures him a monopoly, we think it right to notify the reader that the following description of the process does not give him the least right to avail himself of it in practice until the patent has expired without the formal and written consent of M. Canson.

The inventor operates in this wise: A wax soap is prepared, of which the following are the proportions: to one litre (1.76 pts.) of a solution of caustic soda, marking 5 degrees on Beaumé's hydrometer, is added 0.5 kilog. (1.10 lbs. avoird.) of white wax and the mixture boiled till the wax is completely dissolved. This liquid soap is then poured into 30 or 40 litres (6.60 to 8.80 galls.) of boiling water, and 3 kilog. (6.60 lbs.) of potato starch well mixed with water are at once added. The mixture is stirred till it thickens and forms a paste, which if kept in a cool place, even in summer may be preserved for a fortnight without spoiling.

In using this size it is poured into the rag-engine, containing 30 kilog. (66.14 lbs.) of dry rag pulp mixed with the quantity of water required by the quality of paper to be made, and the composition is allowed to become well incorporated with the pulp. There are then added 300, 400, or 500 grammes (0.66, 0.88, or 1.10 lbs.) of powdered alum dissolved in boiling water. After the cylinder has been worked long enough to penetrate the pulp thoroughly with these ingredients, the ordinary operation of manufacture is continued.

The inventor only makes use of this process for fine papers and especially those destined for writing purposes. For common papers he suppresses the wax soap, and only uses white soap and starch, though he still impregnates the pulp with these substances in the rag-engine.

In the beginning of the year 1827, M. Canson submitted paper of his manufacture to the "Société d'Encouragement," which referred the examination to its commission. M. Merimée made his report upon this subject, at the meeting of the 11th of April, in which it was set forth that sizing in the pulp had answered very well for writing papers; that the cobalt blueing was very handsome, giving the same shade upon both sides of the leaf, and that in this particular it had surpassed the English; that the paper intended for coloring presented irregularities in the sizing, so that several sheets upon which M. Merimée had spread colors were found to be very spotted. In the manufacture of this kind of paper alone, MM. Canson are behind the Dutch or the English.

§ 10. Comparison of the Two Methods.

We have given, with all necessary detail, the two methods of sizing in the pulp, which are at the present time in competition. We have reported, word for word, the opinion of a distinguished manufacturer on the process recommended by the commission of the "Société d'Encouragement," and the opinion of this commission upon the specimens sent by MM. Canson. The result of the comparison of these two methods is, that they have both been entirely successful, with the exception of a few defects in that of M. Canson, which will undoubtedly disappear with increased care in manipulating.

It, therefore, remains for the intelligent manufacturer to choose the method, which experience may prove to be the most advantageous, under the double aspect of cost and facility of operation.

1st. Under the head of cost, we refer to the purchase of material. It cannot be denied that the wax employed by M. Canson is very much more expensive than resin, and the same holds good of potato starch as compared with glue, obtained from the parings of saddlers, leather-dressers, and tanners. Potato starch is undoubtedly lower in price than gelatinous size, and sizing with wax costs double what it does to employ gelatine.

2d. In regard to facility of operation, those necessitated by the commission's process are limited to mixing the size with the pulp in the vat itself, and making the mixture into paper at once; whereas to carry out M. Canson's plan the mixture is made in the rag-engine and has then to be transported to the vat before beginning the operation of manufacturing the paper.

3d. And lastly, as to the right of putting one or the other of these two methods into practice, our choice cannot be very doubtful. M. Canson required the payment of one thousand francs (about $200) to allow a participation in his patent right; whereas the "Société d'Encouragement" has opened the important discovery of its commission to the public, and every manufacturer is free to use it without any compensation whatever.

CHAPTER VI.

DIFFERENT SUBSTANCES SUITABLE FOR MAKING PAPER.

THE increasing consumption of paper and the advance in the price of rags have given alarm to a few croakers, who fear that the supply of this raw material, so essential to paper-making, may eventually give out.[1]

The experiments, undertaken with a view of substituting for rags other substances less costly, and the supply of which could be better depended on, date from the beginning of this century.

Since then, all the products of the vegetable kingdom without distinction have been passed in review, and the amount of time and money spent in the quest of this new philosopher's stone is incalculable. Every day brings fresh hopes and fresh failures, and it will continue to be so as long as inventors will not study the subject upon its true grounds.

We are about to enter into some details, which may serve as a starting point for this kind of investigation.

Paper is formed by the juxtaposition of an infinite number of filaments interlaced in every direction. These filaments are the product of refuse rags, which would have no value if they had not been found adapted to this purpose.

[1] This alarm has not been without foundation in the United States, and American paper-makers have exerted themselves with commendable zeal, enterprise, and success in finding substitutes for rags, and are deserving of all praise. This latter they have been far from receiving.—TR.

Chemical analysis proves that old rags are almost pure cellulose. The constitution of this substance, isomeric with starch, is as follows:—

Carbon	44.44
Hydrogen . . .	6.18
Oxygen	49.38
	100.00

By the incineration of rags we obtain one-half, three-quarters, or one per cent. of ash, whereas cellulose leaves no residue whatever.

Rags being the product of textile matters, we may conclude, *à priori*, that all filamentous substances are suited to the manufacture of paper, which may be regarded as an axiom.

We have united, in the following tables, the principal textile materials, employed at the present day to meet the demands of industry.

Table of Textile Materials.

1. Abaca (Manilla hemp).
2. Agave of Cuba (American aloe or century plant).
3. Cultivated hemp.
4. White hemp of Hayti.
5. Indian hemp.
6. Cotton.
7. Acacia.
8. Fibres of aloes.
9. Spanish broom.
10. Silkweed.
11. Hops.
12. Jute (Bengal hemp).
13. Down of the date-tree.

14. Common flax.
15. Chinese hemp.
16. Textile mallows.
17. Paper mulberry.
18. White mulberry.
19. Chinese nettle.
20. Phormium tenax (New Zealand flax).
21. Fibres of false aloes.
22. Esparto.
23. Linden tree.
24. Yucca.

It must not be supposed that these different substances possess in the same degree the property of being converted immediately into paper, without passing through a long and costly series of manipulations.

Cotton might be employed in the first instance, but unfortunately its high price will not permit it to enter into the composition of paper until after having passed through the condition of texture into that of rag.

The same is true of hemp and flax, constituting the two principal textile materials of Europe derived from the vegetable kingdom.

M. Th. Mareau has prepared a table of the numerous losses in weight experienced by flax before its final conversion into paper.

These figures are of a nature singularly to cool the enthusiasm of inventors in seeking substitutes for rags.

Flax is an eminently textile material, especially fitted for the manufacture of paper, and yet what do we get from one hundred kilogrammes of raw flax? 4.40 per cent. of retted flax, which are reduced to less than two per cent. after their conversion into paper.

Condition of the material.	Original weight.		Nature of the manipulation.	Reduction per ct.	Weight remaining after each operation.	
	French kilog.	English lbs.			French kilog.	Eng. lbs.
Raw picked flax	100.00	220.47	Drying. . . .	75	25.00	55.10
Flakes of dry flax	25.00	55.10	Rippling. . .	30	17.50	37.47
Rippled flax. . .	17.50	37.47	Retting . . .	75	4.40	9.69
Retted flax . . .	4.40	9.69	Combing . .	5	4.18	9.20
Combed flax. . .	4.18	9.20	Spinning . .	15	3.55	7.82
Spun thread . . .	3.55	7.82	Boiling in lye	20	2.84	6.18
Boiled thread . .	2.84	6.18	Weaving . .	0	2.84	6.18
Linen cloth . . .	2.84	6.18	Bleaching . .	15	2.41	5.30
White linen . . .	2.41	5.30	Paper making	30	1.69	3.71

For hemp, the proportions of the loss are still greater. According to M. de Gasparin, 194 kilog. (427.70 lbs. avoird.) of the dry plant produce 5.40 kilog. (11.90 lbs.) of tow. Thus, to produce 100 kilog. (220.47 lbs.) of tow, it takes 3,592 kilog. (3.533 tons) of the dry plants.

Fine textile materials being employed for weaving, it is obvious that only the coarsest kinds can be directly used for making paper, such as those which grow abundantly and without cultivation in a country where the price of land is very low.

Among the plants which best fulfill these conditions, is the Spanish broom, which grows in considerable quantities on the coasts of Spain, Africa, and especially Algeria. But here we are met by a fresh obstacle; for the crude material before being transformed into paper, requires the use of chemical agents to remove the gummy, resinous, alkaline, and coloring matters, in order to obtain the cellulose as nearly pure as possible.

The action of these substances has moreover to be regulated to prevent the strength of the fibres from being destroyed, and thus occasioning so much waste of the material, that its application to industrial purposes would become impossible.

Let us now consider some details concerning the nature and composition of this plant.

Esparto, or Spanish broom, grows in siliceous and ferruginous soils, alternating in Algeria with the dwarf palm, the mastic, the asphodel, and the squill.

As in the case of flax and hemp, this plant should be gathered before it is perfectly ripe. Nevertheless, if too green, the fibres being more or less transparent would give a sort of vegetable paper.

The drying requires eight days. In the process, the plant loses 40 per cent. of its weight. It has been calculated that one man can gather, in a day, from 100 to 150 kilog. (220.47 to 330.70 lbs. avoird.) according to his strength and skill.

In Spain, where this substance is used for making ropes, mats, and carpets, it is not gathered until completely ripe. This is disadvantageous for paper-making, as the silica and iron are more closely combined, and, in consequence, necessitate longer and more costly boiling and bleaching.

Before subjecting this material to the boiling and bleaching processes, it is essential to crush it in the direction of its length, by means of fluted rollers; as the fibres are more permeable to chemical agents when separated.

Esparto, after being boiled with lye, retains enough tenacity to be separated into long shreds. It contains a red coloring matter which becomes soluble under the combined influence of chlorine and caustics.

The waters used in washing them assume a blood red tinge.

The waste of material may be thus estimated:—

Yellow coloring matter . . .	12
Red " " . . .	6
Resin and gum	7
Salts constituting the ash . . .	1.500
	26.500
Paper fibres	73.500
	100.000

The yellow coloring matter being soluble in alkalies, is eliminated after the first boiling.

Although esparto is a textile material, it must not be supposed that the paper it affords possesses the same amount of toughness and suppleness as that made from rags.

Properly speaking, it should only be considered as a supplementary material, allowing the reservation of rags for choice papers.

By mixing esparto with rags of poorer quality, very good printing paper may be manufactured.

The use of Spanish broom is very general in England; and is contained in almost all the daily papers, including the *Times*.

The importation, in 1862, amounted to 18,000,000 kilog. (17,716 tons).

Some daily papers published at Edinburgh are composed of—

75	Spanish broom.
25	rags.
100	

Its application in France is very limited, where the cost of chemicals is too great. Nevertheless some paper-mills are established in Marseilles regularly using esparto, among which we will mention that of M. Horace Boucher & Cie.

Whatever may be the fibrous material employed, the principle of manipulation is the same. It consists of washing, crushing and repeated boiling with lye, combined with the operation of bleaching.

Outside of textile materials, the attention of some manufacturers has been called to straw and wood as capable of replacing rags to a certain extent for different papers.

After these two principal materials, the following numerous vegetable substances have been proposed by inventors.

Substances proposed for the manufacture of paper—

1st. Bark of the acacia.
" " birch tree.
" " hazel tree.
" " maple tree.
" " mulberry tree.
" " plantain tree.
" " linden tree.
" " willow tree, etc.

2d. Leaves of trees, and the acerose leaves of pines, firs, etc.

3d. Various plants, such as—
Algae.
Heather.
Bryony.
Thistle.
Dog-grass.
Clematis.
Oats.
Broom.

Hops.
Canes.
Lichens.
Maize.
Mosses.
Nettle.
Reeds.
Tobacco.

4th. Roots—
Carrots, turnips.
Lucien.
Sainfoin.
Clover, etc.

To complete the list, we should have to add seeds of hemp and flax, beet pulp, the refuse of breweries and distilleries, of sorgo, asphodel, etc.

We will say a few words, further on, of the processes to be employed in order to obtain paper or boards by means of these different substances, the most of which, however, are incapable of advantageous application.

Let us consider the more important study of papers made from straw and wood.

§ 1. Straw Papers.

The first attempts to make paper from straw go back to the beginning of this century, as is proved by the patent taken out by Sequin. The process consisted in subjecting the material to the action of a lye made of a mixture of lime and soda, or potassa, until the substance was softened enough to be crushed between the fingers, After washing followed by trituration, the stuff was converted into paper.

The numerous patents, taken out with the same object, are based upon analogous principles. Schinz managed to make packing paper of considerable strength, by mixing 50 per cent. of coarse rags with straw pulp, prepared in the following manner:—

100 kilog. (220.47 lbs. avoir.) of wheat straw, finely chopped, and 80 kilog. (176.32 lbs.) of quick-lime were placed in a caldron with a sufficient amount of water to form a kind of pulp. The mixture was stirred, and poured into a second boiler every day for a fortnight.

This material was then reduced to pulp, and mixed with the rag pulp in the beating engine. The product obtained was half-sized, of a yellowish tinge and great strength.

Straw contains a yellow coloring matter, which is more or less communicated to the paper, unless subjected to a succession of boilings and bleachings, with gaseous or liquid chlorine. In this case the waste of material is very much increased.

The majority of manufacturers who employ straw are satisfied with subjecting it to maceration with lime, and succeed in making common wrapping paper, for which there is a considerable demand at present. If, however, we wish to make common printing paper, such as newspaper, etc., of straw pulp, it is indispensable to bleach with repeated chlorine and acid baths. The mixture is then made in the proportion of—

25 to 40 per cent. of straw pulp.
75 to 60 " " rag pulp.

The manufacture is thus only profitable in localities where chemicals are at a low price. We have seen very handsome papers made in England, with 80 to 90 per cent. of straw, but it remains to be seen whether the profits will render the process practicable.

The nature of the straw and the composition of the soils in which it is grown are not unimportant matters to the paper-maker. The hardness of straws proceeds from the quantity of silica interspersed throughout their substance, and forming an obstacle to their conversion into paper, by binding together the fibrous parts of the stalk.

The straw to be chosen is that of wheat, as being the most tender. This fact is in accordance with chemical analysis, which gives the following proportions of silica contained in the three principal cereals of our soil:—

1st. Wheat straw,	4.3 per cent. of silica.			
2d. Rye	"	6.3	"	"
3d. Barley	"	6.9	"	"

The knots of graminious plants, in general, are injected with a much greater quantity of silica than the intermediate parts, and should therefore be carefully removed when the straw is to be converted into white paper pulp.

Among other straws which have been tried, we will mention maize, which gives a naturally sized paper of great strength, and which, at one time, very much excited public attention.

Maize stalks unbleached, only boiled with lye, and added to rag pulp, are suitable for making packing-paper. The product possesses a certain tenacity not offered by that of other straws. This substance may then answer very well in countries where it grows in sufficient quantities to allow of its employment in the arts.

In some paper-mills, and especially that of Cusset, attempts have been made to convert into paper the inferior qualities of hay produced in marshy soils. The product obtained was of a dingy, green tinge, and had little consistency. It may, however, answer for common printing paper.

The composition adopted for the pulp was:—

50.0	parts of hay.	
12.5	"	tarred rope.
12.5	"	linen and woollen.
25.0	"	cottons.
100.0		

Boiling hay in lye is an easy operation, and the unbleached pulp may be used for wrapping papers. The paper made of this material is more supple than that obtained from straw.

A Swedish newspaper has been printed, for several years past, upon paper made with horse dung. By washing, all the soluble parts are carried off and used for manure; and the parts of the hay which have not been assimilated by the organism of the animal, having undergone a previous bleaching by means of the gastric and other juices, require a smaller proportion of chemical agents to effect their transformation into pulp.

§ 2. Wood Paper.

For twenty years wood has been the object of numerous, and at first fruitless, experiments. At the present day, thanks to the persevering efforts of a few inventors, practical processes are known which allow us to rely upon this material, when mixed with rags, for making the commoner kinds of white writing and printing paper.

For several years, the *Tilia americana* has been used in America for newspapers.

In France and Belgium white and resinous woods, such as pine, fir, etc., are employed.

It has been shown by the experiments of M. Fremy, that wood is not made up of cells solidified by incrusting materials, as was long supposed, but of two superimposed layers; one exterior, short-grained, and brittle, which he calls *exofibrose;* the other internal, supple, and fibrous, to which he has given the name of *fibrose.*

In order to make wood paper, then, all that is necessary is to dissolve the exofibrose and employ the remaining fibrose.

This first layer is acted upon by alkalies, hydrochloric acid, and the hypochlorites.[1]

The machines employed to separate the fibres of wood are of different kinds. That invented by M. Vœlter consists in a grindstone, which consumes several logs of wood placed against its circumference and pressed in such a manner as to keep them always in contact with it during the entire duration of the work.

The Chauchard machine, on the contrary, crushes the chips between cast-iron rollers, and the material is triturated by means of a cylinder engine. The pulp is strained through a sieve, placed in the cap of the engine, and may then be used immediately for the manufacture of common papers. Wood alone gives too brittle a paper, and the short thick fibres do not yield that suppleness which is characteristic of rag paper.

It has been estimated that it takes $0^{m}.380$ (14.88 in.) of wood to make 100 kilog. of pulp.

[1] The application of this process to the arts has not yet verified the theory.

The motive force necessary to separate the fibres of wood is quite great. It is calculated that a 25 horse power is required for 24 hours, in order to produce 300 kilog. (661.42 lbs.), and a 44 horse power in order to produce 750 kilog. (1653.54 lbs.) of wood pulp.

We give as an example of the mixture the proportions admitted by M. Vœlter, a paper-maker at Heidenheim.

Post paper . .	20	per cent.	of poplar wood,	80	per cent.	of rags.
Writing paper . .	33	"	" "	67	"	"
Fine printing paper .	20	"	" "	80	"	"
Common printing paper	50	"	pine wood,	50	"	"
Brown wrapping paper	40	"	" "	60	"	"
Gray wrapping paper	50	"	" "	50	"	"
Blue paper for covers	33	"	" "	67	"	"

In Belgium, paper for newspapers is made of—

60 parts birch wood,
20 " Kaolin,
20 " coarse gray rags.

The wood pulp is added a quarter of an hour before the end of the beating process. The wood being neither boiled nor bleached, the proportion of bleaching should be diminished, as a part of the coloring matter is not destroyed by acids.

The use of chemical agents to bleach wood pulp requires much skill, otherwise we run a great risk of having a pulp without consistency, and giving rise to considerable loss of material.

The introduction of unboiled and unbleached pulp is considered so great an economy, that several manufacturers of Germany, Belgium, and France have decided to make additions to their paper-mills, in order specially to prepare wood pulp.

CHAPTER VII.

CHEMICAL ANALYSIS OF MATERIALS EMPLOYED IN PAPER-MAKING.

The nature of cotton, linen, and hempen rags may be determined by chemical tests and by microsopic examination, when the material is comparatively new.

The fibres of cotton and hemp seen through the microscope, present the appearance of rigid cylindrical tubes, with intercepted intervals like straws, reeds, &c. They are elongated cells, glued together by a material of denser texture, which is susceptible to the action of acids and alkalies.

During the process of "*retting*," which has for its object the destruction of the gummy matter uniting the fibres with each other throughout their entire length, this substance interposed between each cell is entirely, or in part, destroyed by the fermentation, which proportionally diminishes the strength of the fibres.

The diameter of hemp fibres may be estimated to be from $\frac{1}{20}$ to $\frac{1}{30}$ of a millimetre ($\frac{19}{10000}$ to $\frac{13}{10000}$ of an inch). Those of linen are still finer and have a silkier appearance.

The fibrillæ of cotton, on the contrary, are transparent tubes, flattened in the middle throughout their entire length, presenting the appearance of two parallel rolls, united by a very thin partition. They cannot be better compared than to a T rail, twisted several times upon itself.

The diameters of the fibres vary from $\frac{1}{65}$ to $\frac{1}{85}$ of a millimetre ($\frac{7}{10000}$ to $\frac{4}{10000}$ of an inch).

When these fibres have been brought into the condition of textures, more or less worn, these microscopic characteristics are insufficient; the straight and rigid conformation of the hemp and flax fibres having disappeared.

It is then necessary to resort to chemical reagents. Linen and cotton fibres may be distinguished in several ways.

1st. A boiling solution of potassa colors the fibres of linen quite a deep yellow; whereas its action upon cotton is very feeble.

To make use of this test, a piece of the cloth to be tested is placed in a boiling solution of potassa, composed of one part of caustic potassa and one of water. After two or three minutes' immersion, the excess of alkali is expressed by means of several folds of bibulous paper, and the successive fibres of the warp and woof are counted; those of linen being of a deep and those of cotton of a light yellow, or white.

2d. Concentrated sulphuric acid quickly attacks cotton fibres, and converts them into gum, while linen fibres remain white and opaque. By washing the gummy matter is removed, and the sulphuric acid neutralized by the addition of a small amount of caustic potassa. The threads of the sample having been counted, the missing ones will represent those of cotton.

We owe to M. Vincent the following process for distinguishing linen and hemp threads from those of the Phormium tenax.

The texture to be tested is dipped in nitric acid at 36°, containing hyponitric acid, when a red color at once appears on the raw and imperfectly bleached products of the phormium tenax; whereas the linen and hempen threads are imperceptibly, or very slightly, colored.

We obtain a more striking reaction by dipping the texture in a saturated solution of chlorine gas. If afterwards a few drops of ammonia are poured upon the sample, the threads of the phormium tenax become violet-red; this color may be removed by a few drops of nitric acid.

The hempen threads assume a slightly rosy hue, which somewhat deepens with tow made from hemp allowed to remain in stagnant water. Linen, on the contrary, preserves its original color.

These reactions present no certainty except in the case of crude materials, or such as have been but little worn; we have, however, thought it right to give them, as being, to a certain degree, useful in some instances.

In paper-making linen and cotton rags are distinguished by the touch, and the workwomen very soon acquire sufficient skill to make this distinction rapidly.

§ 1. The Waters.

The degree of pureness of the waters, used in the different processes of paper-making, has a great influence upon the quality of the papers.

Murky water, containing argillaceous and silicious substances, turns the pulp yellow; that containing saline matters in solution, to a certain extent, destroys the brilliancy of the coloring materials, or forms an impediment in sizing with gelatine. If the water contains organic matter in solution, it sometimes prevents the manufacture of superfine papers.

It is, therefore, important to determine, at different seasons of the years, the composition of the water employed in washing and other manipulation.

We obtain by filtration the amount of argillaceous and silicious matters held in suspension in the water.

The calcareous salts held in solution are precipitated by means of a few grammes of alum or carbonate of soda.

If it is desired to make a complete analysis, the most certain method is to evaporate several litres of the liquid and examine the residuum after evaporation, for the different proportions of the substances contained.

The proportion of calcareous salts may be detected in a very simple way, founded on the principle announced by Dr. Clark,[1] that the hardness of water being proportional to the earthy salts it contains, the quantity of the tincture of soap it requires to produce a foam will give the measure of its hardness.

Take in the flask A, Plate I., Fig. 11, forty cubic centimetres (2.44 cubic inches) of the water to be tested, and pour the test liquid into the burette till it reaches a level marked on the scale. The divisions of the scale comprised between the mark and the zero point, represent the proportion of the liquid necessary to produce the phenomenon of foaming with pure distilled water. The composition of this liquid is to be so calculated that each degree of the scale shall represent 0.10 grammes (1.544 grains troy) of soap, neutralized by one litre (1.76 pints) of water subjected to experiment, and correspond with 0.01 gramme (0.154 grains) of carbonate of lime for the same quantity.

[1] Prof. Clark, "Repertory of Patent Inventions," 1841, a pamphlet entitled "A New Process for Purifying the Waters supplied to the Metropolis," and "On the Examination of Water for its Hardness." (*Pharmaceutical Journal*, vol. vi. p. 526. London.)—TR.

When the water is poured into the flask the test liquid is added gradually, by trying at intervals whether by stirring it will produce a light and persistent foam. When the foam is produced, the number of divisions represent the hydrotimetrical degree of the water under examination.

Distilled water	marks		0.0°
Snow	"	"	2.5°
Rain	"	"	3.5°

§ 2. ALKALIMETRICAL TEST.

The soda of commerce has no value, except in so far as it contains soda in the condition of a carbonate, or of caustic soda. To determine the quantity of these materials present, we resort to tests with the alkalimeter.

The principle upon which this experiment is based is as follows: Given a dilute solution of free alkali, of carbonate or sulphate of potassa or soda, of chloride of potassium or sodium, etc. Pure sulphuric acid, diluted with water, is added to the mixture; this acid acts only on the free alkali, or on the carbonate, and, as long as the acid is not present in sufficient quantity to produce a neutral sulphate; the liquid manifests an alkaline reaction; but when the base is saturated, the solution becomes neutral to colored tests, and when this point is exceeded never so little, the liquid will redden litmus paper. We are thus enabled to determine the exact moment of saturation.

Experiment shows that, if the substance analyzed is pure potassa, it would take 5 grammes (77.20 grs. troy) of monohydrated sulphuric acid to neutralize 4.807 grammes (74.11 grs.) of potassa.

Let us suppose that we are operating on the potash of commerce, containing water, carbonic acid, chloride of potassium, and sulphate of potassa. If instead of 5 grammes 2.5 are sufficient, this potash contains 50 per cent. of foreign and worthless matters.

To make this experiment 48.07 grammes (741.12 grs.) of the potash to be tested are weighed off and dissolved in such a quantity of water that the solution shall occupy half a litre, or 500 cubic centimetres (30.50 cub. in.). By means of a pipette take 50 cubic centimetres, or one-tenth the liquid (3.05 cub. in.), and this volume will contain in consequence 4.807 grammes (74.11 grs.) of the potash to be tested.

This alkaline solution is then poured into the vessel, in which it is to be neutralized.

The sulphuric acid is prepared by dissolving 100 grammes (154.42 grs.) of monohydrated sulphuric acid in a sufficient quantity of water to complete the volume of 1 litre (1.76 pt.)

If we now take a burette, graduated according to half cubic centimetres (0.0305 cub. in.), 100 divisions will correspond to 5 grammes (77.20 grs.) of pure acid, and from this it results that, if it takes 100 divisions to complete the saturation, the potash under consideration would be pure. For 60 divisions the proportion of alkali would be 60 per 100.

The number of divisions, or degrees, on the alkalimetrical burette expresses, therefore, the proportion by weight of the alkali contained in the material to be examined.

The operation is performed in the following manner: After having poured into the vessel the 50 cubic centimetres of the alkaline solution, it is colored with litmus, so as to give it a light blue tinge. The vessel is placed upon a white paper to enable us the better to appreciate the phenomenon of discoloration.

The acid solution of the burette is then poured in by degrees, while the vessel is rotated to give greater effect to the chemical reaction.

The color does not change for the first few moments; for the carbonic acid driven off by the sulphuric acid passes over to that part of the carbonate not yet decomposed, which in this way becomes changed to the bicarbonate.

The liquid then begins to assume a vinous red color, which announces the disengagement of the carbonic acid.[1] We continue to pour in the acid with greater care, trying whether a drop of the solution taken with a glass rod, will not produce a red streak upon blue litmus paper. As long as the red color thus produced is not persistent, the reaction is due to carbonic acid; as soon, however, as it becomes permanent and appears brighter the operation is completed.

The number of divisions used are then read off on the scale of the burette. Generally two or three experiments are made to test the accuracy of the first result.[2]

The alkalinity of several of the potashes of commerce is here shown.

Potash of Tuscany	56.°0
" " Russia	53.°1
" (red) of America	55.°0
" (pearlash) of America . . .	54.°1
" " " Vosges	31.°5
" crude of molasses	40.°0
" common purified	59.°7
" purified	69.°5

[1] The reaction in this case may be thus stated:—

$$\underset{\text{1st addition.}}{2\,(KO,CO_2) + HO,SO_3} = KO,SO_3 + KO,2CO_2 \;\underset{\text{2d addition.}}{+ HO\,SO_3} = 2KO,SO_3 + HO + CO_2 \text{ escaping.}$$—Tr.

[2] In this country the alkalimeter is so graduated that one degree of the test acid will exactly neutralize one grain of pure carbonate of soda. —Tr.

For testing soda, the material generally employed in French paper-making, 31.85 grammes (478.74 grs.), are to be taken, as the specific gravity of this substance is greater than that of potash, but the steps to be followed are exactly the same.

The alkalinity of these different sodas of commerce have been given by M. Girardin:—

Soda	of Alicant,		55 to 60	ashy gray.
	" Carthagena		30 " 32	
	" Teneriffe		28 " 32	dark gray.
	" Marbonne or			ashy gray.
	" Salicor		13 " 14	
	" Aigues mortes or			
	" Blanquette		2 " 7	
	" Varechs	crude	4 " 5	blackish.
		refined	2 " 7	dead white powder.
	Artificial crude		18 " 34	violet colored.
Carbonate of soda	crude		40 " 70	yellowish white or gray
	refined	caustic	50 " 80	dead white
		notcaustic	40 " 80	
	Crystals of soda		34 " 36	transparent white.
Natron (native carbonate)	Of Egypt	old	17 " 18	dirty grayish brown.
		new	45 " 58	dead white
	Barbary		20 " 50	

Generally the refined carbonate or crystals of soda are employed. The degree of the first being the highest, it should be preferred in order to economize the cost of transportation of the water of crystallization.

For common papers the crude sodas of the locality in which the mill is situated may be advantageously used.

§ 3. Examination of Limes.

The principal substances to be met with in limes are magnesia, silica, alumina, and traces of the oxides of iron.

The limes to be preferred for use in paper-making are the rich white kinds, which contain at least 90 per cent. of pure lime.

To make an analysis of any given lime, take 10 grammes (154.42 grs. troy) of the material and heat them in a porcelain capsule, at a temperature of 100° to 200° (212 to 392 Fahr.). The difference of weight now represents the proportion of moisture contained in the specimen. Raising it to a red heat in the same capsule, or better still in a platinum crucible, we determine by again weighing the amount of carbonic acid, which might have been left in combination with the lime, through imperfect calcination.

Then take 2 grammes (30.88 grs.) of this material and treat them with dilute hydrochloric acid, gently heating to complete the solution of all soluble principles.

By pouring ammonia into the solution, the alumina, which might have been dissolved by the hydrochloric acid, will be precipitated.

The alumina and silica are separated from the solution by filtering, and then weighed after desiccation and incineration of the filtering paper, the ash of the paper being subtracted from the weight.

In the filtered liquid the lime is precipitated either by oxalate of ammonia or by sulphuric acid. In the first case by calcining we obtain caustic or quick-lime, which is weighed. In the second, the lime is treated in the condition of a sulphate, and after precipitation of the magnesia by the phosphate of ammonia and magnesia, is calcined, and the phosphate of magnesia weighed.

By means of chemical equivalents the proportions of caustic lime and magnesia contained in the material are determined.

The following tables will give an opportunity of comparing the difference in composition of rich and poor limes.

RICH LIMES.

Source.	Lime per cent.	Magnesia per cent.	Clay and sand per cent.
Chateau-Landon (Seine et Marne) .	96.4	1.8	1.8
Saint Jacques (Jura) . . .	95.4	1.8	2.8
Paris chalk	97.2	0.0	2.8
Layneux (Ain)	91.6	1.5	6.9
Vichy (Allier) [limit of rich limes]	86.0	9.0	5.0

POOR LIMES.

Source.	Lime per cent.	Magnesia per cent.	Clay and sand per cent.
Environs of Paris	78.0	20.2	2.0
Villefranche (Aveyron) . . .	60.0	26.2	13.0 including some manganese.

As the caustic portion is alone fitted for the uses of alkaline boiling, it should alone determine the market value of lime; the other substances being, if not injurious, entirely inert.

For manufacturing white paper, perfectly white limes should be used. This quality, indeed, is an indication of their pureness, as poor limes are of a more or less grayish color, owing to the large proportion of clay they contain.

§ 4. Chlorometric Tests.

We owe the chlorometric process generally followed to Gay-Lussac; it is based upon the oxidizing properties of chlorine salts in the presence of water; the water in decomposing yielding its oxygen to the oxidizable body and the chlorine uniting with the hydrogen to form hydrochloric acid; and further, upon the instantaneous discoloration of a solution of indigo by a slight excess of chlorine.

Arsenious acid taken as the oxidizable body becomes converted into arsenic acid (AsO_3 into AsO_5).

The test liquid composed of arsenious acid, which is bought ready prepared at manufactories of chemicals, is such as to necessitate a volume of a solution of chlorine equal to its own, in order to convert all the arsenious acid into arsenic acid.

This liquid contains 4.439 grammes (67.78 grs. troy) of arsenious acid to the litre (1.76 pts.) of the solution. It is prepared by dissolving that quantity of arsenious acid in pure hydrochloric acid, diluted with its own volume of water, and afterwards adding water enough to complete the litre.

To perform the experiment take 10 grammes (154.42 grs.) of the chloride to be examined (chloride of lime, for instance) and wash them well with water several times in a mortar; throw all the water used in this washing into a flask and add more water to make up the litre (1.76 pt.).

Pour 10 cubic centimetres (0.61 cub. in.) of the arsenious solution into the vessel A, Fig. 8, pl. 1, slightly colored by a solution of indigo. The burette B, is then filled with the chlorinated solution. The scale is graduated in such a manner that a hundred divisions correspond with ten cubic centimetres and the test liquid poured in drop by drop until the color disappears.

In order better to determine the instant at which the discoloration occurs, the vessel is placed upon a sheet of paper.

If 100 divisions	are used	the degree	would	be	100
" 200	"	"	"	"	50
" 150	"	"	"	"	66.6

100 degrees indicate that 1 kilog. (2.679 lbs. troy) of the chloride contains 100 litres (6102.70 cub. in.) or 318 grammes (4910.68 grs.) of chlorine gas.

The chlorides of commerce contain about 103 litres (6285.79 cub. in.) or 327 grammes (5049.67 grs.) of chloride to the kilog. (2.679 lbs.).

To avoid the necessity of making fresh calculations for each operation, tables have been constructed, giving, opposite the degree of the scale, the number of litres of chlorine to the kilog. of the chloride, as well as the weight of the gas corresponding to the volume.

It is well, as in the alkalimetric tests, to perform two or three successive experiments, in order to insure the accuracy of the first.

When once accustomed to testing in this way, a person can make several analyses of different chlorides in an hour.

CHLONOMETRICAL TABLE FOR 1 KILOG. (2.679 lbs. troy).[1]

Degree of the scale.	Vol. of chlorine gas in 1 kilog. (2.679 lbs. troy) of the chloride.		Weight of chlorine for 1 kilog. (2.679 lbs. troy) of the chloride.		Degree of the scale.	Vol. of chlorine gas in 1 kilog. (2.679 lbs. troy) of the chloride.		Weight of chlorine for 1 kilog. (2.679 lbs. troy) of the chloride.	
	French litres.	English cub. in.	Fren'h gram's	English grs. troy		Fren'h litres.	English cub.in.	Fren'h gram's	Eng. grs.try
130	76.9	4692	247	3814	104	96	5858	306	4725
129	77.5	4729	248	3829	103	97	5919	309	4771
128	78.0	4760	249	3844	102	98	5980	312	4817
127	78.7	4802	250	3860	101	99	6041	315	4864
126	79.4	4845	251	3876	100	100	6102	318	4910
125	80.0	4882	253	3906	99	101	6163	321	4956
124	80.6	4918	254	3922	98	102	6224	324	5003
123	81.3	4961	255	3937	97	103	6285	327	5049
122	82.0	5004	258	3984	96	104	6346	330	5095
121	82.6	5040	260	4015	95	105	6407	333	5142
120	83.3	5083	263	4061	94	106	6468	336	5188
119	84.0	5126	266	4107	93	107	6529	339	5234
118	84.7	5168	268	4138	92	109	6651	345	5327
117	85.5	5217	270	4169	91	110	6712	351	5420
116	86.0	5248	272	4200	90	111	6774	354	5466
115	86.9	5303	275	4246	89	112	6835	357	5512
114	87.7	5352	278	4292	88	114	6957	363	5605
113	88.5	5400	280	4323	87	115	7018	366	5651
112	89.3	5449	283	4370	86	116	7079	369	5697
111	90.0	5492	285	4401	85	118	7201	375	5790
110	90.9	5547	288	4447	84	119	7262	378	5836
109	91.7	5596	290	4478	83	120	7323	381	5883
108	92.6	5651	293	4524	82	122	7445	387	5975
107	93.0	5675	297	4586	81	123	7506	390	6025
106	94.0	5736	300	4638	80	125	7628	396	6114
105	95.0	5797	303	4678	79	127	7750	402	6207
					78	128	7811	406	6269

[1] Cubic inches and grains are used in the above table to avoid decimals. To find the volume or weight of chlorine contained in a pound of troy of a specimen of chloride marking a given degree on the French chlorometer, find the number of cubic inches or grains set opposite the degree and divide by 2.679; the quotient will be the desired result. For instance, a specimen of chloride of lime marks 98° = 5003 grs. on the scale for 1 kilog. $\frac{5003}{2.679} =$ 1867.48 grs. for the 1 lb.—Tr.

The following, according to M. Payen, is the composition of chloride of lime.[1]

1st. Pulverized, at 100°, that is, containing 100 volumes of chlorine.

Composition by equivalents:—

2 Cl.	=	886.4
4 CaO	=	1400.0
4 HO	=	450.0
		2736.4

Or by hundredths:—

Chlorine	32.39
Lime	51.16
Water	16.45
	100.00

2d. Composition of chloride of lime in aqueous solution.

2 Cl.	=	886.4
2 CaO	=	700.0
4 HO	=	450.0
		2036.4

Or by hundredths:—

Chlorine	43.52
Lime	34.37
Water	22.11
	100.00

These figures clearly establish the fact, that the same quantity of lime will absorb twice the amount of chlorine, when the reaction takes place in the presence of water. There is then advantage in preparing the liquid chloride, when it is not necessary to transport it. The powdered

[1] "Chimie Industrielle."

chloride may be considered as retaining the chlorine by a double equivalent of lime, whereas in the liquid chloride, it is the excess of water, which, in effecting the solution, preserves the stability of the compound.

§ 5. Examination of Manganese.

The market value of this substance, as applied to paper-making, depends upon the amount of chlorine it is capable of liberating in the preparation of chlorine gas, or the decolorizing chlorides. The weight of chlorine disengaged is proportional to the quantity of pure binoxide of manganese contained in the ore.

To ascertain the value of this substance, it is sufficient to act with it upon an excess of hydrochloric acid, and then determine the quantity of chlorine disengaged and collected in an alkaline solution.

Precise analyses have allowed us to determine that 3.98 grammes (61.44 grs. troy) of pure binoxide of manganese disengage 1 litre (6102.70 cub. in.) of dry chlorine at 278°.0. And under a pressure of 0.76 metres (30 inches of the barometer) or one atmosphere.

It is evident from this that the hundredths of a litre of chlorine will represent the hundredths of available manganese contained in the specimen of ore.

To perform the experiment, therefore, we weigh 3.98 grammes (61.44 grs.) of the manganese, reduced to powder, place it in a flask, and gradually add 25 cubic centimetres (1.52 cub. inches) of hydrochloric acid through an S shaped tube. The flask is supplied with another tube, through which the gas is conveyed into the alkaline solution.

The mixture is heated gently, and the operation continued, until the vapor of water has driven off the last traces of chlorine.

The resulting solution of chloride is poured into a flask, bearing an index marking the capacity of 1 litre (1.76 pt.). This measure is completed by adding the water used in rinsing the flask, from which the liquid was taken.

The test liquid being thus obtained, the experiment is concluded by employing the ordinary chlorometric test we have already described.

If 200 divisions of the burette are required the degree is 50.

By means of a proportion it is easily ascertained how many litres of chlorine may be liberated by 100 kilog. (267.95 lbs. troy) of manganese.

The binoxide of manganese is composed of—

Manganese . . .	3.5578
Oxygen	2.0000
	5.5578

and 5.5578 grammes (85.82 grs. troy) are capable of liberating 4.4265 grammes (68.35 grs.), or 1.396 litres (85.19 cubic inches) of chlorine. It follows, therefore, that 3.98 grammes (61.46 grs.) will produce 1 litre (61.02 cub. in.) and 1 kilogramme (15,442 grs. or 2.6795 lbs. troy) will furnish 251.23 litres (15,331 cub. in. or 8.8721 cub. ft.) of the gas.[1]

§ 6. Chlorometric Degrees of Samples of Manganese.

Manganese, pure crystallized .	100°
" German, 1st qual. .	95°
" English . . .	88°
" Burgundy . .	68°
" Cher . . .	53°.5
" Mayenne . .	52°

[1] According to the above figures, 1 lb. troy of the peroxide of manganese would liberate 3.311104 cubic feet of chlorine.—Tr.

The value of manganese also depends upon the proportion of hydrochloric acid which it employs in liberating the chlorine. The binoxide of manganese (MnO_2) requires two parts of hydrochloric acid to disengage one part of chlorine; the sesquioxide (Mn_2O_3) three parts of acid for one of chlorine; and finally the protoxide (MnO) takes one part of acid with which it simply forms a chloride, without any evolution of gas whatever.

These different reactions are expressed by the following chemical formulæ:—

$$MnO_2 + 2HCl = MnCl + 2HO + Cl$$
$$MnO + HCl = MnCl + HO$$
$$Mn_2O_3 + 3HCl = 2MnCl + 3HO + Cl$$

The carbonates of lime and baryta, and the oxide of iron, which are found in manganese ores, also combine with the hydrochloric acid, causing a proportional loss in the amount of gas evolved. The result is the liberation of carbonic acid, which, in the manufacture of chloride of lime, forms a carbonate which the chlorine will not decompose. We thus have a loss in acid, in lime, and in the degree of the chloride. M. Payen, in his *Chimie Industrielle*, gives the following process for determining the amount of acid employed.

To dissolve 3.98 grammes (61.46 grs. troy) of the binoxide of manganese and produce 1 litre (61.02 cub. in.) of chlorine, a quantity of hydrochloric acid equivalent to 176 acidimetric degrees (or to 8.75 grammes [135.10 grs.] of concentrated sulphuric acid) is required; half of the hydrochloric acid, or 88°, forming chloride of manganese, and the other half giving the 100° of chlorine. One hundredth of the acid lost in the operation is replaced.

To determine the amount of hydrochloric acid required by any specimen of manganese, treat 3.98 grammes (61.46 grs.) with 25 cubic centimetres (1.52 cub. in.) of acid, representing 250 acidimetric degrees (equivalent to 12.5 grammes [193.02 grs.] of concentrated sulphuric acid) and collect the chlorine. Admitting that 100 chlorometric require 173 acidimetric degrees, it is ascertained by neutralizing with carbonate of soda (until the carbonate of manganese ceases to be dissolved) how much of the free acid remains. Now, by adding these two quantities we determine how much is needed to complete the 200 degrees of acid employed, and the deficiency will represent the amount of loss occasioned by the specimen of manganese.

The following table indicates the result of a few experiments of this nature:—

Manganese employed.	Chlorometric degrees.	Hydrochloric acid.			Total number of acidimetric degrees employed.
		Acidimetric equivalent to chlorometric degrees.	Excess discovered by neutralizing.	Loss.	
Pure crystallized . . .	100	176	73	1	250
German, first quality . .	95	167	79	4	250
English	88	155	82	13	250
Burgundy	68	120	103	27	250
Cher	53.5	94	147	9	250
Mayenne	52	92	127	31	250

This table shows us that to obtain 52° of chlorine with manganese from Mayenne, 92+31=123 acidimetric degrees were required, representing nearly one and a half times as much hydrochloric acid as would be needed to obtain the same quantity of chlorine by using the German manganese.

§ 7. Antichlorine.

We saw, while speaking of the washing of the pulp, that in order to remove the last traces of chlorine retained with much energy by a sort of special capillary attraction, it was advantageous to make use of alkaline sulphites, or hyposulphites, which, by combining with the chlorine, annihilate its destructive effects.

Antichlorine is used in England upon a large scale. It has been calculated that the annual consumption amounts to 200,000 or 250,000 kilog. (196.85 to 321.45 tons).

To ascertain whether the pulp contains free chlorine, different reagents may be used, all, however, based upon the action of iodine upon starch when expelled by chlorine from its ioduretted compounds.

The test liquid may be prepared in several manners, of which we will here give two.

1st. Carry the following mixture to the boiling point:—

1 part of iodide of potassium.
2 parts of starch
3 parts of water.

This liquid, preserved in a glass-stoppered vial, will color the pulp blue, if it contains chlorine.

2d. Boil for about three-quarters of an hour,

Starch	5 parts.
Fused chloride of zinc .	20 "
Water	1000 "
When the liquid is cool, add	
Iodide of zinc . . .	2 "

To ascertain the presence of chlorine in the pulp, a bolus is made of the pulp by squeezing out the greater part of the water. The presence of chlorine is then manifested by the violet blue color of the iodide of starch.

There is a great advantage in using the hyposulphite instead of the sulphite; indeed,

1 kilog. (2.679 lbs. troy) of sulphite of soda absorbs 281 grammes (4339 grs.) of chlorine.

1 kilog. (2.679 lbs.) of hyposulphite of soda absorbs 1.144 grammes (17.666 grs.) of chlorine, or about 360 litres (12.6903 cub. ft.).

It follows from this that to counteract 315 litres (11.1244 cub. ft.), or 1 kilog. (2.679 lbs.) of chlorine it would take

3.553 kilog. (9.464 lbs.) of the sulphite of soda.
0.874 kilog. (2.341 lbs.) of the hyposulphite of soda.

Since the cost is equally in favor of the hyposulphite, this compound should be considered as the practical anti-chlorine for all industrial purposes.

§ 8. Alums.

Different kinds of alum are met with in commerce.

1st. Alum with a potassa base, of which the formula is

$$KO,SO_3+Al_2O_33SO_3+24HO,$$

presents on analysis the following composition:—

Potassa	10.82
Alumina	9.94
Sulphuric acid . . .	33.77
Water	45.47
	100.00

2d. Alum with an ammonia base, of which the formula is

$$(NH_3HO)SO_3+Al_2O_33SO_3+24HO,$$

gives the following analysis:—

Ammonia	3.89
Alumina	11.90
Sulphuric acid	36.00
Water	48.21
	100.00

Alums contain iron in variable proportions, and the presence of this metal is injurious to the color of pulps of delicate and pure shades. For such purposes it is well to use the purified material, known as refined alum, and proof against the tests of prussiate of potassa, which reveals the feeblest traces of iron. It is sufficient to pour a few drops of ferrocyanide of potassium (yellow prussiate) upon some crushed alum, to obtain a blue tinge, if the alum contains iron.

This method is also employed for purifying alum.

Into a solution of alum enough of the prussiate is poured to precipitate the whole of the iron; after allowing it to rest, the liquid is decanted by means of a syphon, and may be used at once or reduced to the form of crystals.

The precipitate of Prussian blue may be used for coloring pulp.

Instead of alum, sulphate of alumina is also used, which is generally obtained by roasting together aluminous schist and iron pyrites, and is apt to contain considerable quantities of that metal; so that it is necessary to purify this substance with ferrocyanide of potassium, when it is to be employed in making fine-colored papers.

Although alum is more costly than sulphate of alumina, it is preferable because less variable in composition. The sulphate of alumina, which sometimes contains an excess of acid varying from two to six per cent.

of the weight of the sulphate, gives rise, by this irregularity of composition, to considerable practical difficulty.

§ 9. Kaolin.

Kaolin is a basic silicate of alumina, produced by the decomposition of feldspathic rocks. In a crude condition it contains sand of various fineness, of which it must be freed before using in paper-making.

This purification is effected by successive washings, which carry off the finest particles. This clay, although smooth to the touch, when dry adheres roughly to the tongue.

We give the composition of washed kaolin, obtained from Saint-Yrieix:—

Water	12.82
Silica	48.37
Alumina	34.95
Oxide of iron	1.26
Potassium and soda	2.60
	100.00

To ascertain the pureness of kaolin, it is only necessary to wash it and then determine the quantity of quartz granules contained in the specimen.

It is always prudent not to employ kaolin in the preparation of size, until it has been passed through the meshes of a fine sieve.

§ 10. Starch.

Starch is a mealy substance, generally extracted from potatoes. The chemical formula for that of commerce is $C_{12}H_{10}O_{10} + 4HO$.

Starch contains variable proportions of water. What is called dry starch, or that containing four equivalents, has 18 per cent. of its weight made up of water. Placed in a very moist atmosphere it may absorb 10 equivalents, or contain 35 per cent., while other starch which has only been drained contains 45 per cent. of its own weight of water.

It is, therefore, important to make sure of the hygrometric condition of the starch by desiccating it at a temperature of 20° to 30° (68° to 86° Fahr.) in a dry atmosphere. To increase the weight of starch it is mixed with various matters, such as chalk, plaster, sulphate of baryta, &c. The adulteration is, however, easily recognized by incineration. Starch burns up entirely, leaving no residuum, whereas, the incombustible mineral matters are found at the bottom of the porcelain capsule in which the experiment is performed.

§ 11. Coloring Materials.

Coloring materials can scarcely be otherwise tested than by directly staining a certain fixed weight of pulp. A well-supplied paper-mill ought to have a small cylinder engine, holding about 5 kilog. (11.02 lbs. avoir.) of dry pulp. The quality of the coloring matter may then be determined, by gradually increasing the proportion and making several sheets of paper on a small mould. The results obtained in this manner are then compared. This method of experiment renders great service when a new kind of paper is to be made, and we have no very definite idea of the amount of coloring matter necessary to give the required shade.

M. Liverkus, a manufacturer of ultramarine in Germany, recommends the following very practical method, applicable, however, to this substance alone.

After having poured 3 grammes (46.32 grs. troy) of the ultramarine to be tried into a vessel containing 270 grammes (4168 grs.) of a concentrated solution of alum, the material is agitated so as to cause all the coloring matters to become suspended in the liquid.

After resting for some time, say half an hour, the mixture is again stirred.

The coloring power of the ultramarine will be directly proportional to the length of time required for the solution to become discolored.

With some blues the discoloration takes place at the end of three to six hours. In others, on the contrary, no perceptible change in the color can be observed until the second or third day.

The aluminous solution is prepared by dissolving 80 grammes of alum (1135 grs.) in 1000 grammes (15,442 grs. or 2.679 lbs. troy) of water.

Ochres have a commercial value proportional to the care with which they have been washed. It is an easy matter to ascertain the amount of gravelly material they contain, and the same holds good in regard to clays, which are used in considerable quantities for manufacturing common papers and boards. It is, however, important not to pour these matters into the engine, or the vat, until they have been filtered through a long-napped felt, which will retain the coarser particles. For the finer coloring matters, fine felts or flannels are used.

§ 12. Fuel.

The analysis of combustibles has for its object to determine the proportion of ash contained in them, and their calorific power; that is to say, the number of degrees of heat which may be generated by a given quantity of fuel.

The weight of the ash may be obtained by calcining 2 grammes (30.88 grs. troy) of the combustible to be examined in a platinum crucible, and stirring the material several times, in order entirely to consume the carbon. The analysis may be considered perfect, when no difference can be observed between two consecutive weighings.

The ash containing much carbonate of lime, which is transformed by calcination into caustic lime, a few drops of a solution of carbonate of ammonia should be added and the whole carried to a red heat.

The results of this experiment are generally considered sufficient, as they allow us to form an estimate of the commercial value of the fuel. It is, however, also of the greatest importance to have correct notions of the number of calorific degrees which can be obtained.

The examination with litharge is the simplest method, and is based upon the following principle.

The amounts of heat emitted by different combustibles are to each other as the respective amounts of oxygen absorbed by these combustibles in burning.

It will be sufficient then to compare the amounts of oxygen required for the combustion of various specimens of fuel with that already determined for pure carbon.

Take 1 gramme (15.44 grs. troy) of the pulverized fuel and mix it with 20 grammes (308.84 grs.) of litharge. This mixture is placed in a crucible and covered over with 30 or 40 grammes (463.23 or 617.69 grs.) of pure litharge. The capacity of the crucible ought to be such that the volume of the material should not occupy more than one-half in order to allow for the swelling which takes place. As soon as the fusion is completed the substance is allowed to cool after having been heated briskly for ten minutes. The crucible is then broken, and the lump of lead which is found in it weighed. The calorific power of the fuel is proportional to the weight of the lead. This hypothesis, which is not mathematically exact, gives a sufficient approximation, however, for all practical purposes.

It is indispensable to use litharge free from minium (red oxide of lead).

Pure carbon produces with litharge thirty-four times its own weight of lead, and according to experiments made by M. Depretz each part of lead is equivalent to 230 degrees of heat.

Pit coal is the fuel generally employed in France. The calorific power of this material is somewhat variable according to its source and the proportion of ash it contains.

We give, for the sake of information, the following results of analyses.

ANALYSES.

Source.		Ash per cent.	Calorific power.
Hartley (England)		1.50	6781
Anthracite (Wales)		1.60	7406
Mons (Belgium)	Escouffiaux . . .	2.16	7297
	Grand Buisson . .	8.44	7234
	Haut-Flenu . . .	0.70	6920
	Bellevue . . .	3.05	7268
Charleroi	Trien Rasin . . .	1.55	7377
	Beaulet	1.48	7358
	Saas-les-Moulins . .	1.80	7315
Valenciennes	Veine Toussaint . .	3.10	7493
	" Rosière . .	5.70	7278
	" Perier . . .	2.80	7347
	Fosse réussite . .	2.50	7200
Pas-de-Calais	Bully	3.00	7230
	Nouïx	2.40	7365
	Courrières . . .	8.60	7396
Rives-de-Gier	Henry	2 96	7831
	Cimetière . . .	3.57	7307
	Couzon	4.32	7441
Alais (Rochelle)		1.41	7881
Blanzy "		2.28	6626
Commentry "		0.24	7236
Lignite de Dax		4.99	6225
" (Bouches-de-Rhône) . . .		13.44	5395

In certain localities turf is burned, the calorific power of which varies according to its state of dryness. It is generally estimated at half that of coal.

§ 13. Examination of Papers.

Gelatine-sized papers are usually recognizable by their odor; this characteristic is not, however, sufficient for some of those sized in this manner but made by machinery.

By incineration they are found to burn badly, leaving a very black carbonaceous deposit; whereas paper sized with resin in the pulp yields rather a grayish residuum. If the results obtained are uncertain, we must then have recourse to an elementary analysis. Gelatine will be indicated by the amount of nitrogen collected.

As resinous-sized papers always contain starch in greater or less quantities, a blue color is obtained when they are subjected to the vapor of iodine.

The incombustible papers employed in gunnery being composed of intestines, emit ammoniacal vapors when subjected to calcination in a test-tube, and become crisp when boiled with acetic acid.

Generally it is thought sufficient to determine the amount of mineral matters which the paper contains. All that is required, then, is to incinerate 10 grammes (154.42 grs. troy) in a porcelain capsule, and to weigh the remainder after calcination.

Paper made exclusively of rags yields a residuum of a third to a half or one per cent. at most, proceeding from the ash of the textile fibres, and the small amount of mineral matters introduced by the waters.

By deducting a hundredth of the weight of the residuum, the weight of the additional matters is obtained.

The substances generally employed are—

Kaolin.
Chalk or carbonate of lime.
Sulphate of lime.
Sulphate of baryta.
Clays.
Ochres.

The examination of these different substances necessitates a complete analysis, which is more in the line of the chemist than the manufacturer of paper.

We will give, as the course to be pursued, the remarkable report of M. Braconnot, based upon experiments made by him to determine the nature of substances composing the size used in pulps, or resinous sizing.

Chemical Examination of Paper Sized in the Pulp.

"I subjected it to the following tests: Boiled with pure water, it yielded a liquid which restored the blue color to red litmus paper, thus revealing the presence of an alkali. An infusion of nutgalls scarcely affected its transparency, so that it did not contain gelatine; but iodine produced a very intense blue color, indicating that starch formed a part of the composition.

"Twelve grammes (186.28 grs. troy) of the same paper were boiled for about a quarter of an hour in water acidulated with sulphuric acid. The liquid was expressed through a piece of fine linen and the pulp well washed with boiling water. When dried it weighed only 11.16 grammes (172.31 grs.). The acidulated liquid was united with the water used in washing the pulp, and saturated with carbonate of lime. After being filtered it was partially evaporated, in order to remove the greater part of the resulting sulphate of lime; when evaporated almost to dryness, a yellow residuum was obtained, having a gummy appearance, and weighing 0.67 grammes (10.33 grs.). This substance, when heated in a platinum crucible, became swollen, emitted an odor of burnt bread, and gave an ash containing sulphate of lime with the sulphate of a fixed alkali, which I did not determine.

"The solution in water of this apparently gummy substance was only feebly precipitated by an infusion of galls; but assumed a beautiful dark violet color when treated with iodine. This material was, therefore, only slightly modified starch.

"The 11.16 grammes (172.31 grs.) of paper which had resisted the action of the boiling water acidulated with sulphuric acid, were treated with a weak solution of potassa. The expressed liquid, while boiling, was of a transparent yellowish color, but became somewhat turbid on cooling, and gave a lather like soapsuds.

"A small quantity of dilute sulphuric acid was poured into this liquid to neutralize the potassa, when it became very milky and deposited a flaky matter, which did not redissolve by heat. This weighed about 0.2 grammes (3.08 grs.) after evaporation in a capsule smeared with grease. The capsule, as well as the flaky matter, was washed with alcohol, which assumed a brownish color, and became charged with fatty matter.

"The residuum, insoluble in alcohol, was composed to a great degree of starch which had escaped the action of the boiling acidulated water. The liquid, separated from the 0.2 grammes (3.08 grs.) of flaky matter by sulphuric acid, also contained starch; for when evaporated in order to crystallize the greater part of the sulphate of potassa, it yielded a yellowish mother-water, which gave a deep blue color with iodine, and a brownish sediment was formed still containing starch. When distilled in a test-tube it gave an alkaline liquid which turned red litmus paper blue.

"This appears to be due to the gluten contained in the flour of cereals used to size the paper under consideration.

"I return to the brownish alcoholic solution resulting from washing the flaky matter. After evaporation there remained 0.1 gramme (1.54 grs.) of a fatty and somewhat pitchy substance, of a yellowish-brown color, and having about the consistency of lard. Its combination with potassa was very highly colored and had a bitter taste, which led me to suspect the presence of a resin.

To ascertain whether my suspicion was correct, I treated it with water and a small quantity of magnesia to neutralize the fatty acids, and then subjected the residue to the action of boiling alcohol, which, on evaporation, left behind a slight coating of varnish, easily recognized as a resin.

"Five grammes (77.20 grs.) of paper yielded when burnt 0.06 grammes (0.92 grs.) of a very ferruginous ash, which also contained a noticeable quantity of manganese; for when melted with soda in the flame of a blowpipe, it gave a beautiful blue glass. This ash did not effervesce with acids. When heated to redness with sulphuric acid, and the residuum treated with water, it had very little taste at the time of mixture, but at the end of twenty-four hours the liquor had acquired a very distinct astringent taste, and with ammonia produced a gelatinous precipitate of alumina; from which it follows that alum had entered into the composition of the paper pulp."

The author then gives the composition of vegetable size,[1] such as he deduces it from his experiments, which are remarkable when we consider that they date from the beginning of the present century.

A great many machine-made papers become yellow, or present spots of a yellow rust color. These spots are due to the action of the chlorine contained in the pulp upon the iron of the drying cylinders. Indeed the felts soon become spotted with the same color at different points, and sometimes over their whole surface. It may be shown that these spots are really due to an oxide of iron, by employing the sulphocyanide of potassium, which produces a red color, growing deeper as the proportion of the peroxide of iron is increased.

[1] See p. 180.

By digesting the leaves of paper to be tested in dilute hydrochloric acid, the paper becomes white and the presence of peroxide of iron is detected in the solution.

MM. Fordas and Gelis have published a paper upon this subject in the *Journal de Librairie*, from which we extract what follows:—

"On leaving the rag engines the wet pulp is conveyed into a wooden vat and thence to the various apparatus, which constitute the paper-machine, and whose objects are the formation and drying of the paper, and its division into leaves.

"Perfectly washed pulp would be in no way changed during these different operations; for the vapors generated being only those of water could not, by acting on the different materials of which the apparatus is composed, give rise to any soluble compound, capable of becoming incorporated with the leaf during its manufacture.

"But instead of supposing such a case, which is never practically attained, an incompletely washed pulp is used; a large part of the chlorine it contains will, it is true, be carried off by the excess of liquid during the first stages of the operation; but there will always remain a portion, which will be liberated with the vapor of water at the time of drying, attack the cast-iron rollers, dissolve their surface, and form with them a minimum chloride of iron, with which the felts supporting the leaves will become impregnated, and which from them will be introduced into the substance of the pulp itself.

"This impregnation of the felts with a salt of iron cannot be denied. These felts are always spotted with rust, and the yellow color begins to be perceptible during the first days they are in use. The rust actually becomes combined with the tissue, and is the result of a maximum basic salt of iron, produced by the action of the air upon the minimum salt we have before mentioned.

"This salt cannot possibly affect the paper; it is insoluble and combined; but it is the free and soluble part which exists upon the surface of the cylinders, or in the substance of the felts.

"We will admit that the ferruginous compound enters the paper in a soluble condition, and at the minimum of oxidation, because this fact seems to us to be proved by the absence of color in the paper at the time of manufacture.

"The complete state of dryness of the paper maintains the salt of iron for some time at a minimum, and consequently in a colorless condition; but very soon the oxygen of the air, assisted by atmospheric moisture, reacts upon this compound, and, by bringing it to a maximum degree of oxidation, colors it.

"This simple reaction perfectly explains the yellow, and often nankin color which these ferruginous papers assume. It also explains an observation made to us by a printer, namely, that this color is frequently produced when the paper is wetted for printing or accidentally.

"As for the round spots, which have more particularly engaged the attention of manufacturers, they may be quite as easily explained. We attribute them to a phenomenon of crystallization.

"They are formed through the tendency, possessed to a certain degree by the molecules of all bodies, to arrange themselves in groups when they are disseminated throughout a permeable medium. If the spots of which we are speaking are closely observed, it will be remarked that each one of them incloses near its middle an asperity, or hard body, which seems to have served as a centre of attraction.

"As a result of the condition of alternate dryness and moisture, to which the porous and hygrometric material of paper is exposed, an insensible displacement occurs. The molecules of the salt of iron arrange themselves around the most compact parts of the paper pulp, as a salt in concentrated solution is deposited around the glass rods or strings suspended in it; or, to make use of a comparison, which seems to us more exact, these ferruginous molecules group themselves in the sheet of paper, as we find them doing in wet soils to form those globules of oxide of iron, or radiated pyrites, so abundant in all localities where ochrous earths are buried in organic deposits.

"Frequently when the displacement we have just explained does not occur until after printing, it is the printed letters themselves which become the centres of attraction, so that the iron becomes fixed in preference upon the printed portion of the paper, which it deeply stains, while the margins appear relatively colorless."

To save the reader the trouble of having to look them out in chemical works, we give an enumeration of several elementary bodies, with their combining equivalents and densities, as indispensable information in analytical calculations:—

Names.	Symbols.	Equivalents.	Densities.	
Oxygen	O.	100.	1.10563	The atmosphere taken as a unit.
Hydrogen	H.	12.5	0.0692	
Nitrogen	N.	175.	0.9713	
Chlorine	Cl.	443.2	2.44	
Sulphur	S.	200.	2.07	Water taken as a unit.
Iodine	I.	1578.2	4.95	
Silicium	Si.	266.7	4.95	
Phosphorus	P.	400.	1.83	
Carbon	C.	75.	1.60 to 35.0	
Potassium	K.	490.	0.865	
Sodium	Na.	287.2	0.97	
Barium	Ba.	858.4	0.97	
Calcium	Ca.	250.	0.97	
Magnesium	Mg.	157.3	0.97	
Aluminium	Al.	171.	0.97	
Manganese	Mn.	344.7	8.0	
Iron	Fe.	350.	7.7 to 7.9	
Chromium	Cr.	328.	6.0	
Zinc	Zn.	406.	6.86 to 7.2	
Tin	Sn.	735.3	7.29	
Lead	Pl.	1294.5	11.445	
Copper	Cu.	395.	8.78 to 8.96	

§ 14. MATERIALS OF A LABORATORY.

1*st. Instruments and Apparatus.*

Microscope.
Hand lens.
Scales with stand, weighing as low as 0.01 grammes (0.154 grain troy).
Blowpipe.
Stationary furnace.
Hand "
Porcelain capsules of different diameters.
Platinum crucible and accessories.
Porcelain mortar.
Spirit lamp.

Instrument for ascertaining the specific gravity of salts.
Thermometers, graduated upon glass.
Earthen crucibles.
Test-tubes, with stand.
Graduated burettes.
Flasks.
Bottles with one, two, or three necks.
Glass tubes, straight.
" " curved.
" " S shaped, with funnel end.
Glass funnels.
Earthen "
India-rubber pipe for joints.
Wooden tongs and holders.
Alkalimetric apparatus.
Chlorometric "
Acidimetric "
Hydrotimetric "
Filtering paper.

2d. Reagents.

Blue test-paper.
Red " "
Hydrochloric acid.
Sulphuric "
Nitric "
Acetic "
Ammonia.
Iodine.
Potassa.
Soda.
Lime.
Oxalate of ammonia.

Carbonate of soda.
Carbonate of ammonia.
Phosphate of soda.
Alum.
Protochloride of tin.
Acetate of lead.
Ferrocyanide of potassium.
Sulphocyanide of potassium.
Sulphate of iron.
Sulphate of copper.
Litharge.
Tannin.
Starch.
Alcohol.
Ether.
Arsenious acid test liquid.
Sulphuric acid " "
Hydrotimetric " "
Borax.
Salts of phosphorus.
Chromate of potassa.
Iodide of potassium.

CHAPTER VIII.

WORKING STOCK OF A PAPER-MILL.

§ 1. Motive Power.

The motive powers employed are the water-wheel and steam-engine. We only mention, by way of reminiscence, the Dutch wind-mills which used to set in motion the beating mallets and rollers of old-fashioned paper-mills.

Among water wheels we shall assign the first place to turbine wheels, which, by their great initial velocity, very much simplify the transmision of motion. Another advantage not less desirable in certain countries is, that turning under water, they are almost entirely protected from frost.

M. Planche says, in speaking of the turbine wheel as the motive power of a paper-mill:—

1st. It adapts itself in the best possible manner to the use of belts for the transmission of motion to the crushing cylinders, thereby allowing the suppression of a great number of cog-wheels.

2d. It allows the cylinders to be placed at such a height, such a distance, and in such a position as convenience requires.

3d. It gives great facility for setting in motion and stopping at will, one or several cylinders without acting on the others of the engine, which is accomplished by means of two pullies on each spindle of the cylinder, one fixed and the other movable. This arrangement promotes economy of time.

4th. It is finally to be considered that the use of belts renders impossible the breakages which otherwise occur and often disable such engines as are moved by pinions.

We ought to admit that the three last reasons appear to us erroneous. Does not the ordinary water-wheel or steam-engine allow the use of belts? There is simply a suppression of one or two cog-wheels multiplying the velocity.

Whatever may be the motive power employed, the movement being communicated to the main axle, nothing prevents our attaching belts and pulleys, as in the case of turbine wheels.

As far as relates to accidents, at the time we are writing these lines, we learn that the main pinion of a turbine, acting as a fly-wheel, has just broken, and will occasion a month's stoppage in the work of a paper-mill.

At another place a cylinder, moved by a belt, was nearly thrown out of the engine. In speaking of cylinders we shall see the advantage presented by the use of belts to transmit power; but this question is entirely a special one and has no connection with the motive power in itself.

M. Planche has confounded the different parts of all machinery, which may be classed under these heads:—

1st. The motive power.
2d. The transmission of motion.
3d. The instruments or machine-tools.

The advantages of a turbine may be thus enumerated:—

1st. Great initial velocity.
2d. Superior and constant returns at all seasons.
3d. Economy of space.

4th. Simplified transmission of motion to machinery requiring great velocity.

5th. The employment of high water-falls with but a small supply of water.

Nevertheless, in a district where there are no machine shops, in sites where the position would present serious difficulties, in localities where the falls are not high, and the supply of water is abundant, we advise the use of an ordinary water-wheel.

The application of steam as the principal motive power can only be suited to countries where fuel is very abundant, and where the greater part of the water has to be kept for washing and other requirements of the mill.

In most paper-mills, however, a steam-engine is established to supply the deficiency of water wheels in times of drought or repairs.

In this case an engine of variable power should be employed, so as to use only an amount of steam proportional to the additional motive force required.

§ 2. Rag Cutters.

New instruments are being invented every day for cutting rags. Those most in use are the following:—

1st. A cast-iron cylinder with two to four blades of steel cutting like shears, with a fixed blade solidly mounted. The velocity of this cylinder is from 80 to 125 revolutions a minute.

The rags are fed to it by an endless web and grooved rollers. It is estimated that it requires a one-horse power engine to cut 800 kilog. (1763 lbs. avoird.) in a day. This return, however, is very variable, and depends much upon the nature of the rags.

This apparatus offers the inconvenience of violently shaking its foundations. We must, however, admit that this fault may be found with nearly all of them. The mounting is not sufficiently solid; the foundations are too light to extinguish the greater part of the vibrations and deaden the effect of the shaking.

2d. Modification of the preceding: the cast iron cylinder about 0.60 metres (23.62 in.) long by the same in diameter, carries six blades fixed in an oblique direction and only occupying the third of the length, in such a way that the six blades are only equal to two whole ones. This machine requires less power, and its vibrations are less perceptible than the former.

3d. A vertical iron plate 0.05 metres (1.96 in.) in thickness bearing four blades about 0.25 metres (9.84 in.) long and forming shears with a fixed blade set in the mounting. This machine is also fed by means of an endless web.

4th. Cylinders in form of a rolling engine, of which the upper is provided with 10 to 15 circular blades separated by iron washers.

5th. A simple cutter constituted on the principle of the guillotine, the upper blade of which receives an oscilating motion by means of an eccentric.

Behind this blade is a plate of iron which regulates the length of the cut rags; by fixing it nearer or farther off the rags may be cut long or short. This machine is low in price, and adapted to small paper-mills. Its want of velocity reduces the returns. It is advantageously employed for cutting ropes, pack-cloths, and coarse gray rags, which would otherwise require the work of special hands.

White and fine rags in general ought not to be cut by machinery except casually; as the perfection of hand work cannot be obtained by it.

§ 3. Dusters.

The most simple apparatus consists of a truncated cone revolving upon the axis of the great circle, and upon two rollers running in a groove round the crown of the small circle. This is covered with a network of iron. The inner sides are armed with iron teeth arranged in a spiral, which force the rags out by the end opposite that of entrance. This kind of duster will only answer for fine clean and half clean rags.

To render the action of this instrument more energetic, a tree is placed within, bearing iron spokes arranged in a spiral. These spokes force the rags against the wire-netting, which revolves in an opposite direction from that of the rotation of the tree. This contrivance for dusting, of a conical or cylindrical form, is preferable for foul and soiled rags, hems, seams, etc. It naturally requires more power than the first mentioned machine.

When the duster is cylindrical, it is given an inclination of from 25° to 40°; and a diameter of 0.90 to 1.10 metres (2.95 to 3.60 ft.) by 4.50 to 5.0 metres (14.76 to 16.40 ft.) in length.

The wolf (loup briseur) serves to divide and clean the wastings of flax, hemp, oakum, coarse rags containing straw, or hemp and ropes. It is constructed upon the same principle as the preceding apparatus, and offers a resistance proportioned to the work it has to do. The iron axis armed with spokes is alone movable and the impurities fall through an iron grating.

The loss of material caused by this engine is at times so considerable that it has been discontinued in some paper-mills. It nevertheless facilitates the operation of boiling, and various other manipulations by disintegrating the rag filaments, and rendering them more susceptible to the action of the lyes. These rags are softer and more easily reduced to pulp. The machine requires great power, which many mills are not able to bestow.

Whatever may be the style of duster employed, it is indispensable that it should be covered over with a close wooden cage in order to retain the dust and other impurities which, mixed with the rag fibres, are called wastings of the duster. It should be understood that as the quality of these wastings varies with the nature of the rags, it is important not to dust on the same day rags that differ much in quality, so that the refuse may be collected only once a day.

§ 4. Washing Apparatus.

To wash the rags before boiling, we may use with advantage a large wooden vat analogous to the bleaching cisterns, furnished with a washing drum and a large sand trap. The light parts, such as feathers, etc., are carried along with a current of water which is poured out through a strainer covered with wire gauze, and placed at the upper part of the vat. The water, running in at the lower part, produces by its pressure a constant agitation of the rags in the liquid.

With a single vat of this kind we can easily cleanse from 2,000 to 2,400 kilog. (1,968 to 2,362 tons) of rags in twenty-four hours.

For the same purpose a sort of duster or washing drum is used revolving in a trough filled with water. In all cases it is well to conduct all the water, after washing, into cisterns where the filamentous parts which have been carried off may be recovered.

§ 5. Boiling Apparatus.

The old wooden vats with double bottoms and furnished with a sheet iron cover, are scarcely ever employed since the invention of steam rotating boilers. We give, however, a drawing of an apparatus of that nature, easily set up, and which may in certain cases be of advantage. The water is sent up through the central pipe by the pressure of steam and runs over upon the rags.

We have seen, in speaking of boiling, that soluble lyes are preferable to lime, when these boilers are used.

The invention of rotating boilers belongs to an English machinist, Mr. Bryan Donkin. Those met with in France are known under the name of Planche and Rieder boilers; but they only differ from the first in some modifications of detail.

This kind of boiler is at the present day an indispensable apparatus in a paper-mill where common rags, thirds, ropes, etc., are used. It might possibly be dispensed with when exclusively fine white rags are worked; but this would be a poor economy, as the small increase in expense necessitated by setting up the machine is largely compensated by the great advantage it procures, as much in lessening labor as by utilizing more completely the alkaline principles necessary for bleaching.

§ 6. Washing and Beating Engines.

The machines adopted are very numerous, as well as the materials employed in their construction.

1st. The cistern may be of wood.
" " " cast iron.
" " " sheet iron.

The cistern may be of cast iron with wooden bottoms.
" " " brick and mortar.
The cylinder may be of wood.
" " " cast iron.
" " " cast iron and wood.
The blades of the cylinder may be of steel.
" " " " bronze.
" " plate " steel.
" " " " bronze.

There are cylinders with bronze blades and plates.

There are cylinders with steel blades and bronze plates.

There are cylinders with steel blades and plates.

The blades are arranged either singly, doubly, or by threes.

The arrangement by twos is generally adopted for the washing and by threes for the beating engine.

For the manufacture of fine papers it is better to employ a cistern made of cast iron, and cylinders with steel blades and bronze plates, as the rags are less briskly cut and give a richer pulp.

The inconvenience of bronze plates is that they are very expensive and need frequent repairs.

Cisterns of wood and cemented brick are economical. They are suitable for coarse paper or for temporary use.

The cast iron cisterns, though we know of one, are very rare. They are light and therefore suitable for localities where transportation is very difficult. Notwithstanding, this model should not be imitated.

The cylinders are lowered by means of screws or levers.

The engine is, moreover, furnished with washing-drums or strainers, or with both. The water is let in by means of common stopcocks or a sluice valve, and runs off either at the upper or lower part of the cistern. We have dwelt for some time upon the advantages presented by the engine based upon the latter principle.

The engine should be furnished with a sand-trap and hollow to collect nails, coarse gravel, etc. Yet, notwithstanding their evident usefulness, there are a great number of engines in which they are not introduced.

The cylinders are moved by pinions.
" " " belts.
" " " a small special steam engine, as may be seen at the paper-mill of Essonne.

The principle to be attained in the transmission of power is that the cylinder should be drawn down instead of being lifted up, as is unfortunately the case when pinions are used.

We give (Pl. II., Figs. 1 and 2), a plan of transmitting motion to two cylinders, a washer and beater. The beating cylinder is raised. This is an error into which we ought never to fall, for with belts this inconvenience is removed by placing the axle of the transmission on the story below the cylinder-room.

The belts are of leather or gutta percha. These last, though easily mended, are open to the objection of stretching from the effects of heat, principally in summer. Their use should be avoided in warm climates.

The pillow blocks of these cylinders are generally bronze. In a large paper-mill, they may be advantageously replaced by supports of hard, close-grained wood (service tree or pear tree), and lubricated by a current of water. This affords an economy of oil. The pillow blocks should be renewed as soon as they begin to show signs of wearing,

The capacity of the engines varies from 40 to 110 kilog. (88.18 to 242.51 lbs. avoird.) of dry pulp.

The inclined planes are more or less abrupt. The diameter of the waste pipe is variable. It should be carried as high as 0.20 or 0.25 metres (7.86 to 9.82 in.) instead of 0.12 to 0.16 metres (4.76 to 6.28 in.) as is generally adopted.

All things equal, the waste pipe of the washing ought to be larger than that of the beating engines.

§ 7. Apparatus for Bleaching and Draining the Pulp.

When liquid chlorine is used, we have seen that the stuff is bleached in the washing engine, or in special vats called bleachers.

They are sometimes wooden, and sometimes of cemented brick, and contain from 200 to 600 kilog. (440 to 1322 lbs. avoird.) of dry pulp, according to their dimensions.

The chambers for bleaching with chlorine gas are, at the present day, generally built of brick and cement. Formerly, they were lined, with either earthenware plates, slates, or slabs of granite. They contain between 800 and 1800 kilog. (1703 and 3968 lbs. avoird.) of dry half stuff.

The pulp is drained by means of the following different contrivances:—

1st. Hydraulic press.
2d. Lamothe-Ferrand drainer.
3d. Centrifugal drainer.
4th. In the reservoir.

These several drainage chests differ in the nature of the materials employed in their construction; some are of wood with a grated bottom, and others of mason work with bottoms made of a particular kind of hollow brick.

§ 8. Paper-Machines.

Paper-machines are classified according to the width of the paper they are intended to make.

The large, 2.00 to 2.40 metres (7.56 to 8.87 ft.).

The medium sized, 1.40 to 1.90 metres (4.59 to 6.23 ft.).

The small, 1.00 to 1.40 metres (3.28 to 4.59 ft.).

In some mills, the great circular feeding vats of the machine are replaced by large reservoirs of mason-work, where the pulp is stirred by axles with spokes arranged around them in spirals. This is a bad plan; for when the reservoir is not full, the pulp brought up by the paddles is thrown against the sides of the tank, and dries into so many hard cakes. The pulp is then raised by means of a pump and poured upon the sand traps.

These sand traps are very variable in dimensions and arrangement. Some are very short and simple, others, on the contrary, are arranged in a labyrinth, so as to force the pulp to make the longest possible circuit.

The wooden or iron inclined blades are either bare or covered with a felt which more readily retains the sand or other impurities which may have escaped the triturating process.

The different systems proposed for purifying the pulp are numerous. They may be classified into about twelve groups.

The boundary straps or deckles which regulate the width of the layer of pulp upon the wire cloth, and in consequence that of the dry paper, are of dry leather or India rubber. Those of vulcanized India rubber in a single strip are preferred at the present day.

The exhaustion of air is carried on by suction pumps, or automatically by means of a pneumatic apparatus.

The rollers which stretch the web are often of too small a diameter, and wear it out unnecessarily.

The number of wet presses varies from two to five. The older machines had only three. The present tendency, justified by practice, is to increase this number, and regard three as a minimum.

The felts are kept tense by means of:—

Tirettes.
Broken rollers.
Grooved "
Cylindrical rollers bearing two strips of leather arranged in a spiral, one on the right, the other on the left, relatively to the axis of the roller.

The number of drying cylinders is variable:—

3 is the minimum.
5 is the medium; and there are
8 to 10 in some machines.

This last number seems to us exaggerated. Six appear to be the best number, of which four serve to dry the paper, and two the felts.

These cylinders are arranged in one, two, or three tiers. In the last case, the upper cylinder serves exclusively to dry the felt.

We think it preferable not to go beyond two tiers in order not to augment too greatly the resistance of the works. Moreover the repairs are otherwise very much more difficult; as special scaffolding has to be erected.

The reels are of variable diameters. This variation is obtained either simultaneously with all the spokes of the same wheel at once or separately, by increasing or diminishing the distance from the centre of each spoke.

It seems almost unnecessary to say that we very much prefer the first arrangement, which gives the same spread to all the spokes at once.

The paper-machine needing a perfectly regular motion should have a motive power of its own, whether it be water-wheel, turbine, or steam-engine.

When the motive power to be disposed of is abundant, we advise the use of a small turbine, fed by a reservoir, having its water always at the same level, as the reservoir may be placed at a considerable height, say in the upper story of the mill.

Generally a small high pressure engine is employed, and the steam, after being used as a motive power, serves for heating the drying cylinders.

Each paper-machine should be furnished with pinions, admitting different velocities, or graduated pulleys to allow the manufacture of thin or heavy papers. Three rates of motion are considered sufficient, the high, the medium, and the low. To facilitate the management of the machine, it is well to have at each stage of transmission, extensible pulleys, or those with variable diameters, as well as struts to prevent the belts from slipping.

§ 9. Finishing Machines.

1st. Hand and screw presses are still used for some common hand-made papers.

2d. Screw presses, which are generally used in paper-mills to facilitate the operation of packing.

3d. Hydraulic presses, with a power of 200 to 300 kilogrammes (196.85 to 295.67 tons), used for satining some of the handsomest kinds of paper, and bank-note paper, when the clearness of the watermark would be injured by the ordinary rollers.

4th. Rolling machines for satining, glazing, etc., are of several kinds.

1st. Counterpoise rollers.

2d. Rollers whose pinions allow a variable distance between the two cylinders.

3d. Spring rollers.

4th. Rollers consisting of one cylinder, revolving upon a horizontal table, generally called glazing machines, and only used for small sized paper.

5th. Rolling machines are again divided into two classes: 1st. Those having a single, and 2d, those having a double or return motion; the cylinders revolving first from right to left, and then from left to right. This machine ought to be exclusively used in order to avoid accidents.

6th. Continuous rollers consisting of two cylinders, of which one is of metal and the other of paper.

7th. Three cylindrical rollers or calenders, the two extreme cylinders being of polished iron, the middle of paper.

A well-provided paper-mill ought to contain all these machines so as to be able to deliver the different kinds of paper demanded by commerce.

§ 10. General Working Stock of a Paper-Mill.

We give, as a matter of information, an enumeration of the different machines and apparatus used in the Todde paper-mill at Hainsberg (Saxony), the daily production of which reaches as high as 7,500 kilogrammes (7.82 tons) of various kinds of paper.

1 paper machine, 2.33 metres (7.64 feet) broad.
2 " " 1.90 " (6.23 ") "
4 turbines.

3 steam-engines.
11 " boilers.
12 pumps.
5 rag-cutting machines.
2 dusting "
5 rotary boilers.
10 bleaching vats (large model).
30 rag-engines.
3 centrifugal continuous refining machines.
9 large reservoirs for liquid chlorine.
12 chambers for chlorine gas.
5 centrifugal drainers.
4 cutting machines.
4 satining "
13 iron presses.

The cost of the land, hydraulic apparatus, tramways, buildings, foundations, motive power, machines, tools, etc., is estimated at 2,201,000 francs (about $440,000).

We should not, for motives of ill-advised economy, run to the opposite extreme, and in order to avoid too great an original outlay, purchase defective or incomplete materials. This, however, will very much depend upon the style of paper we propose to manufacture. Rag-engine, with wooden or mason work cisterns, are sufficient for ordinary purposes, but would not be suitable for making the finest kinds. The essential point is to have machines well adapted to their peculiar uses.

§ 11. General Remarks upon the Establishment of a Paper-Mill.

To establish a paper-mill requires a profound study of the following questions:—

1st. Is the mill to be situated near a great city? a city of middling importance? in a village, or at a distance from any habitation?

2d. Shall water be used as the motive power?

3d. Does not the water to be used for washing the pulp contain, in suspension, any matters which may impair the quality of the paper we desire to make?

4th. The water being more or less impure, and the soil allowing the use of artesian wells, should we incur the expense of boring?

5th. Will not the use of a water-filter be more advantageous?

6th. Is the fall of water sufficient to move the entire apparatus for transmitting the power?

7th. Is the water-course subject to freshets or droughts? and if so, how many days' delay may it cause in the course of the year?

8th. What hydraulic motive power shall we adopt? the turbine or the ordinary water-wheel?

9th. The fall of water being insufficient for the entire transmission, will it be more advantageous to purchase a neighboring fall and there establish our rag-engines, than to set up a permanent steam-engine in the mill itself?

10th. What are the means of communication at our disposal for transmitting and receiving goods? roads, canals, railroads? Comparative study of the different freightage by each of these methods of transportation. What sort of goods shall be conveyed by each?

11th. What will be the freightage by the hundred weight of each raw material, and for transmitting the paper, when made, to the warehouse?

12th. Shall we employ the rags of the neighborhood, or shall we import them from distant centres of supply?

13th. Cost of labor in the locality, estimate of its value after a certain length of time?

14th. Would there be an advantage in having an establishment for cutting rags in a neighboring city, rather than in the mill itself?

15th. Shall we bleach with liquid chlorine, or chlorine gas?

§ 12. General Remarks in Reference to Building.

1st. Cost of building materials.

- 1st. Stone, brick, slates, tiles.
- 2d. Lime, sand, cement.
- 3d. Wood, iron, zinc, lead.
- 4th. Painting, glazing.

2d. What kind of material shall we choose for the different parts of the building?

3d. Estimate of the expense of building.

4th. Purchase of the material.

5th. Cost of transportation.

6th. Will the plan of the building allow the subsequent addition of a second and third machine?

7th. Is the general arrangement of rooms for the different operations methodical? Do the materials have to be carried over the least possible space, or will a longer route, necessitated by a fixed position, be compensated by peculiar advantage?

8th. What must be the profit on each scale of prices, to compensate for the cost of building and the material employed?

9th. Estimate of the outlay to be made during the first two years following the opening of the mill.

10th. What spare apparatus or parts of apparatus must we have on hand to prevent delay?

11th. Are we limited by a fixed capital which we cannot go beyond?

12th. Would it not be advantageous to lay at the outset certain foundations or water-works in view of a future enlargement of the mill?

§ 13. General Considerations.

The engineer employed to make the plan of a paper-mill cannot bestow too much care in studying the general arrangement of the buildings. Although it is impossible to give any fixed rule for works of this nature which vary for each locality, we shall try to throw some light upon the subject by grouping together the different observations we have been able to collect, and by investigating the qualities and defects of the most approved plans.

The buildings of a paper-mill may be divided into two classes.

1st. Main buildings containing the motive power, the machinery for transmitting it, pumps, rag-engines, apparatus for cutting, dusting, and boiling; store-rooms for crude and cut rags, the paper machine, and the finishing-room.

2d. The secondary building for bleaching-rooms, boiler-rooms, store-rooms for the pulp, work-shops, offices, &c.

The buildings of the first class are sometimes combined in one rectangular edifice of a size proportional to the extent of the proposed works. We prefer, however, a second building annexed to the first at right angles to contain the paper-machine and finishing-room.

Starting with this plan, the subdivisions of the building would be as follows:—

1st. *Main Building.*

On the ground floor: motive power (in the case of steam engines) pumps, and store-chests for the pulp. A basement might indeed be made a store-room for pulp, if the topographical position of the mill would allow the water to drain off.

On the second floor: washing and beating engines, bleaching vats, boiling apparatus, the preparation of size, store-room for pulp, &c.

On the third floor: the cutting and sorting room, store-room for cut rags, duster, reservoir of water, &c.

Loft: the store-room for crude rags.

2d. *Annexed Building.*

Ground floor: the paper machine; parallel with it or in suit, the finishing-room for coarse and wrapping paper.

On the second floor: the satining machine, calenders for finishing fine papers. This story is not carried over that containing the paper machine.

In the case of a paper-mill where two machines are used, the two rooms at right angles to the building may be connected by another serving as the finishing-room on the second floor, and below as a general store-room for the uses of the mill.

There are several mills where both machines are in the same room and placed opposite to each other.

This arrangement does not seem to us to be well devised. As each machine ought to have its distinct set of workmen, there is no economy in labor, and this association of the two may be fatal to the work of the mill in case of accidents or repairs.

It is indispensable, in order to insure regularity in manufacturing, that each machine should have a motive power of its own, whether it be a turbine wheel or steam engine, so that a change in the rate of motion of one may not influence that of the other, and conversely.

It would, therefore, be wrong to derive the motive power of the paper-machine from the same machinery which works the rag-engines and the boiling or other apparatus, all of them subject to constant variations of velocity.

The window sashes of the room containing the paper machine should be of iron, covered with a double coat of paint composed of red and white lead. Wood is too much affected by the succession of dryness and warm moisture to which it is exposed. It soon rots and exudes a blackish liquid, produced by the action of steam upon the coloring matter of the wood, which soils the window panes. The room ought to be light and provided with a ventilator to carry off the vapor arising from the drying cylinders. The floor ought to have an inclination sufficient to carry off rapidly the water used in washing.

Almost all the older machine-rooms are too limited in size, but especially in length. Many even will not allow a cutting-machine to be set up beyond the reels. For large machines a room 45 metres (147.64 ft.) in length may be considered as a good medium.

To give greater solidity to the main building, the thickness of the walls may be increased at certain intervals. This kind of buttress serves to give the building an ornamental appearance, and, the points bearing the principal weights being thus supported, the intervals may be built comparatively thin.

In localities where mason work is costly, it may be advantageous to use iron supports for the machinery, the floors of the rag-engines, boiling apparatus, &c. Generally it is proper to adopt very heavy arches in order that the continual shaking may not affect the solidity of the building.

The steam boilers are placed either within or without the main building. The latter place is very much the best.

At the present day, when we are better informed in regard to the facility of conveying steam to a distance by surrounding the pipes with non-conducting substances, the boilers and chimney are placed at a considerable distance, in order to avoid the chances of fire or explosion.

A simple precautionary measure to diminish the danger of fire is to conduct steam pipes into all rooms containing inflammable or combustible substances, as it has been found from experience that steam, in a confined place, will extinguish fire almost instantaneously. As the market value of drawn out iron tubing has for the last few years been quite low, this kind of apparatus would not require much outlay.

We very much prefer rag-rooms situated in the upper part of the building, as the air will be more readily renewed, and the light better. Nevertheless we know of mills where they are placed on the ground floor, but this arrangement necessitates an increase in the area of the building, which in many cases could not be afforded.

As the rags become quickly heated from being piled together in great heaps, especially if damp, their position has frequently to be changed. In order to avoid the labor of this operation, the depth of the chests should be diminished, and if necessary they should be provided with sheet-iron chimneys pierced with holes, serving to establish a sort of ventilation.

The quarters of the superintendent and employees ought to be at a distance from the mill. (See the discussion of the general plan of paper-mills.)

A paper-mill at a distance from any city ought to be provided with a workshop, and all necessary tools for repairs. Near the centres of population, on the contrary, where machine shops are well supplied, this expense is less necessary.

The intelligence of the engineer or the head of the establishment should, therefore, determine this question, by taking into consideration the necessity of economy in the original outlay, and the probable cost of repairs during the working of the mill.

CHAPTER IX.

THE MANUFACTURE OF PAPER FROM WOOD IN THE UNITED STATES.

THE most successful process of manufacturing paper pulp from wood, ever used in the United States, is the subject of a patent granted July 18, 1864, to Charles Watt and Hugh Burgess, and reissued to Wm. F. Ladd and Morris L. Keen as assignees, April 7, 1863, and now owned by the American Wood Paper Company. This process is now in very extensive operation at the Manayunk Wood Pulp Works, situated at Manayunk, Pa., between the Schuylkill River and the canal. These works are the largest establishment for the manufacture of wood pulp in the world, covering ten acres of land. They were commenced in August, 1864, and completed in April, 1866, at a cost of about $500,000, and there is over $1,000,000 invested in them, and the paper-mills run in connection with them. Their capacity of production is twenty-four thousand to thirty thousand pounds of pulp per day. The whole establishment has been leased by Messrs. Jessup and Moore and Martin Nixon, of Philadelphia.

To bring the process of Messrs. Watt and Burgess to perfection, it has been necessary to devise much apparatus and machinery of a novel character, which is protected by other patents, and the most important of which will be explained in the progress of the description which is hereinafter given of the details of the process.

Messrs. Watt and Burgess' process, as described in the specification of their patent, consists in boiling the wood, after it has been cut into fine chips or shavings, in a solution of caustic alkali, in a closed boiler, under a high pressure of steam, and consequently at a high temperature. After having been boiled to a pulp, the pulp is washed with water, and if the wood used be of a resinous character, the pulp, after having been washed, is subjected to the action of chlorine, or its compounds with oxygen; but in the Manayunk works, only the non-resinous woods, such as poplar, hemlock, and white wood are used, these being plentiful and of comparatively little value for other purposes.

The wood is brought to the works in the condition of cord wood, by teams, railroads, and a fleet of wood barges. It is cut obliquely to the grain, into fine chips, by means of machines having cutters attached to rotary disks, and resembling gigantic straw or fodder cutters, the logs being fed to the cutters through slanting troughs down which they slide to the cutters. The chips fall from the cutters through openings in the floor on which the machines are situated, and are received in wagons running on railways in the basement, for the purpose of conveying them to mechanical elevators, by which they are raised up to a floor above the boilers in which the pulping process is performed.

The boilers above mentioned are of peculiar construction, which is the subject of patents to Morris L. Keen, dated September 13, 1859, and June 16, 1863. They are of the form of upright cylinders with semi-spheroidal ends, and are fed through man-holes at the top, provided with suitable lids which are closed when the boilers have been charged. At some distance below the mouths or upper man-holes, there are horizontal perforated diaphragms, through which the caustic alkaline solution may rise above the chips, which are fed in to the space below through central openings of suitable size. Between the central openings in the diaphragms and the upper man-holes, there are perforated upright connecting cylinders or wells, with man-lids at the bottom to confine the chips below the diaphragm when the boiler is full, and so keep them covered with the caustic alkaline solution which is allowed to rise above the diaphragm. When the boilers have been charged with chips, they are closed up, and filled to a suitable height with the alkaline solution, and the boiling process is commenced. This is continued under a pressure of about seventy pounds per square inch for a sufficient time, according to the nature of the wood, to reduce the chips to pulp, which is then discharged through valves or gates at the bottom, by the pressure of steam above, into closed vessels of larger capacity than the boilers. In these vessels, after it has been allowed to expand, the pulp is drained through strainers in the bottom of the vessels, and after it has been drained the pulp is discharged into wagons in which it is taken away for further treatment. The alkaline solution which is drained from the pulp is collected in underground drains, whence it is conveyed by pipes to the furnaces in which the water is evaporated and the alkali calcined to be used over again on new stock. Some idea may be formed of the immense scale on which the process is carried on, when it is stated that the boilers with the expanding tanks and receiving wagons occupy a building 132 feet long and 75 feet wide.

Before describing the calcining or alkali-recovering furnaces, we will follow the pulp till it arrives at the condition to be worked into paper. The pulp, when it is received in the wagons, is of a dark grayish-brown color, but after having been drained for some time through the bottoms of the wagons, which are suitably constructed for the purpose, it assumes a lighter color. It is then washed by sprinkling it with clean water, which percolates through it and escapes through the bottoms of the wagons before they are removed from the boiling house. By means of railway turn-tables arranged in front of the boilers and expanding vessels, the wagons are run on to railways on which they travel to a building in which there are large pulp engines, like those employed for the reduction of rags. In these engines, the pulp is worked for some time preparatory to being run through cleaning machines, substantially like what are known as cylinder paper-machines, but having no dryers. From these engines the pulp is run off in the form of a web, from which any specks or bad parts are removed by attendants. The pulp delivered from these cleaning machines is taken to the bleach house, where the bleaching is performed in vats in substantially the same manner as other paper stock is bleached; and after bleaching it is ready to be worked into paper by the machines commonly employed.

One of the most important features of the establishment, if not the most important in a commercial sense, is the evaporating and calcining house in which the waste alkaline solution, which is drained from the pulp, has all its water evaporated and its alkali recalcined for use on new stock. Without this or some equally successful means of recovering the greater proportion of the alkali, the process would be commercially a failure, owing to the great expense involved in the consumption of alkali. The amount of alkali saved every time the process of reduction of the wood to pulp is performed is no less than 85 per cent. of the whole quantity used.

The alkali thus recovered has 15 per cent. of fresh alkali mixed with it for every repetition of the pulping process.

The evaporating and calcining house is a large circular building, 200 feet in diameter, and reminds us of the locomotive sheds at some of the largest railway depots. The furnaces, which are of great length, radiate from the centre of the building, and all communicate with one enormous central chimney. They are so constructed according to a patent granted to Morris L. Keen and Hugh Burgess, February 7, 1865, that the flame and hot gases of combustion from the fire, urged by a strong draft, are first caused to pass over the surface of the liquor to be evaporated on the sole or hearth of the furnace, and afterwards caused to circulate both over and under a series of pans through which the liquid flows in its transit to the hearth. The liquor is conducted from the pulp-boiling house to the evaporating house, by the underground drains before mentioned, into a suitable reservoir whence it is pumped up into the evaporating furnaces. The alkali from which the water has been evaporated in these furnaces is transferred to the calcining furnaces, and after calcination is taken to the mixing house, where it has the proper proportion of fresh alkali mixed with it preparatory to its being used over again. The solution is made in immense tanks fitted with revolving stirrers, and from these tanks it is conveyed to the pulp-boiling house, to be fed into the boilers.

It is found in practice advantageous to mix with the wood pulp about one-fourth of the same quantity of straw pulp. Adjacent to the Manayunk Wood Pulp Works are the Flat Rock Paper Mills, owned by Martin Nixon, and in connection with these mills, the manufacture of straw pulp at the rate of from seven thousand to eight thousand pounds daily is carried on for mixture with the wood pulp. The paper made in these mills from the above-mentioned proportions of wood and straw pulp, without any rags, is of excellent quality and color, and far superior to what is used for many newspapers.

A large quantity of the stock made at the Manayunk Wood Pulp Works is worked up into thick paper, to be transported to the Rockland Paper Mills of Jessup and Moore, on the Brandywine, Delaware, and there reworked into printing paper. The daily production of paper of which these mills and the Flat Rock Paper Mills are jointly capable is equal to thirty thousand pounds.

CHAPTER X.

MANUFACTURE OF BOARDS.

BOARDS are made in different ways.

1st. By superposing several leaves of paper, and uniting them by some agglutinating substance.

2d. By superposing several wet leaves at the time of couching.

3d. By means of moulds provided with very thick deckels.

4th. By special machines, analogous to those used for the manufacture of continuous paper.

The first method, strictly speaking, is more the art of the manufacturer of binder's boards than of the paper-maker. Playing-cards come under this head. They are composed of three leaves: the first being destined to receive the impression of the figures or designs, which constitute the different suits of a pack. The intermediate one, formed of a more solid material, gives the firmness, and is sometimes colored black or dark blue to render the card opaque. The third receives the spotted or geometrical designs which ornament the backs. A gummy solution, containing a large proportion of talc, is lastly applied to the cards in order to give them a more elegant gloss.

Before entering into the details of manufacture we wish to establish the following classification:—

1st. White superfine boards.
2d. " half fine "
3d. Colored boards.
4th. Common gray boards.
5th. Boards for satining with watermark.
6th. Boards made of wood or straw.
7th. Boards of several colors.

The majority of boards are made of all kinds of waste paper, and other refuse material of a paper-mill.

The first step is sorting, in order to separate the white and clean parts, which are reserved for fine boards. The material afterwards is triturated and mixed with various proportions of rag pulp, kaolin, chalk, white clays, &c.

The boards are then made either by machine or by hand.

The moulds have high deckels, so as to retain an amount of pulp proportional to the required thickness of the boards. Beyond a certain limit, however, as the drainage would be long and difficult, it is preferable to couch several leaves one upon the other.

The work is performed exactly in the same manner as we have described for making paper by hand. Between each pair of boards is placed a felt, and when a post is finished it is pressed.

It is necessary to resort to the exchange to soften the grain. The boards are rapidly dried in a horizontal position, and in a well-ventilated room. In damp weather, and especially in winter, the boards lack firmness; their manufacture should, therefore, be reserved for fine days.

A little before they are completely dry the boards undergo the process of rolling, in order to remove asperities and render the surfaces smooth and soft to the touch.

If the boards were too dry, this operation would be difficult, and however often they might be pressed under the rollers the surfaces would never be as even.

The quality of boards naturally depends upon that of the material employed in their manufacture. Those which do not require any particular resonance contain an enormous amount of earthy matters.

Common boards are made of all sorts of refuse material, such as damaged pulp, wasting of the duster, residuum left in purifying the pulp, fibrous materials obtained in cleansing the rag-engines, &c.

Colored boards are rarely ever dyed in the pulp, the only exception being in the case of fine and very high-priced qualities. Generally speaking, it is considered sufficient to cover common boards with a thin sheet of colored paper, and submit the whole to the action of a rolling press.

Considerable quantities of boards, made of wood or straw, are employed at the present day for packing and binding purposes.

To facilitate the disintegration of straw it is sprinkled with milk of lime, and after a fortnight's fermentation the softened material crushes more or less readily between the fingers. The trituration of this substance presents no difficulty, and the washing and beating operations are generally carried on in the same engine.

The pulp is turned into great elliptically shaped vats of wood, or mason work, and is converted into boards by means of a great mould, handled by two men, who unite in doing the work of the vatman and coucher successively. In order to give cohesion to this pulp, which is difficult of drainage, it is compressed between two moulds deprived of their deckels.

These boards acquire in drying a certain hardness due in part to their great thickness. They are delivered for sale after having been rolled and pared. The dimensions of some are as great as 1.30 metre in length by 1.00 metre in breadth (4.26 by 3.28 ft.)

The working stock of a mill of this kind is always of the simplest nature, and if the least motive power can be obtained, may be established at a small expense.

Within a few years past it has been proposed to manufacture boards by interposing thin laminæ of wood, shaved off by a plane, between leaves of paper. The product obtained is economical, as we substitute for paper a material of lower price, of greater hardness, and scarcely if at all hygrometric. In weaving, the application which has been made of this invention to the Jacquard loom has rendered some service to that branch of industry. As an extension of this idea, even leaves of metal have been interposed between wet boards, so as to give great solidity combined with comparative lightness.

Double colored boards are made by a machine with two webs or by hand, using two vats and couching a leaf of one color upon that of another.

It seems to us useless to dwell longer upon this subject, which is entirely comprised in all we have said of the manufacture of paper.

Sorting the raw materials.

Boiling and bleaching.

Sizing and coloring the pulp.

Manufacture proper and finishing.

For some time, in France and Germany, the manufacture of boards served as a means of evading the law prohibiting the exportation of rags. Half triturated white linen rags were made into boards and exported as a manufactured product.

England made use of this artifice to supply her paper-mills with the raw materials they lacked; but since a free exchange has been permitted this state of things is no longer in existence, at least in France. We have thought it useful, however, to record the fact.

CHAPTER XI.

MANUFACTURE OF PAPER IN CHINA AND JAPAN.

The Chinese make their paper of different kinds of bamboo and the bark of several trees, of which the most celebrated is the *Kochu*. The leaves of this tree bear much resemblance to those of the mulberry, but the fruit is more allied to the fig.

The method they employ is based upon the same principles as those we have set forth in speaking of the manufacture of rag paper. For boiling, maceration in pure water and immersiom in a milk of lime is substituted.

The bark is then washed with pure water and dried in the sun, which bleaches it. After being soaked in boiling water to remove the gelatinous matter, which unites the fibres, the bark is triturated in a great mortar with mallets, moved by hand or by treadles.

It is easily understood that this primitive method of trituration preserves the fibres of a greater length, and produces a different kind of pulp from that which we see in European paper-mills.

To give adhesiveness to these fibrillæ there is poured into the vat a mucilaginous material, obtained by macerating in water a peculiar plant called *Koteng*.

The paper is made by hand with very light moulds, in which wire cloth is replaced by thin sticks of bamboo, passed through a drawplate in order to make them of uniform size, and boiled in oil to insure their preservation and render them impermeable.

The operation of couching does not require felts, a small piece of bamboo only being interposed between each of the wet leaves.

The large leaves which sometimes attain several metres in length, are manufactured by means of moulds, supported by counter-weights, and handled with great dexterity by several workmen.

These large leaves are dried by applying them to the surface of a wall, which during the winter is heated from within.

As the Chinese write with a brush, it is not necessary that their paper should be as much sized as ours, and it is, therefore, merely dipped in a solution of alum. Sometimes a size is prepared by dissolving isinglass in water, and adding a certain proportion of a solution of alum. The leaves are plunged one by one into the tub and dried separately, and to facilitate transportation are fixed in the end of a split stick.

To soften the surface of the paper, the Chinese spread over it with a brush a clear solution of alum and talc, and by then rubbing the surfaces with a wad of cotton, they are rendered smooth and very soft to the touch. Some kinds of oiled papers acquire greater suppleness, and resemble satin or some woven material so closely that they might be mistaken for them, and are used by tailors for trimming clothes.

Japanese paper is principally made from the bark of the *Morus papifera sativa.*

The branches are cut into lengths of about one metre (3.28 feet), made into bundles and boiled in water with the addition of alum.

After this boiling the bark peels off easily from the wood, and is then sorted very carefully into

No. 1. Shoots of one year old.
" 2. " " less than one year old.
" 3. " " more " " " "

The mixture of these barks would very much impair the whiteness and quality.

The bark is again subjected to the action of a slight lye; after which the material is soft, and only presents to the touch the feel of a very fibrous substance. This operation demands considerable care. After an abundant washing the pulp is triturated upon a table by beating it with round billets of very hard wood.

When the trituration is accomplished, an extract of rice and the root of the *Oreni* is poured into the vat.

The paper is then made by hand in a manner analogous to that of the Chinese.

What distinguishes the Chinese and Japanese papers from those of Europe, is their greater softness, smoothness, and tenacity, which make them resemble silk cloths. It may easily be proved, however, by igniting them, that they are entirely composed of vegetable material, which burns with a clear flame, whereas all animal substances crisp, curl up, and emit abundant ammoniacal vapors.

These processes are very rational, and there is no doubt that by subjecting certain European plants to the same treatment we might be enabled to make paper similar to that of the Celestial Empire; but let us hasten to add that such could only be manufactured as fancy papers, more curious than of any regular commercial utility.

DESCRIPTION OF THE PLATES.

PLATE I.

Microscopic Representations of Fibres of Hemp, Flax, Cotton, Wool, and Silk.

FIG. 1.—The fibres of hemp and of flax are formed of straight, elongated, cylindrical cells; those of flax can be distinguished only by their relatively smaller size.[1]

FIG. 2.—Cotton fibres resemble tubes flattened in the direction of their length, and generally twisted several times upon themselves. Their diameters vary from $\frac{1}{55}$ to $\frac{1}{90}$ of a millimetre ($\frac{71}{100000}$ to $\frac{43}{100000}$ inches.)

FIG. 3.—Filaments of wool, formed by a series of rings articulated with each other, diminishing in diameter from root to point, and thus producing a row of teeth, similar to those of a saw. This conformation explains the peculiar property of felting possessed by wool.

FIG. 4.—Silk fibre, formed of two juxtaposed tubes united by a longitudinal partition.

FIGS. 6, 7, 8, 9, 10, 11, 12.—Different apparatus for alkalimetric, chlorometric, and hydrotimetric tests. We have explained the use of these various instruments in detail, Chap. VII., §§ 1, 2, 3, 4, 5, 6.

[1] The diameter of hemp fibres varies from $\frac{1}{20}$ to $\frac{1}{30}$ of a millimetre ($\frac{19}{10000}$ to $\frac{13}{10000}$ of an inch); those of flax from $\frac{1}{45}$ to $\frac{1}{55}$ of a millimetre ($\frac{87}{100000}$ to $\frac{71}{100000}$ of an inch). The cells of flax are not, like those of hemp, provided with a small appendage.

PLATE II.

Cylinders used in Paper-Making for Triturating the Pulp.
(Different Systems.)

FIGS. 1, 2.—General disposition of the machinery for two cylinders, moved by a water-wheel; velocity of the wheel, 8 revolutions a minute; velocity of the cylinder, from 180 to 200 revolutions.

This transmission of power by means of pinions presents the defect of jarring, as the wooden teeth of the great wheel *R* become worn.

The arrangement of the engines is not to be imitated. The *beater* should be put in place of the *washer*, as the direction of the motion tends to raise the cylinder of the beating engine. This might result in a breakage of the teeth or blades of the plate, and it would also be difficult to obtain a thorough comminution of the pulp.

a. Machinery, with pinions for two cylinders.
b. Washing engine.
c. Beating or refining engine.
d. Water-wheel.

FIG. 3.—Washing engine constructed entirely of cast iron. (In the case of a beating engine, the only difference is in the arrangement of the blades of the cylinder and plate.)

The cistern is entirely of cast iron, and furnished with washing drums.

The cylinder is lowered upon the plate by means of levers, worked by a perpendicular screw, revolving through a fixed nut, furnished with cogs (a screw-jack).

The blades of the cylinder are steel, arranged by twos for the washing, and threes for the beating engine.

FIG. 5.—Bronze plate of the *washer.*

FIG. 6.—Bronze plate of the *beater.*

FIG. 7.—Mixed engine with cistern of cast iron and wood, steel plate, and furnished with strainers and washing drums. This arrangement is well suited to soiled rags requiring abundant washing.

FIG. 8.—(Old System.) Old-fashioned rag-engine with wooden cistern and flat plate. The blades are serrated. We give this arrangement in order to show the progress made since the beginning of this century. The power was transmitted by lantern wheels. Sand traps and washing drums were not then known. At the present day when wooden cisterns are adopted, the staves are arranged in an elliptic curve as with cast-iron engines, and these are tightened with iron hoops held by screw bolts.

FIG. 10.—Scale of Figs. 1 and 2, 0.007 metre to the metre (3.28 ft.).

FIG. 11.—Scale of Figs. 3 to 9, 0.03 metre to the metre (3.28 ft.).

PLATE III.

Representation of an Improved Paper-Machine. (Large Model.)

2.10 metres (6.88 ft.) broad. Scale of 0.025 metre to 1 metre (3.28 ft.).

Four wet presses and eight drying cylinders with disconnected felts. The only fault to be found with this machine, the very finest we know of, is that of having too long a web. The drying apparatus may be considered as a model. The drying taking place gradually renders the paper softer and smoother, and even gives it a somewhat velvety appearance, an indication of incipient satining. The suction boxes are exhausted by means of air pumps.

a. Paper.
b. Felt.
c. Paper.
d. Paper.

PLATE IV.

Paper-Making by Hand—Vats and Accessories—Different Apparatus serving for the Manufacture of Paper by Hand.

FIG. 1.—General plan of two vats.

FIG. 2.—Wooden vats heated directly by steam.

FIG. 3.—Arrangement of two wooden vats heated directly by steam. The posts of paper may be pressed either by a screw or hydraulic press.

a. Position of the vatman.
b. Position of the coucher.
c. Position of the layman.
d. Position of the assistant.
e. Couching table.
f. Stand for the felts.
g. Bench for holding the posts on leaving the press.
h. Tray for carrying the wet posts to the press.

FIG. 3.—Drainage stay.

a. Mould.

FIG. 4.—Representation of an easel or inclined bench.

FIG. 5.—Bridge over the vat.

a. Bracket serving to support the mould when shoved along the bridge.

FIG. 6.—Disposition of the support for the coucher. Two iron uprights, let into the floor, support the screen, which serves as a rest for the coucher.

FIG. 7.—Rod for stirring the material in the vat.

FIG. 8.—Vats for making bank-note paper, heated by a water bath. A pair of copper vats, heated by a water bath for making bank-note paper. This arrangement is indispensable for preserving tne pureness of this paper, as steam used in heating introduces dirt proceeding from the pipes, joints, &c.

These are square vats, lined on the inside with zinc, and furnished at the lower part with stopcocks for washing. Their size and that of the copper basins depends entirely upon that of the paper to be made.

FIG. 9.—Angles of the wooden vat, showing the manner of joining.

FIG. 10.—Cast-iron support, serving to sustain the vertical copper pipes, pierced with holes at their lower extremities.

FIG. 11.—Junction of the pipes and stopcocks, allowing the vats to be heated separately.

FIG. 12.—Lifters for hanging the wet leaves on the tribbles in the drying-room.

FIG. 13.—Scale of 0.03 metre to the metre (3.28 ft.).

PLATE V.

Moulds and Watermarks.

FIGS. 1, 2, 3.—Mould for making paper. Representation of a mould of laid wire.

FIG. 1.—Upper surface.

FIG. 3.—Under surface of the mould, showing the arrangement of the ribs. The size of the mould naturally varies with that of the paper. The thickness of the deckel varies very little, and it should be as light as possible to lessen the labor of the workman.

FIGS. 4, 5, 6, 7, 8.—Details of the method of joining the stock of the frame, and the ribs with the stock. Fig. 8 shows the wire cloth fastened to the frame by means of very fine brass wires. The laid wire moulds have either a single or a double cloth; this last is best suited to strong papers.

FIG. 9.—Joints of the deckel made with double rabbets. To be well done they require a skilful workman.

FIGS. 10, 11, 12.—Different kinds of watermark.

FIG. 10.—Simple watermark made by cutting out a sheet of brass. This watermark is that adopted by the French Government for the paper of playing cards.

FIG. 11.—Another simple but more difficult watermark than the preceding. The couching of the lower part of the talons and thunderbolt presents difficulties. To compensate for this, however, the effect is handsomer.

Fig. 12.—Design reproducing the watermark of a Turkish bank-note. All the dark lines are depressed and the paper shows the design when looked at by transmitted light. In this respect it is a shaded watermark. It could equally well be light by cutting out a copper leaf according to the outline.

Fig. 13.—Isolated light letters, very generally used for bank note paper, letters of credit, &c.

Fig. 14.—Letter of the actual size. The striated edges represented facilitate the operation of couching.

Fig. 15.—Shaded watermark formed by a rectangular depression in the wire cloth. The letters, isolated and simple, are sewed to the bottom and appear in light upon the paper.

Fig. 16.—Section of fig. 15 in the direction *c d*.

Fig. 17.—Light watermark with joined letters. In this manner a regularity in the words is obtained, which it is difficult to arrive at by means of isolated letters, requiring to be delicately fastened. This kind of watermark may also be placed in the depression of fig. 15.

Fig. 18.—Shaded letters obtained by means of undulations in the wire cloth. These kinds of watermarks, the richest in use, are reserved for the paper of bank notes of high value. The impression on the wire cloth is effected by means of two dies analogous to those employed for stamping metals; other shaded letters are also made. The watermarked parts are therefore only moulds in which the pulp is deposited and produce their effect upon the paper by the difference in the thickness of the pulp at different points.

Fig. 19.—Section of fig. 18 in the direction *a b*.

PLATE VI.

General Plan of a Paper-Mill.

FIGS. 1, 2, 3.—Plan of a paper-mill according to M. Planche.

A. Entrance for receiving crude rags, weighing-room.
B. Elevator for crude rags.
C. Store-room.
D. Hatchway for lowering crude rags to the sorting and cutting-room.
E. Gratings for sorting and cutting.
F. Hatchway for lowering cut rags to the store-room of sorted rags.
G. Store-room for sorted rags.
H. Dusting-machine and rag-cutter.
I. Washing and boiling apparatus.
J. Turbine room.
K. Reservoir of water.
L. Machinery of the rag-engines.
M. Washing engines.
N. Bleaching apparatus for liquid chlorine.
O. Bleaching room for chlorine gas.
P. Retorts for the preparation of chlorine gas.
Q. Store cases for the pulp.
R. Beating engines.
S. Room of the paper-machine.
T. Finishing-room.
U. Office.
V. Store-room.
X. Quarters of the superintendent and employés.
a. Sizing-room.
b. Caldrons for melting over broken leaves, parings, &c.
c. Ventilator for the paper-machine.
d. Store-room for felts, wire, cloth, straps, colors, &c.
e. Steam boilers.
f. Work-shop for repairs, forge, joiner's shop, &c.
g. Baths.
h. Water-closets.
i. Sheds, stables, and quarters for the workmen.
m. Bridge.

We shall criticize this plan as follows: The store-room for cut rags is too small and badly placed on the ground floor; it, as well as the boiling apparatus, should have been on the second.

The room for the paper machine is in the main building.

The quarters for the superintendent and employés are in the mill itself.

The steam boilers and chimney contiguous to the main building would be better placed at a distance.

It seems to us preferable to adopt a shorter building with an additional story, and a parallel or perpendicular wing for the accommodation of the paper-machine.

FIGS. 4, 5.—Plan of a mill with three paper-machines, by the same author. The arrangements are the same as in the previous plan, only on a larger scale.

There are 12 washing and 12 beating engines, with 6 bleaching vats. One of the machines is provided with an apparatus using animal size.

FIG. 6.—General plan of a paper-mill with two machines at Krauthausen:—

A. First paper-machine.
B. Second paper-machine.
C. Water wheel.
D. Turbine wheel.
E. Machinery.
F. Steam engine.
G. Caldrons.
H. Bleaching-chest and store-room for pulp.
I. Satining machine.
J. Packing-room and warehouse.
K. Office.
L. Superintendent's room.
M. Stair-drum.
N. Store-room.

The building H E is thns subdivided: On the ground floor, machinery; on the floor above, rag engines; and on the third floor under the roof, store-room for rags.

Building B: on the ground floor, paper-machine; on the second, finishing room; on the third floor under the roof, store-room for rags and reservoir.

We have in figs. 7, 8, 14, different combinations convenient for adoption in the case of a mill with one or two machines.

Fig. 7.—Building parallel with the water-course.

On the ground floor, machinery and store chests; on the second, rag-engines, boiling, bleaching, and sizing apparatus; on the third floor, rag-room, store-room for cut rags and duster; under the roof, store-room for crude rags.

The two perpendicular lines represent, one the room for the paper-machine, the other the finishing-room.

This arrangement allows us to add another machine symmetrically placed in regard to the first.

The arrangement of fig. 8 may be equally well adopted.

The finishing-rooms form opposite sides of the hollow square. As each machine often makes different qualities of paper, there is no objection to having these two rooms separate.

Fig. 9.—Modification of the preceding. The finishing-room opposite the paper-machine; on the second floor satining machine, presses and calenders. This arrangement is open to the objection of necessitating the transportation of the paper across the court-yard after leaving the machine.

Fig. 10.—Machinery and finishing-rooms parallel with the main building. This arrangement is convenient when our available space is limited.

Fig. 11.—Main building perpendicular to the current; machine and finishing-rooms at opposite sides of the square. For two machines.

Fig. 12.—Modification of the preceding for one or two machines.

Fig. 13 —Arrangement for a single machine. The finishing-room may be continuous with that of the machine. Too costly work in the foundation for the water wheel may result from this plan, unless the banks are sufficiently high.

Fig. 14.—The two machine-rooms parallel with the main building; the finishing-rooms on opposite sides of a square. This arrangement is only suitable when space is wanting. Mills built across water-courses are more rare than those established upon one shore.

The different out-buildings for bleaching with chlorine gas, workshops, steam-boilers, office and quarters of the superintendent, who should command a view of the entire mill, must be grouped as convenience and the site of the mill may require.

Pl.1.

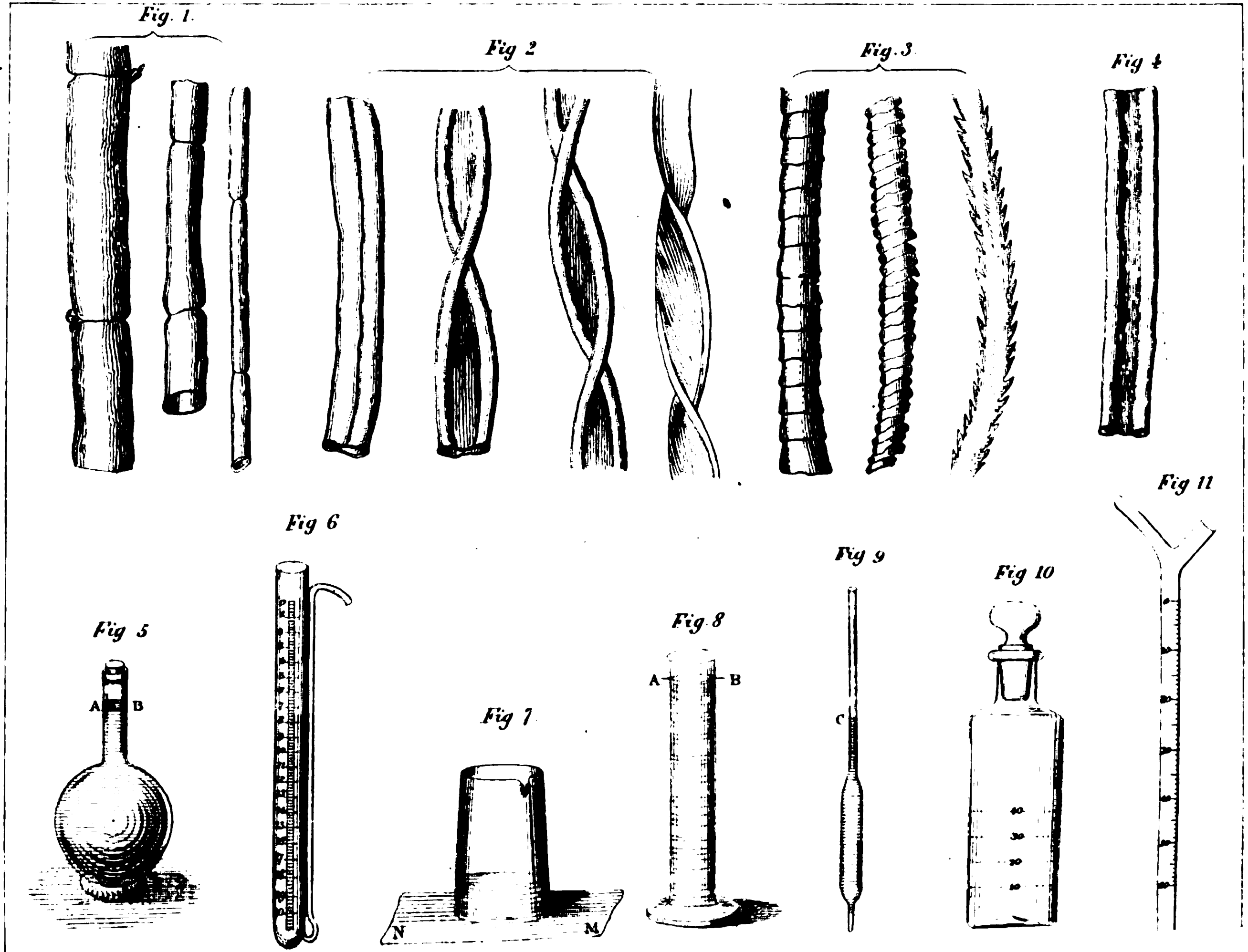


Fig. 1.
Fig 2
Fig. 3
Fig 4
Fig 5
A
B
Fig 6
Fig 7
N
M
Fig 8
A
B
Fig 9
C
Fig 10
40
30
20
10
Fig 11

Pl 2.

Fig 7

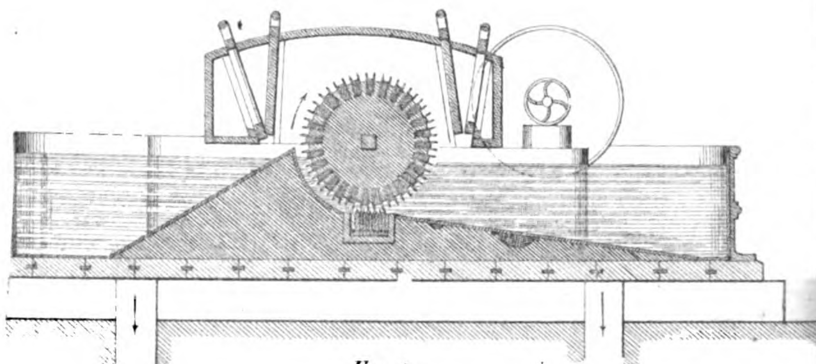


Fig 8

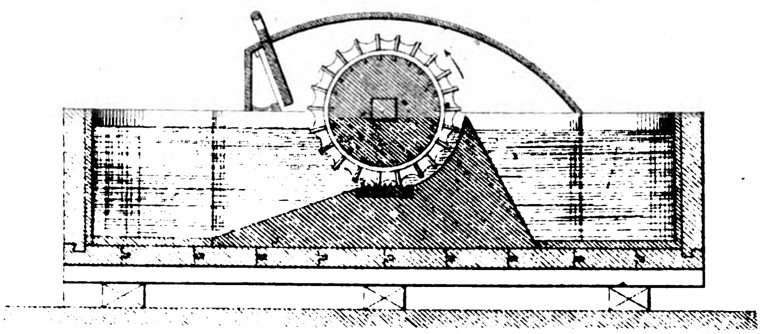


Fig 9

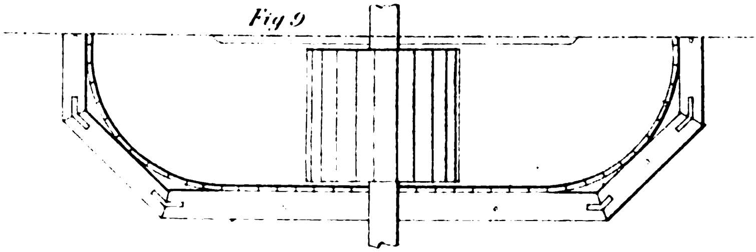


Fig 5

Fig 6

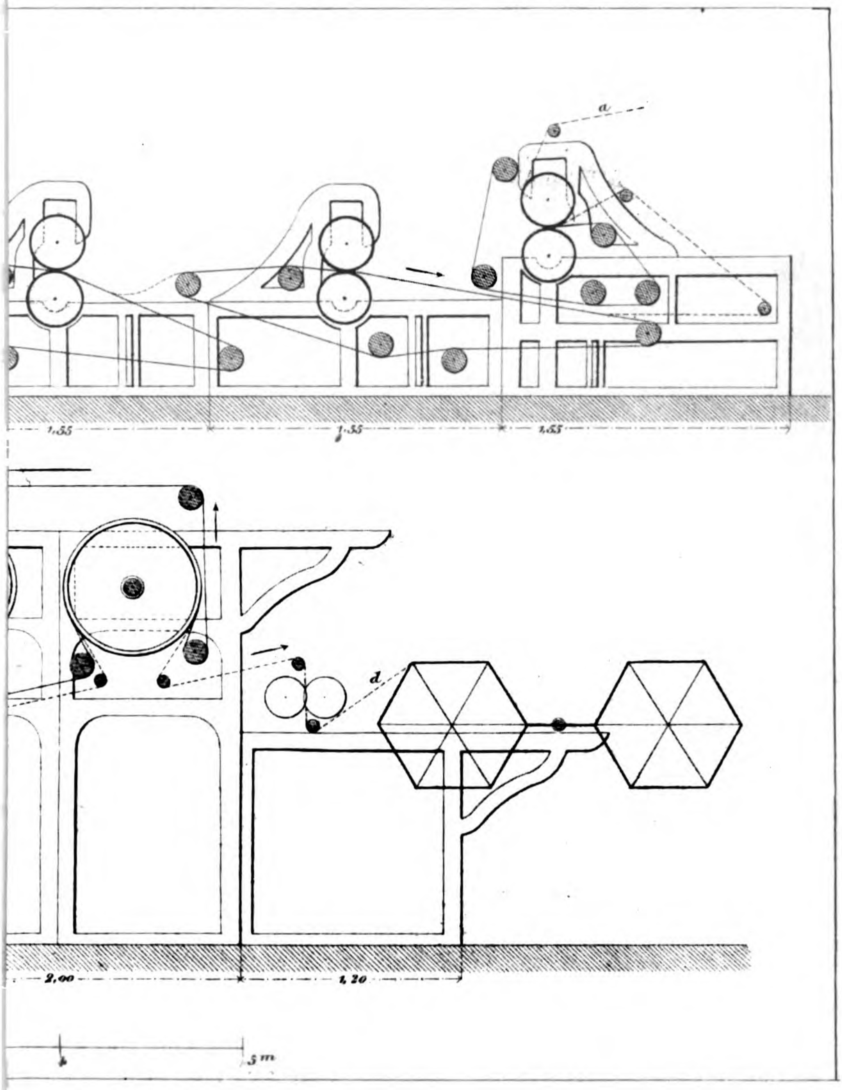
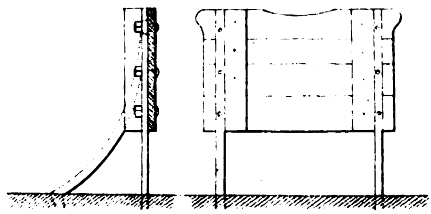
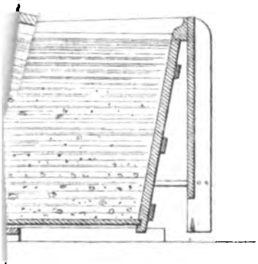

a
1,55
1,55
1,55
d
2,00
1,20
3 m

Fig. 6.





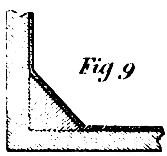


Fig. 9

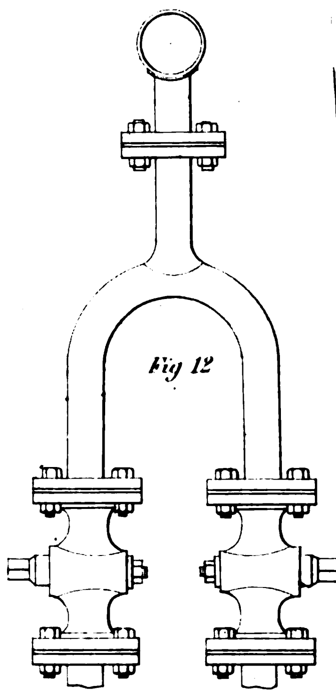
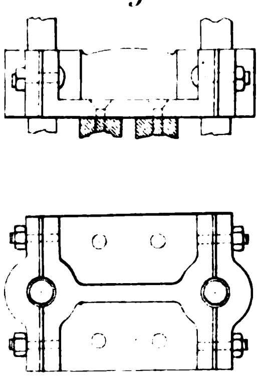
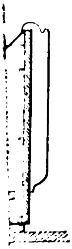


Fig. 12

Fig. 10





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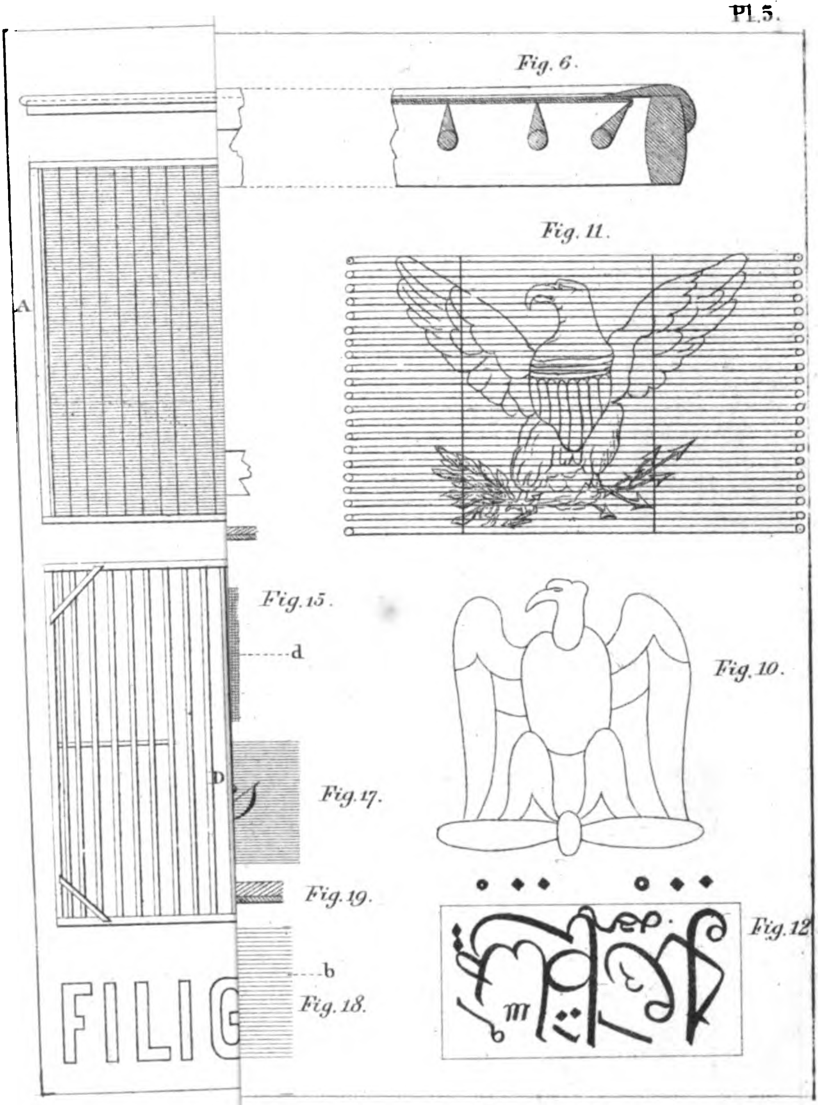

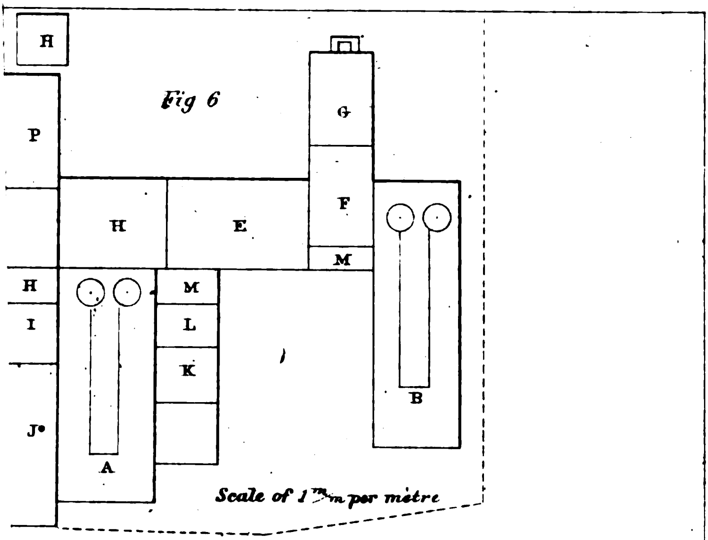

Fig 6

Scale of 1 m per mètre

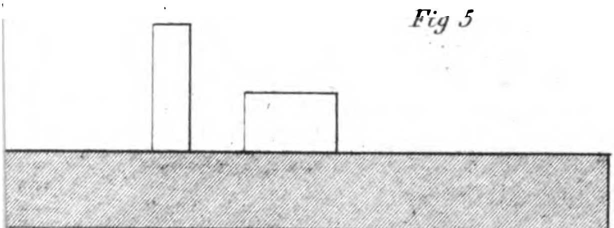

Fig 5

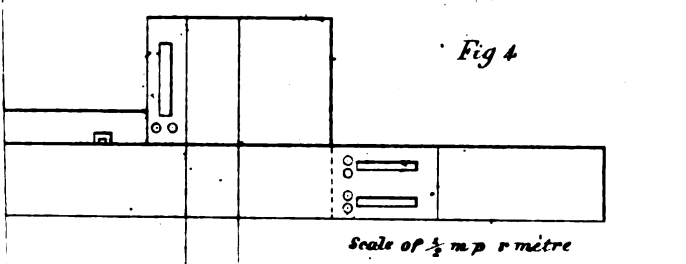

Fig 4

Scale of ½ m per mètre

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