MODERN PULP *and* PAPER MAKING

A Practical Treatise

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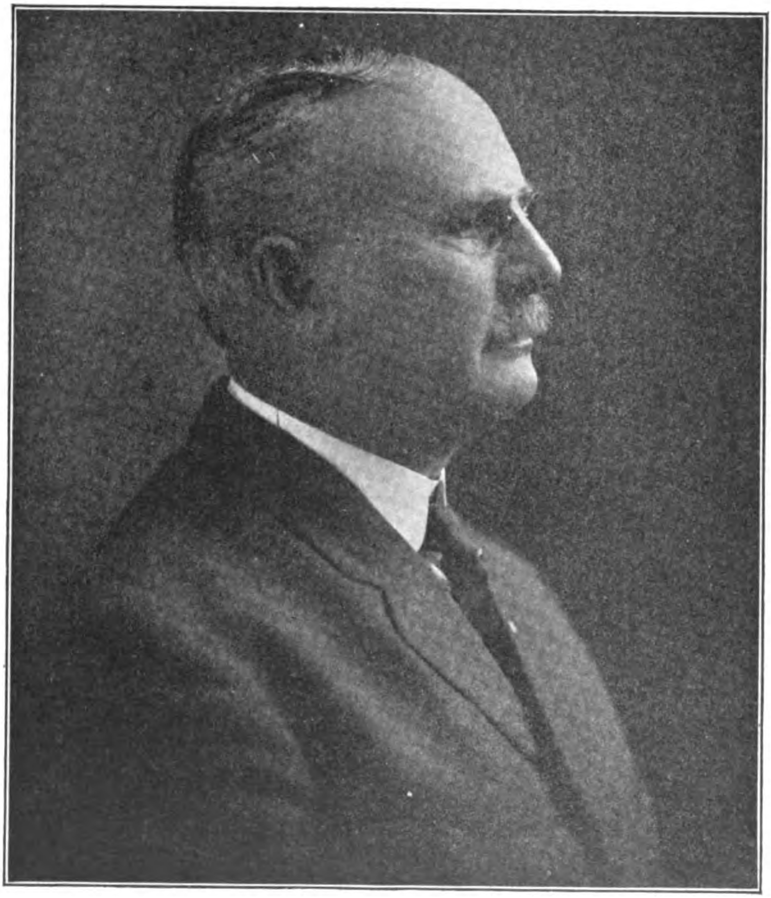

Preface.

During thirty-seven years of experience in the pulp and paper industry the author has frequently and repeatedly felt the need of a practical work on the manufacture of pulp and paper, as carried on in America, that would not be so abstruse and technical as to be beyond the grasp of the average papermaker, and which at the same time would not merely skim the surface of the various subdivisions of the art.

In the present volume an attempt has been made to describe the equipment and processes actually used in pulp and paper plants on this continent today, giving such practical information as would be of help to men working around these plants from day to day. It is hoped that the present volume will be useful to practical papermakers and, at the same time, that it may possibly be of service to technical men not intimately in touch with the pulp and paper industry and desiring to know the salient facts about it.

No attempt has been made to describe every piece of equipment ever used in the industry. Neither has the author attempted to deal with the historical aspect. Also, while recognizing the great importance of chemistry in connection with papermaking, no chemical considerations have been introduced which would not readily be comprehended by one with no special knowledge of that science.

It may seem strange to some readers of this book that the author has not devoted more space to detailed information concerning bag paper—with which branch of the industry he is particularly identified. In the first place, relatively few of the readers of this book are likely to be especially interested in bag paper, and if overmuch space were devoted to this subject readers interested in other branches might justifiably feel that their interests had been neglected. Of course, this difficulty might have been avoided by giving equally detailed attention to every variety of paper, but such a treatment would have necessitated a much larger book and, consequently, one so expensive as to be beyond the reach of many men actually engaged in the industry. Moreover, the author has felt a certain reluctance to devoting too much space to the particular branch of the industry with which he is commercially identified.

Whenever the author has made use of ideas and experience of others as expressed in the literature serving the pulp and paper field, he has endeavored to give due credit.

Thanks are due to the many manufacturers of equipment, who have so kindly furnished material for illustrations, as well as much important information that is incorporated in this book. The author also is much indebted to the Union Bag and Paper Corporation for permission to use many illustrations taken in the company's plants. He is also duly appreciative of the assistance rendered by Mr. G. S. Witham, Jr., who has contributed many useful hints, especially concerning the power plant chapter; by Mr. H. S. Ferguson of New York, who kindly checked all the figures on power consumption, and by Mr. William P. Cutter, to whom is due the index at the back of the book.

Finally, the author wishes to express his grateful appreciation of the assistance rendered on behalf of the Publishers by Mr. Francis M. Turner, Jr., Technical Editor of the Chemical Engineering Catalog, who has co-operated with the author throughout the preparation of the manuscript, covering a period of nearly two years.

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MODERN PULP AND PAPER MAKING

I. Processes by Which Pulp is Produced.

Wood is, at the present time, the raw material most used in the paper pulp industry; consequently, the manufacture of wood pulps possesses the greatest interest from a technical and industrial point of view. The processes by which rags and other materials are converted into pulp will be fully dealt with in a later chapter.

Wood is converted into pulp suitable for the manufacture of paper by two distinct classes of methods. The first class includes the *mechanical* methods which produce mechanical wood pulp or ground wood. The second class includes the various *chemical* methods, which produce chemical pulp or cellulose; this class comprises such methods as the sulphite, soda, sulphate and Kraft processes.

Mechanical Process.

Mechanical pulp is frequently called ground wood, which name signifies a product consisting of wood pulp obtained by grinding wood into a fibrous condition. Mechanical pulps may be divided into two classes, ordinary mechanical wood pulp and brown pulps or semi-chemical pulps which are made by subjecting the wood to a slight steaming before grinding. The ground wood process is a very simple method of manufacture, as it merely involves the wet grinding of wood blocks. The composition of the mechanical pulp is practically identical with that of the wood itself with the exception again of the semi-chemical pulp, which, as a result of its slight steaming, has lost some of the soluble resinous incrustants of the fiber.

Ground wood made from fresh wood has a distinctive color, bearing on light yellow when it is properly ground and several shades lighter than when ground with dull or hot stones. As a matter of fact, by careful observation and practice, one can judge the base of good ground wood, when properly made, from its color. If sap rot wood is ground these fibres can be detected owing to the fact that the wood is so soft that the pulp is torn off in fine chunks and will appear as such in the pulp itself. Made from such material, the pulp will invariably be dark, bulky, spongy and lifeless. In addition, a lighter colored pulp will result from a wood that is too dry, from which the sap and other life-giving bodies have been dried out.

The pulp produced by the mechanical process is inferior to that produced by the chemical processes and consequently it is only used in making those kinds of paper where high quality is not demanded and price is the chief consideration, e. g., in newsprint, or else in judicious combination with chemical pulp, as in the manufacture of certain bag and wrapping papers. The inferiority of paper containing mechanical pulp is due to the shortness and weakness of the fibres, together with the fact that such paper will quickly deteriorate and turn yellow owing to the action of the atmosphere on the lignins contained in the wood pulp.

Mechanical pulp is, however, much cheaper to make than any other form of paper pulp. In the first place, only about two per cent of the raw material is lost, as compared to fifty per cent or more in the chemical processes. Secondly, there are no chemicals required. Finally, the equipment necessary for making mechanical pulp is much cheaper, both as regards first cost and maintenance than that required for making chemical pulp.

Semi-chemical pulp is a variety of mechanical pulp in making which the wood is steamed and softened before being ground. In this way certain characteristics are brought out that make the pulp more suitable for some finished products, stronger and more flexible than that produced by the ordinary mechanical process. Owing to the action of the steam on the wood the fibers are colored brown as a result of oxidation, and this limits the application of this kind of pulp to uses, such as the making of brown boards and wrapping paper, where this color is not objectionable.

Sulphite Process.

Sulphite pulp is obtained by digesting wood chips with an acid liquor at a high temperature and pressure. The acid liquor is chemically known as bisulphite of lime liquor. This liquor is prepared at the pulp mill in a special plant known as the Acid Plant, which will be described in detail in a subsequent chapter.

The liquor dissolves and removes all the constituents of the wood chips except the cellulose, which in impure form constitutes the unbleached sulphite pulp. When bleached this pulp consists of practically pure cellulose. The yield of cellulose will vary from 49 per cent to 53 per cent of the weight of the prepared wood, depending upon the exact process employed. The Mitscherlich process employing a slow indirect cook will give the highest yield, while the short, direct cook will give the minimum yield.

Sulphite pulp costs considerably more to make than mechanical pulp. In the first place only about 50 per cent of the raw material is retained in the finished product. Moreover, much labor and power must be spent on the preparation of the wood before it reaches the digesting process proper. Also, it involves the upkeep of a large chemical plant for making the acid liquor. Finally, the machinery is expensive both as to first cost and maintenance, the upkeep being high as the acid nature of the process makes for rapid deterioration. The sulphite process requires about 1,300 to1,500 lbs. of coal per ton of pulp; 232 lbs. of sulphur; 300 lbs. of limestone.

However, the greater length and higher pliability and strength of the sulphite fibres, together with the freedom from deterioration causes it to be used instead of mechanical pulp for all except the cheapest grades of paper in spite of its higher cost.

Soda Process.

In the soda process wood and other fibres are digested in various forms of equipment with caustic soda solution which combines with the acid constituents of the non-fibrous parts of the wood, leaving pure cellulose in an insoluble state, which is then washed to free it from the impurities that may have been formed during the reaction.

The soda process is of general application for many woods and fibres that cannot readily be treated by the sulphite process. Ordinarily the soda process is used for the reduction of short fibre woods such as poplar, beech, etc. Unbleached soda pulp is used in the manufacture of wrapping paper where color is not a consideration. In the bleached state it is used in the manufacture of book, magazine and envelope papers where soft texture and bulk are the essential requisities.

Sulphate Process.

The term sulphate pulp was originally used to designate a thoroughly cooked pulp that could be bleached with a reasonable amount of bleach, made by digesting wood chips with sodium, sulphate and sulphide liquor. This pulp found application in the manufacture of papers quite different from those made from Kraft pulp. The term Kraft pulp was originally intended to mean practically uncooked sulphate pulp which was further disintegrated by means of a kollergang before being put on the paper machine. Now, however, the two terms sulphate and Kraft have gradually merged into each other as a result of the decreased output of true sulphate pulp and the increased production of and demand for the Kraft pulp.

Kraft Process.

Kraft pulp derives its name from the German word for strength, which is its chief characteristic. The name Kraft pulp originally referred to a practically uncooked sulphate pulp which was further worked up in a kollergang before being put on the paper machine. The treatment in kollergangs has been almost entirely abandoned, at least in America, the disintegration now being completed in the beaters and Jordan engines. At the present time the terms Kraft and sulphate pulp are used practically interchangeably.

Kraft pulp is of a dull brown shade when unbleached and it is rarely bleached since the process would require an immense amount of bleach and under no conditions would the bleached pulp have the purity and brilliancy of bleached sulphite pulp. Consequently it is used for the manufacture of products where color is not a consideration and where strength and ability to resist all kinds of wear and tear is desired, as for instance in wrappings and bag papers.

The Kraft process is especially adaptable to the pulping of long fibered resinous and non-resinous woods. Certain kinds of wood that are useless in the manufacture of sulphite pulp are adaptable to the Kraft process. This fact, together with the fact that Kraft pulp is ideal for certain much used kinds of paper has given a great impetus to the Kraft branch of industry.

In the Kraft process several valuable by-products are formed which have found commercial use. The recovery of methyl alcohol, oil of turpentine and various resins is being carried out on a commercial scale. The lime sludge obtained in the causticizing of the lime liquor has been successfully worked up into a satisfactory coating material. It is only of late that attention has been paid to the utilization of these various by-products, but with the increasing cost of raw materials, labor, etc., such economies are rapidly becoming essential in all branches of the industry in order to meet the figures of the competitor.

So far we have merely enumerated and briefly described the general processes of mechanical and chemical treatment of raw materials ordinarily used for making pulp. Each of these processes will be the subject of further and much more detailed treatment in subsequent individual chapters. Besides the above main branches of pulp manufacture there are numerous special modifications, such as treatment of straw, esparto, bamboo, cotton linters, ramie, bagasse, etc. Besides the varying chemical treatments of the above and other fibers, we have the treatment of rag, rope, jute and waste paper stocks, which are more of the nature of cleaning and purifying processes. The de-inking and repulping of waste papers on a large scale has recently assumed a position of great importance and introduced many new problems into the industry. Descriptions of these processes are incorporated in the chapter on Materials of Pulp.

II. Materials of Pulp.

For the manufacture of paper vegetable substances have come to be of the greatest importance and the commercial value of any one vegetable substance is governed by the following:

1. The quantity of cellulose that the fibres contain.
2. The quality of this cellulose.
3. The facility with which the cellulose can be extracted from the fibres.

Cellulose.

Cellulose is a definite chemical compound with the formula $C_6H_{10}O_5$ almost always of vegetable orgin and always existing in an organized condition, i. e., formed into fibres of definite form as the result of some special plant organism. However, it must be borne in mind that whatever the form in which cellulose occurs it is chemically the same.

One of the purest forms of cellulose of natural occurrence is ordinary cotton wool, the analysis of which according to Müller, is:

Cellulose........................	91.35 per cent.
Water..........................	7.00 per cent.
Fatty Substances...............	0.40 per cent.
Nitrogenous....................	0.50 per cent.
Ash (mineral)..................	0.12 per cent.
Cuticular matter................	0.63 per cent.

Cellulose in its purest form is a white substance, the form varying according to the substance from which it has been prepared. It is prepared, when desired pure, by washing some natural cellulose-containing material with various chemical reagents which wash away all the other bodies present except the cellulose. As could be inferred from the above remarks regarding its method of preparation, cellulose is a very inert substance, hardly being affected at all by chemicals. An ordinary laboratory filter paper, which resists most chemical solutions, is almost pure cellulose.

Almost the only chemical reagent that will dissolve cellulose is Schweitzer's Reagent, which consists of copper hydroxide dissolved in ammonia. This reaction is made use of in the preparation of artificial silk and also in numerous tests for cellulose.

Apart from the role it plays in paper technology, cellulose is important as being the basic material of gun-cotton, many military and industrial explosives, celluloid, collodion, artificial silk, airplane dopes, etc.

According to Griffin and Little,[1] spruce ground wood contains about 53 per cent cellulose. Reid[2] reports poplar wood as yielding 41 per cent cellulose. Griffin and Little[3] state that unbleached sulphite pulp made from spruce contains 80.8 per cent cellulose and the same authors mention[4] experiments in which poplar wood yielded by the sulphite process 55.18 per cent cellulose.

According to Müller,[5] the following are the percentages of cellulose contained in a number of European woods:

Poplar	62.77 per cent.
Fir	56.99 per cent.
Birch	55.52 per cent.
Willow	55.72 per cent.
Scotch Pine	53.27 per cent.
Chestnut	52.64 per cent.
Linden	53.09 per cent.
Beech	45.47 per cent.
Ebony	29.99 per cent.

The following table[6] gives the composition of some of the more important Canadian woods:

Material	Age by annual wings	Diam. without bark	Cellulose %	Liquids %	Soluble in boiling water %
Black spruce	74	9½	50.64	27.59	7.24
Red spruce	69	10½	51.80	28.45	5.08
White spruce	83	10⅜	56.48	27.58	3.00
White spruce	50	7⅜	56.40	27.00	4.93
Balsam	54	6¾	50.98	32.75	4.80
Jack pine	61	8⅜	49.24	30.43	6.73
Hemlock	120	12	47.70	.....	....

Of the materials other than woods, linen (the fibers of the flax plant) contains from 70 to 80 per cent cellulose; jute, from 60 to 64 per cent cellulose; various straws from 48 to 53 per cent cellulose; esparto grass from 46 to 59 per cent cellulose; manila hemp about 50 per cent.

Such figures are the result of laboratory experiments where analytical means were adopted leading to the separation and estimation of all the cellulose present. They do not necessarily have any definite relation to the amount of pulp that could be produced from such substances under practical working conditions.

[1] The Chemistry of Paper-Making, pg. 120.
[2] Jl. Soc. Chem. Ind. 5 (1886), 273.
[3] The Chemistry of Paper Making, pg. 267.
[4] The Chemistry of Paper Making, pg. 269.
[5] Die Pflanzenfaser.
[6] Dr. Bjarne Johnsen. "Paper" XX, No. 8, pg. 16 (1917).

In this connection the following table[1] giving the yields of pulp on a manufacturing scale may be of interest:

YIELDS OF PULP ON A MANUFACTURING SCALE

Rags	70–80 per cent paper
Esparto	40–45 " "
Straw	40–50 " "
Wood (by sulphite process)	40–50 " "
Waste fibres, waste paper, bagging, etc.	75–90 " "
Bamboo	40 " "
Jute	50 " "

It should be remembered that in general the percentage yield varies with the quality of the paper being produced and as a rule the higher the quality of the paper the lower the percentage yield owing to the greater severity of the processes the raw material is submitted to.

Almost all vegetable structures contain cellulose in some form and to some extent and consequently a great variety of materials have been suggested from time to time as raw materials for paper. It is not possible in this book to deal with all these materials, and attention will be directed only to those that are the basis of large actual manufacturing operations. It should not be inferred, however, that study and research concerning new materials for paper is not worthy of constant attention, as it indeed is, owing to the strain the modern demand for paper is putting on the ordinary present-day sources of pulp.

As stated above, almost any vegetable material of fibrous nature can conceivably be used as a source of pulp. The determining factors as to whether such a line of manufacture is attractive or not are the value of the product and the cost of manufacture. Scientific researches will indicate whether a usable paper can be made from a given material, but they will not yield an answer to the problem as to whether it can be made profitably. The locality has a considerable bearing on this. There are, undoubtedly, places where, on account of the distance of sources of supply of the usual raw materials, extraordinary materials can be profitably used to supply the local demand.

It is impossible here to submit a detailed analysis of the cost of making paper from different materials, but in general it might be said that the cost of chemicals is greater per ton of product for paper made from wood than from most other materials. Also the time required for cooking is greater. However, wood yields a desirable product—long, strong fibres—and when the whole cost of treatment—the subsequent operations as well as the cooking—is taken into consideration the result will be found to favor the use of wood.

A new paper material has little chance of success in ordinary localities unless it will give an equal amount of as good a quality of paper as the present materials.

[1] F. P. Veitch: U. S. Dept. of Agriculture, Bur. of Chem., Cir. 41.

Fibres Used In Paper Making.

Griffin and Little[1] divide the fibres commonly used in papermaking into the following classes:

(1) Seed-hairs, of which cotton is the only representative.

(2) Bast-fibers, such as linen, jute, manila, etc.

(3) Those derived from whole cells or leaves, such as straw and esparto.

(4) Those derived from wood.

The first two classes find their way into practical paper making, chiefly as rags and jute materials; the third class is used in straw boards, papers made from esparto, etc., while the fourth is by far the greatest in importance in modern paper making, especially in America, being the raw material of most of our paper—newsprint, book papers, bag and wrapping paper, and all but the finest writings.

While it is intended to deal with the treatment of rags, jute, straw, esparto, etc., in an adequate manner in the present work, it is the author's conviction that the preponderance of emphasis should be on the use of wood in paper making, as that is the line of most importance in modern —American papermaking.

Wood.

Different characteristics are required of woods according to whether they are to be used for chemical pulps or for mechanical pulp. There are, however, many types of wood which are suitable for both branches of pulp making, and this is especially true of spruce, at present the most important raw material of the papermaking industry.

In the manufacture of wood pulps the chief woods used are as follows:

For the manufacture of mechanical pulp: spruce, hemlock, balsam, fir, aspen, poplar and willow.

For the manufacture of sulphite pulp, usually the same woods as in the above list for mechanical pulp.

For the manufacture of soda, sulphate and Kraft pulps: spruce, tamrack, larch, hemlock, redwood, cypress, balsam, jack pine, southern pine, poplar and aspen.

The best white pulps are obtained from spruce. It is by far the most important of all species for both mechanical and chemical pulps. From a chemical standpoint it is desirable as it contains a maximum percentage of cellulose. The fibres are longer, more flexible and stronger than most other woods. Moreover, abundant supplies of spruce are obtainable in the United States and Canada, as well as in other countries, although well regulated plans of forest conservation will need to be carried out if this supply is to be maintained indefinitely.

From a microscopical standpoint the cells from different trees present different appearances, and those of the conifers, such as

[1] The Chemistry of Paper-Making, pg. 330.

PULPWOOD CONSUMPTION: QUANTITY OF WOOD CONSUMED, BY KINDS AND PROCESSES OF MANUFACTURE, 1918 [1]

Kind of Wood	Aggregate quantity	Reduced by—			
		Mechanical process	Sulphite process	Soda process	Sulphate process
	Cords	Cords	Cords	Cords	Cords
Total	5,250,794	1,345,435	2,860,172	748,638	296,549
Spruce:					
Domestic	2,204,143	911,483	1,250,909	5,612	36,139
Imported	666,164	232,914	426,114	5,792	1,344
Hemlock	836,406	51,803	745,640	1,134	37,829
Balsam fir	368,117	80,016	245,904	7,753	34,444
Poplar:					
Domestic	210,849	19,124	37,072	154,653	....
Imported	78,354	6,468	8,099	63,787	....
Jack pines	152,124	17,487	....	124,090	10,547
Yellow pine	133,774	7,662	3,576	31,546	90,990
Yellow poplar	61,247	665	....	60,582	....
Tamarack	52,031	728	6,438	....	44,865
Gum	47,145	28	....	47,117	....
White fir	35,119	7,506	27,613	....	....
Cottonwood	18,685	....	72	18,613	....
Basswood	12,110	21	....	12,089	....
White pine	10,183	1,546	....	....	8,637
Beech, birch, maple and chestnut	202,930	....	1,000	201,930	....
All other species	6,810	....	....	6,810	....
Slabs, and other mill waste	154,603	7,984	107,735	7,130	31,754

[1] *Pulpwood Consumption and Wood Pulp Production, 1918.* United States Department of Agriculture, Forest Service, in co-operation with the News Print Service Bureau. Bulletin (unnumbered) by Franklin H. Smith, Statistician in Forest Products.

spruce, pine, fir, hemlock, balsam, etc., closely resemble one another. By the use of a microscope and careful training along that line, the different fibres can be recognized and the different types of wood that have been used to make up a sheet of paper can be detected. This subject will be more fully dealt with in the chapter on the testing of paper.

Spruce: This is the most important wood for the manufacture of both mechanical pulp and chemical pulp. There are several species such as black spruce, and white spruce which, from the paper maker's point of view, may be considered as identical. Spruce readily yields a strong, long fibre when treated by the sulphite process. With the mechanical process, when carefully ground with tolerably dull stones at a low temperature, the corrugations of the stones being kept fine and uniform, spruce yields the best class of ground wood, i. e., that which approximates most nearly to sulphite. This involves a high power consumption (e. g., 55 to 100 H. P. per ton of product). In the manufacture of market paper, where long flexible, strong fiber is desired, spruce is an ideal material. Spruce will yield about 1,150 lbs. air-dry pulp per cord of wood by the sulphite process.

Balsam: This wood does not equal spruce as raw material for either the sulphite or the mechanical process. It gives a smaller yield of pulp per cord of wood and produces a fibre of an altogether different character. The fibre carries more pitchy

PULPWOOD CONSUMPTION: QUANTITY OF WOOD CONSUMED, BY KINDS AND STATES, 1918[1][2]

State	Number of establishments	Total	Spruce		Hemlock	Balsam fir	Poplar		Jack pines	Yellow pine	Yellow poplar	Tamarack	Gum	White fir	Cottonwood	Basswood	White pine	Beech, birch, maple, and chestnut	All other
			Domestic	Imported			Domestic	Imported											
		Cords	Cords	Cords	Cords	Cords	Cords	Cords	Cords	Cords	Cords	Cords	Cords	Cords	Cords	Cords	Cords	Cords	Cords
United States	250	5,250,794	2,204,143	666,164	836,406	368,117	210,849	78,354	152,124	133,774	61,247	52,031	47,145	35,119	18,685	12,110	10,183	202,930	6,810
Maine	33	1,234,969	799,649	136,487	18,482	89,234	136,591	20,230	....	....	....	....	....	....	....	1,017	454	5,343	....
New York	75	1,003,742	428,284	328,185	68,408	69,055	48,847	51,776	....	....	....	....	....	....	....	8,922	....	....	....
Wisconsin	46	860,857	230,557	32,153	472,310	65,207	2,576	....	25,045	....	....	27,164	....	....	....	....	172	....	....
Pennsylvania	14	383,699	36,851	89,854	5,151	7,000	8,851	5,400	92,867	7,104	....	....	19,492	....	....	171	....	77,049	....
New Hampshire	11	345,272	185,334	55,119	436	101,804	538	....	....	....	....	....	....	....	....	....	....	....	....
Michigan	12	203,516	72,332	10,783	54,521	23,373	1,270	....	881	....	....	10,322	....	....	....	....	8,637	....	....
Minnesota	6	182,002	167,457	....	....	....	....	....	....	....	....	14,545	....	....	....	....	....	....	....
Virginia	7	129,637	60,197	....	17,840	....	....	....	1,488	17,341	32,771	....	....	....	....	....	....	....	....
West Virginia	5	109,885	60,290	....	27,933	....	....	....	620	....	665	....	28	....	....	....	920	....	....
Vermont	9	99,687	75,563	11,704	....	11,304	838	278	....	....	....	....	....	....	....	....	....	....	....
California, Oregon and Washington	9	239,774	35,385	....	145,583	....	....	....	....	....	....	....	....	35,119	16,107	....	....	....	6,810
All other states[1]	23	457,754	52,244	1,879	25,742	1,140	11,338	670	31,223	109,329	27,811	....	27,625	....	2,578	2,000	....	120,538	....

[1] Includes Delaware, District of Columbia, Georgia, Louisiana, Maryland, Massachusetts, Mississippi, North Carolina, Ohio, South Carolina, Tennessee and Texas.
[2] Same source as preceding table.

material. This causes trouble later on, and is a detriment when the pulp is to be bleached. Although the balsam fibres are of a length about equal to the spruce fibres, they are much softer and more flexible, and when made up into a sheet of paper it is very easy to tell the difference. Balsam when pulped by the sulphite process will yield about 950 lbs. air-dry pulp per cord of wood.

Balsam pulp, mixed with a small percentage of spruce sulphite, is very satisfactory for some bag papers. Such papers have good tearing and cleavage quality, a soft silky feel, and are very flexible. The above results can only be achieved, however, when the stock has been made with great care.

Hemlock: The general character of hemlock sulphite pulp is similar to spruce, but of somewhat inferior quality. Hemlock ground wood has a decided reddish tinge, which is an undesirable feature. The fibres from hemlock are shorter than spruce, but probably sufficiently long for the cheaper sorts of paper.

J. H. Thickens[1] says: "One who is accustomed to handling spruce ground wood will not be favorably impressed with the appearance of either hemlock or jack pine pulp. This is particularly true of the hemlock sheet. Both pulps are somewhat softer in texture than spruce, and, altogether, are not of so pleasing an appearance as the present commercial product."

Hemlock sulphite is highly adaptable to making high water finish papers. It has the property of taking on a high water finish more readily than any other kind of sulphite stock. Hemlock will yield by the sulphite process about 800 lbs. air-dry pulp per cord of wood.

Poplar and Aspen: These woods are very largely used in making soda pulp, although poplar is quite extensively used for sulphite pulp also. It has been found that under careful treatment these woods give a highly characteristic soda pulp that is soft, silky and pliable and well adapted to book and other such papers.

According to H. E. Surface[2] of the U. S. Forest Service, "Soda poplar pulp is the best known substitute for esparto pulp. Its principal use is in the bleached form, in conjunction with other pulps, and it enters into the highest grade of papers for which it is especially adapted. Such papers are book, magazine, antique, coated, lithograph, map, envelope, writing, wood blotting, and the soft bulky papers sometimes required for special purposes. The pulps usually mixed with the soda pulps in making these papers are the longer-fibred pulps, such as rag pulps and sulphite wood pulps; and the proportion in which they enter the product varies from 0 to 80 per cent, depending upon the quality of the product and the uses to which it is to be put."

Poplar soda pulp lacks strength, and consequently it will generally be found with some other pulp which adds the necessary

[1] Experiments with jack pine and hemlock for mechanical pulp. U. S. Department of Agriculture, Forest Service, 1912.
[2] Paper: xxiii (1919), 23, pg. 50.

long, strong fibre to give strength and endurance. Poplar soda pulp is also desirable becaues of its opacity, a sheet made up largely from this pulp being more bulky and opaque than one composed more of sulphite or rag pulp.

Some poplar, aspen and similar woods are worked up by a modification of the sulphate process to form what is known as "American aspen cellulose," or sometimes as "poplar soda pulp." The fibers are shorter than in spruce sulphite, but the pulp bleaches easily and it is extensively used in European papers as a substitute for rag pulp.

Yellow Pine: Considerable work has been done, resulting in at least some cases in commercial operations, on the use of yellow pine chips in the Kraft process. The pitch present in this wood prevents its use for the manufacture of sulphite pulp. During the cooking operation in the Kraft process, however, the resins and pitch present in the wood are saponified and thus rendered soluble so they can be washed out. The fibers are characterized by unusual strength. Some work has been done in the South on extracting the resins and pitch with solvents and then using the extracted chips as raw material for pulp. Planer shavings have been utilized in this manner with some success.

The series of tables on page 13 and succeeding pages, which record experiments carried out by the U. S. Forest Service in a miniature pulp mill, afford valuable data as to the pulp making properties of a large number of American woods.

Straw and Esparto.

Straw is converted into a bleached pulp for use in newsprint and magazine papers, and is also extensively worked up into pulp for strawboard. The treatment differs, depending on whether bleached pulp for paper manufacture or strawboard pulp is to be made.

The following description of the process whereby the various kinds of straw are converted into bleached straw pulp will also apply in general to esparto.

In America esparto is of less importance than in Great Britain and on the continent of Europe, where it is a very important raw material. It is a grass which grows wild in Spain and the North of Africa. Spanish esparto is the better grade. The fibers are shorter than straw fibers, but tougher. The following analyses of esparto are those made by Müller:

	Spanish	African
Cellulose	48.25	45.80
Fat and wax	2.07	2.62
Aqueous extract	10.19	9.81
Pectous substances	26.39	29.30
Water	9.38	8.80
Ash	3.72	3.67

Record of Experimental Cooks Using the Sulphite Process

Species	Shipment number	Cook number	Chip charge, bone-dry weight	Water in chips	Cooking liquor charge at start of cook: Concentrations: Total SO_2	Combined SO_2	Free SO_2	Combined MgO	Combined CaO
			Pounds	*Per cent*	*Grams per liter*	*Grams per liter*	*Grams per liter*	*Grams per liter*	*Grams per liter*
Bald cypress	S-3	1	36.7	9.1	43.8	15.4	28.4	......	......
		2	40.5	11.1	43.4	15.0	28.4	......	......
		3	29.6	18.2	42.6	14.3	28.3	......	......
Cotton gum	S-2	1	34.8	14.9	42.2	14.1	28.1	......	......
		2	39.8	13.1	43.1	14.7	28.4	......	......
		3	22.3	12.2	42.8	14.2	28.6	......	......
		4	22.7	10.2	42.8	14.3	28.5	......	......
Douglas fir	S-498	1	16.0	56.4	41.0	10.3	30.7	2.7	5.3
		2	17.0	47.2	38.5	10.4	28.1	2.7	5.4
Engelmann spruce	S-502	1	13.9	79.9	41.5	10.8	30.7	2.8	5.6
		2	14.0	78.1	41.3	10.8	30.5	2.8	5.6
		3	13.7	118.4	41.5	10.8	30.7	2.8	5.6
		4	12.7	96.3	41.2	10.5	30.7	2.7	5.4
		5	10.9	128.8	40.7	11.0	29.7	2.9	5.7
		6	18.7	33.6	40.0	10.3	29.5	2.7	5.3
		12	17.0	47.1	39.5	11.7	27.8	3.0	6.0
Grand fir	S-39	1	14.6	71.8	41.0	11.0	30.0	2.9	5.7
		2	15.4	62.6	41.0	12.2	28.8	3.2	6.3
		3	16.9	47.7	41.5	10.8	30.7	2.8	5.6
		4	18.8	33.3	40.5	10.8	29.7	2.8	5.6
		5	21.3	17.5	36.1	12.7	23.4	3.3	6.5
Hemlcok	S-8	1	36.4	9.9	43.3	14.8	28.5	......	......
		2	36.1	10.8	42.5	13.4	29.1	......	......
Incense cedar	S-36	1	14.4	38.9	35.5	9.0	26.5	2.3	4.6
		2	15.5	28.9	40.0	9.6	30.4	2.5	4.9
		3	16.7	19.5	38.7	9.7	29.0	2.5	5.0
Jack pine	L-26B	6	13.9	80.4	41.0	11.5	29.5	3.7	5.0
		7	14.6	70.8	40.0	11.5	28.5	3.7	5.0
		8	13.7	82.0	40.0	11.0	29.0	3.5	4.7
		9	14.8	78.6	45.3	15.0	30.3	4.8	6.5
Loblolly pine	S-5	1	29.5	18.6	41.0	11.5	29.5	......	......
		3	42.0	13.1	43.8	15.2	28.6	......	......
	S-33	1	15.8	58.2	43.2	14.3	28.9	......	......
		2	19.2	30.2	42.2	13.9	28.3	......	......
		3	19.2	30.2	42.6	14.2	28.4	......	......
Lodgepole pine	S-499	1	15.1	66.1	41.0	9.6	31.4	2.5	4.9
		2	15.2	64.7	39.8	9.6	30.2	2.5	4.9
		3	15.8	57.8	40.6	12.9	27.7	3.3	6.6
		6	17.3	44.3	39.5	10.7	28.8	2.8	5.5
		7	17.1	45.9	40.0	14.1	25.9	3.7	7.3
		8	19.4	28.7	40.7	11.5	29.2	3.0	5.9
		9	20.2	23.8	34.7	12.8	22.4	3.2	6.3
Red spruce	S-11	2	30.0	16.7	40.0	12.3	27.9	......	......
		3	28.9	21.1	42.2	11.7	30.5	......	......
		4	29.2	19.8	42.9	15.9	27.0	......	......
		5	17.2	16.3	38.5	10.0	28.5	......	......
Scrub pine	S-19,21	1	30.3	15.5	43.3	15.2	28.1	......	......
		2	35.0	14.3	42.5	15.2	27.3	......	......
		3	37.3	11.9	43.5	15.1	28.4	......	......
Tamarack	L-26E	14	23.2	7.6	49.0	18.5	30.5	5.9	8.0
		15	23.2	7.7	50.0	19.0	31.0	6.1	8.2
		16	23.2	7.7	49.0	19.0	30.0	6.1	8.2
		17	23.2	7.7	51.0	19.5	31.5	6.2	8.4
Western hemlock	S-38	1	15.4	29.9	36.9	9.6	27.3	1.0	7.0
		2	19.0	58.0	38.7	9.2	29.5	2.4	4.7
		3	18.3	36.5	40.0	9.6	30.4	2.5	4.9
		4	45.3	32.5	40.7	11.3	29.4	2.9	5.8
		5	46.7	28.5	38.0	10.2	27.8	2.6	5.3
White fir	S-35	1	16.0	24.7	37.0	8.5	28.5	2.2	4.4
		2	16.1	24.1	40.0	9.6	30.4	2.5	4.9
	S-35,37	1	12.6	58.8	43.0	10.0	33.0	2.6	5.1
		4	25.4	57.3	36.3	8.3	28.0	2.2	4.3
		5	26.8	49.1	41.1	8.7	32.4	2.3	4.5
		8	48.9	22.7	40.1	9.6	30.5	2.5	4.9

RECORD OF EXPERIMENTAL COOKS USING THE SULPHITE PROCESS—*Continued*

Species	Shipment number	Cook number	Cooking liquor charge at start of cook — Quantity per pound of chips, bone-dry weight					
			Total liquor	Total S.	Combined S.	Free S.	Combined MgO	Combined CaO
			Gallons	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Bald cypress......	S-3	1	1.09	19.9	7.0	12.9	....	....
		2	.99	17.9	6.2	11.7	....	....
		3	1.52	27.1	9.1	18.0	....	....
Cotton gum.......	S-2	1	1.15	20.2	6.7	13.5	....	....
		2	1.01	18.2	6.2	12.0	....	....
		3	2.02	36.1	12.0	24.1	....	....
		4	1.98	35.4	11.8	23.6	....	....
Douglas fir........	S-498	1	2.82	48.2	12.1	36.1	6.3	12.5
		2	2.65	42.6	11.5	31.1	6.0	11.8
Engelmann spruce.	S-502	1	3.24	56.1	14.6	41.5	7.6	15.0
		2	3.20	55.2	14.4	40.8	7.5	14.9
		3	3.28	56.7	14.7	42.0	7.7	15.2
		4	3.53	60.7	15.5	45.2	8.1	15.9
		5	4.11	69.9	18.9	51.0	9.8	19.5
		6	2.41	40.2	10.6	29.6	5.4	10.6
		12	2.65	43.6	12.9	30.7	6.8	13.3
Grand fir.........	S-39	1	3.09	52.9	14.2	38.7	7.4	14.6
		2	2.92	50.1	14.9	35.2	7.8	15.4
		3	2.66	46.0	12.0	34.0	6.2	12.3
		4	2.40	40.5	10.8	29.7	5.6	11.1
		5	2.11	31.9	11.2	20.7	5.8	11.6
Hemlock.........	S-8	1	1.10	19.9	6.8	13.1	....	....
		2	1.24	22.1	7.0	15.1	....	....
Incense cedar.....	S-36	1	3.13	47.3	12.0	35.3	6.1	12.1
		2	2.90	48.4	11.6	36.8	6.0	12.0
Jack pine.........	L-26B	6	2.89	49.3	13.9	35.5	8.9	11.9
		7	2.73	45.7	13.1	32.6	8.4	11.3
		8	2.91	48.7	13.4	35.3	8.6	11.6
		9	2.70	51.2	16.9	34.2	10.8	14.6
Loblolly pine......	S-5	1	1.35	23.1	6.5	16.6	....	....
		3	.95	17.4	6.0	11.4	....	....
	S-33	1	2.85	51.4	17.1	34.2	....	....
		2	2.34	41.3	13.6	27.7	....	....
		3	2.34	41.7	13.9	27.8	....	....
Lodgepole pine....	S-499	1	2.99	51.2	12.0	39.2	6.2	12.3
		2	2.96	49.2	11.9	37.3	6.2	12.2
		3	2.84	48.1	15.3	32.8	7.9	15.8
		6	2.60	42.8	11.6	31.2	6.0	12.0
		7	2.63	43.9	15.5	28.4	8.0	15.9
		8	2.32	39.4	11.1	28.3	5.8	11.5
		9	2.23	32.2	11.4	20.8	5.9	11.8
Red spruce.......	S-11	2	1.33	22.5	7.0	15.5	....	....
		3	1.38	24.4	6.7	17.7	....	....
		4	1.37	24.5	9.1	15.5	....	....
		5	2.62	42.2	11.0	31.2	....	....
Scrub pine.......	S-19, 21	1	1.32	23.9	8.4	15.5	....	....
		2	1.14	20.2	7.2	13.0	....	....
		3	1.21	22.0	7.6	14.4	....	....
Tamarack........	L-26E	14	1.72	35.2	13.3	21.9	8.5	11.4
		15	1.72	35.9	13.6	22.3	8.7	11.7
		16	1.72	35.2	13.6	21.5	8.7	11.7
		17	1.72	36.6	14.0	22.6	8.9	12.1
Western hemlock..	S-38	1	2.92	45.0	11.7	33.3	2.4	17.1
		2	2.11	34.0	8.0	26.0	4.2	8.3
		3	2.45	41.0	9.8	31.2	5.1	10.2
		4	.66	11.2	3.1	8.1	1.6	3.2
		5	.94	14.9	4.0	10.9	2.1	4.1
White fir.........	S-35	1	2.81	43.3	9.9	33.4	5.2	10.2
		2	2.79	46.6	11.2	35.4	5.8	11.5
	S-35, 37	1	2.78	49.8	11.6	38.2	6.1	11.9
		4	1.77	26.8	6.2	20.6	3.2	6.3
		5	1.68	28.7	6.1	22.6	3.2	6.3
		8	.61	10.2	2.4	7.8	1.3	2.5

RECORD OF EXPERIMENTAL COOKS USING THE SULPHITE PROCESS—*Continued*

Species	Shipment number	Cook number	Total	Duration of cooking: At zero gauge pressure	Duration of cooking: At maximum gauge pressure	Duration of cooking: Below zero steam pressure	Duration of cooking: At maximum steam pressure	Maximum pressures: Gauge	Maximum pressures: Steam
			Hours	*Hours*	*Hours*	*Hours*	*Hours*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Bald cypress	S-3	1	8.0	0.0	4.0	2.0	2.7	85	58
		2	10.0	.0	3.8	2.0	3.8	88	60
		3	11.0	.0	6.0	3.0	4.7	90	60
Cotton gum	S-2	1	8.0	.0	3.0	2.0	3.0	85	60
		2	7.5	.0	2.5	1.2	1.8	84	58
		3	9.0	.0	5.5	3.5	4.0	80	56
		4	9.0	.0	4.0	3.0	4.0	86	56
Douglas fir	S-498	1	8.0	.3	4.5	3.0	2.0	80	60
		2	9.0	.3	5.5	3.3	3.0	80	60
Engelmann spruce	S-502	1	10.0	.3	4.3	3.0	3.0	90	70
		2	10.0	.3	4.0	3.0	3.0	90	70
		3	9.0	.3	4.5	3.0	3.0	80	60
		4	10.0	.3	4.3	3.0	3.0	90	70
		5	10.0	.3	5.5	2.8	4.0	80	60
		6	10.0	.3	4.5	3.3	2.8	90	70
		12	10.0	.3	5.8	3.3	4.0	80	60
Grand fir	S-39	1	8.0	.3	4.0	3.0	2.0	80	60
		2	9.0	.3	3.0	3.5	2.0	80	60
		3	9.0	.3	4.0	3.0	2.0	80	60
		4	9.0	.3	5.0	3.0	3.0	80	60
		5	8.0	.3	4.0	3.0	2.0	80	60
Hemlock	S-8	1	8.5	.0	4.0	1.7	3.0	86	59
		2	9.0	.0	4.0	3.0	2.0	85	60
Incense cedar	S-36	1	8.0	.3	4.0	2.8	2.0	80	60
		2	9.8	.3	3.8	3.0	2.5	88	64
		3	12.5	.3	4.5	3.0	4.0	90	68
Jack pine	L-26B	6	10.0	.8	6.2	3.0	3.2	80	40
		7	10.0	.2	5.8	3.0	3.2	80	46
		8	15.0	.2	12.2	3.0	4.8	73	46
		9	15.0	.2	8.8	3.0	5.0	75	46
Loblolly pine	S-5	1	10.0	.0	2.0	2.7	.1	80	60
		3	8.0	.0	3.0	2.0	2.0	85	60
	S-33	1	10.0	.0	4.5	2.0	4.3	85	60
		2	10.0	.0	5.5	3.0	4.0	85	60
		3	11.0	.0	6.0	2.7	5.3	85	60
Lodgepole pine	S-499	1	8.0	.3	3.8	2.0	2.0	80	60
		2	9.0	.3	3.5	3.0	2.0	90	70
		3	12.0	.3	5.8	3.0	3.0	80	60
		6	10.0	.3	5.3	3.0	3.0	90	70
		7	9.0	.3	4.5	2.5	2.8	80	60
		8	11.0	.3	6.3	3.0	3.0	90	62
		9	12.5	.3	8.8	3.3	1.5	90	60
Red spruce	S-11	2	10.0	.0	7.0	2.5	.1	70-80	50
		3	10.0	.0	7.0	3.0	.1	70-80	60
		4	8.5	.0	4.0	3.0	2.0	85	60
		5	8.0	.0	4.0	3.0	2.0	80	60
Scrub pine	S-19,21	1	7.7	.0	3.0	3.0	2.5	84	60
		2	9.0	.0	3.0	1.0	3.0	85	59
		3	9.7	.0	4.5	2.3	3.5	90	60
Tamarack	L-26E	14	10.0	.2	5.5	4.5	3.0	80	46
		15	16.0	1.0	9.0	5.0	4.0	80	46
		16	16.0	1.3	9.5	5.0	5.0	80	46
		17	20.0	.8	12.5	5.0	9.0	80	38
Western hemlock	S-38	1	8.0	.3	4.0	1.5	2.0	80	60
		2	10.0	.3	5.0	3.0	2.0	80	60
		3	9.0	.3	4.0	3.0	2.0	80	60
		4	9.0	.3	3.0	3.0	2.0	80	60
		5	9.0	.3	4.0	3.0	2.0	80	60
White fir	S-35	1	9.0	.3	5.3	1.8	4.0	80	60
		2	8.8	.3	4.0	2.6	2.8	80	62
	S-35,37	1	8.0	.3	3.3	2.5	1.5	80	60
		4	8.8	.3	5.5	2.3	4.0	80	60
		5	8.8	.3	4.7	2.8	3.0	80	54-68
		8	9.0	.3	4.5	3.3	2.0	80	60

Record of Experimental Cooks Using the Sulphite Process—*Continued*

Species	Shipment number	Cook number	Yields: Screened pulp	Yields: Screenings	Quality of pulps: Ash	Quality of pulps: Cellulose	Quality of pulps: Bleach required	Quality of pulps: Loss on bleaching
			Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Bald cypress......	S-3	1	43.5	[1]3.9	1.18	72.0	....	....
		2	46.9	[1]2.4	.68	75.6	126.0	12.9
		3	....	[1].5	.52	81.5	52.0	3.8
Cotton gum.......	S-2	1	43.0	[1]1.8	.99	83.5	35.0	4.6
		2	42.6	[1].3	.78	83.6	17.0	2.1
		3	44.5	[1].9	1.13	81.5	20.5	3.3
		4	43.5	[1].4	.99	82.7	35.0	5.2
Douglas fir.......	S-498	1	38.8	16.0	1.25	....	70.0	11.9
		2	32.9	25.8	....	....	....	....
Engelmann spruce.	S-502	1	34.7	1.9	.89	86.7	15.0	2.9
		2	39.0	.3	.75	87.2	13.5	2.5
		3	45.2	1.2	.89	85.7	22.5	5.1
		4	45.7	.5	1.12	87.7	12.0	2.4
		5	52.5	.5	.98	88.0	12.3	2.2
		6	40.0	.3	.86	85.9	12.5	2.3
		12	40.1	.5	1.35	85.6	21.0	5.1
Grand fir.........	S-39	1	51.4	1.7	1.71	....	80.0	12.8
		2	24.1	19.4	2.00	72.8	....	....
		3	46.0	.6	.76	....	26.6	1.6
		4	46.9	1.5	.86	....	28.0	5.7
		5	46.4	2.4	2.78	....	40.0	7.8
Hemlock.........	S-8	1	43.8	[1]1.5	.75	81.2	85.0	10.0
		2	39.2	[1]3.7	.38	85.8	37.0	4.9
Incense cedar.....	S-36	1	40.8	8.3	2.37	71.3	....	....
		2	37.9	[1].3	1.38	78.6	....	....
		3	16.3	.4	1.35	80.8	....	....
Jack pine.........	L-26B	6	45.5	4.9	....	....	....	....
		7	34.8	17.2	....	....	....	....
		8	40.7	5.9	....	....	....	....
		9	53.2	3.0	....	....	....	....
Loblolly pine......	S-5	1	....	1.3	.83	85.4	35.0	7.7
		3	....	[1]2.1	.57	83.1	39.0	5.7
	S-33	1	....	....	4.50	....	....	....
		2	....	....	1.06	76.6	72.0	9.3
		3	....	....	1.45	....	80.0	12.9
Lodgepole pine....	S-499	1	43.6	7.6	1.15	80.3	50.0	8.8
		2	43.1	2.4	1.29	81.6	39.0	7.0
		3	39.9	3.1	2.53	81.2	29.0	6.6
		6	36.8	.5	.60	78.5	22.8	3.8
		7	50.9	5.3	6.84	75.5	43.0	13.7
		8	32.4	5.7	.65	....	23.0	3.6
		9	33.5	.3	.44	....	16.8	2.5
Red spruce.......	S-11	2	....	....	....	....	....	....
		3	....	[1]8.2	1.96	73.5	98.0	22.0
		4	....	[1].7	.67	86.1	17.0	3.6
		5	53.9	1.7	2.00	84.4	35.0	6.3
Scrub pine........	S-19, 21	1	....	[1]6.7	1.13	....	65.0	9.5
		2	....	[1]3.1	.59	....	67.0	7.0
		3	....	[1]1.1	.43	....	20.4	4.1
Tamarack........	L-26E	14	42.8	8.4	....	....	....	....
		15	46.0	.8	....	....	....	....
		16	45.8	1.5	....	....	....	....
		17	46.7	1.7	....	....	....	....
Western hemlock..	S-38	1	43.6	.8	2.41	85.1	44.8	7.7
		2	45.2	2.5	1.29	83.1	41.0	7.6
		3	47.3	1.1	1.13	84.7	35.0	6.4
		4	28.6	18.1	1.24	80.3	72.0	11.7
		5	42.0	.3	.66	85.9	25.0	4.5
White fir.........	S-35	1	40.6	1.3	1.03	85.8	20.5	4.0
		2	42.7	.9	1.22	85.1	23.5	4.7
	S-35, 37	1	45.5	.2	1.23	85.6	28.0	4.9
		4	48.3	.8	.66	88.0	19.0	1.8
		5	44.8	.4	.90	83.8	17.0	3.2
		8	41.4	.7	.43	86.0	12.8	1.1

[1] Air-dry screenings. Percentage based on bone-dry weight of chips.

RECORD OF EXPERIMENTAL COOKS USING THE SODA PROCESS

Species	Shipment number	Cook number	Chip charge, bone-dry weight	Water in chips	Cooking liquors at start of cook: Concentrations: NaOH	Cooking liquors at start of cook: Concentrations: Na_2CO_3	Cooking liquors at start of cook: Concentrations: Total Na_2O	Cooking liquors at start of cook: Causticity
			Pounds	*Per cent*	*Grams per liter*	*Grams per liter*	*Grams per liter*	*Per cent*
Aspen............	L-19	2	39.4	9.1	80.5	2.2	63.7	97.9
		4	40.3	8.2	80.2	3.1	64.0	97.1
		7	39.9	9.8	71.6	2.7	57.1	97.2
		25	39.0	8.2	70.0	2.1	55.5	97.8
Beech............	S-7	5	21.8	14.6	91.0	5.2	73.5	95.9
		6	22.1	13.0	90.0	6.4	73.5	94.9
		7	22.1	13.3	90.0	4.6	72.5	96.2
		8	21.9	14.2	100.0	5.8	80.9	95.8
Cotton gum.......	S-4	3	22.4	11.8	90.0	5.1	72.7	95.9
		4	22.1	13.0	90.0	8.1	74.5	93.6
Douglas fir.......	S-498	1	40.4	9.1	90.0	2.7	71.4	97.8
		2	40.4	9.1	90.0	2.4	71.2	98.0
Engelmann spruce.	S-502	4	21.4	16.9	90.0	5.0	72.7	96.0
		5	21.3	17.2	90.0	3.0	71.5	97.5
		6	21.1	18.6	80.0	2.7	63.6	97.5
		7	21.2	17.7	90.0	3.4	71.8	97.2
		8	22.1	13.4	80.0	3.2	63.8	97.1
Grand fir.........	S-39	5	21.9	14.3	90.0	7.6	74.2	94.0
		6	21.8	14.9	90.0	3.4	71.7	97.2
		7	21.9	13.9	90.0	6.1	73.3	95.1
		8	22.1	13.2	90.0	4.2	72.2	96.6
		13	21.4	17.1	80.0	5.7	65.3	94.9
		15	22.7	14.7	90.0	6.7	73.6	94.7
Incense cedar.....	S-36	3	21.9	14.4	80.0	3.7	64.2	96.6
		4	21.6	15.6	80.0	4.4	64.6	96.0
		5	21.8	14.7	80.0	3.7	64.2	96.5
		6	22.0	13.6	80.0	3.8	64.2	96.5
		7	22.0	13.9	90.0	3.9	72.6	96.0
Jack pine.........	L-105	1	35.8	39.8	90.0	2.4	71.2	98.0
		2	35.8	39.7	90.0	2.4	71.2	98.0
Loblolly pine.....	L-2	1	41.0	22.1	90.0	2.7	71.4	97.8
Lodgepole pine....	S-469	1	22.2	12.6	90.0	3.4	71.7	97.2
		2	22.4	11.7	90.0	3.2	71.7	97.4
	S-499	4	21.8	14.7	90.0	4.9	72.6	96.0
		5	21.8	15.0	90.0	4.9	72.6	96.0
		7	22.2	12.9	80.0	3.2	63.9	97.1
		8	21.9	14.4	80.0	2.8	63.6	97.4
Longleaf pine.....	L-3	1	41.9	14.6	90.0	2.7	71.3	97.8
		2	41.9	14.6	90.0	2.4	71.2	98.0
		3	41.9	14.6	90.0	2.4	71.1	98.0
Red alder........	S-524	4	21.8	14.7	80.0	4.4	64.5	96.0
		5	21.5	16.4	80.0	3.9	64.3	96.5
		8	22.0	13.8	80.0	2.1	63.2	98.0
		9	21.5	16.3	80.0	4.0	64.3	96.4
		10	21.4	16.8	80.0	4.0	64.3	96.4
		11	21.5	16.1	80.0	3.7	64.2	96.6
Red maple........	S-14	2	22.3	12.1	80.0	4.4	64.4	96.0
		3	22.2	12.9	80.0	5.9	65.5	94.7
		4	22.2	12.9	80.0	8.1	66.8	92.8
Sycamore.........	S-18	1	22.0	13.6	80.0	4.2	64.4	96.2
		2	22.1	13.2	80.0	4.6	64.7	95.8
Tamarack........	L-26E	18	40.8	10.4	90.0	2.7	71.4	97.8
		19	40.8	10.4	90.0	2.4	71.2	98.0
Tulip tree........	S-16	4	21.7	15.5	80.0	4.6	64.7	95.8
		5	21.7	15.2	80.0	5.7	65.3	94.9
		6	22.0	13.7	89.1	5.4	72.2	95.6
Western hemlock..	S-38	8	17.6	13.8	80.0	4.7	64.7	95.9
		9	20.1	14.4	80.0	7.4	66.3	93.6
White fir.........	S-35	4	11.8	9.3	87.2	2.3	69.0	98.0

RECORD OF EXPERIMENTAL COOKS USING THE SODA PROCESS—*Continued*

Species	Shipment number	Cook number	Cooking liquors at start of cook: Quantity per pound of chips, bone-dry weight: Total liquor	NaOH	Na_2CO_3	Total Na_2O	Duration of cooking: Total	At zero gauge pressures	At maximum gauge pressure
			Gallons	*Per cent*	*Per cent*	*Per cent*	*Hours*	*Hours*	*Hours*
Aspen	L-19	2	0.399	26.8	0.8	21.2	8.0	0.4	7.0
		4	.594	39.7	1.6	31.7	7.0	.2	6.0
		7	.376	22.4	.9	17.9	7.0	.2	6.0
		25	.429	25.0	.8	19.9	8.0	.4	7.0
Beech	S-7	5	.371	28.2	1.6	22.7	8.5	.3	8.0
		6	.370	27.8	2.0	22.7	8.3	.3	8.0
		7	.371	27.9	1.4	22.4	8.3	.3	8.0
		8	.362	30.2	1.8	24.4	8.3	.3	8.0
Cotton gum	S-4	3	.392	29.5	1.67	23.8	8.3	.3	8.0
		4	.405	30.3	2.7	25.2	8.3	.3	8.0
Douglas fir	S-498	1	.333	25.0	.7	19.8	8.0	.3	5.0
		2	.333	25.0	.7	19.8	7.0	.3	6.0
Engelmann spruce	S-502	4	.353	26.5	1.4	21.4	6.5	.3	6.0
		5	.384	28.8	1.0	22.9	6.3	.3	6.0
		6	.428	28.6	1.0	22.7	9.3	.3	9.0
		7	.441	33.1	1.3	26.3	9.5	.3	9.0
		8	.431	28.8	1.1	22.9	9.3	.3	9.0
Grand fir	S-39	5	.398	29.9	2.5	24.6	7.3	.3	7.0
		6	.400	30.0	1.1	23.9	9.3	.3	9.0
		7	.462	34.7	2.4	28.2	7.3	.3	7.0
		8	.462	34.7	1.6	27.8	9.3	.3	9.0
		13	.332	22.2	1.6	18.1	10.3	.3	10.0
		15	.349	26.2	1.9	21.4	8.3	.3	8.0
Incense cedar	S-36	3	.477	31.8	1.5	25.6	5.5	.3	5.0
		4	.481	32.1	1.8	25.9	6.5	.3	6.0
		5	.477	31.9	1.5	25.6	9.5	.3	9.0
		6	.326	21.8	1.0	17.4	12.3	.3	12.0
		7	.343	25.8	1.4	20.8	12.3	.3	12.0
Jack pine	L-105	1	.333	25.0	.7	19.8	7.0	.3	6.3
		2	.333	25.0	.7	19.8	8.0	.3	7.0
Loblolly pine	L-2	1	.333	25.0	.7	19.8	7.0	.3	6.0
Lodgepole pine	S-469	1	.390	29.4	1.1	23.3	9.3	.3	9.0
		2	.367	27.5	1.0	21.9	10.3	.3	10.0
	S-499	4	.368	27.6	1.5	22.3	7.5	.3	7.0
		5	.373	28.0	1.5	22.5	10.5	.3	10.0
		7	.442	29.5	1.2	23.6	10.3	.3	10.0
		8	.392	26.2	.9	20.8	12.3	.3	12.0
Longleaf pine	L-3	1	.333	25.0	.8	19.8	7.0	.5	6.0
		2	.266	20.0	.5	15.8	7.0	.3	6.0
		3	.267	20.0	.5	15.8	8.0	.3	7.0
Red alder	S-524	4	.388	25.9	1.4	20.9	8.3	.3	8.0
		5	.403	26.9	1.3	21.6	5.5	.3	5.0
		8	.520	34.7	.9	27.4	4.3	.3	4.3
		9	.534	35.6	1.8	28.6	6.3	.3	6.0
		10	.536	35.8	1.8	28.7	6.3	.3	6.0
		11	.681	45.4	2.1	36.5	6.3	.3	6.0
Red maple	S-14	2	.383	25.6	1.4	20.6	8.3	.3	8.0
		3	.386	25.8	1.9	21.1	10.3	.3	10.0
		4	.402	26.8	2.7	22.4	10.3	.3	10.0
Sycamore	S-18	1	.434	25.9	1.5	23.3	8.3	.3	8.0
		2	.387	25.9	1.5	20.8	10.3	.3	10.0
Tamarack	L-26E	18	.333	25.0	.8	19.9	7.0	.3	6.0
		19	.400	30.0	.8	23.8	7.0	.3	6.0
Tulip tree	S-16	4	.421	28.1	1.6	22.8	7.3	.3	7.0
		5	.427	28.5	2.0	23.3	10.3	.3	10.0
		6	.319	23.7	1.5	19.2	11.3	.3	11.0
Western hemlock	S-38	8	.385	25.7	1.5	20.8	8.3	.3	8.0
		9	.423	28.2	2.6	23.4	10.0	1.0	8.0
White fir	S-35	4	.346	25.2	.7	19.9	7.0	.3	6.0

Record of Experimental Cooks Using the Soda Process—*Continued*

Species	Shipment number	Cook number	Maximum gauge pressure	Yields		Quality of pulps		
				Screened pulp	Screenings	Ash	Bleach required	Loss on bleaching
			Pounds per square inch	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Aspen	L-19	2	100	50.3	0.0	0.81	8.0	1.1
		4	98	46.5	.0	.95	6.0	.4
		7	100	52.6	.0	.85	9.0	1.6
		25	100	50.8	.0	.79	9.5	1.4
Beech	S-7	5	110	50.7	.1	.73	13.2	2.1
		6	110	44.7	.2	.76	15.3	1.8
		7	110	45.4	.8	.78	14.7	3.0
		8	110	39.8	1.0	.92	....	....
Cotton gum	S-4	3	110	....	....	1.51	23.2	1.5
		4	110	43.7	.1	1.73	26.5	1.7
Douglas fir	S-498	1	110	45.3	.1	....	....	....
		2	100	46.1	.0	....	....	....
Engelmann spruce	S-502	4	110	46.0	1.0	.71	93.0	....
		5	110	37.8	.9	.82	67.0	7.4
		6	110	39.4	1.0	.69	69.0	8.2
		7	110	36.2	.1	.71	42.5	4.9
		8	110	42.4	.4	....	....	....
Grand fir	S-39	5	110	41.7	.1	.52	63.0	6.1
		6	110	41.5	.1	.60	46.0	4.8
		7	110	41.6	.1	.66	47.5	8.9
		8	110	40.8	.1	.59	44.6	4.4
		13	110	46.0	3.7	....	....	....
		15	110	47.9	.5	....	....	....
Incense cedar	S-36	3	100	38.6	1.3	.96	....	....
		4	110	39.5	.2	.78	90.0	....
		5	110	35.2	.1	.73	80.0	9.1
		6	110	41.7	3.3	1.05	....	....
		7	110	36.3	.2	.69	....	....
Jack pine	L-105	1	100	48.1	.0	....	....	....
		2	90	51.8	.1	....	....	....
Loblolly pine	L-2	1	110	45.4	.0	....	....	....
Lodgepole pine	S-469	1	110	38.1	.1	.64	41.0	4.6
		2	110	40.9	.1	.90	51.5	....
	S-499	4	110	44.4	.1	.82	46.0	5.4
		5	110	39.0	.2	.87	41.0	5.4
		7	110	40.4	.1	.73	46.5	5.5
		8	110	42.1	1.1	....	....	....
Longleaf pine	L-3	1	100	48.6	.0	....	....	....
		2	100	46.7	4.4	....	....	....
		3	100	50.4	.0	....	....	....
Red alder	S-524	4	110	45.4	.1	.76	23.8	3.2
		5	110	48.7	.1	.77	25.5	3.5
		8	110	42.7	.1	.69	20.8	2.5
		9	110	38.2	.1	.71	20.1	2.8
		10	110	41.1	.1	.66	18.5	2.8
		11	110	39.1	.1	.87	18.0	2.3
Red maple	S-14	2	110	44.6	.2	.91	15.5	2.6
		3	110	....	....	.63	13.0	....
		4	110	42.6	.3	.78	12.4	....
Sycamore	S-18	1	110	43.4	.1	1.08	13.7	3.2
		2	110	45.4	.2	1.27	15.0	....
Tamarack	L-26E	18	110	35.0	8.7	....	....	....
		19	110	37.8	.0	....	....	....
Tulip tree	S-16	4	110	42.2	.0	.85	15.0	3.0
		5	110	40.7	.1	1.01	14.1	2.4
		6	110	40.5	.1	.98	18.8	3.1
Western hemlock	S-38	8	110	45.7	.8	....	....	....
		9	110	42.6	1.0	....	66.4	....
White fir	S-35	4	100	49.0	4.7	....	....	....

The esparto is shipped in bales, from which the ropes and hoops have first to be removed. The bundles are then treated in a machine like a rag duster which breaks them up and frees them from dirt.

According to Clapperton[1] from 4,000 to 5,000 pounds of esparto can be boiled in from 2½ to 3 hours, under a pressure of from 30 to 40 pounds, using 14 to 16 per cent of 70 per cent caustic soda on the raw material.

Preparing Straw for Bleached Pulp.

The straw is digested with caustic soda under pressure, yielding, when bleached, a white paper pulp which is nearly pure cellulose. The fibres are very fine and shorter than those obtained from wood, but very strong. Such material imparts to paper a certain hardness and "rattle" that is distinctive of fine writing papers.

The following is the composition of various straws, according to Müller:

	Winter Rye %	Winter Wheat %	Summer Barley %	Winter Barley %	Oats %
Water	14.3	14.3	14.3	14.3	14.3
[2] Total organic material	82.5	80.2	79.7	80.2	80.7
Ash	3.2	5.5	....	5.5	5.0
Cellulose	54.0	48.0	43.0	48.4	40.0

Rye straw is the first choice, then wheat and lastly oat straw. The straw is carefully picked over for the removal of all impurities, such as weeds, roots, etc. This picking is done by hand, the straw being spread on a long table at which are seated the workers. When the picking is completed the straw is cut into pieces from two-fifths of an inch to one inch in length by means of a straw cutter which, according to the extent of the operations at the mill, is capable of turning out from 600 to 2,500 pounds hourly. The cut straw is freed from any grain, nodes or sand it may contain by means of a gentle current of air produced by a fan. The nodes of the straw do not contain any fibres and are very hard, being composed chiefly of insoluble siliceous matter. Consequently it is necessary to remove them so they cannot pass into the digesters as they absorb a good deal of soda, render bleaching difficult, stain the pulp and reduce its value. In some mills handling esparto and straw the material is charged into the digesters without being cut, but this is older and less efficient practice.

For boiling it is customary to use rotary horizontal or spherical digesters. Sometimes stationary vertical digesters are used. The spherical digesters are better than the cylindrical ones, as in the latter there is danger of the straw forming a compact mass unless special interior arrangements are provided, and these are trouble-

[1] Practical Paper Making, London, 1917.
[2] Includes cellulose.

some. One of these devices is a system of bars riveted to the wall, but repairs to these bars are difficult, and, moreover they interfere with loading and unloading the digester.

The usual capacity of the digesters is 2,000 pounds of cut straw. The straw is introduced through a manhole by manual labor, or else by means of a blower. The mass is then treated with caustic soda solution of from 10 to 15 per cent strength at a temperature of from 140° F. to 150° F. In the English mills the usual practice is to use 16 pounds of caustic per 112 pounds of raw material and to digest from one and a half to two hours at 40 pounds pressure. In American mills the pressures vary from 10 to 50 pounds, and the duration of the operation from one and one-half to five hours. The heat and pressure is supplied by the injection of direct steam.

When the boiling is complete, the digester is emptied. Sometimes this is done through a manhole and sometimes the pulp is blown into a washing machine similar to a beater where it is both beaten and freed from chemicals.

The further treatment of the pulp is practically the same as in the manufacture of soda pulp from wood, which is described fully in a subsequent chapter. The soda liquor is also recovered in the same way.

Esparto is sometimes pulped by a modified sulphate process, instead of by the soda process above described. In this way a pulp is made the value of which for high class printing and medium quality writing papers is well known. This material has qualities that cannot readily be obtained from other fibres such as rag and wood pulp. It is chiefly used in papers intended for lithographic printing, books, etc., and other purposes where a sheet is demanded which must have a good surface and yet be soft and pliable.

Straw Board.

The following is a description of the treatment of straw to make pulp for strawboard:

The straw is subjected to a cooking process with steam and milk of lime in large ellipsoidal rotary digesters. The digester is filled with straw and liquor, steam admitted, the mass cooked down and then more straw and liquor put in until the maximum capacity of the digester is reached. The final charge consists of about 6 tons of straw and 2,100 pounds of lime in the form of milk of lime. The mixture is then rotated under 40 pounds steam pressure for 12 hours. By this process the straw is reduced to a dark-yellow, pulpy mass. The yield of pulp is from 75 to 80 per cent of the original material. The stock from the digesters is stacked in pits and allowed to drain for 24 hours or more. It contains practically all the lime and about 50 per cent of water.

The stock is then placed in a washing machine, similar to that used in making rag pulp, only somewhat cruder in design. It contains a beater roll and bed plate and a revolving brass screen through which the water escapes carrying the lime in solution together with the finer particles of fiber.

After the washing is complete the stock is conducted to a kind of cylinder machine, similar to the cylinder paper machine described in another chapter, and formed into strawboard or pasteboard.

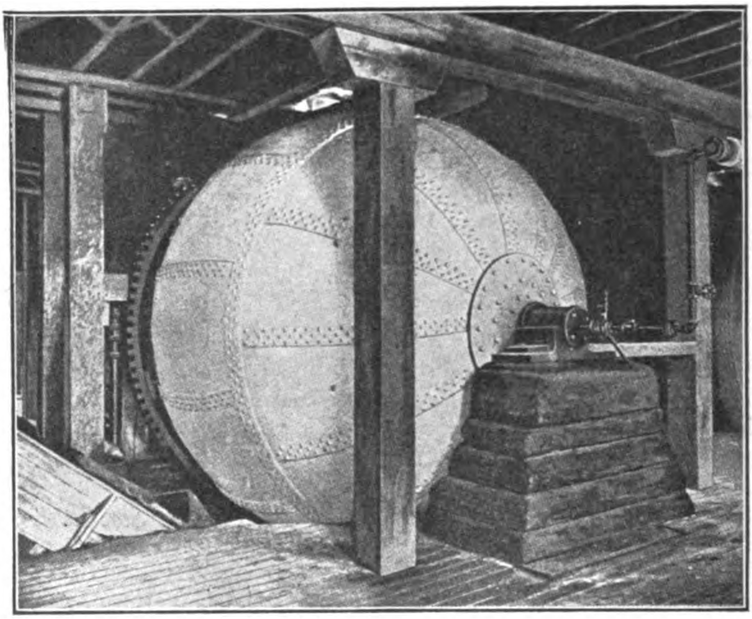


Fig. 1.—Type of rotary digester used in strawboard industry.

Bamboo.

The British have displayed great interest in bamboo, because there are in the British Isles no forests suitable for supplying wood for wood pulp, and consequently British paper makers have been somewhat more inclined than others to investigate new materials. In the British tropical possessions there are unlimited supplies of bamboo.

These investigations are of some interest in this country, as in the southern Atlantic states there are quantities of canes very similar to the bamboo that may have to be used for paper in the future.

As long ago as 1875 Rutledge[1] (who introduced esparto into England) advocated the use of bamboo. About 1906 R. W. Sindall made a very thorough invetigation of the subject for the

[1] Rutledge had his original pamphlet printed on paper made from bamboo.

British Government. Since then actual manufacturing operations have been carried on in India and in the Philippines.

The stems are cut in such a manner that the nodes are rejected. In India the cook is carried out at 60 pounds pressure for 10 hours with 30 pounds of 76 per cent caustic per 100 pounds of dry bamboo. Bleach is used in the proportion of 20 pounds per 100 pounds of pulp.

The bamboo has also been worked up in Burmah by the sulphite process at a cost of about $24.00 per ton, the yield being over 50 per cent and less bleach being required than with the soda process described above.

In the Philippines the soda process has been used, from 40 to 43 per cent of bleached fiber being obtained.

Paper made from bamboo is excellent for book and writing purposes. An interesting point about bamboo is the fact that once cut it grows again very rapidly. On a conservative estimate only about 16 square miles would be required to supply a 100-ton mill indefinitely. The chief reason bamboo has not been used more is that the lands where it is indigenous are so far from the great paper markets.

Jute.

Jute is received in the paper industry in the form of old gunny sacks and rope and also as jute cuttings, which are the parts of the plant rejected in making jute fabrics.

According to Müller raw jute fibre contains 63.76 per cent cellulose and the jute cuttings contain about 60.89 per cent.

Jute fibre is strong and suitable for many kinds of paper. It cannot be used in fine papers on account of the great difficulty in bleaching it. So much bleach has to be used to render it white that all advantage gained through cheapness in the original material is lost and also the strength of the fibres is weakened by the large amount of bleach.

Jute materials are generally boiled with lime, sometimes some caustic soda being added. The equipment used and the general conduct of the process are the same as described for rags.

Manila, Hemp, Etc.

Manila hemp is a fibre produced in the Philippines, which is of interest as being the original source of the class of papers known as Manilas, which are very desirable for wrapping and for other purposes, being very smooth, clean, soft and flexible, taking an excellent and characteristic finish, and being quite strong at the same time.

According to Müller Manila contains 64.07 per cent cellulose. Many of the Manila papers on the market today contain none of this fibre at all, being clever imitations.

Other varieties of hemp, such as Italian Hemp, Sunn Hemp, etc., are sometimes used as raw materials for paper, generally in the form of discarded fabrics or cordage. When hemp is spoken of, Italian Hemp (Cannabis) is usually meant.

Agave fibre, of which Sisal Hemp is one well known form, is largely used in rope and cord, and in this form it reaches certain types of paper mill. This plant is a native of tropical America.

Rags.

At one time rags formed the only raw material of paper. Of recent years the importance of this kind of paper stock[1] has steadily been decreasing, and with the more extensive use of other kinds of pulp only minor importance is attached to the preparation of rag pulp, in America, at least. However, at the present time rags to the value of about $12,000,000 annually are used for paper making, chiefly in the more expensive grades of paper, such as paper used for fine writing purposes, fine books, the printing of stock certificates, bonds, money and legal documents, etc., where fine finish and permanency are the object and where expense is not an objection, and (in the case of cheap rags) in such specialities as roofing paper, and consequently the subject merits some discussion.

The word "rag" is used to designate a very wide range of raw material for conversion into paper. The prices which various kinds of rags bring vary very widely according to their suitability for various kinds of paper. Naturally those rags which, with the minimum of treatment, constitute suitable raw material for the highest grades of writing paper, bring the best prices. The following table taken from one of the trade papers, shows how carefully this class of material is graded and the range of prices. It will be noted that white rags bring considerably more than colored ones, and clean rags more than soiled. Unsorted rags bring much lower prices than sorted rags because the paper maker does not want a mixture of old and new rags, clean and dirty, or white and colored in the same lot. They also must be sorted by materials. Cotton rags must not be mixed with linen or hemp, etc.

In the case of high class writing papers, only the best qualities are considered, such as new linen and cotton cuttings, or well sorted rags of domestic origin. However, the majority of rags used in the paper industry are more or less foul and require somewhat drastic treatment.

Sorting. The first operation involved is that of sorting, either done by hand or mechanically. Different materials are sorted from each other. Different colors are sorted out. Buttons, pins, etc., are removed. Notwithstanding the increased cost of sorting by hand, and the objection to it on account of the danger to the

[1] The term "paper stock" is applied in the trade to a large variety of materials used for making paper. It applies generally to waste material, whether paper, rags, cotton, linen, jute, hemp, flax or Manila. It may come in the form of new clippings from the fabrics made of the various fibres or old pieces of the same, or may come in the form of threads, strings, twines or ropes, or in the form of waste of various qualities, such as card waste, rove waste, washed flax waste, etc. Manufacturers of roofing and felt paper use many thousands of tons of such miscellaneous material each year, much of it being of foreign origin.

COMMERCIAL GRADES OF RAGS

From "The Paper Industry," June, 1920

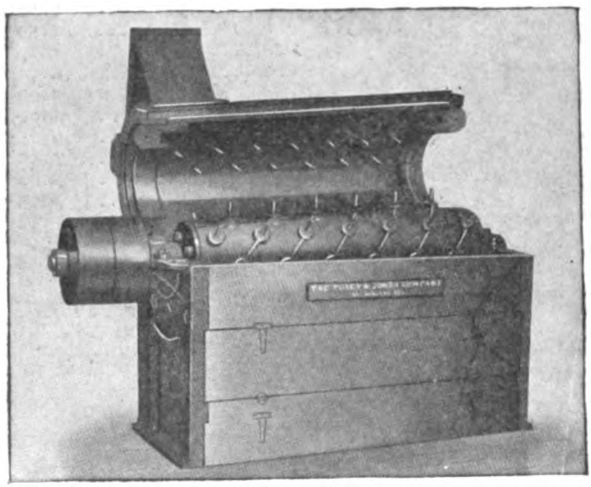
New Stock—	New York and Chicago
White shirt cuttings, No. 1	19.50–20.00
White shirt cuttings, No. 2	13.00–13.50
Fancy shirt cuttings	12.50–13.00
Washables, No. 1	10.50–11.00
Unbleached muslins	16.00–16.50
White lawns	17.50–18.00
Overall cuttings, blue	13.00–13.50
Black Silesias	7.50– 8.00
Old Stock—	
Whites, No. 1 repacked	14.00–16.00
Whites, No. 2 repacked	7.50– 8.00
Whites, house soiled	4.50– 4.75
Whites, street soiled	4.25– 4.50
Thirds and blues, repacked	4.75– 5.00
Thirds and blues, rough	4.00– 4.25
Black stockings	4.60– 4.80
Lace curtains	9.25– 9.50
Cotton canvas, No. 1	5.50– 6.00
White cotton batting	5.00– 5.25
Roofing, No. 1	3.25– 3.50
Roofing, No. 2	3.15– 3.25

health of the workers, this plan is generally conceded to be the best in the end, especially for the better grades of paper, as more thorough sorting and removal of impurities result.

Dusting. Following this operation of sorting and cutting, is that of dusting, which is done mechanically. One machine for doing this is a rag "willow," which takes the material to be treated through a hopper into a compartment where a revolving cast-iron cone, armed with spiral flanges bearing pins, passes it rapidly and regularly to the discharge opening. This process opens up the material, separates the dust from it and does this without such violent treatment as to cause injury to the fibres.

The case is of wood, with cast-iron ends containing the bearings. Tight and loose pulleys comprise the drive, which turns the cone at 300 revolutions per minute. Over the ends of the cone are the cast-iron collars of the lid, neatly fitting in order to prevent the escape of dust. In the center of the lid at the top is a steel plate containing pins which permit those on the cone to pass between, thus opening up the stock . Below the cone is a bottom of wire through which the dust sifts and is removed by swinging doors at the side. The floor space occupied by such a machine is about 3 feet by 6 feet.

Rag Thrashers are similar in effect to willows. One type of thrasher consists of a wooden case in which a horizontal octagonal drum revolves at a speed of about 120 revolutions a minute. This drum is armed on two opposite sides with heavy teeth bound by iron and filled with wood. These play between corresponding teeth which are planted in a beam fastened to the top of the case. Below the drum is a wire cloth, through which the dust falls as a combined result of thrashing the rags between the two sets of teeth and vigorously moving them over the wire itself. The drive consists of two loose pulleys, between which is run a tight one. Belts, giving right and left rotation, run upon the loose pulleys until either belt is moved to the tight pulley. One manufacturer of such machines states that, when attended by one man, one of them will thrash from 800 to 1,000 pounds of cotton rags per hour, and that the actual loss of weight from the time the rags are taken from the bale until they have passed through the rag cutters is 15 per cent.



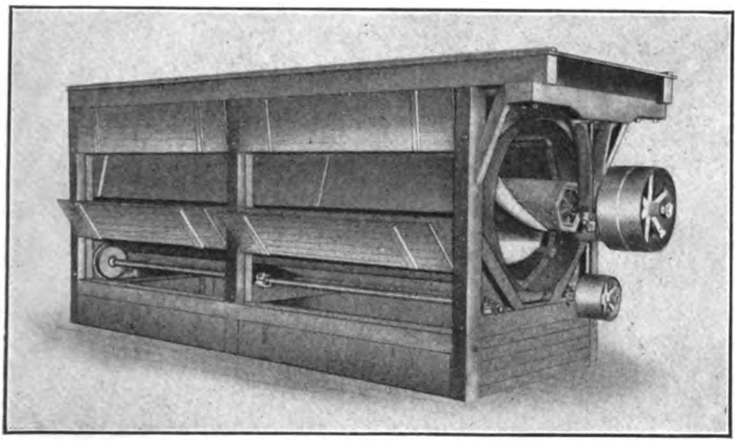
Courtesy: The Pusey & Jones Co., Wilmington, Del.

Fig. 1a.—Typical rag willow.

Rag dusters are generally built of hardwood boards firmly bolted together and reinforced at points of wear by iron castings. In the center is a wooden drum 15 inches in diameter, bolted to cast-iron spiders, which are in turn keyed to a shaft, designed to turn, by means of tight and loose pulleys, at 100 revolutions a minute. Fastened to the drum is a series of steel plates set at such an angle as to insure the traveling of the rags from the inlet to the discharge end. In doing so they are thrown open and blown free from dust.

Cutting. A rag cutter consists of an iron table bolted on the top of a heavy cast-iron stand. This table supports the bearings of the two driving shafts. To one of these shafts, driven by a tight and loose pulley, a cutter head is attached, which carries three fly knives firmly bolted within heavy cast-steel shoulders. At the other end of this shaft is a fly wheel to relieve the shock when cutting. The bed knife is contained in the table and is held by both adjusting and tightening bolts.

A separate belt, on a small pulley to the right of the operator, propels a series of gears which drive a drum studded with projections set in rows and staggered. This drum spreads the feed of rags to the knives and serves as a protection to the operator. It is carried on a curved frame, which may be lifted by the operator



Courtesy: The Pusey & Jones Co., Wilmington, Del.

Fig. 1b.—Typical rag duster.

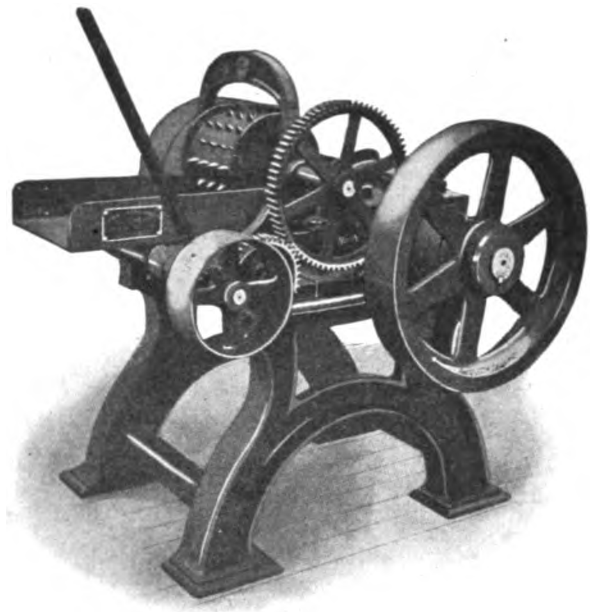
by means of a lever to ease the passage of rags, should they get choked in the feed trough.

The length of the rag cut may be controlled by a difference of speed imparted to the two belts.

Boiling. After all this mechanical treatment, the rags are ready to be boiled. The boiling is usually done in vessels of steel plate which may be of spherical, cylindrical or vomiting types. The object of the boiling is to remove the grease and dirt and by means of the high temperature, the agitation and the chemicals used, bring the rags into such condition that the impurities can readily be removed by washing, leaving fibre suitable for paper.

The rotary boilers commonly employed are of cylindrical readily be removed by washing, leaving fiber suitable for paper. The trunnions are of cast iron or steel and are firmly attached to the boiler by large flanges, in some cases these flanges serving as the head of the boiler. The trunnions are hollow for the admission of steam. Manholes are provided for filling and emptying.

In some cases ribs or projections are arranged around the inside to prevent the stock packing against the sides. The boilers are supported on steel, masonry or wooden supports, as may be

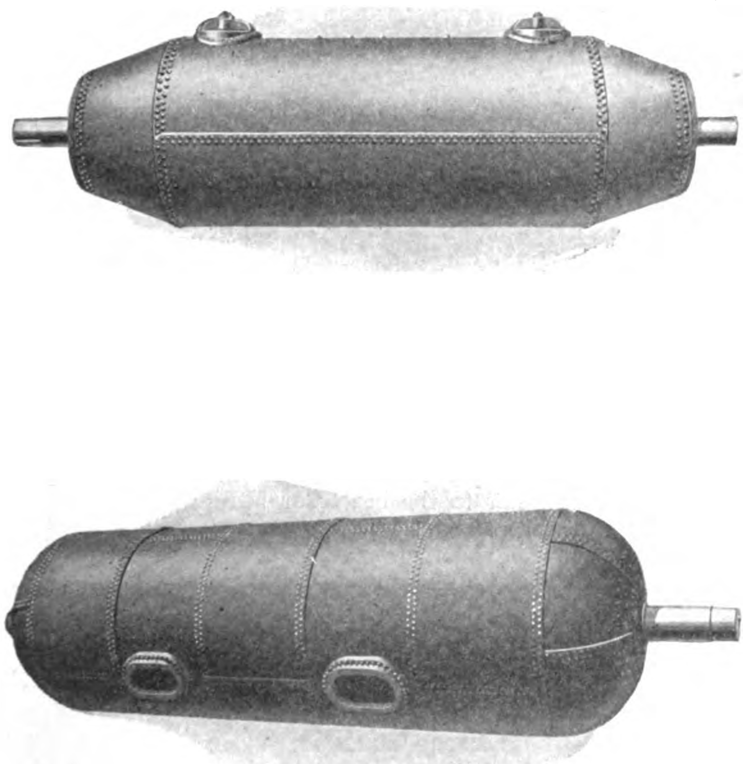


Courtesy: The Pusey & Jones Co., Wilmington, Del.

Fig. 1c.—Rag Cutter.

required and are driven by means of worm gearing countergeared to suit conditions. The usual speed at which they rotate is from 1/3 to 3 revolutions per minute. The usual sizes are from 6 by 10 feet (capacity 270 cu. ft.) to 8 by 24 feet (capacity 995 cu.. ft.). The internal pressures used vary from 60 to 120 pounds.

The chemical usually added in America is milk of lime. In England caustic soda is chiefly used. The lime forms soaps with the grease in the rags and is not a sufficiently strong alkali to damage the fibre as soda is prone to do. Sometimes a little soda is added to increase causticity of the solution. In some cases, rags are boiled with soda alone, but this is unusual. The usual practice is to fill the rotary about two-thirds full with rags and milk of lime and run for from twenty minutes to half an hour before steam is admitted. The lime used for this purpose should be ascertained to be free from iron before being used as iron will discolor the stock, and should also be free from gritty material such as sand and coal dust. The amount of lime used varies. About 15 per cent of lime based on the dry weight of the rags is quite a usual proportion but as high as 20 per cent and some-



Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 2.—Two typical rag boilers.

times as low as 4 per cent is used. The higher grades of rags require less lime and also lower temperature and pressure and a shorter boiling period. However, this also depends largely on the kind of paper being made. Conditions have to be determined by experiment at each mill.

Various practices prevail with regard to emptying the rotaries. Some operators relieve all the pressure before removing the stock. Others blow off under pressure just as in a sulphite digester. This latter procedure is hard on the stock, but it is claimed it gets rid of more dirt.

The rags are generally drained on draining floors or in shallow pits. Sometimes they are let stand some days after boiling to soften.

A device known as a Mather Kier is frequently used for rag boiling, especially in England, instead of a rotary boiler. It consists of a sort of tank into which cars can be run containing the rags. There is a device for spraying the hot liquid over the rags. The advantages claimed are saving in steam and floor space, improved quality of fibre and saving in quantity of water used for washing.

Vomiting boilers are sometimes used. These are cylindrical stationary tanks in which the steam is conducted to the bottom through a pipe which enters through the top of the boiler. This steam forces the liquid which has collected beneath a false bottom upwards, through a vomit pipe surrounding the steam inlet, and it is sprayed over the stock by a spreader. There are manholes for filling and emptying and a safety valve. This is quite like the ordinary domestic coffee percolator.

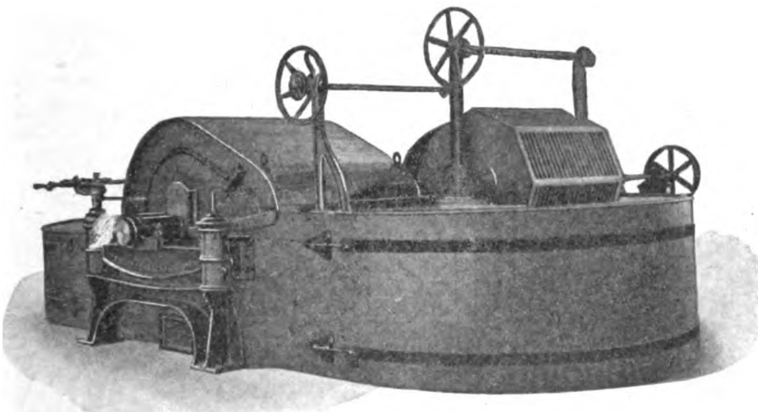
Washing. Following the boiling of the rags comes the washing to remove all alkali used in the cooking, as well as all dirt and greases that were loosened during the chemical treatment. This washing is usually performed in a rag engine or Hollander. This machine is similar to the beater or beating engine (which is described in detail in Chapter XII) except that on the side of the midfeather opposite the beater roll is a revolving cylinder or octagon covered with wire cloth. This permits the wash water to run through but keeps the fibres in the machine. There may be more than one of these cylinder washers; in some machines as many as four or five are used. Sand catchers are usually inserted in the base of the engine in front of the roll to catch dirt, buttons, etc., in the stuff. In this way the machine serves not only the purpose of a beater, breaking up the bundles of fibres and drawing them out, but also permits all alkali and impurities to be carried away with the wash water. In some mills machines are used having a paddle in place of a beater roll. This propels the stock around the machine but does not break up the fibre bundles or brush out the fibres, all of this work being left for the regular beaters in which the stock is placed after bleaching.

The clean, washed and disintegrated rag stock is now bleached, either by means of bleaching powder or electrolytic bleach (bleaching will be dealt with fully in Chapter XI), after which it is thoroughly washed to remove any excess of bleach remaining.

The rag stock at this point is known as "half stuff," and, in order to convert this half stuff into paper, it must be further treated in beaters or beating engines to obtain a complete separation of the fibres into single units and to stroke out the fibres so they will felt and form paper, as explained in detail in Chapter XII.

Bagasse.

Of all the different materials investigated during the last few years, during which period millions of dollars have been spent to advance the art of cellulose utilization, few materials have received more attention than bagasse, the residue of sugar cane after the juice has been pressed from it.



Courtesy: Dowingtown Manufacturing Co., East Dowingtown, Pa.

Fig. 3.—Hollander or washing engine, as used in manufacture of rag paper, showing cylinder washer.

Before the introduction of a process whereby this waste could be utilized for paper pulp it was piled and burned in the furnaces of the sugar mills. It has been found that the bagasse contains fibres of a high quality suitable for many grades of paper. The sugar cane stalk is largely composed of two constituents, fibrous cellulose and non-fibrous cellulose in about equal parts. A process is now being investigated whereby these two constituent parts can be separated mechanically and the fibre treated chemically either by the soda or the sulphite process. Bagasse boards are manufactured in Louisiana by the Lee process in which the bagasse is digested with a liquor prepared by treating low grade molasses from the sugar mills with lime, its principal constituent being saccharate of lime. The boiling causes a hydration of the non-fibrous cellulose which toughens it and thus makes it possible to make pulp out of material that really hardly contains any fibers at all, the cells of the non-fibrous cellulose being too short to correctly be called fibres.

Interesting experiments have also been carried out on making semi-transparent, glassine and parchment papers from bagasse by utilization of this hydration effect.

Waste Flax Fibre.

Some work has been done on the utilization of this material for paper. The fiber would be of excellent quality for making high grade papers, provided that it could be obtained entirely free of seeds which make grease spots in the stock and defects in the paper. Up to date this has been the chief obstacle. It has been estimated by the U. S. Government that sufficient of this material is now wasted annually in the Northwestern States to make 480,000 tons of good paper.

In connection with the above remarks on various of the new materials proposed for paper, the following table[1] may be of interest:

ESTIMATES OF WASTES SUITABLE FOR PAPER MAKING PRODUCED ANNUALLY

Material	Waste		Yield of Paper (Tons)
	Quantity (Tons)	Value $	
Waste textiles suitable for papers of the highest quality and strength	1,000,000	20,000,000	800,000
Flax fiber suitable for the best and strongest paper	600,000	18,000,000	480,000
Forest waste from lumber industry suitable for medium and low grade paper	[1]12,000,000	60,000,000	5,000,000
Waste paper suitable for high quality and lowest quality	1,000,000	10,000,000	900,000
Cereal straws suitable for medium quality paper and boards	70,000,000	350,000,000	28,000,000

[1] Cords.

Waste Paper.

According to U. S. Government statistics more than 6,000,000 tons of paper are now made annually in this country, of which fully 80 per cent, or 4,800,000 tons, becomes waste material in three or four years. Of this, about 25 per cent, or 1,200,000 tons, is again used in the form of cuttings and trimmings and old paper for making new. While there must always be some waste impossible to recover, with proper precautions a much larger percentage could be recovered than is now the case. The recent war has given a considerable impetus to the saving and utilization of waste paper.

Not all waste paper is suitable for the manufacture of high

[1] U. S. Department of Agriculture, Bureau of Chemistry. Circular No. 41

grade papers, such as book, but almost all of it can be worked up into some kind of wrapping, cover or blotting paper, building paper, boards, etc.

The principal difficulty in getting satisfactory results in an attempt to substitute waste paper for chemical or mechanical wood pulp consists in the fact that the equipment of the average mill does not lend itself readily to such substitution. Beaters which are most efficient in treating rags, bagging, rope, sulphite, etc., are not well adapted to the treatment of waste paper. It must be borne in mind that waste papers have all been once, at least, through the process of manufacture of paper. Hence, it is only reasonable to assume that such grinding, beating and brushing as may have been necessary to produce the best results have already been applied to the fibres and that a repetition of the process cannot help but have a tendency to unduly shorten the fibres and weaken the resultant sheet.

Treatment of Waste Paper.

The papers when received at the mill have to be sorted. This should be done in a light, well ventilated room; light being necessary if the papers are to be properly sorted and all dust having to be carried off by exhaust fans to preserve the health of the workers. The paper is received in bales. The foreman who receives should be an experienced man who can tell at a glance if the bale is not up to grade so it can be rejected before it is distributed in the sorting room. The sorters are usually payed at the rate of so much per hundred pounds, which makes for efficiency, and with practice they become wonderfully adept at this work. If the grades of bales received contain mixtures of a great many kinds of paper, it is generally necessary to pay the sorters by the day, as sorting of this kind of stock goes very slowly.

There are certain standard classifications for waste paper stock which have been decided on by the biggest firms in the business of handling this material. These grades are:

No. 1 Book and Magazine Stock. Such stock must be free from ground wood paper, parchment paper, leather or cloth book covers, magazine covers of highly colored paper, school paper, paper shavings, photogravure paper and books with burnt edges. Certain of the cheaper magazines will not be accepted as No. 1 stock, such as "Popular." "All Story," "Blue Book," etc. Cheap novels, telephone directories, mail order catalogs, are all excluded from this class. Thick books, like Dun's Agency books, must be ripped apart into sections the size of an ordinary magazine.

Ledger Stock. Consists of high class writing paper, account books, ledgers, letters, checks, bonds, insurance policies, legal documents, etc., but such material must not be torn into little pieces. Ledgers, etc., must be free from covers. Postal cards, school books, telegrams, envelopes, tissue paper, copying paper, manila, highly colored paper, bills of lading, etc., will not be accepted in this class.

Mixed Paper Stock. Consists of all kinds of clean, dry paper from office, schools, etc. For instance, wrapping paper, cardboard boxes, pamphlets, telephone books, magazines not good enough for No. 1, envelopes, paper torn into little pieces, crumpled newspapers, etc. Must be free from rubbish, string, leather, rags, cloth book covers, wire, wood, etc.

Newspaper Stock. Clean, folded newspapers. No crumpled newspapers, pamphlets, etc.

These grades are further subdivided by speaking of "Extra No. 1," etc.

Prices of such material fluctuate very rapidly. The following table, taken from "The Paper Industry" for June, 1920, will indicate how this material is quoted on and roughly what is the range of prices. The prices are in cents and fractions thereof per pound.

	New York and Chicago
Hard white shavings, No. 1	6.75–7.00
Hard white shavings, No. 2–3	5.50–6.25
Soft white shavings	6.00–6.25
Colored shavings	2.50–2.75
Heavy book, No. 1	3.70–3.80
Crumpled, No. 1	3.00–3.25
Ledger stock	3.80–4.00
Kraft, No. 1	4.00–4.25
Manilas, No. 1	2.40–2.60
White blank news	4.25–4.50
Overissue news, No. 1	2.30–2.40
Folded news	2.00–2.10
Mill wrappers	2.00–2.15
Box board cuttings	1.90–2.00
Mixed paper, No 1	1.80–1.90
Common paper	1.10–1.20

The old process of working up waste paper consisted in pulping the paper in a beating engine, after which the stock was placed in agitators where it was treated with caustic soda and finally thoroughly washed, drained and furnished to the beaters along with other grades of stock to form new paper.

Another process used what were known as "bleach tanks" although such equipment was never used for what could properly be called bleaching. These tanks were large, cylindrical, steel plate tanks, provided with a false bottom perforated with small holes. In the center is a vomit pipe, the top of which is equipped with a baffle plate, to spray the cooking liquor over the papers. The papers were charged into the tank through a chute. The liquor consisted of caustic soda solution about 2.1° Be. at 180° F., that being the temperature at which the cook is conducted. The liquor sprays over the papers in an intermittent manner, like an ordinary coffee percolator. With this process it is stated that 1,750 pounds of caustic soda will cook 6,000 pounds of waste paper stock. The cook requires from 5 to 15 hours, according to conditions. The charging of the tank requires from 1½ to 2 hours. Longer cooks produce better results, about 10 hours being generally very satisfactory. This system is very wasteful of steam. Covered tanks have been tried, but without much success. When the cook is completed the papers are removed by a hoisting device, operated by a motor. The cooked paper is forked into cars or onto a conveyor. This work requires the services of two men for two hours for each tank. The work is very unhealthy and disagreeable. From the cooking tank, or "bleach tank" as it is called, the papers are taken to washers, which may be either chests with agitators, or else Hollanders fitted with paddles instead of beater rolls. Sometimes the papers go first, by means of a conveyor to an agitator, in which they are pulped sufficiently fine that they can be pumped with a fan pump to the washers. The pipe leading to the washers is arranged in a continuous loop so that the stock will always be in circulation and no clogging will result, the feeders to the washers being led off from this system at intervals.

The above methods are wasteful of steam, floor space, labor and chemicals. Moreover, they tend to disintegrate the stock much more than is necessary for stock which has already once been through the process of paper making. They are gradually giving way to more modern, efficient and economical methods.

Improvements in Treatment of Waste Paper.

Efforts towards improvements in the treatment of waste papers might be classified into three general divisions, which are, in what seems to us to be the order of their importance:

(1) New pulping or defibering devices.

(2) Improved washing devices designed particularly for the treatment of pulp made from waste papers.

(3) New chemicals to be used as detergents to take the place of caustic or soda ash.

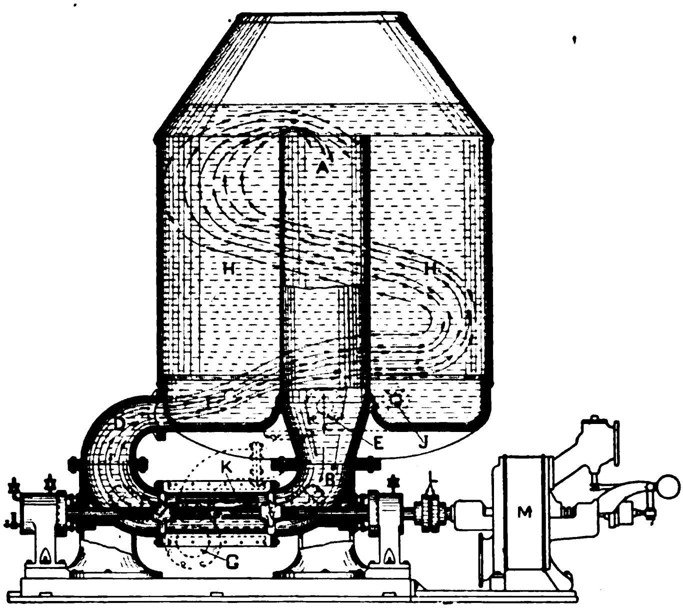
During the last few years several machines have been placed on the market for working up waste papers, for which the inventors make various claims. Some of these machines are designed to be used merely to give the papers what might be called preliminary treatment. Such machines break up the books, or large bundles of paper which are fed into them, and thus prepare the material for further mechanical refinement and complete defibering.

Another class of pulpers consists of those which, while designed to pulp the papers so that they are ready for the Jordan, or possibly for the paper machine, are not intended to do more than this. In other words, it is not claimed that they are designed to liberate the ink or color, both of which remain in the pulp and are not capable of being liberated except by special treatment.

Still another type is on the market for which the inventors claim not only pulping and de-fibering qualities, but also that the action of the machine in connection with the use of a suitable detergent, will liberate the ink and color during, and coincident with, the process of de-fibering.

Winestock De-Fibering and De-Inking Process.

It is claimed for the Winestock De-fibering and De-inking Machine and Process that, in addition to reducing the papers to a single fibre unit without appreciable shortening or weakening of the fibres, the same operation also liberates the ink and color from the fibres, so that by thorough washing the fibres are restored to the color of the original pulp before coloring matter ever was added. It is also claimed that this result can be obtained whether the papers contain ground wood, or are completely free from it.



Courtesy: Castle, Gottheil & Overton, New York.

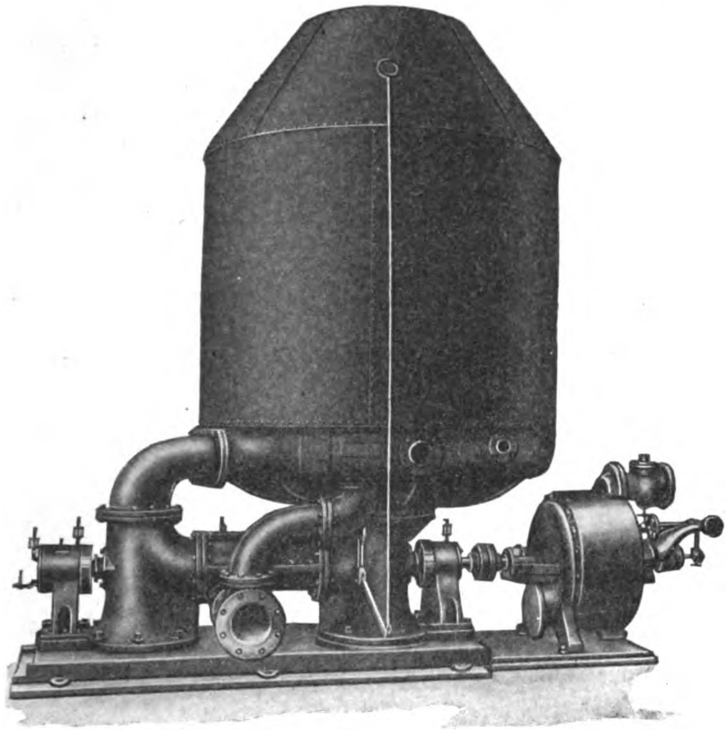
Fig. 4.—Vertical cross-section of Winestock de-fibering and de-inking machine, showing circulation of stock.

Most black printing ink consists of a suspension of finely divided carbon (lampblack, carbon black, etc.) in some oil such as pine oil or linseed oil. After the type has transferred the ink to the paper, some of the oil evaporates and the remainder is absorbed by the paper, holding the carbon with it. As carbon is not affected by any bleaching agents, the only way to get rid of the black color is to loosen the mixture of oil and carbon from the fibres so the carbon will fall off during the washing. Alkaline material, such as soda ash, will break up the oil and free the carbon and will also attack the rosin with which the paper is sized, which also helps in the removal of the ink.

Consequently, the de-inking and de-fibering of waste paper is a process which combines chemical and mechanical effects.

The principle involved in the Winestock machine is novel, being what the inventor terms "an Inertia Process."

The de-fibering action is performed by two propellers revolving rapidly—about 2,000 revolutions per minute—so that the



Courtesy: Castle, Gottheil & Overton, New York.

Fig. 5.—Winestock de-fibering and de-inking machine.

water is unable to take up the rotary speed of the propellers and in consequence there are always two opposing factors—the speed of the propeller and the inertia of the liquid stock.

A simple illustration of this principle could be obtained by floating a flat sheet of paper in a vat of water and then striking the floating paper a sharp, quick blow with a wooden lath, a switch or a straight piece of wire. The inertia of the floating paper could not be overcome quickly enough for it to follow the course of the striking object and the result would be a *cleavage*—not a *cutting*—of the paper.

This describes the action of the propeller blades on the paper floating in the liquid. This action is facilitated by the soda ash or other detergent used, which softens the size in the paper as well as the binder in the ink. The rapidly moving propeller blades, while disintegrating the paper into single fibre units are, at the same time, knocking the loosened ink and color from the fibres themselves, thus accomplishing the de-fibering and de-inking at the same time, as before mentioned.

A novel and effective method of circulation is provided, whereby the pulp, after passing through the propeller tube, is discharged tangentially into a large circulating tank, entering the tank at the bottom and working to the top with a spiral motion. At the top it cascades over into an upright cylindrical tank which, in turn, leads the stock again to the propeller tube.

The circulation is very active and continues until the paper is thoroughly de-fibered.

Softening tanks should always be used in connection with this machine, as they enable the machine to complete its work in appreciably shorter time.

A type of softening tank that has been found to work very satisfactorily consists of an upright chest with a perpendicular shaft running through the center. In place of the ordinary agitators two sets of fans are bolted to the shaft with the blades so pitched that the mass is thrown upwards. One set of fans (there are two blades to each set) operates at the bottom of the tank with just room enough for clearance, and the second set is located midway between the top and the bottom. The speed of the shaft is 25 revolutions per minute.

In some cases "breaking up" engines are being used with excellent results and this method is especially good where solid stock is used such as solid ledgers, telephone books, etc., which may be fed into such a machine without first tearing the books apart.

Books and magazines to be manufactured into white paper require from 35 to 40 minutes of treatment, while hard-sized paper containing writing, printing, engraving, etc., requires a somewhat lengthier treatment to obtain most satisfactory results.

The machine holds from 700 pounds to 900 pounds of dry papers at a charge, and the average production ranges from 12 to 15 tons per 24 hours. From the Winestock machine the papers go to a washer and then follow the usual process of manufacture.

Owing to the fact that the paper is completely de-fibered and the color and ink thrown into a solution or emulsion in the water, the pulp washes more quickly than stock treated by rotary or open bleach. The mass as it comes from the Winestock machine has an entirely different and more satisfactory appearance than the product of the rotary or open bleach.

Book papers, for example, instead of being brown or nearly black, give a grayish colored pulp. If this pulp be thoroughly washed on a small hand screen, the individual fibres will be found to be as white as the original paper from which the pulp was made. Under actual mill conditions the ordinary washing engine does not give the stock the proportionate amount of flushing and agitation that is obtainable by hand washing, and it may be found necessary to use a small amount of bleach to tone up the color. This is, however, more a limitation of the washing engine than of the de-fibering machine itself, for the hand washing shows conclusively that the fibres are in no way discolored. It is asserted that this result is obtained because the mechanical action of the machine, and the principle involved, enables it to accomplish its work in the shortest possible time, with a minimum amount of chemicals, and at a low temperature—from 160 degrees to 190 degrees Fahrenheit.

It seems only reasonable to assume that, inasmuch as the ink and color are actually knocked off the fibres and into the water, that the result would be a pulp that would require less washing than would be the case if the ink and color were cooked into the fibre during a treatment lasting several hours, or kneaded in by the action of an ordinary pulper.

In addition, the violent scrubbing to which the fibres are subjected in the soapy, alkaline liquor is a big factor in producing bright, clean pulp.

III. Varieties of Paper.

The art of paper making having been known for over 1,800 years, naturally paper has come to be used for a great variety of purposes, and as the uses for paper have broadened, there has come to be a corresponding specialization in the kinds of paper manufactured for these various uses.

The following tabulation of the Pulp and Paper Industry of the United States was made by S. L. Wilson, Chief of the Manufacturing Section of the Pulp and Paper Division of the War Industries Board:

There were (in 1918) 821 pulp and paper mills in the United States producing annually about 5,658,000 tons of paper and boards. Classified according to general grades, these are divided as follows:

	Tons Yearly	Production Daily	Approximate Value
Newsprint	1,360,000	4,200	$136,000,000
Book[1]	780,000	2,600	125,000,000
Boards	1,950,000	6,500	156,000,000
Wrappings	705,000	2,350	89,000,000
Fine Writings	405,000	1,360	142,000,000
Tissue	132,000	440	27,000,000
Building Felts	249,000	830	50,000,000
Miscellaneous	177,000	590	55,000,000
Imported from Canada—(Newsprint)	560,000	1,840	
	6,218,000	20,700	
Exported—(6 months actual)	147,875		
Yearly—(6 months estimated)	147,875		
Total Domestic Consumption	5,922,250		

1 Book paper totals in government statistics include practically everything used for printing purposes except the newsprint. The periodicals would use the larger proportion of this 780,000 tons, and circulars, bulletins, catalogs, government reports and job printing of every description the balance. Books in bound form probably do not use over 5 or 6 per cent of this total of book paper.

Writing and Book Paper.

The different kinds of paper are made by using different kinds of raw stock and varying the processes to which this raw stock is submitted.

One of the oldest and most important branches of the paper industry is that involving the manufacture of writing, book and high grade printing papers. The properties of papers of this type are such as to exhibit the following main characteristics:

(1) An even, uniformly closed sheet.

(2) A soft, strong, pliable sheet.

(3) A high finish with an even bulk.

To obtain the above characteristics, specially prepared pulp must be used. The ideal fibre is one which retains its original length, strength and elasticity as completely as possible after having been prepared into "half stuff," i. e., after the cooking and bleaching processes are finished. The pulp must be an easy bleaching stock, or otherwise a hard, brittle fibre will be produced with very poor felting qualities and the resulting sheet will be unsatisfactory no matter what precautions are taken later on in the beater room and machine room.

Book paper is chiefly made from rag (cotton and linen) pulp, sulphite and soda wood pulp and, in the cheaper grades, some ground wood, all of which are bleached. Esparto pulp has also found a wide application in the manufacture of medium quality book papers and writings.

In addition to the various combinations of stock that may be used in the making of book paper, loading materials must be added to the extent of from 10 to 15 per cent, so as to make the paper more absorbent and opaque, and to enable a clear print to be made. Such materials also lessen to a large extent the friction when the paper and type come in contact during the printing. In selecting the loading materials a number of considerations have to be kept constantly in mind.

First: The chemical nature of the substance itself must be examined. Any substance containing free acid or chlorine compounds cannot be used.

Second: A finely graded material, of uniform consistency, free from sand and grit is necessary.

Third: The material must be of such a color that it will not interfere with the shade of the finished paper.

Kaolin, or clay,[1] is the chief substance used for loading book paper. It fills up the pores of the paper, giving a sheet of closer texture that will take up ink rapidly and it enables a high finish being obtained in the calenders.[2] Papers requiring a higher finish than is possible to achieve with the machine calenders are generally finished in supercalenders,[3] where the high pressure and the contact between the upper metal and the bottom paper-covered rolls has the effect of imparting a velvety surface necessary for illustrated work where halftones are used and for the finer sorts of printing.

The highly surfaced papers on which some books are printed, especially when fine half-tones have to be brought out, are known as coated papers. The preparation of such papers is a line of in-

[1] See Chapter XII for full discussion of use of clay.
[2] See Chapter XIII for construction and operation of calenders.
[3] See Chapter XIV for construction and operation of supercalenders.

dustry really separate from the manufacture of paper, but a few words of description may not be amiss at this point.

The solution with which the paper is coated is usually composed of clay or talc suspended in a sort of size made of casein, starch or some other adhesive. Blanc fixe (barium sulphate) and various special white substances such as "paper-makers' white," "satin white," etc., are sometimes used instead of clay.

The rolls of paper received from the paper mill are unwound and pass over rollers where one side comes in contact with a brush device which applies the coating liquid. There is a system of other brushes to distribute evenly the coating, after which the coated sheet is suspended over a series of wooden bars borne by traveling chains at each end so that it hangs in a series of festoons

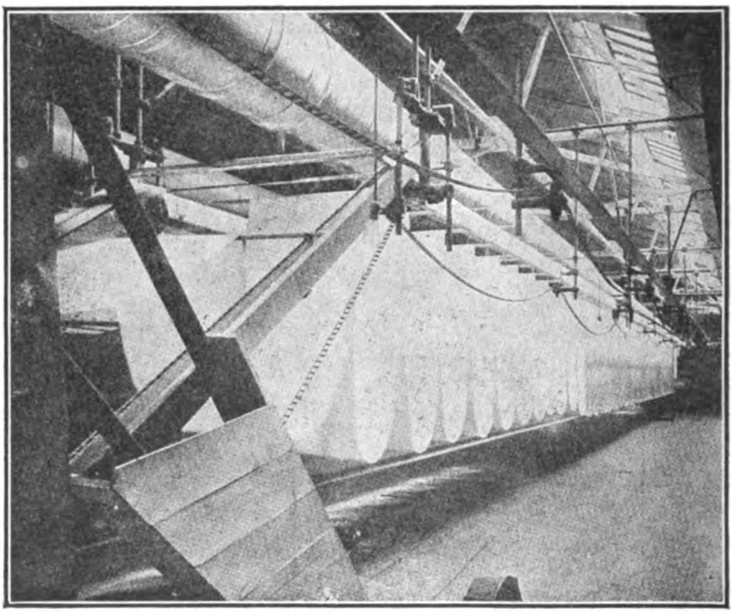


Fig. 6.—Interior of coating mill showing festoons.

while drying. This equipment is of sufficient size that several hundred feet of paper are exposed to the air at one time, with the result that by the time the end of the system is reached the coated side is sufficiently dry that the paper may be rolled up. Sometimes it is run back through the machine to coat the reverse side. Other machines have been devised which coat both sides in one operation. After the paper has been coated and dried it is run through various calendering machines to produce exactly the finish desired and is then rolled or cut into sheets for shipment.

Grades of Book Paper.

According to the U. S. Government Report on the Book Paper Industry[1] Book Paper is a general term designating roughly all of the grades of printing paper except newsprint. The chief distinction between book paper and newsprint is that the former is made chiefly of chemical pulp while the latter consists mainly of mechanical pulp. Standard newsprint consists usually of about 80 per cent mechanical pulp and 20 per cent sulphite. Between standard newsprint and book paper there are various intermediate grades containing more or less ground wood and known as half-tone news, special news, novel news, catalog news, etc.

The principal grades of book paper are machine finish (M. F.), sized and supercalendered (S. & S. C.), coated, and cover. The difference in the first three grades lies mainly in the finish given the paper. This book, for instance, is printed on sized and supercalendered paper. Cover paper is a strong, heavy grade, and is usually coated. It is used mainly for the covers of magazines, catalogs, etc. Within each of these grades there are numerous variations in the specifications for size, weight, color, etc.

Machine finish book paper goes through practically the same manufacturing process as newsprint. It receives no finish but that given by the calender rolls at the dry end of the paper machine. Some variation in finish is possible, however. Such variations are laid, wove, English finish, high bulk, eggshell, etc. The term *"laid"* denotes certain markings in the sheet consisting of prominent vertical watermark lines some distance apart and somewhat smaller horizontal lines much closer together. *"Wove"* is ordinary machine finish with fine, almost imperceptible, equidistant markings. *"English finish"* denotes a dull surface with a velvety feel. *"High bulk"* is a thick, blotter-like paper, soft and not much compressed. *"Eggshell"* is a rough finish in imitation of the texture of an egg shell. These different finishes are made by watermarking, by rollers of different design which press on the paper while it is still moist, and by variations in the pressure applied at the calenders. Machine finish paper is used largely by publishers of books and for trade catalogs, etc.

Sized and supercalendered paper is machine finished paper which has undergone an additional process of sizing and calendering to give it a high finish. This is the paper most used for the higher grade of illustrated magazines and also for trade catalogs, advertising literature and many books.

The uses of book paper are not confined to the printing of books, magazines and catalogs, etc. It is used for cheap writing pads and school exercise books, for wrappings for soap and pharmaceutical products, and for lining and covering paper boxes. Very fine papers for money, stock certificates, etc., are made in mills where the most extreme precautions as to boiling, washing,

[1] Senate Document No. 79, 1917.

bleaching and beating are exercised. Quantity production is no object, small size equipment is used, and time and attention lavished on each process.

Writing Paper.

The manufacture of writing paper calls for about the same requirements as book paper. However, in writing paper special watermarks, engravings and finishes are more generally applied. The one usually called for is linen finish.

Linen Finish: This effect is made only on high class work. The paper is taken from the machine in a moist condition in the form of sheets. It is then hung up on poles to dry in a drying loft, where it is usually kept for about 24 to 30 hours. When taken from the loft the paper must still be a trifle damp in order that the impression of the linen may be more easily taken. The paper is now ready to receive the linen finish, which operation is conducted on plate rolls operated under great pressure. A sheet of the best grade of linen is placed upon a sheet of heavy tin. Then a sheet of paper is placed on the linen, followed by another sheet of linen, and so on until a pack of sheets of tin, linen and paper is made about 4 inches thick. This pack is then run through the plate rolls and the paper receives the imprint of the linen.

Wrapping Papers.

Wrapping papers are made from various combinations of Kraft, sulphite, ground wood and waste paper. Frequently sulphite screening stock[1] is used in conjunction with the above materials. Jute and various combinations of jute and inferior stocks have had a wide application in the past but such materials are now being supplanted by Kraft wrappers.

Kraft wrapping, although a variety of paper still in its infancy, is leading all the other combinations for wrapping heavy bundles. As a result of the great strength of its fibres and their flexibility and compactness, a wonderful sheet can be made for this kind of service.

Depending upon the specific service that is to be required of a wrapping paper, there are many modifications that can be made in the furnish used to make up a desirable paper. It is not desirable to incorporate mechanical wood pulp in a wrapper of heavy weight that is going to encounter hard usage. As a result of the shortness of the fibres in such paper, and their weakness, it is devoid of all flexibility and strength. However, such combinations (colored up to resemble the true Kraft color) are often sold as Kraft wrappers.

A variety of pulp that at one time made a very good imitation of Kraft is the so-called *"brown wrapper."* This was made from pulp obtained by steaming the wood at a high temperature, thus

[1] For origin of sulphite screenings see Chapter VI.

softening the fibre to a certain extent, and then grinding by the regular mechanical process. The wood is thus easily ground and yields, a pulp containing long fibres, which, in their physical properties, closely resemble those of pure wood cellulose. However, all the original constituents of the wood besides cellulose are present, chiefly lignins, and these are almost unchanged, as in the mechanical pulp. Such paper has been almost entirely replaced by Kraft, and mixtures of Kraft and sulphite and other combinations.

Another well known form of wrapping paper is the so-called "*Butchers.*" The prime requisite for such papers is sizing quality. They must be so sized as to stand what is known as the "blood test." This is a test devised to determine the resistance of the paper to blood, as such papers are intended for the use of butchers in wrapping meats. These papers are ordinarily made by using 60 per cent sulphite and 40 per cent ground wood in the unbleached state. Nearly all these grades are given a slight water finish which tends to raise the sizing of the sheet. The standard weight on such sheets has been taken at 40 pounds, 24x 36 inches, 480 sheets to the ream. There are, however, some manufacturers making weights both above and under the above weight.

Manila papers have also obtained considerable importance in the wrapping paper field. Such papers were originally made from pulp prepared from Manila rope,[1] but the term is now applied to papers made from sulphite and ground wood and colored to imitate the characteristic Manila shade. One of the essential features of a good Manila sheet is cleanliness. In order to obtain this quality many manufacturers apply special screening devices so as to get good stock quite free from dirt specks and uncooked shieves. A careful examination of Manila sheets made throughout the country would lead one to the opinion that there are many different ideas as to what kind of a finish is suitable for a first class Manila sheet. It is generally conceded, however, that a high steam finish is mainly to be desired. This gives a soft, flexible sheet, which, when crumpled up, will give one the impression of a silky feel.

Cutlery papers are required to show complete freedom from chemical residues which would tarnish the polished metal goods which are wrapped in them. The residues most likely to be present are sulphur compounds and these may easily be tested for by warming the paper with dilute acid in a test tube, holding a slip of filter paper dipped in lead acetate across the mouth of the test tube and noting whether or not the paper saturated with the lead acetate solution is blackened. If it is blackened it indicates the presence of sulphur in the paper being tested. Acidity in cutlery wrapping papers is also highly undesirable.

The papers used for packing small goods, such as silverware

[1] See Chapter II.

and other delicate articles, are generally tissues, the better qualities of which are made from sulphite and rag stock. Such papers must also be entirely free from sulphur and acidity which would have a damaging effect on silver and other fine metal articles.

Tissue and Cigarette Papers.

These papers constitute a distinct class on account of their extreme thinness. They cannot well be made on ordinary paper machines as the web of paper has not the necessary strength to carry across from one part of the machine to another, and must, at all times, be supported on a felt. Also, being very thin, they do not need as much pressing and drying as ordinary paper, one set of press rolls usually being sufficient. The Harper Fourdrinier machine is excellent for such papers. This machine will be described in detail in the chapter on the machine room. The drying part of the machine is frequently equipped with a Yankee dryer, which will also be described in the chapter on the machine room. Special devices are used in many mills for imparting crêpe finish to tissue papers. These are like calenders with corrugated rolls. The extended use of paper towels has led to the development of special papers resembling both tissue and blotting in qualities.

Cigarette Paper: Cigarette paper is best made on a Harper Fourdrinier or a Flying Dutchman or Yankee machine (known in England as an M. G. machine). Only recently the best cigarette paper has been made chiefly in France, Germany, Italy and Austria, but now very satisfactory grades are being made in America.

A good cigarette paper should be absolutely neutral in flavor and aroma while the cigarette is burning. As very few vegetable fibres possess these properties, the selection of material is most important in making this kind of paper. Pure flax, or linen fibre, hemp fibre and ramie, are usually used. Rice straw was formerly extensively used for making cigarette paper but this stock does not possess strength to satisfy the requirements of modern cigarette making machinery. Chemical wood pulp is only used for the cheapest grades of cigarette papers. It is deficient in tensile strength unless it is too thick. Straw papers usually contain silicic acid which is undesirable in cigarette papers as it confers disagreeable burning properties to the paper. Excessive use of cotton fibre gives the lamp wick odor found in some of the cheaper grades of cigarette paper.

According to Stroud Jordan the analysis of samples from reels of paper actually running on cigarette machines revealed that these papers were made up chiefly of linen fibre slightly sized with starch or dextrine and filled with magnesium or calcium carbonate. The filler in three of the samples (Austrian) averaged 24.05 per cent and in two other samples (French) averaged 9.13 per cent.

A good cigarette paper should weigh from 10 to 20 grams per square meter. With the former weight the paper should be 0.014 mm. thick and a 20 gram paper should be 0.037 mm. thick.

Porosity is necessary to admit air for the proper combustion of the paper. Cigarette papers are being made somewhat thicker today than formerly on account of the necessity for strength in paper to be used on cigarette machines and the manufacture of paper of the proper thickness and strength with sufficient porosity is quite a problem. Opaqueness is also necessary in order to give a good appearance to the finished cigarette. If the paper is not sufficiently opaque, the tobacco will show through the paper giving the cigarette a grayish or mottled appearance when packed which is undesirable from the cigarette manufacturers' point of view. Securing the necessary opaqueness without making the paper too thick is one of the nice points in the manufacture of this variety of paper.

The boiling of the stock is very important. The slightest variation in the cooking process, whether in time, temperature, pressure or chemicals employed, may disastrously affect the character of the material, interfering with beating to the proper consistency and causing a great deal of trouble through tearing on the machine. Cigarette paper should be beaten with very dull knives. After beating, it is bleached, very thoroughly washed and then drained and stored for several months to ripen. This ripening process is necessary to give the paper the desired opaqueness and soft, silklike feel.

The operation of the machine in manufacturing cigarette paper is a very delicate problem. With no paper is exactness in regulating the flow of stuff on to the wire so necessary. The machine must be very carefully cared for as very fine wires are used which easily become filled up with slime and dirt. Such paper is usually made at a speed of about 130 feet per minute on a machine giving a web 58 inches wide.

In making very thin papers on fast running machines, there is always a danger of the paper sticking to the upper press roll. In order to avoid this trouble, most careful attention must be given to the condition of the stock. If this is not right, that is, if the stock has not been cooked and beaten in just the proper manner, no amount of adjustment of the machine will give satisfactory results.

In making very thin papers in which ground wood is used, careful attention must be paid to the selection of the ground wood, that prepared by the hot grinding process being most suitable. If sulphite pulp is used, it must be entirely free from pitch and sticky resinous matter and must possess a soft but sound fibre. If the original quality of the pulp is not right, it cannot be made right by any treatment in the beater or on the machine. If a sulphite pulp has been cooked too quickly, or with an unsuitable acid, or an unsuitable pressure, or if a mechanical pulp has been ground from old wood or with the wrong kind of stones, the pulp will never do for tissue or any other kind of unusually thin paper.

Bag Paper.

The required qualities in bag paper are: tensile strength, pliability, tearing and bending qualities, a certain resistance to moisture, a smooth printing surface and, in some lines, a considerable bulkiness (e. g. in sugar bags, sacks, etc.).

The materials and the method of manufacture must both be chosen with a specific view to the fact that the paper is to be used for bag purposes. Paper does not become *bag paper* merely by virtue of having been run through a bag machine and made into a bag. Conversely, there are several uses for bag paper other than the manufacture of bags.

Bags serve not only as *containers,* but also as *carriers,* and the stock must be sufficiently strong and pliable to permit of the bag being twisted, folded and gathered into improvised "handles." This feature of the use of paper bags submits the bag to a strain unique in paper usage. The strain applied to a paper bag in carrying home, say, a few pounds of nails, is only under other circumstances applied to materials much stronger than paper.

Good bag paper must be soft and pliable; must not be harsh or brittle; and must have good folding qualities to survive unimpaired the sharp creasing it receives in use. Moreover, since not all the strain the paper bag receives is tensile, one of the strains being the potential rupture of the sheet due to pressure of merchandise (individual *pieces* of merchandise in many cases, such as apples, vegetables and the like) we see that the fibres must not run too definitely in any one direction, i. e., they must not form a distinct "grain" running lengthwise of the bag. That would invite easy splitting of the sheet. Consequently, it is necessary to exert every effort to make a sheet that will have equal tearing-strength in all directions. From the very beginning of the art of making paper, this has been regarded as very difficult. In addition to eliminating a definite "grain" the sheet must be properly "closed," which will be more completely understood after the chapter on the paper machine has been studied. If the sheet is exclusively formed of long fibres, it will be all the better if it is properly closed and the fibres properly criss-crossed, on the paper machine, avoiding variation of strength in one square inch of the sheet compared to the next inch. Hence the fibres must always be long enough so that the edge of the sheet will present a ragged and truly fibrous appearance when torn in any direction. A sheet of bag paper will frequently, against the light, appear to be relatively "wild" (that is when compared with varieties of paper other than bag and wrapping) and yet with splendid bag qualities in general, and without appreciable variation of strength inch by inch. Further, just enough size and alum must be used. There must be enough size to enable the bag to withstand quite a little moisture in the course of its use, and also to prevent too great penetration of moist materials. Only enough alum must be used to precipitate the sizing material otherwise the sheet will be made too brittle.

Bag papers for the most severe service can best be made of Kraft pulp, and with lessening severity of service, larger percentages of sulphite can be intermixed, until a point is reached where the bag is intended for uses where very little stress is ever applied to its surface, when combinations of sulphite and ground wood will suffice. The above remarks refer to the regular grades of bag paper. There are many specialties on the market which call for specially prepared paper consisting of jute, bleached soda pulp, bleached sulphite pulp, heavily loaded papers, parchment, etc.

Parchment Papers.

Real parchment paper consists of unsized rag, or other high grade stock which has been treated in a bath of dilute sulphuric acid. After treatment with the acid the paper is washed with water and then with dilute alkali to neutralize any trace of acid remaining and finally with pure water again to remove the alkali. This is done on a special machine where the web of paper passes into a vat for treatment with the acid and then between rolls to remove surplus liquid after which it passes into the vats containing the dilute alkali and water. This treatment increases the tensile strength of the paper to a remarkable degree and yields it many of the properties of animal parchment. The acid transposes the surface fibres into a tough, gelatinous mass which forms a protective coating for the unaltered fibres beneath. Such paper is impervious to air and moisture. In some instances zinc chloride is substituted for the sulphuric acid. Its action is quite similar.

In the manufacture of *vulcanized fibre,* used for trunks, tubs, waste baskets, trucks, etc., sheets of paper which have been treated with zinc chloride are pressed together and then thoroughly washed to remove the chemicals.

Another modification of parchment paper is the *Willesden Paper* obtained by saturating a sheet of paper with Schweitzer's reagent (an ammoniacal solution of copper oxide) thus causing a gelatinization to take place on the outside of the paper so that when the sheet is dried it is impregnated with a green varnish consisting of a compound of the reagent with the cellulose, which is waterproof and very strong. Sometimes several sheets are pressed together, making a board. The reagent is prepared on a commercial scale by allowing concentrated ammonia liquor to trickle down towers packed with copper scrap, air being blown up the towers at the same time. The same treatment is applied to textiles.

In the manufacture of these different forms of parchment paper it is advisable to use a bleached stock and inadvisable to use mechanical wood pulp. Unbleached stock, when treated with these chemicals, takes on a dirty, brown color. The presence of mechanical wood pulp is apt to give a charred effect. Formerly an unsized cotton rag stock was entirely used for making these special grades, but this is now supplanted almost entirely by the use of bleached sulphite stock.

Newsprint.

The importance of the newsprint branch of the paper industry can be gauged when we note that, according to the United States Census of 1914, there were at that time some 2,500 daily and Sunday and about 14,000 weekly and semi-weekly newspapers in the United States. According to the census data the daily papers had a circulation of about 30,000,000 copies, the Sunday papers about 17,000,000 and the weekly and semi-weekly papers about 24,000,000. The size of the papers and the consequent consumption of newsprint has shown a constant increase. In 1899 the United States produced 569,212 tons of newsprint, and in 1916 1,355,196 tons. As shown in the Census of 1914, newsprint formed one-fourth of the total paper tonnage of the United States and about one-sixth of the total value of paper produced. Only a very small part of the newsprint produced in the United States is exported (in 1916 only about 75,000 tons) and in addition large amounts are imported from Canada (in 1918 about 560,000 tons, or about 75 per cent of the total Canadian production) and a little from other countries.

The uses of newsprint are by no means confined to the printing of newspapers. Large amounts are used for catalogs, telephone directories, railway guides, school tablets, scratch pads, handbills, wrapping paper, etc.

Most newsprint is made entirely of ground wood, or ground wood with about 20 per cent of sulphite added. In all cases unbleached stock is used. In the manufacture of this paper it is necessary to run the machine at high speed, and since a sheet of newsprint is comparatively light, it necessitates the use of comparatively slow stock. The explanation of this will become apparent after the chapter on the machine room has been studied. Some modern newsprint machines run at a speed in excess of 900 feet per minute and make a sheet more than 150 inches wide —in some cases as wide as 199 inches.

Blotting Paper.

By reason of the physical properties of cotton fibre which has the greatest capacity for sucking up liquids of any of the fibres used in the manufacture of paper, the best blotting papers are invariably composed of cotton rag stock. Before treating the stock in the beaters it is essential to allow it to become well matured and it is frequent practice to allow the rag stock to sour after boiling in order that any lime salts that have been left may become decomposed. For this process a pure, soft water is essential, since calcium salts have a tendency to harden the fibre and render it less absorbent.

Just as in other grades of paper there are many gradations in quality from the best blotters made of pure cotton rag stock to cheap blotters made almost entirely of mechanical wood pulp. In the medium grades soft soda pulp, either alone or with an admixture of cotton rag pulp, is extensively used. Blotting stock is beaten quickly, the beater being of ample capacity so the circulation will be rapid and thorough. Usually one hour in the beater is enough.

The principal requirements of good blotting paper are: absorbency, freedom from hairiness and a good printing surface. Hairiness gives rise to fluff that tends to cause smudging of the ink. A good blotting paper should only yield a slight quantity of ash on being incinerated.

Filter Paper.

Filter paper is in many respects similar to blotting paper. Just as in blotting paper, the fundamental requirement is marked ability to absorb water and other liquids. The manufacture of filter paper for scientific purposes is a branch of paper manufacture which has received most expert attention and forms an art in itself. There are a number of firms in England, France, Germany and Sweden that have given special study to this subject and produced a wide variety of filter papers suitable to the various requirements of the chemist. For some purposes a very fast filtering paper is required, i. e., one that will let the liquid run through in a minimum of time, and this effect is sometimes secured at the expense of making the paper so loose and open in structure as to allow some of the finer particles of the precipitate to pass through. For other purposes papers are required which will make as near a 100 per cent retention of the precipitate as possible, even if the filtering operation is very slow.

A good filter should possess sufficient mechanical strength, even when wet, not to be broken by the weight of the liquid in the filter or by a moderate amount of suction. Filter papers intended to be used with suction naturally have to be stronger than others. A good filter paper should have a smooth surface free from hair or down or fluff of any kind that will detach itself from the surface of the paper and come off when a precipitate has been dried in it.

The best filter papers consist of stock made from the best qualities of cotton rags, sometimes with a little wool fibre mixed in. In order to extract any mineral matter in the fibre (silica, etc.), the stock is treated with hydrochloric and hydrofluoric acids, dilute alkalis and frequent washings with the purest water. The extent of this treatment depends, naturally, on the ultimate quality desired. For rough qualitative work and industrial purposes such treatment is not necessary. For filters for accurate quantitative analytical work (e. g. the ashless filters), such treatment is necessary. Such filter paper is almost perfectly pure cellulose.

After being made into sheets, filter paper is ordinarily stamped out in disks of various diameters, which are packaged together in bundles for sale. A good deal, however, is sold in sheet form. The heavier grades are sold in large sheets for filter presses and other industrial work.

Considerable quantities of filter paper stock are never made into paper at all, being dried and sold in bulk form for "filter mass" which is packed into various forms of stoneware and metallic filtering apparatus. For this sort of filtering medium sulphite wood pulp has been found to be an effective and cheaper substitute for cotton rag pulp in some lines of manufacture.

Swedish filter paper manufacturers frequently freeze the wet sheets of paper. The crystals of ice force apart the fibres leaving the paper with a porous structure when it is thawed and dried.

Hangings.

Wallpaper stock is made usually from a mixture of 85 per cent ground wood and 15 per cent sulphite, both being used in the unbleached state. About 10 per cent of clay is added to the combination in order to render it opaque and give a suitable surface. The surface must be capable of receiving a good impression.

Hanging paper must be sufficiently well sized that when it is applied to a wall it will stand the application of the paste without breaking. Undersized hangings are very objectionable. Like all other classes of paper, special attention must be given to the moisture content of the finished paper. If it is over-dried, it will become brittle and practically worthless. The prime feature to look for in hangings is softness combined with pliability, resistance to water and a certain bulk.

The quality of the product of a mill making hangings depends largely on its ground wood department. Good hangings are made in the ground wood mill. Without properly made stock it is impossible to manufacture a good product, no matter how much care is exercised in subsequent operations. In no branch of paper making is this more true.

Since this is necessarily a comparatively cheap grade of paper, and thus it is necessary to run the machine at a high rate of speed (in order to have an output of finished paper that will yield sufficient dividends) ground wood stock of a very free nature must be employed since the paper is a comparatively heavy sheet. If slow stock is used, the machine must be slowed down to get the water out of the sheet. This results in a loss in production serious in the case of an inexpensive product. It is therefore essential that the ground wood stock should be prepared in a free state as closely resembling sulphite fibres as possible. The details of accomplishing this effect will be explained in the chapter dealing with the ground wood mill.

The users of hangings, or wall paper stock, have adopted as standard certain weights of paper, as follows:

Weight in Ounces	Basis Weight 24 in. x 36 in.—480 sheets
9	34
10	42
11	44
12	48
14	58
15	60
16	62
18	74

Surface of Paper: 9 yards long x 19⅜ inches wide.

Roofing and Building Papers.

These papers are made from very coarse and cheap materials such as low grade rags, old gunny sacks, coarse jute wastes, sulphite screenings, etc. The principal points aimed at are cheapness and bulkiness, together with a certain absorbency, which is necessary when the papers are to be impregnated with asphalt, etc.

In addition to ordinary building and roofing papers, a large number of specialties containing asbestos, etc., and impregnated with various chemicals and asphaltic substances have been developed. In some cases the papers are marketed in rolls and in other cases handled as boards.

The machines for making these boards are very highly specialized and are generally of the cylinder type. The principle and operation of such equipment will be described in the chapter on the machine room.

IV. The Saw Mill.

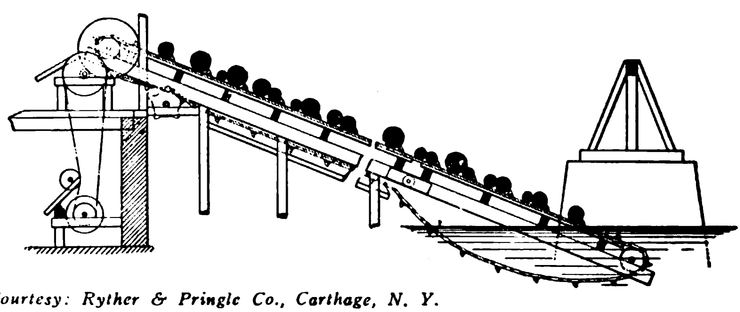
At first sight the saw mill might not seem to really be part of the pulp mill at all, but as we proceed to study in detail the manufacture of pulp, and later of paper, we will see that the preliminary steps necessary to the suitable preparation of wood for further processes of manufacture have a very direct bearing on the quality of the pulp and the paper produced, and that the efficiency of the saw mill department is vitally connected with the efficiency of the plant as a whole.

The saw mill comprises a collection of machinery for bringing the logs into the mill, reducing them to a uniform short length (usually either 2 or 4 feet) and delivering them to the wood room (described in the next chapter) where the bark is removed and the wood is converted into chips.

In addition to sawing equipment, the saw mill naturally requires conveyor systems so adapted as to handle the various materials at a minimum of labor and expense.

Log Haul-Ups, or Jack Ladders.

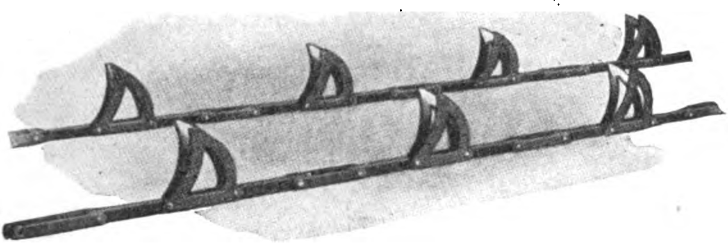
Whenever possible, it is advisable to use parallel chain haul-ups, which bring the logs up sideways, instead of end for end. This form of hauling is especially advisable when the logs are of uniform length and are to be cut into blocks with a multiple saw slasher.



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

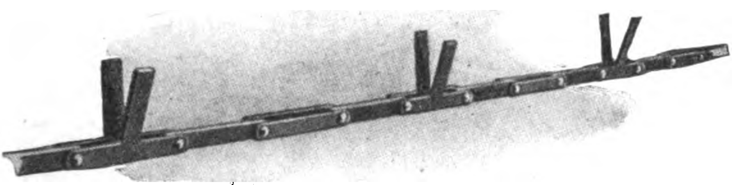
Fig. 7.—Parallel chain log haul-up.

The diagram shows the arrangement of such a system. Two or more chains are used, running parallel to one another. The logs are floated into such a position that they will be pulled up by the chains as these emerge from the water. The incline should not be more than 30° if 24-inch logs or larger are to be handled. Smaller logs can safely be handled at a greater angle. In fact, 24-inch logs can be handled at angles exceeding 30° if specially designed chains are provided. The above remarks refer to the usual forms of chains, two typical kinds of which are illustrated.



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 8.—Steel wing link chain.



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

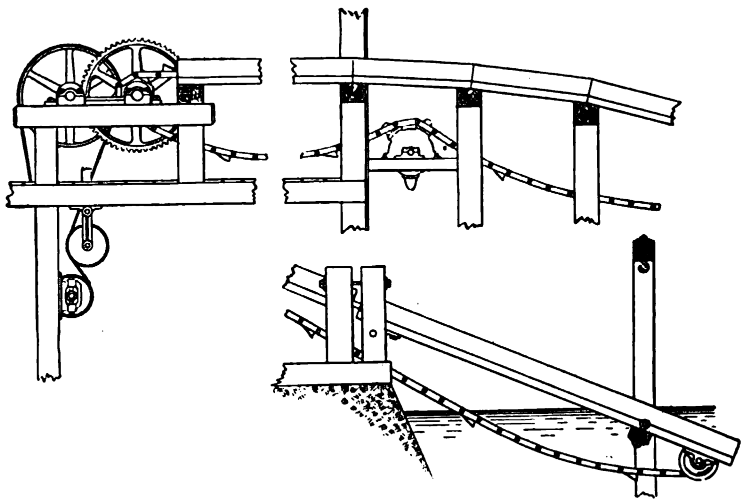
Fig. 9.—Iron wing link chain.

The logs discharge automatically from the head end of the haul-up onto an inclined deck, and roll onto the slasher. Automatic counting devices are sometimes installed which record the number of logs passing, and thus afford accurate records of the numbers of logs brought into the mill from day to day.

When it is found more convenient to bring the logs up end to end, an endless chain haul-up is installed, as shown in the illustration. Several types of chain are used on such conveyors, three of which we illustrate.

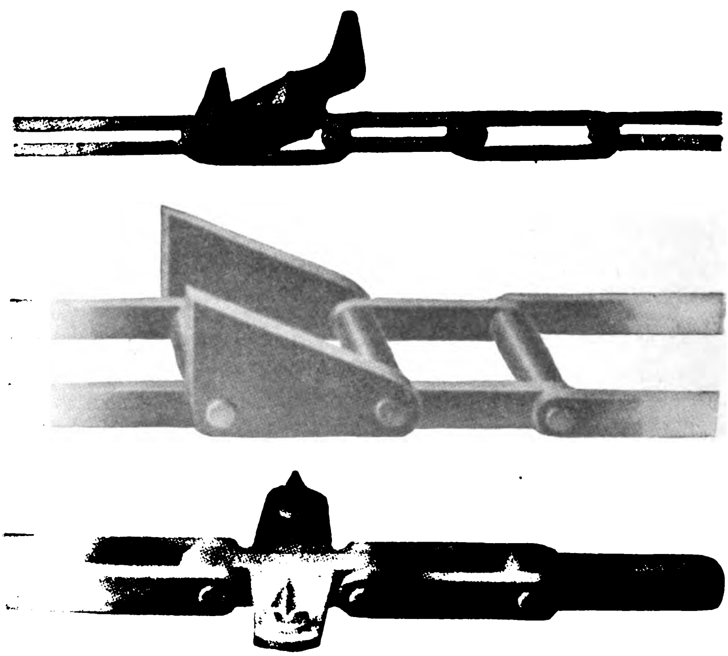
The lower end of the haul-up should be so arranged that it can be raised and lowered, thus accommodating the chain to various levels of water met with during a season's operations.

The illustration shows the drive for this haul-up located above the floor. This is not imperative. It can very conveniently be located below the floor. The drive can be either spur or bevel gear, and starting and stopping is usually provided for by means of iron and leather frictions, or by means of a belt tightener.



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 10.—Endless chain haul-up.



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 11.—Typical chains used with endless chain haul-up.

Log Kickers.

When logs are brought into the mill end to end, a kicker must be used to expel them from the log haul trough. The usual form of this machine is a rocker shaft, to which as many cast iron arms are attached as may be required (this depending on the length of the logs being handled). To these arms are attached shover arms, which are made up of two castings with heavy wrought iron riveted sides, working through cast iron guide troughs, located at the side of the log haul trough. The rocker shaft and arms are in turn operated by means of a steam cylinder, attached to the shaft by a connecting rod or pitman. This machine may be operated by means of a foot tread or lever. In most cases the former device is used and the tread placed on one side of the log way. The operator by stepping on the tread admits steam to the cylinder, and throws the logs out of the trough onto the inclined deck leading to the live rolls. The shover arms pass up through the guide troughs in such a manner as to strike the log at the easiest point to set it rolling. The cylinder is stationary, steam piping rigid and all possibility of leaky cylinders thereby avoided.

Saws.

There are two chief types of saws used in saw mills in the paper industry. These are: (1) *Slashers,* which are intended for the economical reduction of long logs of nearly uniform length to blocks of a short uniform length in large quantities. (2) *Swing Saws,* which are intended for use in mills where the logs are of extreme length, or where the lengths vary to such a degree as to render a slasher impracticable. In many saw mills both slashers and swing saws are required.

Slashers.

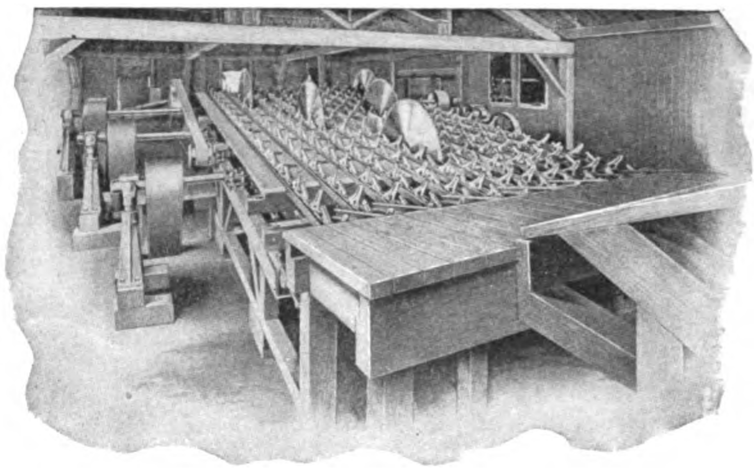
These machines consist of an arrangement of one or more stationary saw arbors equipped with the ordinary type of circular saw, revolving at a high rate of speed and mounted upon a slightly inclined table. This table is provided with a number of feed chains, so arranged as to receive the logs automatically from an inclined deck, carry them to and through the saws, and deliver them at the upper end to a conveyor or whatever other means may be provided for removing them.

The arbors should be made of the best quality of cold rolled, open hearth steel, of superior quality and temper, combining both strength and stiffness. The arbors themselves should be accurately turned and keystead, and the saw collars fitted with the utmost care. The diameter of the arbors should be exactly the same throughout the entire length.

Each arbor should be equipped with three self-oiling bearings of liberal strength. Two of these bearings should be attached to the framework of the slasher, and one bearing should be mounted in an adjustable floor stand and arranged to be placed outside of the arbor pulley, thus insuring a perfect and permanent alignment of the arbor.

The arbor pulleys should be all made extra heavy and solid, turned and perfectly balanced, keyed and fitted to the arbors.

The saw collars should be made of cast iron, and when fitted for 60-inch saws should be 10 inches in diameter, with a 2-inch



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

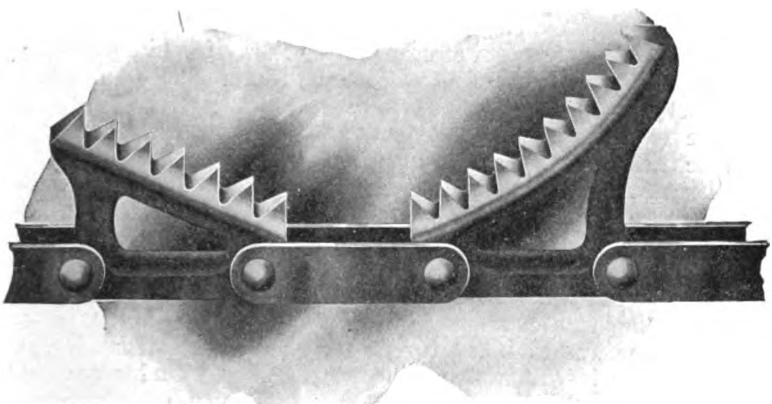
Fig. 12.—Typical five-saw slasher installed in wood preparing plant.

arbor hole and two lug pins, 5/8 inch diameter and 3½ inches center to center. The tight collar is fitted against a slight shoulder turned on the arbor and then shrunk on. The loose collar, which clamps the saw against the tight collar, is secured by means of a 2-inch hexagon nut, fitted with a special thread to permit of securely clamping the saw. The above arrangements are necessary to guard against any danger of the saws working loose while in operation.

The saw arbors are arranged in such a manner relative to the feed chains and other parts of the slasher that, by merely removing the nut and the loose collar, the saws may be changed very quickly, without removing the arbors or any other part of the machine.

The feed chains are a very important part of the slasher. They run parallel with the saws, pick up the logs at the receiving end of the machine, carry them to and through the saws, and deliver them sawed to length at the discharge end of the machine.

The nature of these chains will readily be seen frcm the illustrations. The shape of the pockets formed by the link is



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 13.—Detail of slasher chain.

such that a log of any diameter from 4 inches to 24 inches is firmly held in position while being sawed, thus avoiding any possible cramping of the saws. There are two lines of chain for each sawed piece resulting from the sawing of the log, thus providing for securely holding in position each block of wood throughout the cut and until the blocks are released at the head end of the machine.

When passing the sprockets at the delivery end, the chains free the blocks of sawed wood automatically, and they are delivered onto the conveyor, or whatever means may have been provided for removing them. The chains should run in steel trough irons, to which are riveted cast iron chairs, by which they are secured to the frame of the machine. The chains must be accurately built to template, so that when there are a number of chains used, the alignment of the chain pockets will be perfect, thus bringing the logs squarely against each saw.

The sprocket wheels which drive the feed chains should be of cast iron with chilled teeth surfaces to insure long life. The head, or driving sprockets, should be keyed to the head shaft, particular care being used to preserve a perfect alignment of the sprockets, and, in consequence, the chains themselves.

The head shaft, to which the driving sprockets are keyed, should be back-geared through a pinion countershaft, from a belt countershaft, which, in turn, is driven from a pulley keyed to one of the arbors. In this manner, the speed of the feed chains is reduced to about 25 feet per minute. This feed should be self-contained and capable of being started or stopped instantly, independently of the saws by a hand lever.

In large slashers, where the chains are of great length, it is advisable to provide bottom idlers to relieve the driving sprocket of the weight of the chains.

One prominent manufacturer of this class of equipment states that, as the result of a number of observations taken from different slashers working under varying conditions, the following definite statement can be made as to the power required to operate the same successfully:

"Eighteen H. P. should be figured for each 60-inch saw operated to full capacity. This amount of power will also operate the necessary log haul, or jack ladder, required to bring the logs to the slasher. For saws less than 60 inches diameter, the power required will be proportionately less."

According to the writer's experience, the above figure is correct. The power required for the log haul, or jack ladder, depends on the length and pitch of the ladder. Under ordinary conditions a 15 H. P. motor will take care of a jack ladder 75 feet from center to center of sprockets.

The following two descriptions of the saw mill equipment installed in two well known pulp mills by Messrs. Ryther & Pringle Company, of Carthage, N. Y., are typical:

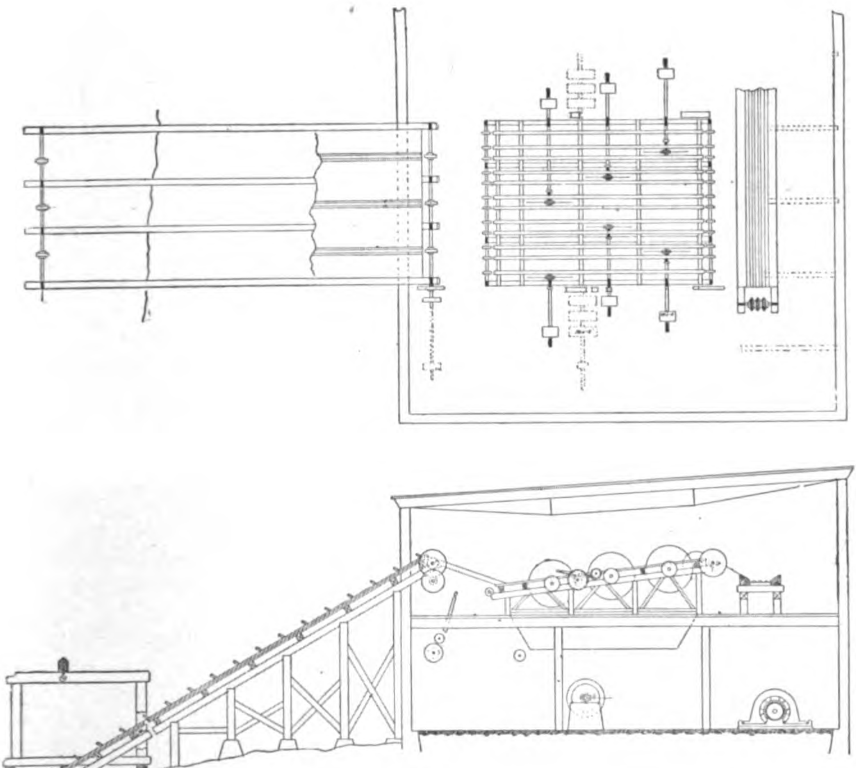
At a plant in New York, the logs, which are 12 feet long, are brought into the mill by a parallel chain log haul and delivered automatically to the slasher which is equipped with five 60-inch saws so arranged as to cut the 12-foot logs into six 24-inch pieces. The sawn blocks are delivered automatically from the head end of the slasher to a cable conveyor, which in turn carries them to a storage pile outside the mill.

This machine (Fig. 14) is operated with a crew of eleven men, distributed as follows: Seven men are stationed at the foot of the log haul to guide the logs onto the elevator chains, two men are on the slasher itself, and the other two men are on the cable conveyor which carries the sawn wood away from the slasher. The direct labor cost resulting from this arrangement (Note: this statement made in 1912) is less than 3 cents per cord, and includes all of the labor necessary to take the logs from the river, cut them to 24-inch lengths, and deliver them to the storage pile.

During four seasons this machine handled 163,000 cords of wood, the daily average being about 500 cords per ten hours. The total amount of repairs and replacements for that period averaged less than $5.00 per season. The saws did not have to be changed in four years, during which time they wore from 60-inch diameter to 55¾ inch diameter.

Indicator diagrams taken at the above plant at various intervals during the operations showed a total power consumption of not to exceed 90 H. P. which included the power necessary to operate the entire combination of log haul and slasher.

A similar machine installed at a Canadian plant exceeded the record of the above machine, owing to more favorable river con-



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 14.—Plan and elevation of wood preparing installation consisting of five-saw slasher, parallel chain log haul-up and distributing conveyor. This is the same installation shown in Fig. 12.

ditions. The average at the Canadian mill was over 600 cords per ten hours. On one day as high as 16,815 logs were put over, this being more than 800 cords per ten hours.

At another Canadian plant a seven saw slasher is installed. Owing to the location of the wood room relative to the pond from which the logs were drawn it was necessary in this instance to take the logs from the water endwise, by means of a single strand log haul, instead of broadside by a parallel chain log haul, as is ordinarily done. Operating in this manner it was not possible to cut as large a number of logs per hour as is done where the parallel chain log haul is used.

One man, stationed at the table where the log haul delivered the logs from the pond, commanded a view of the entire operation from the water to the conveyor for sawn blocks and controlled the log chain and the kicker to the slasher and counted the logs. The kicker throws the logs from the log haul trough to the slasher table, and at the same time, lines up the logs, so that the head ends follow a regular line through the saws. The last end of the logs is trimmed first to 16 feet, plus a slight allowance for sawdust loss. The first saw cuts the 16-foot logs once in two and spreads the logs sufficiently to prevent any possibility of cramping the saw ahead. Next, the two 8-foot blocks are each cut into two 4-foot pieces, and finally another pair of saws cut each 4-foot block once more in two, thus resulting in eight 24-inch pieces. From 5,000 to 6,000 logs can be handled from the water, sawed and piled in 10 hours. The handling, sawing and piling of the logs in 24-inch lengths is done at a cost (in 1912) for labor of 10 cents per cord.

It should be taken into consideration that a great variety of factors, apart from the efficiency of the machinery, influence the operation of such an installation.

It is not always possible, for a variety of reasons, to install the machinery in the position and arrangement ideal from a mechanical point of view. The case of the Canadian Mill, described above, is an illustration of this. In such cases the best has to be made of the conditions at hand.

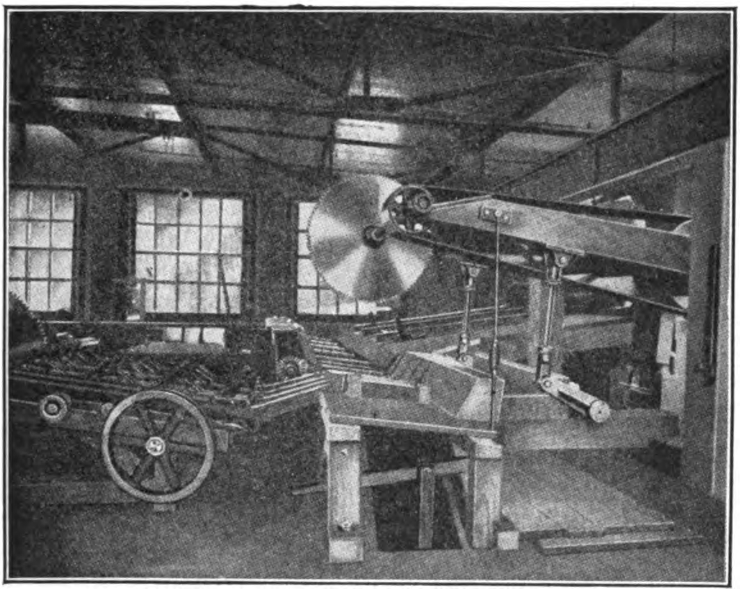
River conditions will have a great effect on the problems of the saw mill, and these will not be the same at any two plants, and will vary at one and the same plant from time to time.

The labor available at different points will vary. The operation of this kind of equipment requires both physical strength and intelligence, as well as ingenuity. It will be found to pay to have this department overmanned, if anything, rather than undermanned.

Swing Saws.

Where logs of varying lengths and diameters have to be reduced to short blocks of uniform length, a swing saw system is generally used.

The logs are brought into the mill end for end, by means of a single strand conveyor chain fitted with spurred links at intervals. The log haul drive is so arranged as to be under the control of an operator stationed at the head of the log deck, and may be stopped, or started, as required. A log having been brought to the head of the deck, the drive is stopped by means of a lever, the operator admits steam to the kicker cylinder, and the log is kicked, or rather rolled, from the trough onto the inclined deck. This deck is of sufficient size to hold in reserve a supply of logs. From the deck, as required, logs are released by means of a steam trip, or loader, and roll onto the live rolls. The live rolls are arranged to operate in series—the length of the train over all being sufficient to accommodate the longest



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 15.—Overhead type of swing saw installation showing kickers and slasher.

logs being cut. The operation of these live rolls is under the control of the sawyer, who engages, by means of a lever, the frictions which drive the rolls, and advances the log or logs as the case may be to the gauge block. The gauge block is located at a distance beyond the saw to correspond with the required length to be cut, and as soon as the log is brought in contact with the gauge block and stopped, the block disappears. The sawyer then, by means of a lever, admits steam to the cylinder, which operates the saw frame, bringing the saw through the log until the cut is completed. The sawn block is then kicked onto the conveyors.

Care of Saws [1]

It is very important that the saws should be kept in the best of condition. If too much sawdust is produced and if it is allowed

[1] Adapted from Lumberman's Handbook: Henry Disston & Sons, Inc.

to adhere to the ends of the blocks it will cause trouble later on. Holes and defects in the paper can sometimes be traced right back to the saw mill.

The following are some of the causes which give rise to unsatisfactory conditions in saw mills. Frequently the saw or the

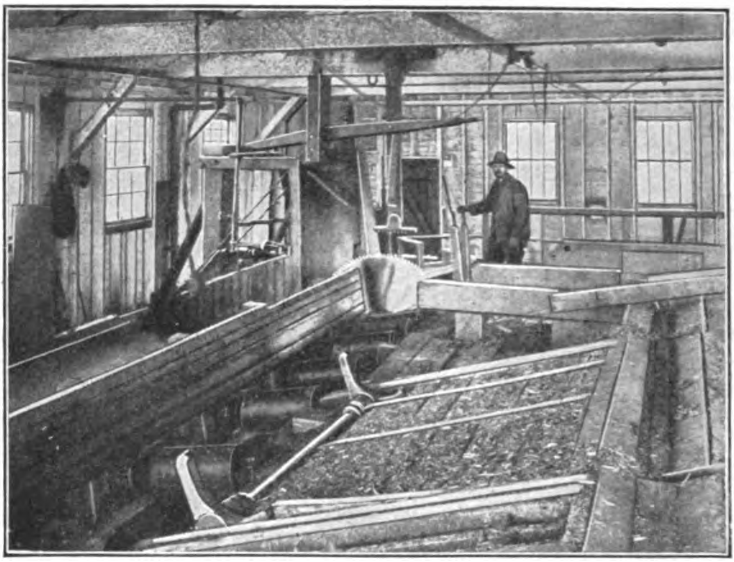


Fig. 16.—Another swing saw installation in which the under-cut type of frame is used.

saw maker is blamed when actually one or more of the following circumstances is the cause of the unsatisfactory operation:

Insufficient power to maintain regular speed.
Too thin a saw for the class of work required.
Not enough for too many teeth for the amount of feed carried.
Weak and imperfect collars.
Collars not large enough in diameter.
Ill-fitting mandrel and pin holes.
Uneven setting and filing.
Not enough set for proper clearance.
Too much pitch or hook of teeth.
Irregular and shallow gullets.
Out of round and consequently out of balance.
A sprung mandrel, or lost motion in mandrel boxes.
A carriage track neither level nor straight.
Carriage not properly aligned with saw.
Lost motion in carriage trucks.
Heating of journal next to saw.

Guide-pins too tight or not properly adjusted.
Backs of teeth too high for clearance.
Attempting to run too long without sharpening.

Setting the Carriage Track and Husk or Saw Frame: It is very essential to good work that the foundation of the mill should be amply strong to withstand the shocks it is subjected to in turning logs; the track stringers should be good sound heart lumber, preferably Yellow Pine, as this is a firm wood and will resist moisture. The size of the stringers should not be less than 8 inches by 8 inches and as few pieces as possible to make up the necessary length. The stringers should be set perfectly level and parallel with the mill house and gained into the girders and joists of the mill floor or foundation timbers, and secured by keyes and bolts so that they will not change position when logs are rolled against the head blocks. The track irons, particularly the V side, should be firmly bolted to the stringer and when finished be perfectly straight and level.

It is quite as important that the saw frame should be firmly secured to its place as that it should be level and solid, for the vibration and strain are of such a nature that the frame would quickly change position unless very firmly secured. The slightest change would make a vast difference in the running of the saw and necessitate relining. When putting in the husk stringers, use well seasoned wood and put them down in such a manner that they cannot possibly change their position, then find the position of the husk on the stringers and fasten down securely with through bolts.

Lining the Saw with the Carriage: The amount of lead required for circular saws should be the least amount that will keep the saw in the cut and prevent it heating at the center. If the lead into the cut is too much, the saw will heat on the rim; if the lead out of the cut is too much, the saw will heat at the center, it is therefore advisable to give the least amount that is used, which is one-eighth of an inch in twenty feet.

Of the various methods used for lining a saw with the carriage, the following is the one that we think will be the most easily understood: First, see that the mandrel is set perfectly level, so that the saw hangs plumb and true when screwed between the collars, and is flat on the log side. Draw a line running ten feet each way from center of mandrel and parallel with the V track, fasten a stick to the head-block, so that it comes up to the line at the end in front of saw; run carriage forward the twenty feet, move the rear end of line one-eighth of an inch away from former parallel position, then slew the end of mandrel either forward or backward until it is exactly at right angles to the new position of line, and the saw parallel with same.

All end play must be taken out of the mandrel and carriage trucks when lining a saw to the carriage, and the truck must be laid solid, level and true, so that the carriage will run straight and smooth.

Collars for Saws: For a perfect running saw it is indispensable to have the collars and stem of mandrel true and well fitting; any imperfection in these points is multiplied as many times as the saw is larger than the collars; they should fit exactly.

Large saws should have collars that have a perfect bearing of three-quarters of an inch on the outer rim, the other part clear, as they hold tighter than a solid flat collar. Examine the collars carefully to see if they are true, if not, have them made so; also be sure that stem of mandrel fits the hole nicely and offers no obstruction to the saw slipping easily up to and against the fast collar. The use of six inch collars for portable and semi-portable mills is advocated. Collars for steam feed mills should be larger.

Test the saw with a straight edge, and if it is found true, place it on the mandrel, tighten up the collars with the wrench, test again with a straight edge and see if the position of the blade has been altered; observing whether it shows true, if not, the fault is sure to lie in the collars and will be likely to ruin the saw. The best results cannot be obtained from the mill until the defects are remedied.

The best circular saws are finished by a process which insures each side of the saw plate being perfectly true throughout its entire surface; by this invaluable process, every particle of unevenness is removed; the saw never requires packing (providing the collars are true) and all the trouble which has hitherto perplexed the sawyer in this particular is removed.

Adjusting Saw to Mill: See that the saw slips up freely to fast collar and hangs straight and plumb when tightened up; that the mandrel is level, in proper line with the carriage, and that it fits in its boxes as neatly as possible without heating, for when the mandrel heats, by transmission, the saw will heat also and thus expand in the centre, which will make it work badly, injure, and perhaps ruin it. A saw cannot be expected to run on a mandrel that heats, although if it were known exactly to what degree it heats a saw could be made that would admit of that much expansion. However, a heating mandrel will always give more or less trouble. To get the best results from a saw this must be overcome.

Take up all end play or lateral motion in mandrel as the grain of the wood will draw or push the mandrel endwise, no matter how well the saw is kept. See that the carriage track is level, straight, solid and in proper line, also that rolls or trucks have no end play. Keep all gum or sawdust off the tracks.

Speed of Saws: This is a very important point for consideration, since a hundred revolutions, more or less, will always make a great difference in the running of the saw. The tension of saws can be adjusted to overcome a slight variation in speed provided full instructions are given when ordering the saw though we would advise a regular speed at all times. Our experience has been that saws work better when run at a regular speed even if it is necessary to reduce the number of revolutions one hundred below that given in the table, than to have a variable speed. If the power is too light to maintain the standard speed, run the engine at a higher regular speed, put a larger diameter receiving pulley on the mandrel, and the results will be better both as to quality and capacity. This will be much better than the throttle plan, even if the speed does fall below that given in the table; the regularity is the most desirable point to look after. Following is a table of speeds:

Speed of Saws Running 10,000 ft. per Minute on the Rim

72 in.,	530 revolutions	per	min.		36 in.,	1080 revolutions	per	min.
68 "	560 "	"	"		32 "	1225 "	"	"
64 "	600 "	"	"		28 "	1400 "	"	"
60 "	640 "	"	"		24 "	1630 "	"	"
56 "	700 "	"	"		20 "	1960 "	"	"
52 "	750 "	"	"		16 "	2450 "	"	"
48 "	815 "	"	"		12 "	3260 "	"	"
44 "	890 "	"	"		10 "	3920 "	"	"
40 "	980 "	"	"		8 "	4600 "	"	"

Portable mills, of limited capacity, are usually run at a speed about one-third less than given above.

Rules for Calculating Speed, etc.

PROBLEM 1. The diameter of driving and driven pulleys and the speed of driver being given, find the speed of driven pulley.

RULE. Multiply the diameter of driver by its number of revolutions, and divide the product by the diameter of the driven; the quotient will be the number of revolutions of driven pulley.

PROBLEM 2. The diameter and revolutions of the driven pulley being given, find the diameter of the driver.

RULE. Multiply the revolutions of driven by its diameter and divide the product by the revolutions of the driving shaft; the quotient will be the diameter of driver.

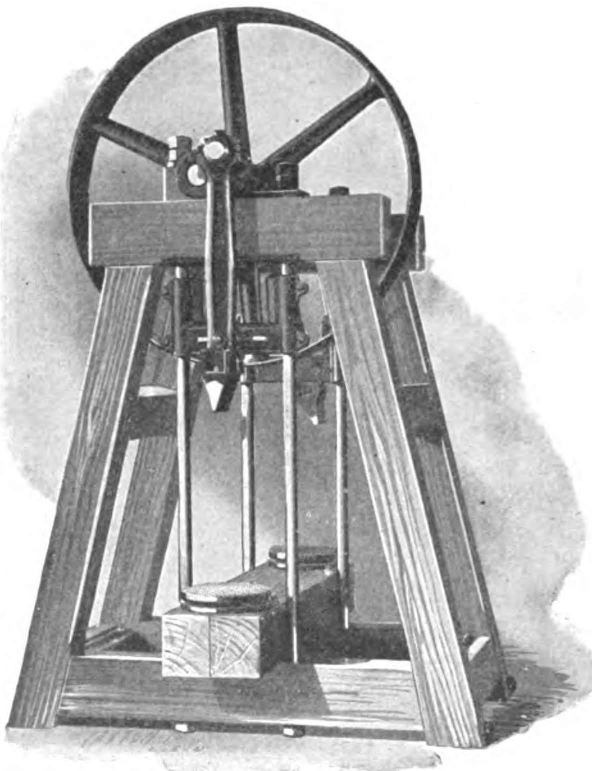
Splitters.

Sometimes when very large wood is being handled, which would not be capable of being put into the chipper spout, or into a pulp grinder, a device known as a splitter is employed to separate the large blocks into two or more smaller ones. This machine is simply a mechanically operated axe of powerful construction, standing about 10 or 12 feet high. The nature of the machine will be readily understood from the illustration.

Another excellent type of splitter[1] is of a horizontal design. This splitter is run by an electric motor, belted to a pulley.

[1] See "Paper," Vol. 21, No. 14, Dec. 12, 1917, for more detailed description.

Motor drive is convenient and economical because it is in use only when wanted and does not require an extra attendant. The motor runs continuously during the splitting process, and if for any reason the operator wishes to stop the axe he merely shifts a hand lever which operates a clutch connecting the driving pulley with the axe mechanism.



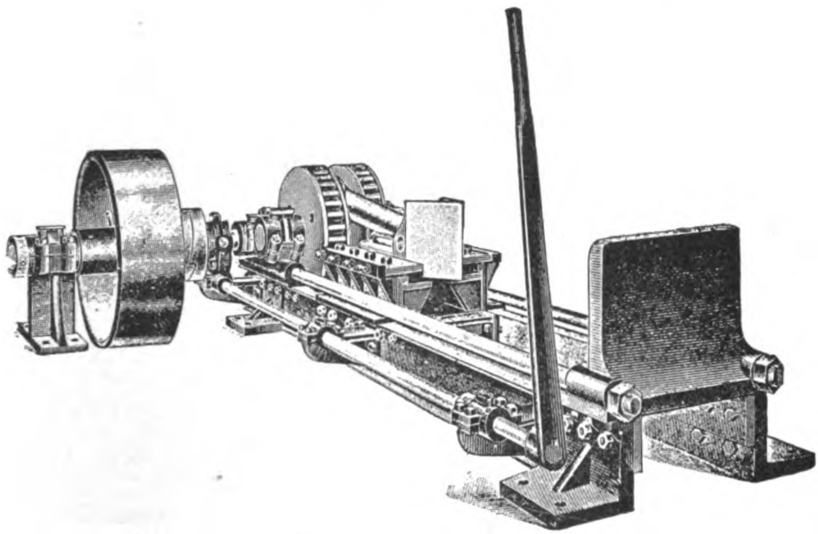
Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 17.—Vertical type of splitter.

Power tests have shown that 7½ H. P. furnishes ample power for splitting 4-foot wood. When operating normally splitters will sometimes consume no more than 3½ to 4 horsepower. In cases of this kind, however, it is always well to be safe and furnish too large a motor with the splitter rather than one that is too small. A 10 H. P. motor should be all right. The cost of the power is a very small matter compared with the increased output developed by a good splitter.

The base of the horizontal splitter is made of two channels securely bolted to heavy cast iron cross bars. Heavy cast iron double gear shaft-bearings are mounted on the channels and are made to receive both gear and pinion shafts.

A heavy cast iron splitting block is mounted on the channels securely bolted to them, thus forming part of the base. This block is slightly rounded and has a corrugated face to prevent the wood from slipping when the machine is in operation. It is obvious that should slipping occur in any way the operator



Courtesy: Appleton Machine Company, Appleton, Wis.

Fig. 18.—Horizontal type of splitter.

would be in danger. The double shaft bearings and splitting block are connected by steel tie rods. The axe guides are mounted on the base very rigidly and consist of two steel slides so arranged and fitted that the axe has a bearing on the under side as well as on the steel sides. Experience has shown that it pays to use plenty of bearing surface for the axe in order that there will be no appreciable wear and to reduce power consumption to the minimum. This design also affords a simple and excellent means for thorough lubrication.

The axe is provided with a first-class steel cutting edge and is also carefully machined to fit the slides and bottom bearing as above explained. By increasing the size of the gears and the radius of the crank pin it is possible to give a splitter a stroke of almost any length. Generally, however, this type has a stroke of 15 inches for splitting 4-foot wood.

There are two crank gears on the machine. They each have thirty-six teeth, are made of cast iron, and are shrouded on both sides of the teeth. These gears are driven by two cast steel pinions each having twelve teeth. The pulley, therefore, makes three times as many revolutions a minute as is made by the crank gears. In other words, to find the number of strokes made by a given splitter of this type, multiply the r. p. m. of the driving pulley by the number of teeth in the pinions and divide by the number of teeth in the crank gears.

The connecting rod is usually made of cast steel and is of great strength.

For splitting 4-foot wood a 40-inch pulley is usually recommended as the proper size, this to run at a speed of about 110 r. p. m. If this pulley is 11 inches in width it is sufficiently large to transmit the power through a 10-inch belt.

NUMBERS OF 13-FT. LOGS OF VARIOUS DIAMETERS IN 1 CORD OF 128 CU. FT.[1]

34 logs 5″ diameter	10 logs 12″ diameter
27 logs 6″ diameter	9 logs 13″ diameter
22 logs 7″ diameter	7 logs 14″ diameter
18 logs 8″ diameter	6 logs 15″ diameter
17 logs 9″ diameter	5½ logs 16″ diameter
15 logs 10″ diameter	5 logs 17″ diameter
12 logs 11″ diameter	

[1] Courtesy of Ryther & Pringle Company.

Loose piled pulp wood in blocks 24 inches long as dropped from a Cable Conveyor or loose piled in a car, occupies 163 cubic feet for every cord of 128 cubic feet close piled.

One cord of 128 cubic feet of close piled rossed wood contains approximately 96 cubic feet of actual wood.

A log 19 inches diameter at butt and 13 feet long equals one market.

3 Markets equals 1 Cord.

5 Markets equals 1,000 feet B. M.

Average Adirondack Spruce runs 15 to 20 markets to the acre.

Hardy S. Ferguson, Consulting Engineer, 200 Fifth Avenue, New York City, estimates the approximate amount of wood required to one ton of newspaper in the following manner.

Assumptions

1. 1.08 cords of rough wood will yield 1 ton Air Dry Ground Wood Pulp.

2. 2 cords of rough wood will yield 1 ton Air Dry Sulphite Pulp.

3. In the Paper Mill 2 per cent. of the Sulphite is wasted.

4. In the Paper Mill 8 per cent. of the Ground Wood is wasted.

(A) Paper containing 25 per cent. Sulphite (neglecting fillers).

$$1 \text{ ton Paper requires } \frac{2 \times 25}{98} + \frac{1.08 \times 75}{92} = 1.39 \text{ cords.}$$

(B) Paper containing 22½ per cent. Sulphite (neglecting fillers).

$$1 \text{ ton Paper requires } \frac{2 \times 22.5}{98} + \frac{1.08 \times 77.5}{92} = 1.37 \text{ cords.}$$

(C) Paper containing 20 per cent. Sulphite (neglecting fillers).

$$1 \text{ ton Paper requires } \frac{2 \times 20}{98} + \frac{1.08 \times 80}{92} = 1.35 \text{ cords.}$$

The following Table taken from "The Woodman's Handbook," published by the U. S. Department of Agriculture, gives the volume of unpeeled pulp wood in cubic feet of trees of varying heights and diameters as determined by measurements obtained in southern New Hampshire.

Diameter breast-high	Height of Tree (Feet)						
	40	50	60	70	80	90	Basis
	Volume (Cubic Feet)						
Inches							Trees
5	1.9	2.5	3.0	....	....	....	29
6	3.5	4.2	5.2	6.4	....	....	98
7	5.0	6.2	7.5	9.0	....	....	128
8	6.6	8.4	10.0	11.7	....	....	165
9	8.5	10.8	12.7	14.8	....	....	161
10	....	13.5	15.6	18.0	....	....	113
11	....	16.5	18.8	21.5	....	....	78
12	....	19.5	22.3	25.4	....	....	63
13	....	....	26.0	29.5	34.5	....	42
14	....	....	30.0	34.0	39.5	....	55
15	....	....	34.5	38.5	44.0	....	56
16	....	....	39.0	43.5	49.0	....	49
17	....	....	43.5	49.0	55.0	63.5	38
18	....	....	48.0	54.5	61.0	70.0	44
19	....	....	53.0	60.5	67.5	77.0	30
20	....	....	58.0	67.0	74.5	83.5	21
21	....	....	....	74.0	82.0	90.5	18
22	....	....	....	81.5	89.0	98.0	16
23	....	....	....	88.5	96.5	106.0	10
24	....	....	....	95.5	104.5	114.0	5
25	....	....	....	102.0	112.0	123.0	2
26	....	....	....	109.0	120.0	131.5	2
27	....	....	....	....	128.0	140.0	2
28	....	....	....	....	135.5	148.5	1
							1,226

Stumps varying from ½ to 1½ feet and tops above 4-inch diameter point are excluded.

To reduce to cords divide by 100 or point off two places. Some use 95 cubic feet per cord.

Bark = 11 per cent of volume

V. The Wood Room.

The wood from the saw mill is either carried directly on conveyors to the wood room, or else stored in large piles until it can be used. The extent to which piles of wood are accumulated is governed by a number of factors. It is advisable to use wood as fresh as possible, both in the chemical and the mechanical processes of pulp manufacture but, on account of the distance of most mills from the source of wood supply, it is generally necessary to have some wood stored in piles.

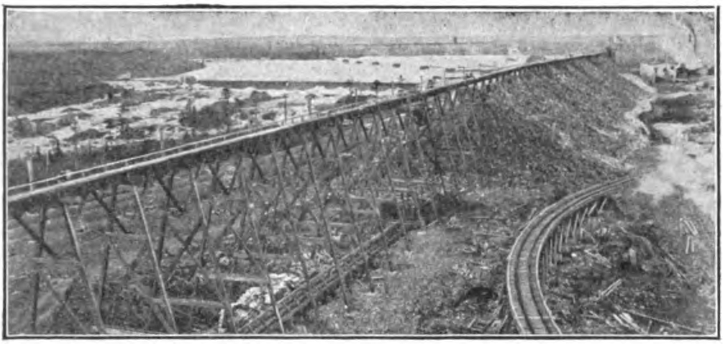
Wood Piles.

The number of cords the piles should contain and the distance from the mill buildings, or from each other, if insurance on the property is to be obtained at minimum rates, depends on the rulings of the insurance companies. Disregard of these stipulations will cost many thousands of dollars each year in the case of a large mill in addition to presenting a constant menace of fire. The value of the wood in these piles running into many thousands of dollars, it pays well to take every precaution against fire and to have fire hydrants located conveniently to all the piles of wood.

The wood should be carefully piled. Piles which lean outward, are irregular in shape and faulty in general arrangement frequently are the cause of serious accidents to employees. In freezing weather dynamite is frequently used for loosening piles of wood. This work should only be trusted to a careful and experienced person, who should be held responsible for the receiving, storage, handling and firing of the explosive. If possible this work should be done at the beginning of the working day and precautions should be taken to see that all persons are out of the way of possible danger.

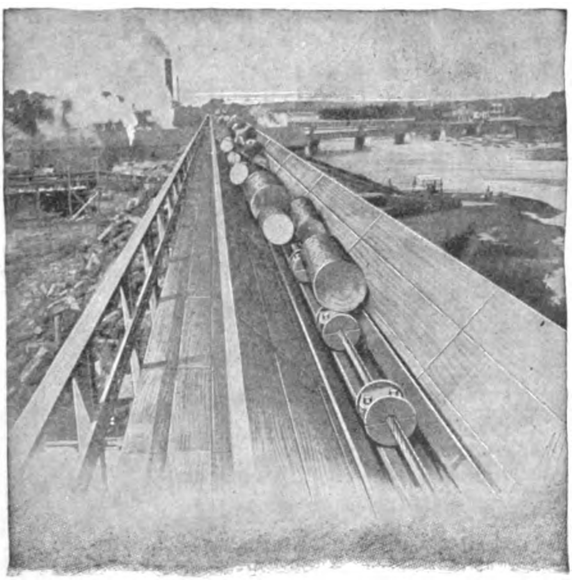
Wood Storage.

The usual manner of storing wood is to have a conveyor supported on a rigid structure either of wood or of structural steel. This is built as high as may be necessary, in the case of wooden construction the height being limited by the length of timber it is possible to procure for the legs of the structure. The higher the structure the greater the storage capacity in a given space. Of course, the structure should not be too high. This will be regulated by considerations of strength and of expense. The wood is conveyed by a wire rope cable to which are attached at intervals iron discs or blocks. The cable travels in a wooden trough lined with iron strips. The iron discs are so spaced as to



Courtesy: Jeffrey Manufacturing Co., Columbus, O.

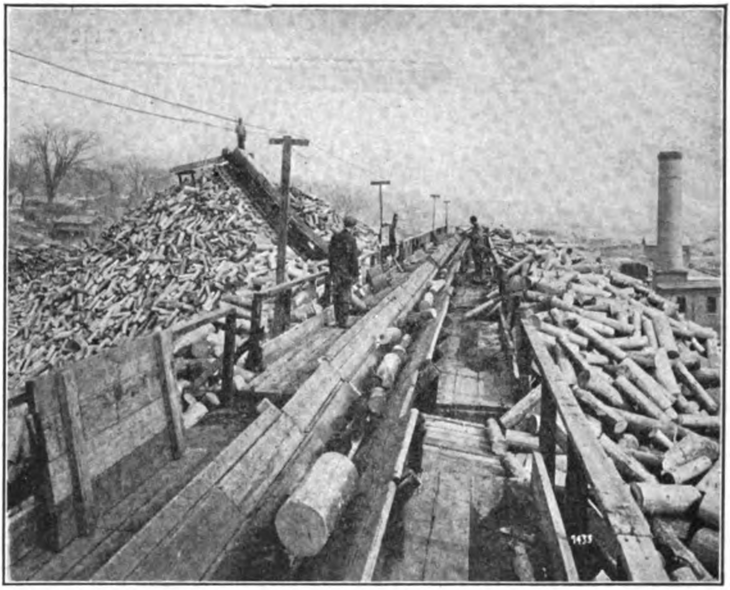
Fig. 19.—Wood storage conveyor mounted on wooden trestle at large mill in Newfoundland. This installation will take care of 40,000 cords of wood.



Courtesy: Kyther & Pringle Co., Carthage, N. Y.

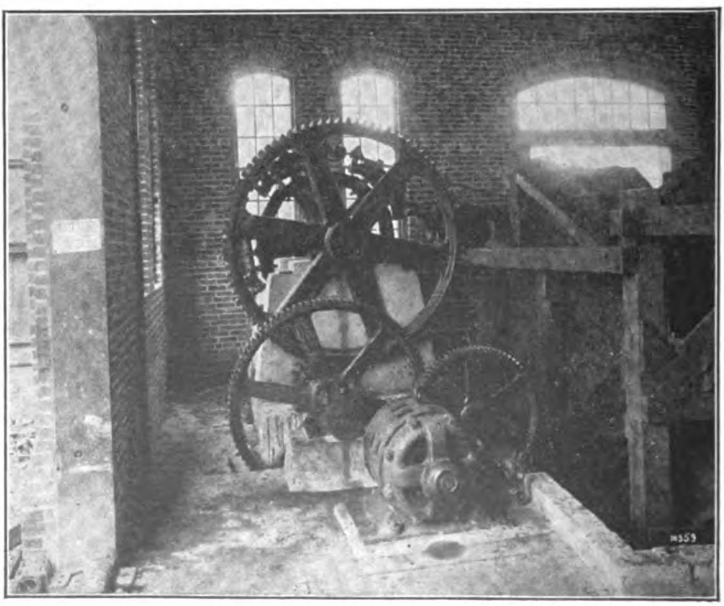
Fig. 20.—Type of conveyor used for wood storage.

accommodate 2 foot or 4 foot blocks and to fit the teeth of the driving sprockets at the ends of the conveyor. The drive is usually furnished by an electric motor. This motor should be in an accessible position and it is wise to have a hydrant located



Courtesy: Jeffrey Manufacturing Co., Columbus, O.

Fig. 21.—Wood storage conveyor showing how sections of trough can be removed and pulp wood discharged from conveyor to accomplish continuous storage.

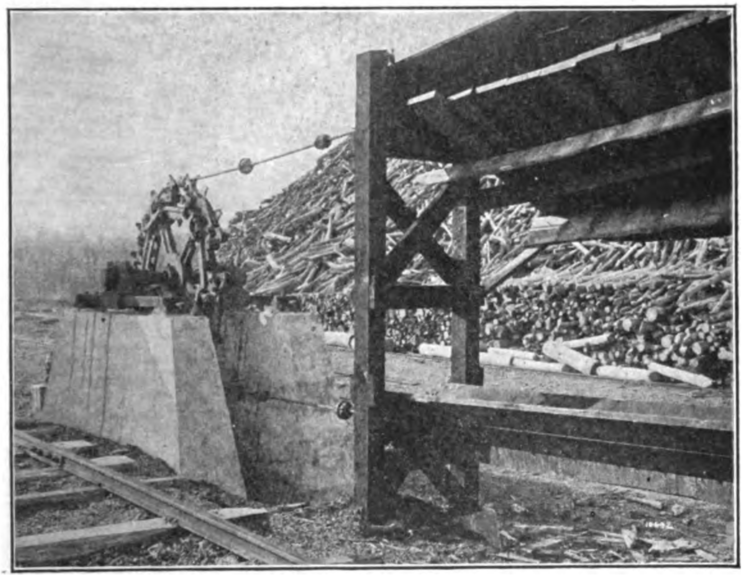


Courtesy: Jeffrey Manufacturing Co., Columbus, O.

Fig. 22.—Drive end of a pulp wood storage conveyor.

at this point, as this is one of the most likely places for fires to start in the wood storage, the motor being the cause. If a hydrant is not possible a good fire extinguisher should be kept convenient to the motor. The motor should be kept clean and in good order and inspected regularly and every precaution should be taken against fires at this point.

The wood is delivered to the pile by the upper run of the conveyor and sent to the mill by the lower or return run. The lower run is placed in a trench or trough beneath the surface of the ground and this trench is roofed in with heavy planks when



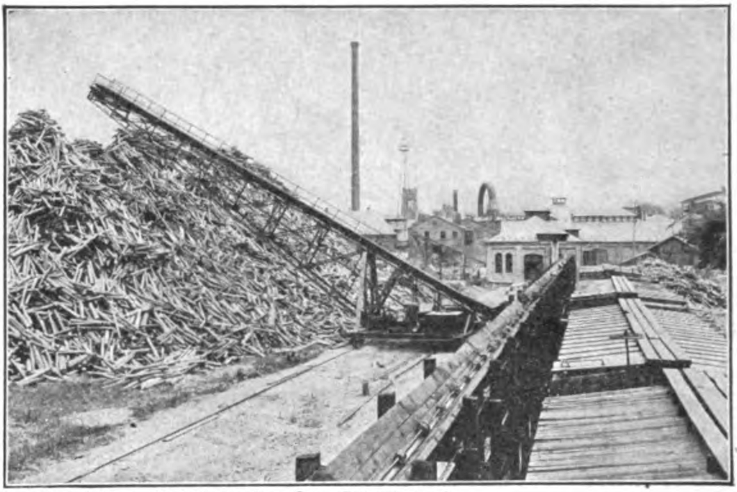
Courtesy: Jeffrey Manufacturing Co., Columbus, O.

Fig. 23.—Foot end of a pulp wood storage conveyor as installed at a mill in Pennsylvania, showing the method used to maintain proper tension in the cable.

the wood is being stored. When the pile is being depleted and sent to the mill the covering is removed.

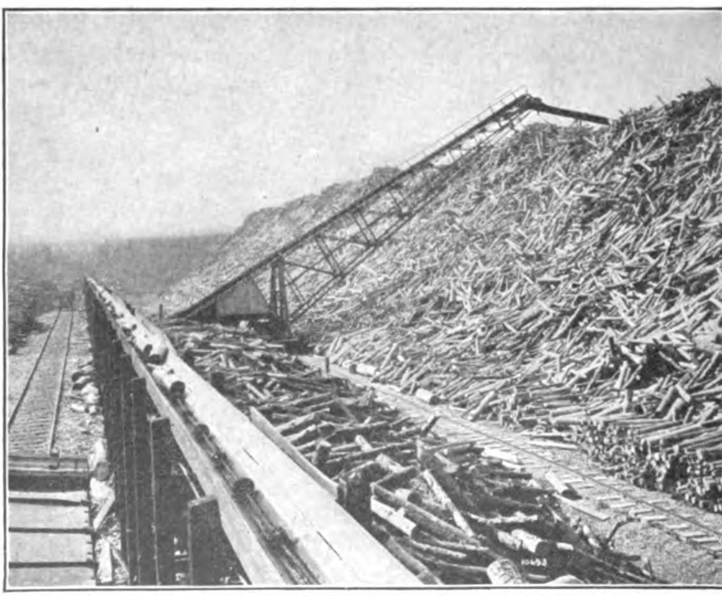
Another more modern system of storage is to have a structural steel stacker, the base of which rides on a truck running on rails. This stacker is built like a section of a cantilever bridge. An endless belt carries the wood up to the tip of the stacker where it falls off onto the pile. The wood is fed to the stacker from a short conveyor. This scheme has the advantage that several cars can be unloaded at once, no long conveyor is necessary and the track on which the stacker moves can be taken up and moved along as the pile develops.

A third system is to have two or more tall towers of structural steel, concrete or wooden construction, with a conveyor



Courtesy: Jeffrey Manufacturing Co., Columbus, O.

Fig. 24.—Portable stacker and feeder conveyor as used for storing wood from railroad cars at a mill in Pennsylvania.



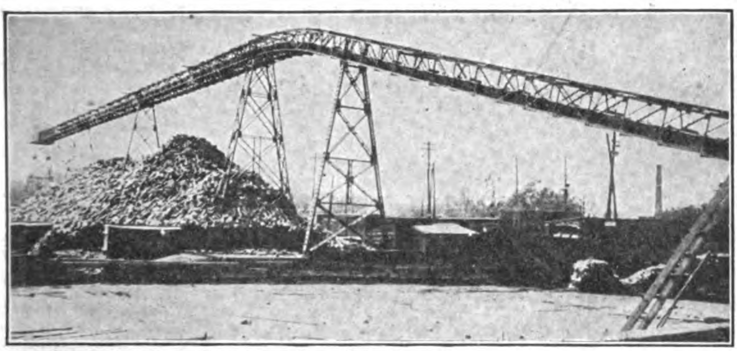
Courtesy: Jeffrey Manufacturing Co., Columbus, O.

Fig. 25.—Another view of a portable pulp wood stacker showing barked wood stored and unbarked wood waiting to be barked.

running between them. A runway extends the length of the conveyor and wood can be dumped off it at any point.

The usual type of conveyor will handle 250 cords in 10 hours and requires 1½ H. P. per 100 feet of conveyor, travelling at 100 feet per minute.

Since too dry wood is not desirable raw material because, while enabling an increase in production and lowering the sulphur bill (because stronger acid is needed with green wood), it decreases the strength of the paper; it is obvious that there must be a certain degree of flexibility in the arrangements for utilizing the wood. A large mill storing from 50,000 to 80,000 cords of wood, some of which is rough, some peeled, some fresh from the forest, will have to be so organized that when a bad pile is struck the wood from it can be gradually worked in with better grades;



Courtesy: Jeffrey Manufacturing Co., Columbus, O.

Fig. 26.—Wood storage conveyor mounted on permanent steel towers at plant in Quebec. This installation utilizes a conveyor 500 feet center to center and takes care of 8,000 cords of wood.

otherwise the quality of the paper would be immediately and noticeably affected.

The Work of the Wood Room.

The wood room is a system of machines, conveyors, etc., for cleaning wood, for removing bark and, in those mills where the pulp is to be manufactured by a chemical process (sulphite, sulphate or soda process) for chopping and screening the wood into designated sizes for the digestors. In the case of mills making ground-wood or mechanical pulp the blocks are delivered direct to the grinders from the wood room.

Removing the Bark: It is essential that every trace of bark should be removed from wood that is to be used for making pulp. The bark colors the pulp and fills the paper with dirt specks. Bark seems to hold its original state unaffected by the chemicals used in either the sulphite or the Kraft processes of pulp manufacture. It is equally necessary to have the wood free from bark if it is to be used for ground wood.

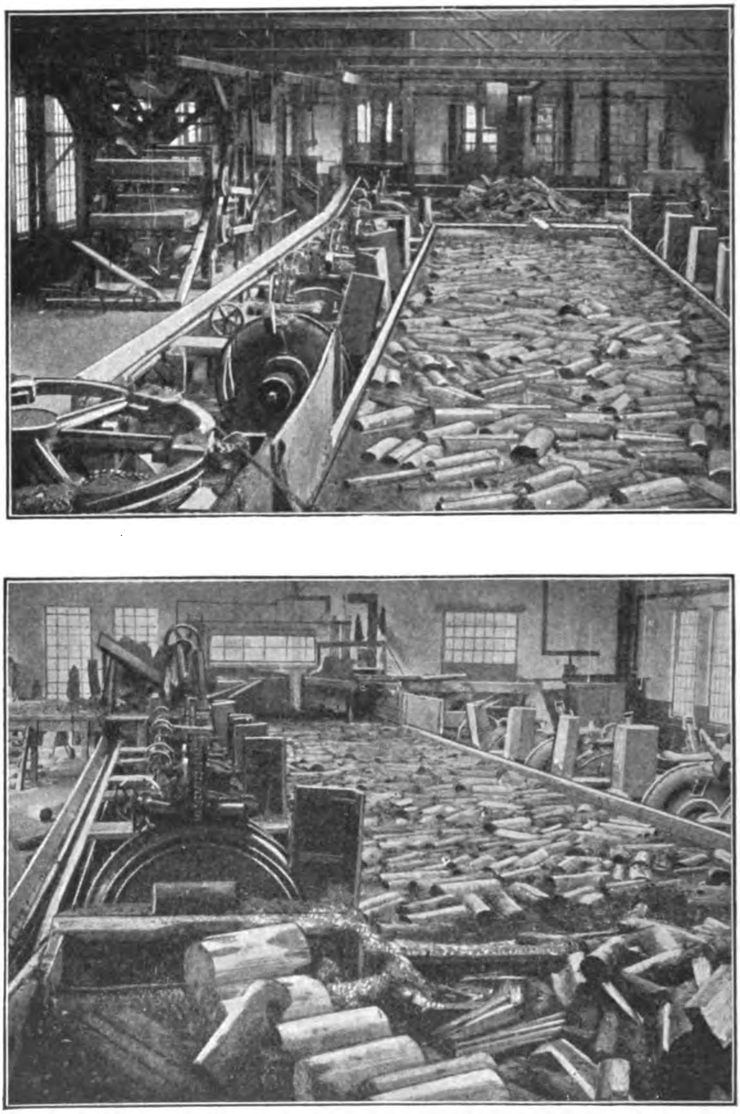


Fig. 27.—Two views of typical wood room pond.

In some mills the bark is removed in tumbling drums and in others by means of "barkers" or barking-machines. The latter are less efficient both from the standpoint of labor and waste. Tumbling drums will save sometimes fifty per cent of the labor and ten per cent of good wood which the barking-machine wastes. However, the first cost of the equipment is much higher.

The two-foot or four-foot blocks are delivered to the wood room by means of a chain or cable conveyor. This device possesses the following advantages for this purpose:

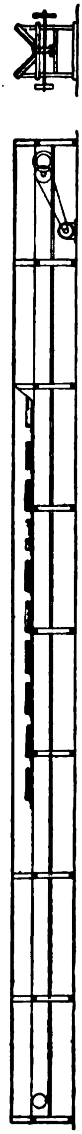


Fig. 28.—Diagram of typical wood room conveyor.

It is cheaper than teams; the blocks of wood may be singly and easily inspected as they pass a given point along the conveyor; two or three different qualities of wood may be conveniently mixed in exact proportions, as is often desirable from necessity on account of having a variety of kinds on hand which it is always best to mix; finally, the blocks can be counted to determine the number of cords used in a given time. The number of two-foot blocks contained in a cord varies according to the diameter of the logs from which they are cut—ranging from seventy-five to one hundred and twenty-five blocks per cord. The average number is generally determined by piling several cords, counting the blocks and taking the average. This method, while not absolutely correct, is a convenient way of checking other measurements. All wood is "scaled" (measured) several times before it is finally reduced to pulp. One cord of green, peeled wood weighs (approximately) 3,000 lbs.

Arriving at the wood room, the wood is usually dumped from the conveyor into a pond or tank of water. There is usually a centrifugal pump which takes water out of the lower end of the tank and delivers it to the head end, thus causing a continuous current which floats the logs towards the tumbling drums or barking-machines. There are several reasons why this floating process is preferable to mechanical conveyors. First, the maintenance of the floating process is very small compared with other methods; second, the wood in winter time is freed from ice, and the dirt attached to the ice, by heating the water with exhaust steam; third, all dirt adhering to the wood is pretty sure to be removed during its progress through the pond; fourth, it serves as a storage reservoir holding a surplus of wood so that there will always be the needed supply on hand for the chippers or grinders. This pond is usually from 3 ft. to 4 ft. deep, made of pine or concrete. A pond 80 ft. x 12 ft. x 4 ft. deep requires 21,000 board feet of lumber. An 8 inch slow speed centrifugal pump, capacity 600 to 800 g. p. m. requiring 6 H. P. and running at 450 r. p. m. will provide for the water circulation.

Tumbling Drums: The use of tumbling drums for removing bark in the paper industry was first introduced into this country by Bache Wiig. His equipment took the form of closed cylinders of steel plate, into which were packed four-foot blocks parallel with each other and the sides of the cylinder. Water was injected through an opening at the center of the ends. When the machine had rotated long enough the logs were removed and another batch put in. The cylinder rested on trunions. In some cases there was a large girth gear by means of which the cylinder was rotated.

These drums have since given way to drums made of steel channel open at each end and operating continuously, the logs

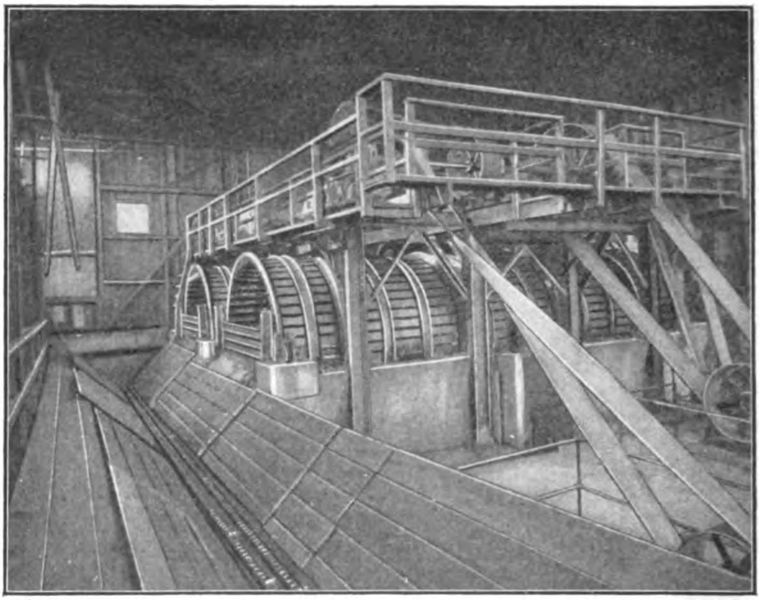


Fig. 29.—Barking drum installation showing conveyor for removing barked logs.

being fed into one end of the slightly inclined drums and after having all the bark rubbed off by jostling against one another and the drum, gradually working out of the other end. The drums dip in a pond of water which is scooped up by the channel irons. Water pours over the logs constantly while in the drums and washes away the bark, which accumulates in a waste pile and is generally burned. From the lower end of the tumbling drums the blocks fall onto a conveyor which takes them to the chippers, in the case of sulphite mills, etc., or to the grinders in the case of ground-wood mills. A man is stationed at a convenient point who transfers to a conveyor, leading back to the pond in the wood room and back through the drum for rebarking, all logs from which the bark has not been completely removed. The usual

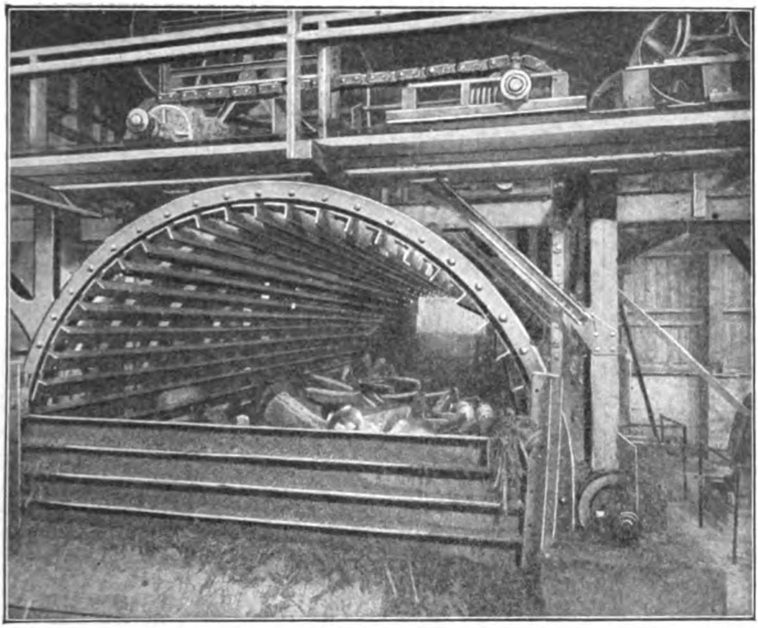


Fig. 30.—Barking drum showing driving and supporting chain.

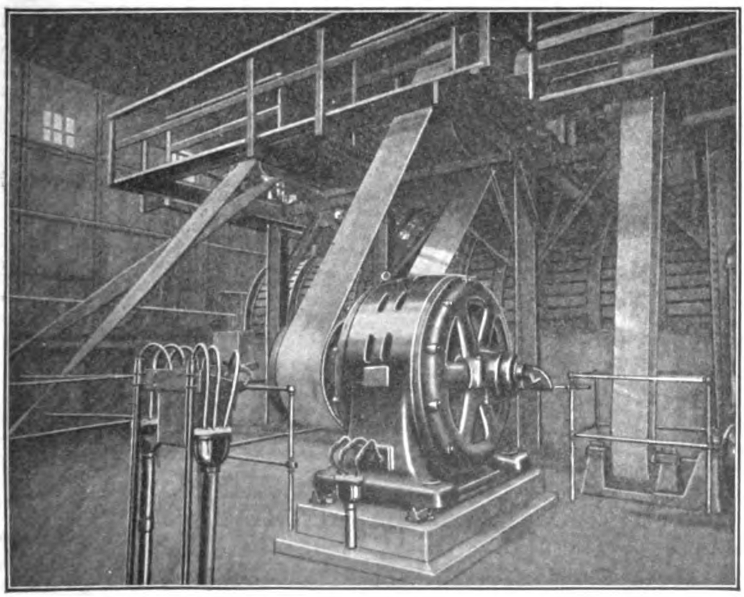
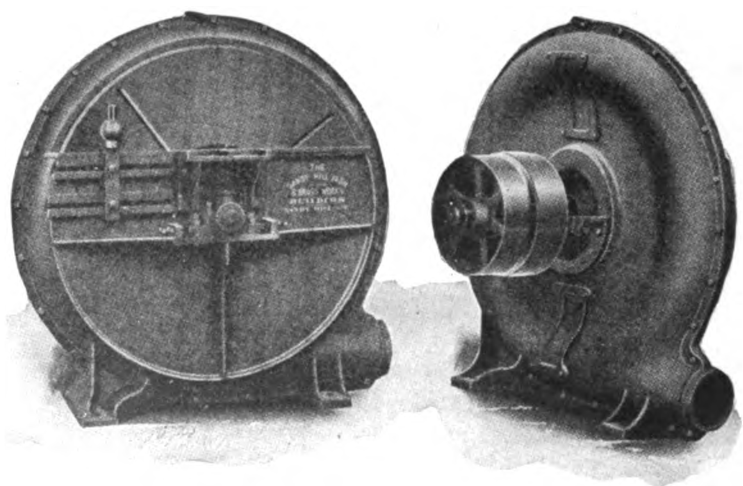


Fig. 31.—Typical electric drive for barking drum.

size for these drums is 9 to 10 ft. diameter by 25 to 30 feet long and the capacity is 12 to 15 cords per hour of 4-foot wood. A drum 10 ft. by 30 ft. requires about 100 H. P. to drive.

Barking-Machines: Although barking-machines are more wasteful of wood than barking drums, and although it requires more labor to operate them, they are still ordinarily found in American mills. Barkers sufficient to take care of the incoming of a tumbling drum installation. The first drum installations in this country were not conspicuously successful and the fact that improved equipment has removed the causes of the early failures has not yet become as universally appreciated as might be desired.

A barking-machine works on the same principle as a carpenter's plane. Four knives, analogous to the blades of the plane, are set in a round, flat-faced disc. The knives are set in the disc an equal distance apart. If a block of wood is held against these revolving plane-knives the wood or bark will be shaved from the block. Turning the block will thus cause the bark to be removed from the entire circumference.



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

Fig. 31a.—Two views of a typical disc barker.

Barking machines differ very little in general construction and style. A Barker, to produce good results, should have a disc at least 42 inches in diameter, and should contain four knives. The discs must be in perfect balance so that in revolving they may run true, as any extra weight on either side causes an eccentric motion to the revolving disc. They are properly balanced before leaving the shop and every reasonable effort should be made to keep them so. This is a very important matter, as the discs run at a high rate of speed—from 750 to 950 revolutions per minute, and when out of balance, cause the machine to jump and pound, quickly destroying the bearings, and affecting the proper running of the machine. It may be said that some discs are run so thoroughly out of balance as to be really dangerous to life and property.

The discs should be equipped with proper clearing irons, or clips, which serve to keep bark and refuse from binding and lodging between the disc and shell or hood of the barker, causing undue friction and waste of power.

In a supply of knives for these machines, there may be some which have been worn considerably narrower than others; in many cases these knives of various widths are put into the same barker, no attention being given as to whether or not the wide knives are all on the same side of the disc. The result is that the disc is thrown out of balance to a dangerous extent. If it is necessary to use various widths of knives, they should be carefully gauged or weighed, and heavy and light knives placed opposite heavy and light ones respectively, so that the disc will retain its proper balance.

The barker must be equipped with tight and loose pulleys so as to be stopped at will for the purpose of re-setting the knives.

Barker knives should be of the best quality of steel, tempered to stand hard usage, as wood is very gritty, containing many hard and dry knots. They should never be allowed to run after they become dulled, but should be kept in proper condition, even if it becomes necessary to change them three or four times a day. They should be ground with an automatic emery grinder with water running on them to prevent drawing the temper. Care should be taken to grind them in sets, all the knives in a set being of the same width and thickness; they should be set in the grinder carriage so that the back or blunt edges are lined up against a straight edge, so that in grinding, they shall be kept of the same width.

It very often happens that barker-men put in a set of knives of various widths and line up the cutting edges with the emery wheel; the first time the carriage runs across, if the emery wheel does not touch all the knives, they are promptly rapped into line with no regard as to variations in width. The result of a continual operation of this kind is that there are no two knives of the same width and weight in the entire supply.

After removal from the grinder, the knives should not be placed in the barker disc until finished with an oil-stone to remove the burr or wire edge left by the emery wheel.

Knives should always be set by a gauge—never left to the judgment of the barker-man, as it is known to be more laborious to properly bark wood when the knives protrude but slightly;

while knives set rank (or protruding noticeably), will usually remove the bark and considerable good wood. However, they should be set out not farther than 1/8 of an inch beyond the surface of the disc, to avoid wasting wood.

The shell, or casing, of the barker is designed to carry off the bark and shavings. The high speed of the disc inside the case produces a blast similar to that resulting from the use of an air-blast fan, sufficient to blow the shavings to a considerable distance. Sometimes small wings are bolted to the disc to increase the velocity of the shavings. These shavings are blown into cone-shaped receptacles, called cyclones, which are supposed to give vent to the air-pressure made by the revolving disc, and retard the velocity to a speed suitable for the conveyors. They then pass, by means of the conveyors, to the Boiler House for fuel.

The barker should always be equipped with a suitable table, adjustable to large and small wood. The end of this table should always be equipped with a stop to prevent the wood from sliding endwise as the knives strike it; or, in other words, to counteract the force.

Most barkers are equipped with an automatic attachment for turning the wood. Some manufacturers prefer not to use this attachment, as it is claimed to be rather wasteful. There is no doubt that by its use more wood can be barked per day than when this work is done by hand; it is a question of figuring the loss of wood against the low production. Every effort should, of course, be made toward saving wood.

A good workman can bark approximately ten cords of wood per day without this attachment, provided such wood is of reasonable size and good quality—that is, does not contain too many gum seams and knots, the best sizes ranging from 8 inches to 12 inches. The wood should be thoroughly cleaned of all bark, gum and knots, to prevent the entry of dirt into the pulp or ground wood.

Care must be taken to protect employees against accidents on these machines. The floor must be kept free from bark and never allowed to become wet and slippery. Suitable guards should be provided and there should be ample room around the barkers. All attachments must be kept in proper repair. Suit for criminal negligence can be brought against the superintendent in case of accident to an employee if it is found that any part of the mechanism was at fault, thus causing the accident.

The barkers must be kept carefully oiled. Loose pulleys must be oiled. Special care must be taken never to allow the belt to run on the loose pulley any longer than is absolutely necessary. If, for any reason, the supply of wood to the barkers is stopped for any length of time, it is better to shut off the power than to shift the belts to the loose pulleys.

Chippers.

Two-foot or four-foot blocks free from bark are brought, by a mechanical conveyor, or by means of another pond, from the tumbling drums or barking machines to the chippers. These are powerful machines which slice the blocks crosswise of the grain into sections seven-eighths of an inch thick, at the rate of eight hundred slices per minute.

Before explaining the construction and operation of this machine, it might be well to explain why the blocks are not sawed into sections of the right thickness. This method has been tried, but has been found too wasteful and too slow. It is wasteful

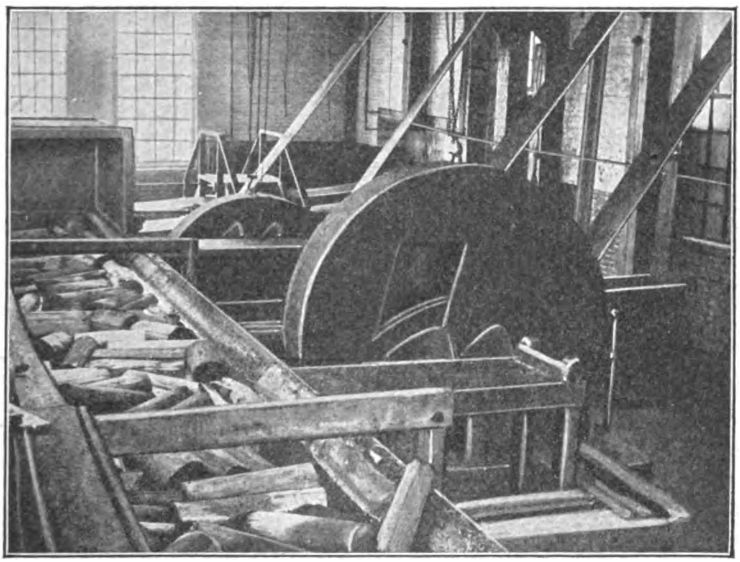
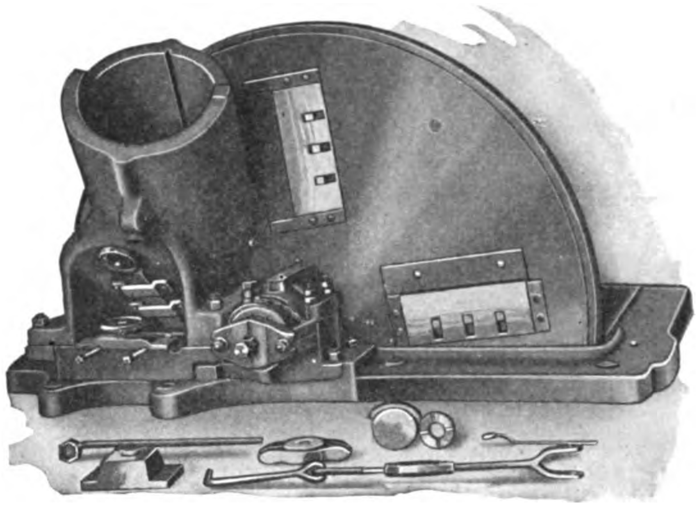


Fig. 32.—Chipper installation showing end of pond and platform for feeding chipper.

because any saw suitable for this work will make a "scarf" (wood turned into sawdust) at least a quarter of an inch wide. In sawing sixty thousand cords of wood—a fair year's supply—into sections seven-eighths of an inch thick there would be a loss of about 14,000 cords of wood, worth about $280,000. Moreover, the sawdust would be objectionable in the digesters, as will be explained later. Wood for soda pulp is chipped a little shorter than for sulphite or Kraft.

The modern "Four-Knife Chipper" consists of a flat-faced disc of solid cast iron on the rim of which a steel ring is shrunk for safety. The disc is about 84 inches in diameter, 4 inches thick and weighs about 3 tons. It is run at a speed of from 200 to 225 revolutions per minute. This disc is firmly keyed to a shaft that passes through its center. On either end of this shaft are journals supported in journal-bearings. Keyed to this same shaft is a driving-pulley of suitable dimensions, by which the disc is driven in a vertical position—similar to a car wheel.



Courtesy: Carthage Machine Co., Carthage, N. Y.

Fig. 33.—Typical chipper with hood removed showing knives.

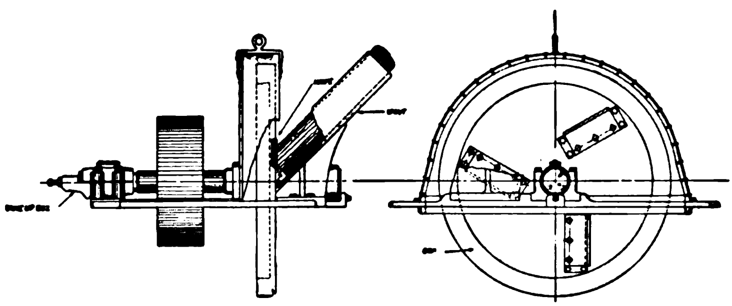


Fig. 34.—Diagram showing construction and operation of standard chipper.

The disc-shaft and pulley, thus assembled, are all mounted in a very substantial cast-iron frame, designed to stand the violent hammering and strain. This disc, like the barking-machine, has three or four knives placed in a circle. The knives are much stronger than the knives on the barking-machine and are ground at an angle varying with the make of the knife and regulated by the quality (whether wet or dry, etc.) of the wood to be chipped. By multiplying the revolutions per minute by the number of blades (4) we arrive at the number of cuts per minute, and knowing that the chips are always ⅞ inch thick, and knowing the number of sticks to a cord we can calculate the theoretical capacity of a chipper. Allowance should be made, of course, for the efficiency of the feeding system.

Chippers are built in the extremely strong fashion explained above on account of the *terrific* violence of the strains to which they are subjected. The centrifugal force on the rim of such a disc, running at the required number of revolutions per minute, together with the force with which the knives strike a 12-inch block of sound spruce wood hard enough to cut a clean slice seven-eighths of an inch thick, across the full diameter, demands the sturdiest construction of every portion of the machine.

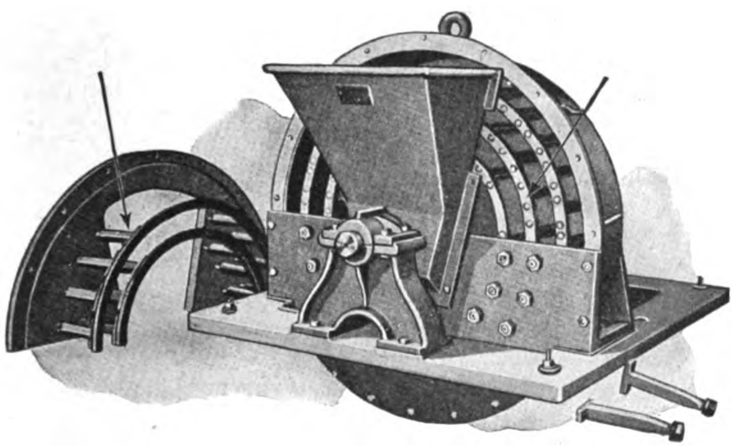


Fig. 35.—Cage type of crusher.

The spout of the chipper is of cast iron, generally square, but sometimes round, and inclined at an angle of forty-five degrees to the disc. The reason for this angle is to feed the blocks against the disc so that the knives will strike in an oblique manner. This may be likened to whittling with a knife, which is held at an angle of about forty-five degrees instead of holding it straight. Morever, if the chip is cut at right angles the area at the end, and consequently the number of pores exposed, is less. It has been found that the acid penetration in the digesters takes place through the ends of the chip, consequently it is desirable to have the end area as large as possible.

At the base of the spout is a hardened steel bed plate, intended to prevent undue wear in the spout, and to make the chipper cut clean chips. This bed plate must be renewed frequently. If worn and rounded bed plates are used they have a tendency to allow the wood in direct contact to turn over, yielding a ragged chip. A good hardened steel bed plate ought to last during the chipping of a large number of cords of spruce under normal conditions.

It is very important that the knives should be kept sharp and in perfect condition. The chips must be *sliced* off clean, without bruising. Dull knives will *pinch* off the chips, bruising them, closing the pores and thus rendering them impermeable to the acid when they reach the digesters.

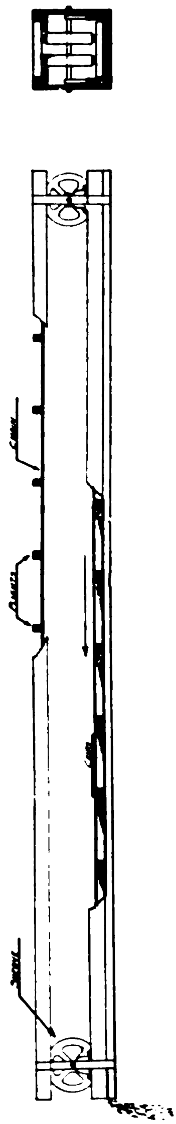


Fig. 36.—Type of conveyor used for conveying chips from chippers to screen.

It is, of course, imperative that the disc should be run in perfect balance. With the great weight and high speed of the disc it will rapidly injure the journal bearings, which, apart from the damage to the machine, is very dangerous.

Given proper attention and sufficient driving-power the chipper will handle from 8 to 13 cords of wood per hour. About 150 H. P. is usually required to drive a standard chipper.

The chippers have an endwise adjustment controlled by a screw so the disc can always be kept snug up against the bed plate. The chippers discharge through a hopper into the crusher, placed immediately below.

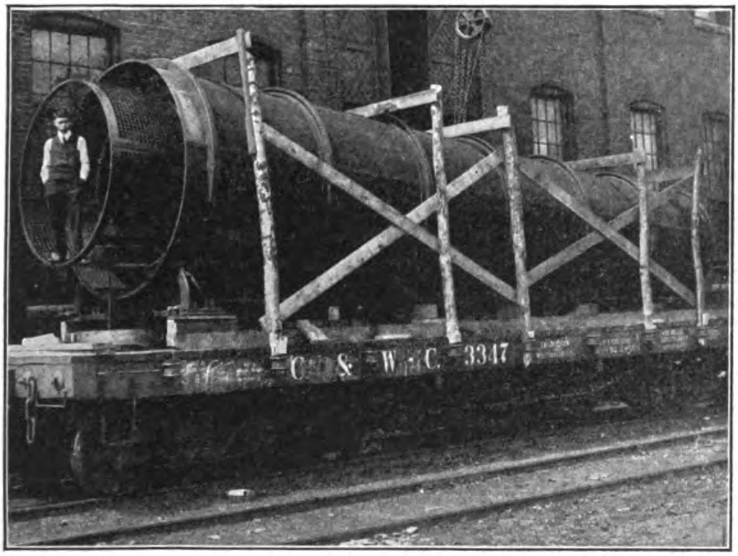
Crusher.

The crusher is a machine for disintegrating the chips into specified weights and thicknesses directly after passing through the chipper. One type of crusher consists of a rotor to which are attached swinging pins, held reasonably positive by the action of centrifugal force. These pins are held on pivots of lignum vitæ or oak, thereby preventing undue binding and protecting the fingers, which throw back in case a spike or bolt inadvertently passes through the crusher, thus saving the machine from being wrecked. The pins should be maintained complete and in good condition. Operating the crusher with missing pins permits coarse chips and knots to be delivered to the belt, and while the screens will reject these to the refiner, the efficiency of the whole installation will be lowered on account of the excessive amount of waste of poorly prepared chips, etc., rejected by the screens. The usual speed of the crusher is from 2,000 to 3,000 revolutions per minute. Another type of crusher is designed on the cage principle, as illustrated.

Screens.

The chips must be screened very carefully, not only to eliminate large chips that have failed to be disintegrated in the crusher, knots, etc., but also to separate too finely divided particles, sawdust, etc.

Many theories have been advanced as to the undesirability of sawdust in the chips. One of these is that sawdust will not cook in the digesters. This has been disproved by suspending a copper basket filled with sawdust in the digester. It will cook.



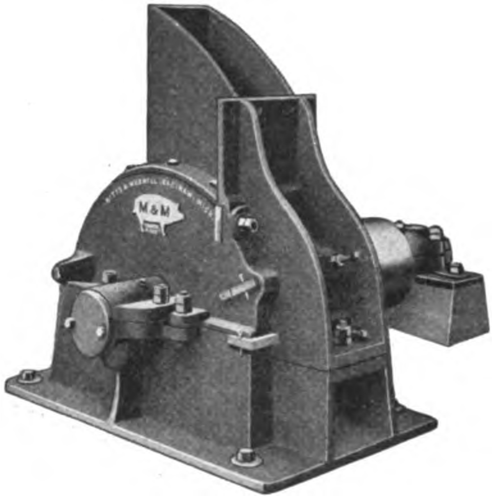
Courtesy: Carthage Machine Co., Carthage, N. Y.

Fig. 37.—Rotary type of chip screen.

However, it is very apt to be overcooked. In other words, if a ⅞ inch chip predominates, it takes a specified time for the acid to penetrate and if the digester contains 95 per cent of these ⅞ inch chips, this 95 per cent of the digester will be properly cooked, and if the other 5 per cent consisting of sawdust will be overcooked. Morever, any attempt to cook the sawdust would result in poor circulation. There are some conditions when the digestor is first started off, where the sawdust would plug the strainer. As a result of poor circulation a large part of the sawdust might remain undercooked and appear in the sheet as dirt.

The chips from the crushers are elevated to the screens by means of a scraper or drag conveyor which passes beneath the crusher and receives the chips from the crusher through a hopper.

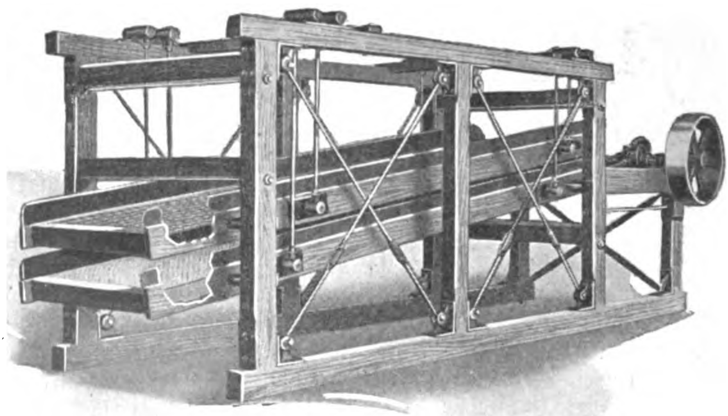
Several types of screens are in use. The Lombard, or Rotary



Courtesy: Mitts & Merrill, Saginaw, Mich.

Fig. 38.—Re-chipper.

Type, resembles a tumbling drum. The first section consists of a fine sawdust section, removing all sawdust and particles smaller than the standard chips. The second section consists of a coarse



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

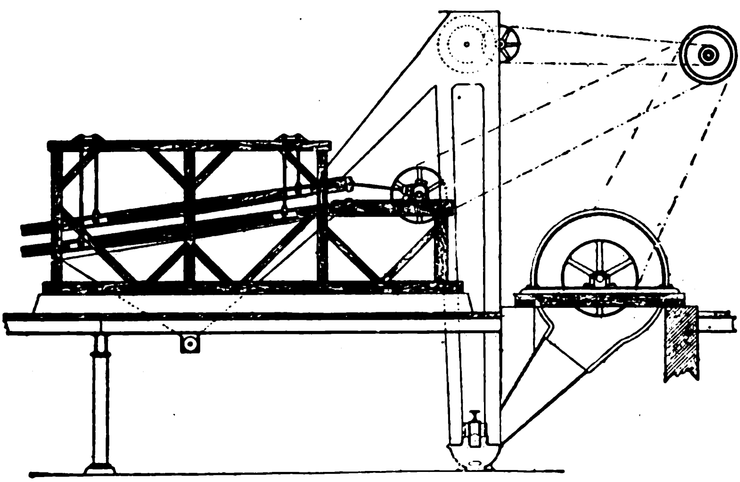
Fig. 39.—Standard type of shaker chip screen.

mesh screen with perforations approximately 1 in. in diameter, permitting the standard chips to fall through and ultimately go to the digestor, and rejecting the balance. The chief objection to this type of screen is that long slim chips which should go to the re-chipper stand on end and go through.

Shaker Screens.

The Shaker Type Screen is preferable and works more efficiently. The shaking motion has a tendency to hold the long slivers parallel to the screen and sift them off. In the rotary type these slivers sometimes get stood on end and fall through the openings, thus finding their way to the digester.

The Shaker Screen consists of two large, flat trays, one directly above the other. The top tray is covered with perforated metal or wire with openings (about 1 in. by 1¾ in. in size), which let out the chips, but retain the large knots and slivers. The motion of the screen moves these rejected particles to the discharge end, where they fall into a tank of water. The slivers and large pieces of sound wood float and are skimmed from the



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 40.—Typical screening installation showing chipper, elevator, and chip screen.

top of the water by a conveyor chain, passing into the re-chipper. The chips from the re-chipper then pass back to the screens. The knots, being heavier than water, sink in the tank and are removed from the bottom at intervals. Knots are useless as material for pulp.

The bottom tray of the screen is covered with perforated metal having openings only large enough for sawdust and fine particles of dirt to fall through. This waste is automatically conveyed to the boiler house for fuel.

The standard sized chips, freed from those particles that are either too large or too small, fall from the screen to a belt conveyor by which they are carried to the chip bins.

Re-Chipper.

This machine consists of a disc or cylinder with sharp knives on its periphery. It is not at all like the chipper, being a sort of cutter similar to those used for scrap leather, etc. It requires about 2 H. P. per cord per hour. Its usual speed is from 500 to 600 r. p. m.

Chip Bins.

The chip bins are large steel plate storage bins, the bottoms

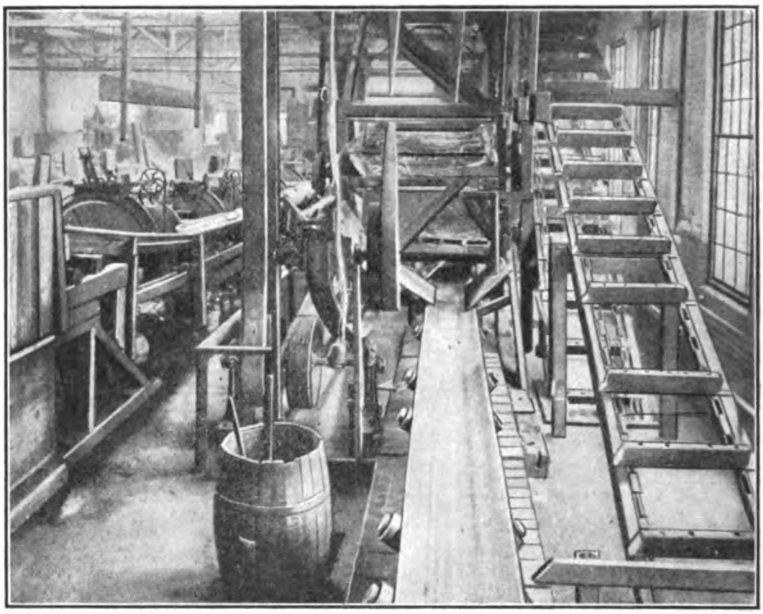


Fig. 41.—View in chipper department showing shaker screen with belt and scraper conveyors.

of which are wedge shaped to permit the chips to flow freely from the openings at the base.

The chip bins are located just above the digesters. The opening at the base is closed by a sliding gate operated by a hand-wheel. A portable hopper, suspended to rails, can be placed to coincide with the openings in the chip bins and the digester-head, serving as a "funnel" for chips when filling the digester.

The chip bin capacity should be so planned that it will not only serve to accumulate the desired charge of the digesters, but will also act as a reservoir to take care of the fluctuation in chip requirements and in the chip production of the wood room. It is customary to regulate the chip bin capacity so as to be able to charge each digester every eight to ten hours on running schedule in wood room of ten hours. Also to enable the digester to be charged Sunday nights and the cooking process started without running the wood room overtime. Conditions vary, but as a general rule, a cord of wood when put into chip form will occupy from 175 to 210 cu. ft.

Chip Conveyors.

The chip conveyor from the chip screen in the wood room to the chip loft is quite a large piece of conveying equipment, owing to the fact that the chip bins are located at the extreme top of the digester building, which is itself necessarily a tall structure, and the wood room frequently has to be some distance away. In many cases, this conveyor passes over several other buildings on a trestle. The conveyor is usually of the drag type with maple flights. The width is usually 18 inches and the spacing 24 inches. The H. P. required to drive this conveyor depends on the layout and the length and pitch of the conveyor. A conveyor 100 feet, center to center, with 25 to 30 degrees pitch, requires 18 H. P. for a speed of approximately 125 feet per minute. The above specifications give a carrying capacity of 12 to 15 cords of chips per hour. Sometimes the flight conveyor does not reach

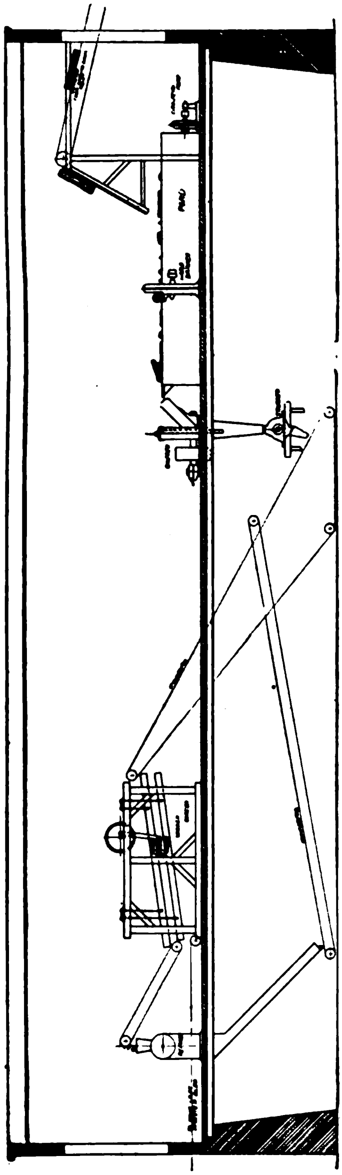


Fig. 42.—Diagram showing typical chipping and screening plant designed so as to simplify the conveyor installation as much as possible. In order from right to left are shown the conveyor from the barking drums, the pond, the chipper, crusher, shaker screen and re-chipper together with the necessary conveyors and a hand barker for removing bark from any logs failing to receive proper treatment in the barking drum.

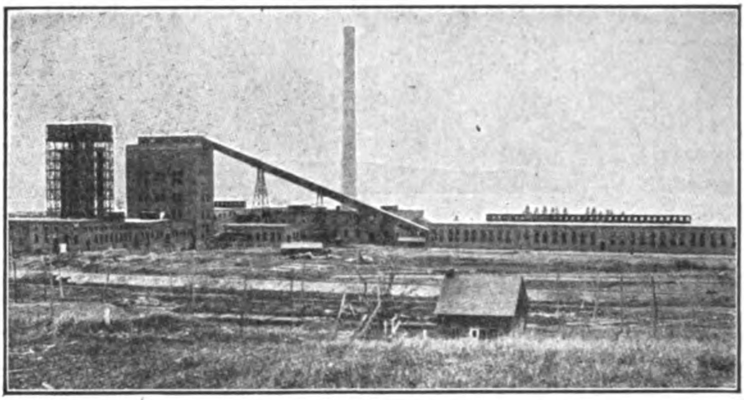


Fig. 43.—External view of Canadian plant showing chip conveyor from wood room to chip bins.

to the chip bins, discharging into a hopper at one of the lower floors of the digester building, from which point the chips are elevated by a bootleg (bucket) elevator.

Inspection of Chips.

Chip tests are made on this material going to the bins by passing the chips through standard mesh sieves, the "Ro-Tap" machine being excellent for this purpose. Two analyses are given below to show how these results may be interpreted. (See also chapter on testing.)

Fraction	Size	Percent	
(1)	Over ¾" Square	18.38	21.63
(2)	½" to ¾" Square	74.77	54.50
(3)	¼" to ½" Square	5.08	12.33
(4)	Thru ¼" Square	1.77	11.53
		100.00	99.99

Fraction 1 is very coarse, 2 is good material, 3 is irregular and 4 is sawdust. Test No. 1, although showing an abnormal amount of coarse stuff, is nevertheless a very good test while No. 2 is very poor for fractions one and four are large and two is small. The season of the year affects the size of chips, as frozen wood is much more friable than dry material.

VI. Sulphite Mill.

In this chapter we will consider the processes and equipment required for the manufacture of chemical pulp by the sulphite process. This includes not only the actual equipment for the sulphite process, but also the various appliances by which the pulp is washed and freed from impurities and made ready for use in the paper mill. The acid plant, which is the part of the pulp mill devoted to preparing the acid liquor used in the sulphite digesters, will not be considered in this chapter, but will be dealt with in a separate chapter immediately following this one.

Sulphite Process.[1]

The sulphite process is today the most important method of making chemical wood pulp. It was invented by B. C. Tilghman of Philadelphia, who established the process virtually as it is carried on today, although numerous chemists and engineers have subsequently made important contributions to its theory and practice which have led to the present efficient and valuable process. Tilghman's original patent was taken out in 1867, but it was not till considerably later that the sulphite process became a real working proposition.

Tilghman originally proposed digesting the wood in lead lined iron cylinders which proved impractical for large scale operations. A few years later Swedish engineers introduced changes in the process that made it commercially practical, using digesters similar to the modern digester, only much smaller, and using an indirect cook, i. e., not letting the steam come immediately in contact with the wood and acid, but having the heat applied by means of a jacket and coils.

About ten years after Tilghman's patent, Mitschlerlich began experimenting with the process in Germany and used a digester lined with brick, a form of equipment which has since become almost universally adopted. The original Mitschlerlich boilers were from 10 to 12 feet in diameter and about 36 feet long. These digesters were heated indirectly by means of coils of lead covered pipe. The Mitschlerlich process is still used for certain classes

[1] It is not the intention of the author to deal at great length with the historical development of the sulphite process, which, although of great interest, would take up too much space in a book intended for practical paper makers. An excellent account of the history of the process can be obtained in Griffin and Little's "Chemistry of Paper Making," and also in numerous articles in the various technical periodicals of the paper industry. But for convenience in reference we have included in this chapter a copy of Tilghman's original patent, taken from Griffin and Little.

Moreover, no attempt has been made to discuss in detail the chemical aspects of the process. Again we must refer the reader to Griffin and Little and to the technical journals in English and German dealing with the paper industry, as well as to numerous articles that have appeared in the publications of the various chemical societies.

Finally, we have tried to confine the discussion to types of equipment and variations of the process now in actual use so as to avoid confusing the practical reader.

of pulp and will be described in greater detail later in this chapter; however, the apparatus used for the modern Mitschlerlich cook has been altered a good deal and the digesters are larger.

The first practical working sulphite mill in America used the Partington process, which called for spherical digesters of the rotary type.

Larger scale manufacturing operations were commenced by Wheelwright, who overcame great difficulties and succeeded in producing pulp of excellent quality cheaper than it had ever been made before. Wheelwright devoted great attention to the form of the digester and the nature of the lining and, according to Griffin and Little, succeeded in reducing the cost of repairs on linings from $10.00 per ton of product to about $1.50 per ton of product in three years.

Tilghman's Patent.

"The process of treating vegetable substances which contain fibres with a solution of sulphurous acid in water, either with or without the addition of sulphites or other salts of equivalent chemical properties as above explained, heated in a clost vessel under pressure, to a temperature sufficient to cause it to dissolve the intercellular incrusting or cementing constituents of said vegetable substances, so as to leave the undissolved produce in a fibrous state, suitable for the manufacture of paper, paper-pulp, cellulose, or fibres, or for other purposes, according to the nature of the material employed.

"I also claim as new articles of manufacture the two products obtained by treating vegetable substances which contain fibers with a solution of sulphurous acid in water, either with or without the addition or sulphites or other sales of equivalent chemical properties as above explained, heated in a close vessel, under pressure, to a temperature sufficient to cause it to dissolve the intercellular or incrusting constituents of said vegetable substances, one of said products being soluble in water, and containing the elements of the starchy, gummy, and saline constituents of the plants, and the other product being an insoluble fibrous material, applicable to the manufacture of paper, cellulose, or fibres, or to other purposes, according to the nature of the material employed.

"I also claim the use and application, in the manufacture of paper, paper-pulp, cellulose, and fibers, of the fibrous material produced by treating vegetable substances which contain fibers with a solution of sulphurous acid in water, either with or without the addition of sulphites or other salts of equivalent chemical properties as above explained, heated in a close vessel, under pressure, to a temperature sufficient to cause it to dissolve the incrusting or intercellular constituents of said vegetable substances.

"I also claim the use and application of sulphites of other sales of equivalent chemical properties as above explained, in combination with a solution of sulphurous acid in water, as an agent in treating vegetable substances which contain fibers, when heated therewith in a close vessel, under pressure, to a temperature sufficient to cause said acid solution to dissolve the intercellular or incrusting constituents of said vegetable substances.

"I also claim the recovery and re-use of sulphurous acid and sulphite from the acid liquids which have been digested on the vegetable fibrous substances, by boiling said liquids or neutralizing them with hydrate of lime."

Chemistry of the Sulphite Process.

The following outline of the chemistry of the sulphite process is adapted from Griffin and Little[1]:

"It is well known that many of the more complex members of the carbohydrate group, to which cellulose belongs, undergo more or less pronounced changes upon being boiled with water, especially if the boiling is conducted at the higher temperatures obtained under pressure in a closed vessel. Sugar, which is the typical member of the group, becomes inverted; that is, the sugar combines to a limited extent with the elements of water, and the more complex molecule thus formed breaks down into the two simple ones of dextrose and levulose. Such an action in which, as a result of taking up the elements of water, a molecule is broken down, is called a hydrolytic action, and the decomposition itself is called hydrolysis. Similar changes are brought about through the action of water alone upon cellulose and its incrusting matters, but these changes proceed far more rapidly and completely in the presence of dilute acids. Cellulose itself is comparatively stable under these conditions, unless the temperature is considerably raised, but Lignin, probably from its greater complexity, is broken down with considerable rapidity at temperatures not much higher than that of the boiling-point of water. The products of the decomposition are largely organic acids, and the direction of the decomposition is toward the production of these acids, but among the earlier products there undoubtedly occur a considerable proportion of substances having, at least, the general character of the aldehydes. When the ordinary mineral acids, as sulphuric or hydrochloric acid, act in the dilute form, and at moderately high temperatures, upon wood, the decomposition products rapidly accumulate in the liquor, and undergo further secondary decompositions, the course of which tends toward the production of insoluble, dark-colored, and tarry matters. It is obviously impossible under these conditions to look for the production of cellulose in any condition of purity.

The reaction undoubtedly takes a somewhat similar course when sulphurous acid without any base is used; indeed, this acid is well known to have a decomposing action upon many groups of organic compounds.

[1] The Chemistry of Paper Making.

The primary action of a bisulphite liquor in resolving wood proceeds upon the same lines as that of a solution of sulphurous acid, but the presence of the base in this combination materially modifies the subsequent course of the reactions. The bisulphites possess the remarkable property of forming, with the aldehydic products of the first stage of the decomposition, true double compounds which are soluble and comparatively stable. Compounds of this class have been found in the waste liquors. It is characteristic of the aldehydes that they pass by oxidation into organic acids, and in spite of the presence of sulphurous acid, which tends to prevent oxidation, there is some formation of these acids. Once formed, they displace the sulphurous acid from an equivalent portion of the base, and form soluble organic salts. By these two actions the bisulphites take up the products of the resolution of the wood, and prevent for the most part the extreme degradation of the products which is characteristic of the water treatment or of the soda process. The combination of the acid products with the base is shown by the steady rise in the gas pressure observed during the last part of a sulphite cook, and which is avoided by blowing off. It is also shown by the composition of the waste liquors. A. Ihl finds that the resinous matter obtained by evaporating liquors consists mainly of the calcium salts of acids similar to arabic acid, and that these acids, as indicated above, decompose carbonates, sulphites, and sulphides.

An incidental advantage of considerable importance is obtained by the use of sulphurous acid in connection with a base, and is due to the power of this acid to form with various coloring-matters compounds which are themselves colorless. The practical effect of this latter action is the production of a fibre which may be at first of a color as good as that of well-bleached pulp, although, as in case of all sulphurous acid bleaching, this high color does not persist for any considerable length of time.

Although all the bisulphites act in general in the manner specified above, the character of the liquor is modified in several important particulars, according as one base or another is in combination with the acid. Bisulphite of lime is a very unstable salt which upon being merely heated decomposes; one-half of the acid being set free. The resulting monosulphite is practically insoluble, so that when this decomposition occurs in the boiler, this latter salt is precipitated throughout the pulp, from which it is difficult to remove it by washing. When lime liquor is used, there is therefore more gas pressure in the digester, and the resulting pulp is comparatively harsh, hard and transparent. It is also more difficult to make a straight lime liquor of high test than it is to prepare similar liquors from magnesia or soda, but on account of the insolubility of sulphate of lime the former liquors never contain more than three-tenths per cent of sulphuric acid, while soda or magnesia liquors may contain an indefinite amount. In the case of lime liquors, any excess of sulphate over the amount given is precipitated and may be settled out.

Bisulphite of magnesia is somewhat more stable than the corresponding lime salt, and its action on the incrusting matter is milder, but even more effectual. The sulphates or monosulphites which may be present in magnesia liquors remain in solution, and are easily washed out from the pulp. The resulting product is much softer and whiter than any which is ordinarily made with lime without some subsequent treatment. These desirable qualities of magnesia are possessed in a still higher degree of soda. Sodium bisulphite is so permanent that it may be easily obtained and preserved in the crystalline form. The gas has so strong an affinity for the base that liquors of 35° Be. may be made without difficulty. Both the sulphite and sulphate of soda are very soluble, and there is therefore no precipitation either in the luiqor apparatus or in the digester. Pulp made with soda liquor is white and soft, and almost entirely free from the last portions of incrusting matter.

It has been held in some quarters that sulphuric acid in considerable amount is formed in the digester during boiling, but numerous experiments show that in reality this oxidation of the sulphurous acid is very slight; it is obviously so when we consider that making no allowance for the chips and liquor in the digester, but supposing the whole interior to be filled with air at the ordinary temperature and pressure, the total amount of oxygen contained therein only amounts to 22 pounds in a digester of a capacity of 1,200 cubic feet, a quantity so small when compared to the weight of sulphurous acid in the liquor that it may be disregarded."

Digesters.

The typical form of digester used in the sulphite process to-day is a tall cylindrical vessel of steel plate construction with a dome-shaped top and a conical bottom, as shown in the drawing. The size of the digester depends on the method of cooking the wood. The steel plate is usually ⅞ to 1¼ inches in thickness. The joints are triple riveted. Several firms are offering welded digesters instead of riveted ones. These should be good if the welding is well done, which is a matter of great difficulty with such huge pieces of apparatus. The welded digesters have hardly been introduced long enough to say how this development will succeed.

The riveting must be done with the utmost care and faithfulness and the whole construction must be of the strongest and most thorough type on account of the great pressure and high temperature prevailing at certain stages of the operation. The outside of the digester should be kept neatly painted and clean so incipient defects can be detected before they go so far as to become dangerous. The surrounding building should be well lighted. Windows and doors should not be allowed to stand open in cold weather so as to chill the sides of the digesters as this produces periodical local contractions and expansions that strain the digester, often causing cracks.

The digesters are located in a tall structure which supports the chip bins over the digesters. The digesters rise through two floors, one being placed just where the cylindrical portion begins and the other being located so that the digesters' heads just rise through it. The digesters should stand alone, no floors coming in contact with them. The digester house should be strongly constructed, well illuminated and accessible at all levels by good stairways. It should also be provided with a good system of ventilation to carry off fumes.

A digester of the shape described 15 feet in diameter and 49 feet high will hold approximately 27 cords of chipped wood and 28,850 gallons of acid.

Essential Parts of the Digester:

1. Shell.
2. Lining.
3. Opening provided with cover at top for receiving chips.
4. System for filling the digester with the acid.
5. System of pipes for supplying the steam for cooking.
6. System of relief lines for getting rid of steam and acid gas.
7. Thermometers to record the temperature.
8. Gauges for recording the steam pressure.
9. The blow valve and blow pipe through which the pulp is discharged under pressure when the cook is completed.

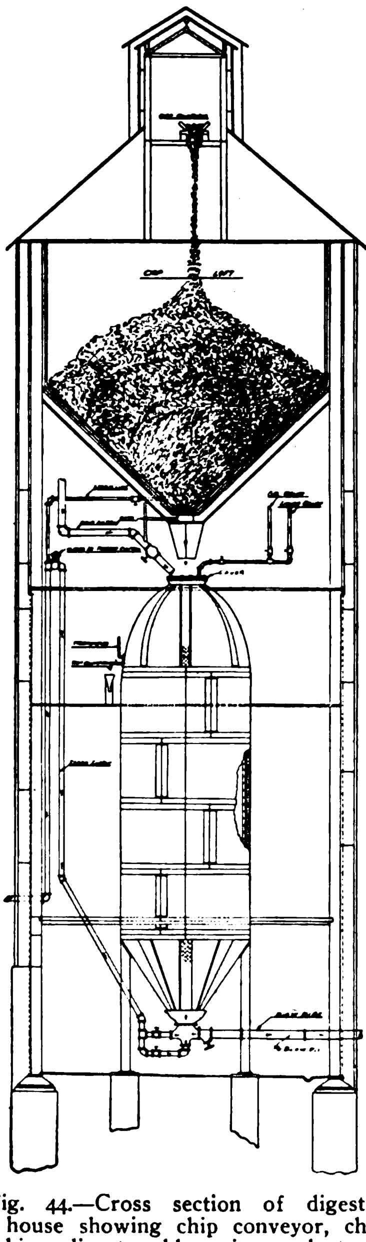


Fig. 44.—Cross section of digester house showing chip conveyor, chip bins, digester, blow-pipe, and steam and acid connections.

The shell has already been discussed above. We will now pass on to a discussion of digester linings, one of the points which gave the most trouble in the early days of the sulphite process and which required much patient experiment on the part of Mitscherlich, Partington, Wheelwright and others. The present method of lining is largely the result of work by G. F. Russell.

Lining: The acid used in the sulphite process will rapidly disintegrate naked iron. Therefore, some kind of lining is necessary. Lead is chemically the material best adapted to resist this acid, but after years of experiment with lead lined digesters, they have largely been abandoned. This is because the coefficient of expansion of lead is so different from that of iron that the two metals will pull away from each other when subjected to alterations in temperature. Lead, however, when once expanded, does not contract to its original shape and size when the temperature is lowered as do most metals. It tends to remain in the expanded form. This has the result that lead will "crawl" or pull away in one direction from any point where it is held, thus making a round bolt hole gradually into an ellipse and permitting leakage.

We will not dwell on the immense amount of ingenuity that was expended in attempts to overcome the fatal faults of lead before lead linings were finally given up in favor of brick ones. Digesters built of bronze were also tried. This bronze, however, did not perfectly resist the action of the acid, as was proved by chemical tests, and did not possess the necessary mechanical strength at the temperatures encountered in the digester. No bronze has been found that will overcome these defects. Numerous kinds of enamels and cements have also been tried. Although all of these have their advocates, the brick lining has come to be almost universally used.

There are generally two layers of brick, the first separated from the shell by a 1-inch layer of Portland cement. The bricks are laid with a cement made as follows:—one part of sand or crushed quartz, and one part of litharge are mixed dry and then glycerine added to form a thick paste. The glycerine should be slightly warmed before it is used. Sometimes a little silicate of soda is added to the glycerine. This helps the cement to set well. After the glycerine is added the cement is kneaded like bread till it is of an even consistency. The glycerine should be added to small portions of the dry ingredients at a time, the cement thus being prepared about as fast as it can be used. A ball which a man can nicely hold in both hands will lay about five bricks. Frequently the first layer of brick is common red brick and the inner layer special vitrified acid resisting brick. The two layers are separated by a thin layer of cement, either a special cement or ordinary cement mortar mixed 1 to 2. The inner layer of vitrified brick is laid with great care in the special cement described above.

A number of manufacturers produce bricks specially adapted to digester linings. In general such bricks should be hard, homogeneous and non-absorbent to water. They should be thoroughly baked and well annealed so as to resist temperature changes. They should be free from iron and similar metals. The best bricks will split and crack to some extent under the action of acid, temperature change and the mechanical agitation of the liquid, but careful selection of brick can do much to reduce the quantity of such waste matter getting into the pulp and also delay the necessity of relining the digester.

When a digester has been shut down to be relined, or for any

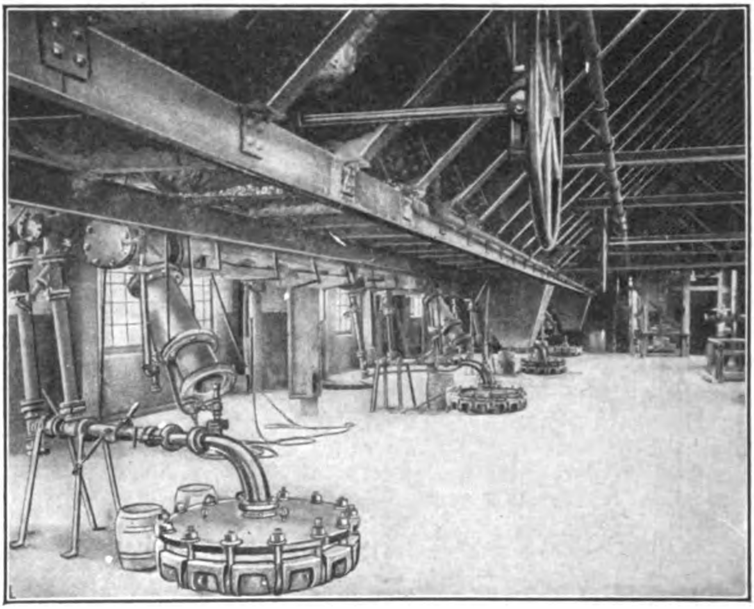


Fig. 45.—Charging floor of digester house showing digester heads and acid and relief connections; also, traveling hopper for charging chips into digester, with large hand wheel for regulating flow of chips.

other cause, or is being started for the first time, so that it is cold, it should not be heated up to a high temperature suddenly. The brick should be allowed thoroughly to dry out and then the digester should be gradually brought up to cooking temperature. The digester should be at least 24 to 36 hours in warming up from cold to ordinary cooking temperature.

Disregard of these precautions will crack and disintegrate the brick lining, strain the shell and may result in a disastrous explosion.

Insurance inspectors should never be misled and no attempt should be made to conceal anything from them. Their advice as to safe pressures, repairs, etc., should be regarded as these men are selected for their practical knowledge and have a wide experience from inspecting mills throughout the country.

Head: The "head" or cover of the digester is removable. It is fastened to a casting which forms the top rim of the digester proper by means of clamps which hold it securely in position against the internal pressure of the digester. The head is lined with a sheet of some acid-resisting metal such as aluminum. Between the head and the rim on which it sits is inserted a gasket, which it has usually been found economical and efficient to make out of a lap of sulphite pulp.

A chain hoist is provided for removing and replacing the digester heads, which have to be removed every time the digester is filled with chips and acid.

The head is fitted for the connection to the relief line. This is usually a 2½-inch bronze pipe. It relieves the pressure in the digester after the steam has been turned on and allows the gas that forms in the top or neck of the digester to escape to the recovery system, which will be described later. After leaving the digester this line divides into two separate lines. One is a liquor relief line and one a gas relief line. These lines are controlled by valves and the attendant can tell by the sound whether liquor or gas is coming off from the digester and thus direct it into the proper line. Both these lines are of bronze and usually 2½-inch diameter.

Strainers should be provided to prevent pulp getting into the relief lines, thus plugging them up. These are usually hard lead or bronze globes or hemispheres provided with numerous holes about 3/16 of an inch in diameter.

Steam Supply: At the base of the digester are the inlets for the steam. The connections between the boilers and the digesters should be as short as possible to prevent condensation of the steam and reduction of the steam pressure. Suitable traps should be provided and all lines should be covered with an efficient heat insulating substance such as magnesia.

Where a number of digesters are used, as is usually the case, the piping system should be designed so that all the digesters will receive steam at the same pressure, which will not be the case unless the main line leading from the boilers is adequate in size.

The steam pipe for the digester is usually carried up to a point near the top of the digester and then down again, entering the digester at the bottom. This forms a trap which prevents anything being forced from the digesters back into the boiler system should the steam pressure through any cause become less than the pressure in the digesters. This arrangement permits of the reducing valve being located on the working floor, i.e., the floor where are the digester heads, gauges, etc., and thus being under the eye of the operator at all times. This line should be provided with one or more suitable check valves, one in the horizontal section of the pipe accessible to the working floor. The location of the second, if such is installed, between the first check valve and the digester.

To the bottom of the digester is fastened a bronze tee, the side outlet being attached to the digester. To one end of the tee the 4-inch bronze steam line is connected. It is of bronze in case

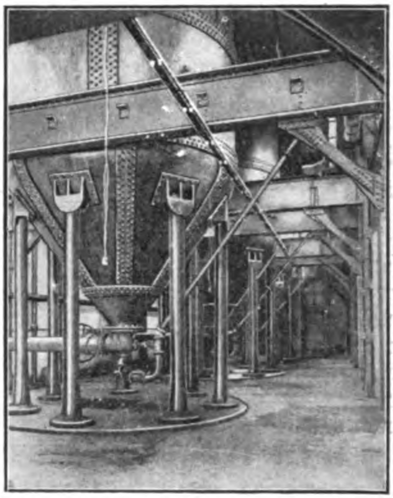


Fig. 46.—Bottom floor of digester house showing conical base of digesters, and blow-pipe.

any acid from the digester should by any chance get into it. To the other end of the tee is fastened a bronze blow-off valve and to this a 10-inch cast iron pipe increasing in diameter to 12 inches at the farther end and passing through the side of the blow pit.

Fig. 47.—Typical valve used for blowing digester.

A digester such as has been described will require a maximum of about 1,200 boiler H.P., the average being about 300 H.P. per hour,

Cooking.

There are in general three methods of cooking sulphite pulp. The oldest, which is still used for certain grades of pulp, is the Mitscherlich process, which is an indirect cook, the steam never coming in direct contact with the pulp and which requires a special form of digester, which has already been described. The second method, which is that in general use, is the Direct Cook, sometimes known as the Ritter-Kellner Process (after the men who first introduced it in Europe) using the vertical digester we have already described. The third method is known as the Morterud System and is of recent invention. This is an indirect system with forced circulation, i.e., the acid is heated in a heater separate from the digester and forced through the digester by means of a pump. All of these methods have their advantages and their drawbacks.

Mitscherlich Process: The pulp produced by the Mitscherlich process is of excellent quality, but the process has been largely abandoned on account of the following disadvantages. This is a very slow process to operate, the cooking time being very long, usually 35 to 40 hours and in some cases upwards of 60 hours. The pressure rarely exceeds 45 pounds. The digester has from 1,000 to 3,000 feet of lead or copper pipe coil in it for heating purposes which is constantly leaking and in need of repair. When the heating coils have to be repaired the digester has to be shut down. On account of leaks, the acid liquor gets into the condensate from the steam used for heating, thus making it impossible to use this condensate in the boiler plant and thus increasing the consumption of coal. Calcium monosulphite collects on the lead pipes and has to be removed and will frequently drop into the pulp during the cooking, where it is very undesirable. The chips are brought into direct contact with the heating surface, frequently causing overcooked pulp and lower yield from the wood. On account of uneven circulation and the fact that the heating coils are entirely in the lower part of the digester, the bottom part of the pulp will be digested first. The pulp is not blown out of the digester, as in the case with the direct cook, but is removed by shovels and rakes through a large manhole near the bottom of the digester after the pressure has been relieved.

In spite of all drawbacks the Mitscherlich process is found advisable in some cases. It makes a very strong pulp ideal for certain purposes, which cannot be exactly imitated with a direct cook. It is also economical of sulphur. A much weaker acid can be used than is customary with the direct cook. However, it will be seen from the above remarks that the process is a very troublesome one.

Direct Cooking Process: The first great advantage of this process is the fact that it is quick, the time varying in different mills, but never being anything like as long as for the Mitscherlich process. The second great advantage is the comparative simplicity of the equipment, leaks and other causes of stoppage being cut down to a minimum and repairs being as low as possible.

In charging the digester it is filled as completely as possible with chips which, before the cooking operation has proceeded very far, will have settled enough to be entirely covered with the liquor.

A digester 15 feet in diameter by 49 feet high will hold approximately 27 cords of chips and requires about 28,850 gallons of liquor. Such a digester will produce about 12 or 13 tons air dry pulp.

The liquor should be run in as quickly as possible. The pipe for this purpose should be at least 6-inch and maybe larger. Like all other connections with which the acid comes in contact, it is of hard lead or bronze. An 8-inch centrifugal pump of hard bronze is satisfactory for pumping the acid into such a digester. Running at approximately 850 r.p.m. it will fill the digester in 25 minutes. It requires 24 h.p. against a 60-foot head. All connections from the tank to this pump and from the pump to the digester can best be made of hard lead, containing 8 per cent antimony in its composition. Modern mills are frequently designed so that the acid flows into the digester from tanks placed at a higher level than the digesters, thus obviating the use of such a pump.

In some mills the acid is pumped into the bottom of the digester, a check valve being inserted to prevent the acid running back in case of accident to the pump, this valve being closed before stopping the pump. In this way the acid rises gradually through the chips. This method does away with fumes. However, this method is not to be recommended, as the chips float and do not become thoroughly saturated with acid and it is hard to tell when the digester is full.

When the digester is filled with chips and acid, the cover is securely bolted on and the pressure and temperature recording instruments noted, and at times calibrated. The relief valve is slightly adjusted to let out the air. The steam valve is then opened and the digester allowed to come gradually to 65 or 70 pounds pressure. It is very important that the pressure should not be applied too suddenly. The acid should be allowed to thoroughly saturate the chips and penetrate every particle of them before any notable increase in temperature takes place. This is necessary to produce the proper chemical changes in the material and to prevent charring and overcooking of the chips.

Moreover, if the heating is forced at the beginning of the cook, the steam striking the cold liquid will hammer, which is hard on the digester. However, the chief reason for raising the temperature slowly is the effect on the chips mentioned above. If reddish or brown bundles of fiber are found in the pulp it is an indication that the pressure has been applied too early before the acid had a chance to thoroughly saturate the chips.

The pressure carried throughout the main portion of the cook depends on the grade of stock required, physical conditions of the digester, maximum pressure allowed by the insurance companies, etc.

In general the temperature should not be allowed to exceed 110° C. until after 2½ hours have elapsed.

When the steam pressure has been brought up to standard the

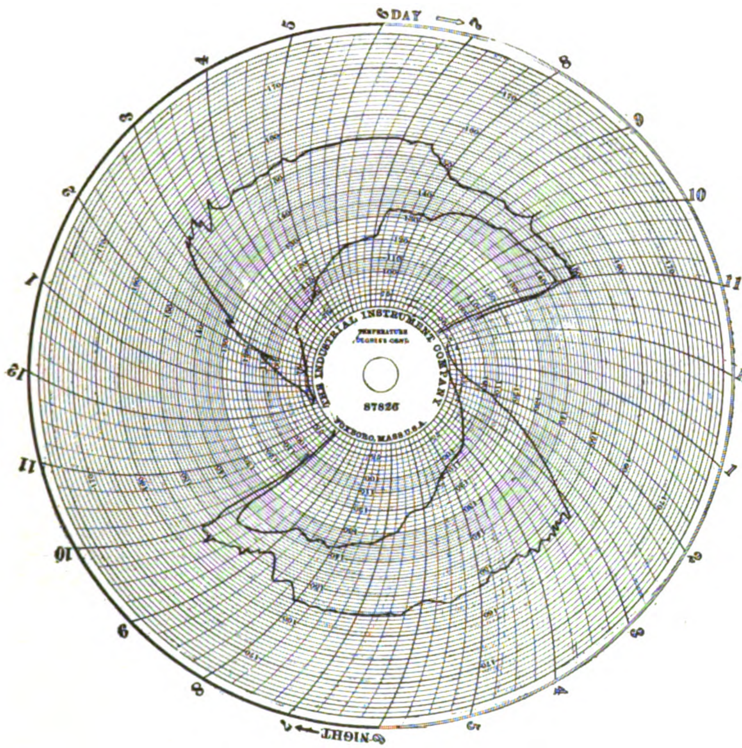


Fig. 48.—Temperature diagram for typical sulphite cooks. The inner curve is a pressure curve plotted on the temperature diagram for purposes of comparison.

relief valves are opened sufficiently to shake up the contents and bring the acid up over the top of the chips.

It is impossible to give any general directions for cooking. The cook varies in every mill, depending on the materials being used, the grade of pulp being produced and the personal ideas of the man in charge of operations. In some mills very elaborate records are kept of the temperature and pressure throughout the cooking operation, as well as of the chemical composition of the samples drawn off at various stages, and careful deductions are made from these facts and the digesters operated accordingly. In other mills rule of thumb methods prevail and the operation of the digesters depends entirely on the idiosyncrasies of some one man.

The methods of relieving, in particular, vary greatly, and many mills attach peculiar importance to keeping their method of performing this operation a secret. Many times after the digester is started, particularly within the second and third hour before the

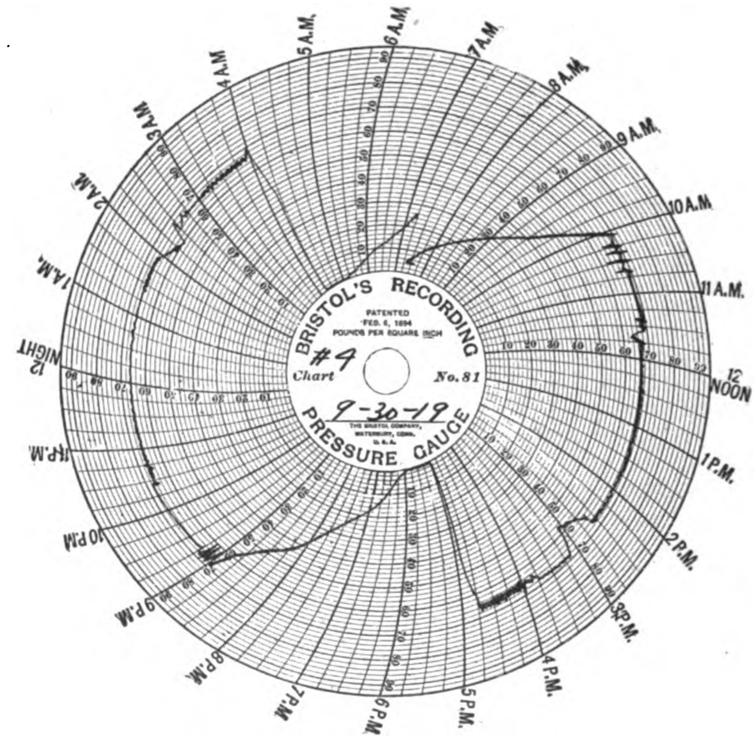


Fig. 49.—Pressure diagram for typical sulphite cooks.

final blowing time, the cook will note a wet or dry relief, sometimes detected by the sound or sing of the relief valve. With proper cooking conditions, the digester relieves 100 per cent gas almost continuously for two or three hours before the end of the cook. The cook tries to hold the gas as long as possible and take it all out of the digester just before the blowing point. He must do this as far as possible, and yet not have the temperature exceed the predetermined maximum at the time of blowing.

Authorities vary as to the proper temperature. The writer finds a temperature of 145° C. at the time of blowing desirable.

Certainly the temperature should not exceed 149° C. and it is better to have it somewhat lower, especially if strong acid is being used. When weaker acid is used the time of cooking has to be prolonged also. In this case the blow is much darker in color.

For strong pulp which will have a low bleach consumption, strong acid, a short cook and a low temperature is the proper combination. Such a cook produces high screenings, uses a great deal of sulphur, and makes repairs heavy, owing to the action of the strong acid on the bronze castings.

With weaker acid satisfactory pulp can also be obtained with lower percentage of screenings, lower sulphur consumption and decreased repair cost. However, the cook must be prolonged and the temperature maintained high.

The pressure is not an accurate indication of the temperature, especially in the later stages of the cook, as this pressure may be largely due to gas set free by the process proceeding in the digester. The temperature should be judged by an accurate thermometer placed about one-third of the way down on the digester.

The reader may wonder, why, if the grade of pulp to be produced has been settled, the strength of the acid, the temperature, the pressure at every stage of the cook and the duration of the cook cannot be absolutely standardized and the operation made to conform to these standards. The chief factor preventing this is the wood which will always vary in moisture content and in other regards. This variable factor makes it necessary for the cooking operation to be in charge of a capable and experienced man who can exercise judgment.

However, much can be done to simplify the operation by making sure that the acid is of constant strength and that the condensed water and consequent dilution of the liquor is kept steady by preventing radiation as far as possible and by keeping the pressure of the steam constant.

Testing.

During the cooking operation the cook draws samples which he analyzes for total, free and combined SO_2. Combined SO_2 is that in chemical combination with lime or lime and magnesia, free SO_2 is that in solution in the liquid, total SO_2 is the sum of the two preceding amounts.

The cook also tests the smell of the cooking liquor and an experienced man can frequently be guided by this more perfectly than by the most extensive system of chemical control. The appearance of the liquor is also of importance.

The method usually employed for determining the end of the cook is that of drawing off a portion of the cooking liquor from time to time and determining the total, free and combined SO_2, smelling it and noting its appearance. Other means are employed such as blowing a small sample of stock from the digester through a plug cock against a small target. After examining this a very small portion of the sample should be diluted in a clear glass bottle filled with clear water. By holding this up to the light every fiber stands out prominently. If there is any uncooked wood these particles will apear in a strong contrast to the cooked fibers. When a digester has been blown which meets all the requirements, a sample of this stock should be saved and diluted in a bottle as above for future reference. It is surprising how uniform the stock can be blown from time to time when the operation is in charge of an experienced cook.

It has not seemed to the author desirable to take space in this book to give details of the chemical methods by which acid, liquor from the digesters, etc., is analyzed. Such details would consume much space and are of interest only to the chemist, who already knows where to find such information. The technical publications serving the pulp and paper industry go into this matter in great detail and describe all the standard methods which have been worked out, together with all the various improvements and criticisms that develop from time to time.

Morterud Process.

The Morterud Process embodies an attempt to get away from the disadvantages of the Mitscherlich Process, at the same time retaining the advantages of that method of cooking. It is in extensive use in Europe and has been introduced with considerable success into several mills in America. Up to date it has been applied to a greater extent in connection with the sulphate and soda processes than the sulphite.

The system calls for a specially constructed heater with bronze pipes in which the acid is heated by steam passing through the pipes. A special circulating pump is used for pumping the acid from the heater into the digester. Another pump removes the condensate from the heating tubes and returns it to the boilers. It is claimed that the amount of acid required for a cook by this process is 30 per cent less than by the direct cooking process, and also that a weaker acid can be used, on account of the perfect transfusion of the acid provided for.

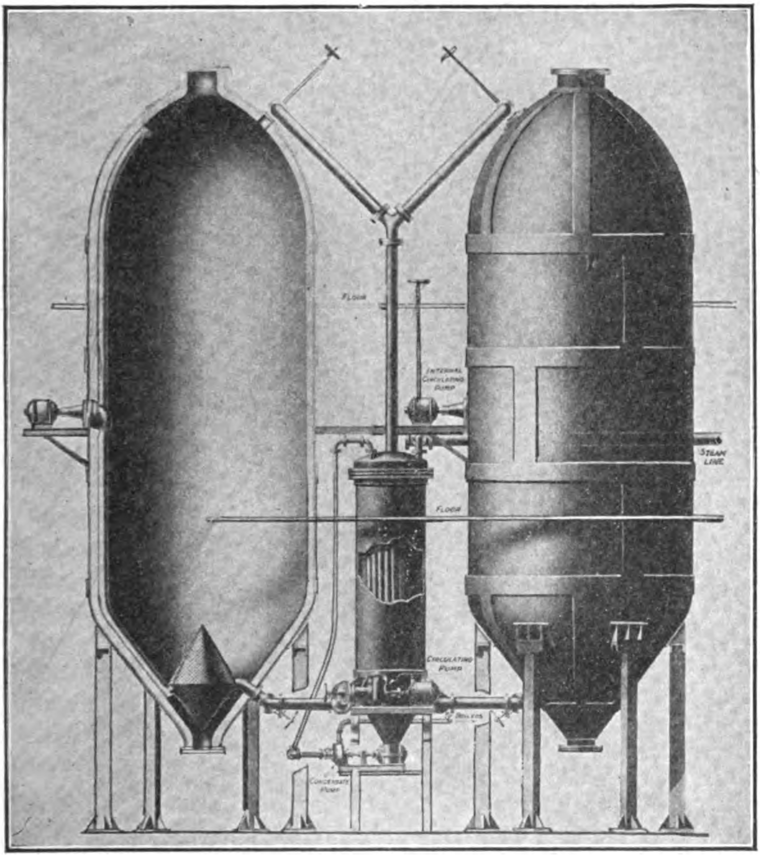
The disadvantages, as compared with direct cooking, are:—power is required for operating pumps; the pumps and the heating apparatus require repairs; there is a possibility of acid from the heater getting into the boiler system should the heater tubes be leaking at a time when the pressure in the digester is greater than the steam pressure in the heater.

Rotary Digesters.

Rotary digesters have been used for the sulphite process and are still extensively used in Europe. They have the disadvantages of having to be used in small units for reasons of construction, constant trouble with repairs to drives and steam connections and numerous other minor disadvantages. They secure uniform temperature and pulp, save fuel and use less liquor, and consequently can be used successfully in countries where operations are carried on on a smaller scale and where labor and construction and repair charges are lower.

Blow Pit.

When the cook is finished the stock is blown from the digester through the blow pipe into the blow pit. The blow pit is a ver-



Courtesy: Fibre-Making Processes, Inc., Chicago, Ill.

Fig. 48.—Sulphite digesters arranged for indirect cook by Morterud process showing acid heater placed between the two digesters.

tical tank of wooden or concrete construction of sufficient capacity to hold two blows, i.e., twice the capacity of the digester. It is strongly reinforced with iron hoops, if of wood, and has a target placed on the side opposite the blow pipe. This is to protect the tank from the violent pounding of the stock as it is blown from the digester under pressure. The target is usually of cast iron, about 1 inch in thickness, and is fastened to the tank with heavy bronze bolts. The blow pit has a chimney-like opening at the top containing baffles to prevent any stock being forced out. This is called a vomit pipe.

The bottom of the blow pit is equipped with a false or second bottom. This second bottom is usually of 3-inch matched plank and is set approximately 6 inches above the actual tank bottom and is provided with holes approximately 1½ inches center to center. These holes are usually ⅛-inch diameter at the top and flare to ½-inch diameter at the bottom.

Sometimes this false bottom is made of perforated vitrified brick tile set on planks provided with large holes and held in position by wooden fillers wedged between the tiles.

The purpose of the false bottom is to permit of washing the stock after it has been blown into the pit. The pit is filled with fresh or white water to a height of two or three feet on the stock. Fresh water is preferable because white water always contains some acid and it is necessary to wash all acid out of the stock if paper that will not deteriorate rapidly after being made is to be achieved. This water filters down through the stock and passes through the perforated bottom, carrying much of the acid with it, to the sewer or a save-all. This operation is repeated until the stock is washed free from all acid.

The blow pit is fitted with a lead pipe connection at a point just above the drainer or false bottom. This is usually 8 inches in diameter and leads to the pump used to pump the stock from the pit to the intermediate stock chest. This pump is usually a centrifugal stock pump. A pump running at approximately 1,000 r.p.m. will deliver the stock against a head of 40 feet with a power consumption of about 25 h.p.

The stock as it is left in the blow pit after washing is of a consistency of about 12 to 15 per cent air dry, and in order to get it out it is necessary to use fresh or white water to thin it down. This is done by cutting it with a high pressure hose line. This operation is called hosing or sluicing, and the usual method is to cut the stock nearest to the suction line of the pump and then to cut and hose towards that point. The hose is usually a standard 2½-inch fire hose and should have approximately 35 or 40 pounds nozzle pressure to obtain good results.

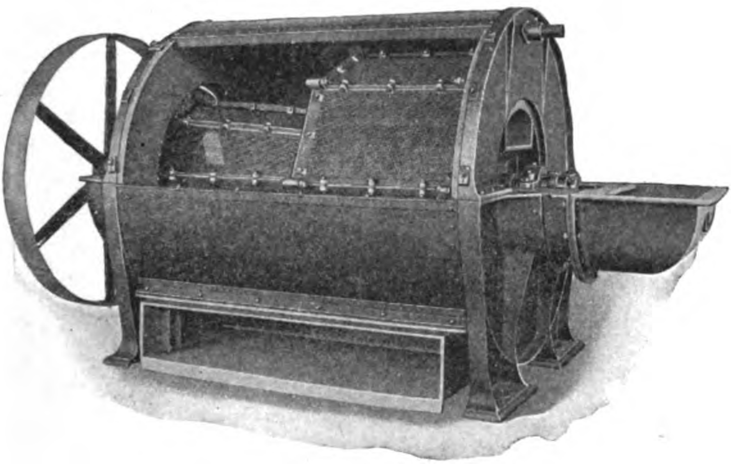
Intermediate Tanks.

The object of the intermediate tank is to supply a storage between the blow pit and the screens. This tank should be of approximately 2 or 3 tons capacity, air dry stock, and should be equipped with an agitator. Such tanks make sure of the stock being of a much more uniform consistency than if it were pumped direct from the blow pit to the screens. The power required to drive the agitator is about 8 h.p. in a tank 15 feet in diameter.

In making fine writing papers from sulphite frequently a number of intermediate tanks are used in which the stock is washed systematically, first with white water and finally with pure soft water.

Knotter Screens.

The stock from the intermediate tank gravitates (or is pumped if it is not possible to arrange the equipment so it can gravitate) to the knotter screens. The flow of stock is regulated by a gate



Courtesy: Improved Paper Machinery Co., Nashua, N. H.

Fig. 49.—Typical knotter screen with outer casing removed showing screen plates.

valve. If there is more than one knotter screen there is a header and the stock is distributed to each knotter screen.

The general type of knotter screen is the rotary type which is fitted with screen plates that allow the good stock to pass through but reject the large knots or lumps of uncooked fibre. These

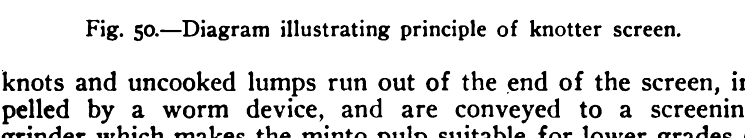


Fig. 50.—Diagram illustrating principle of knotter screen.

knots and uncooked lumps run out of the end of the screen, impelled by a worm device, and are conveyed to a screenings grinder which makes the minto pulp suitable for lower grades of paper, such as mill wrappers. While going through the knotters the pulp is showered with water to wash off any zbres that might adhere to the knots or large uncooked lumps. The amount of water (which may be either pure water or white water) dilutes the stock to approximately 1 per cent air dry.

The capacity of a standard make of knotter screen is approximately 30 tons per 24 hours at a speed of 22 r.p.m. and with a power consumption of approximately 2 h.p. The pressure on the shower pipe of the knotter screen should be from 15 to 20 pounds, preferably the latter.

Riffler.

The stock in passing from the knotter screen to the next set of screens (which are either centrifugal or diaphragm screens)

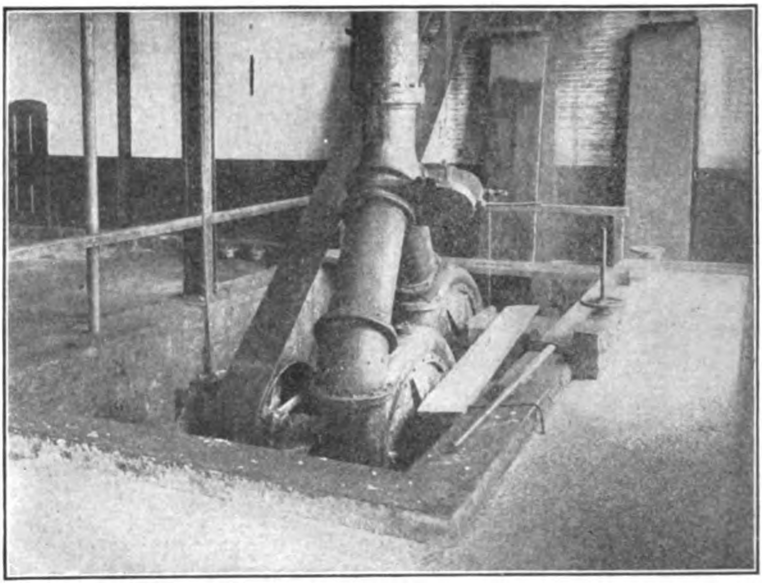
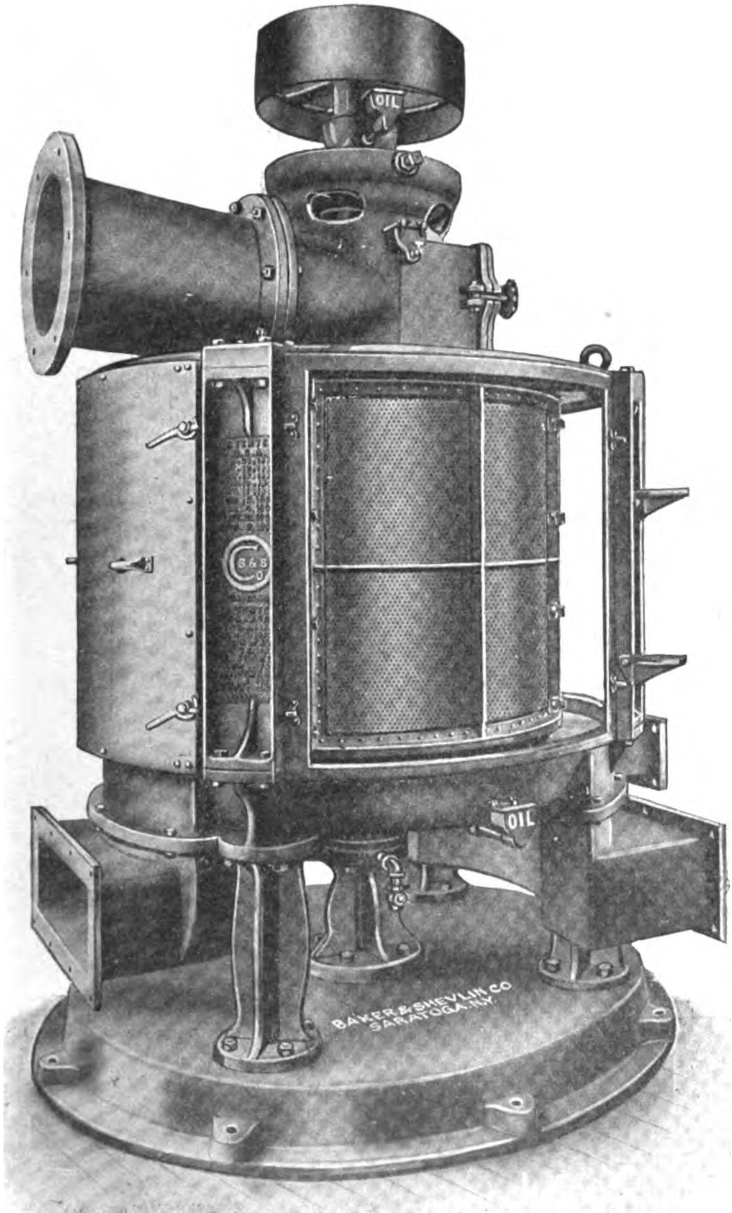


Fig. 51.—Discharge end of riffler showing pump.

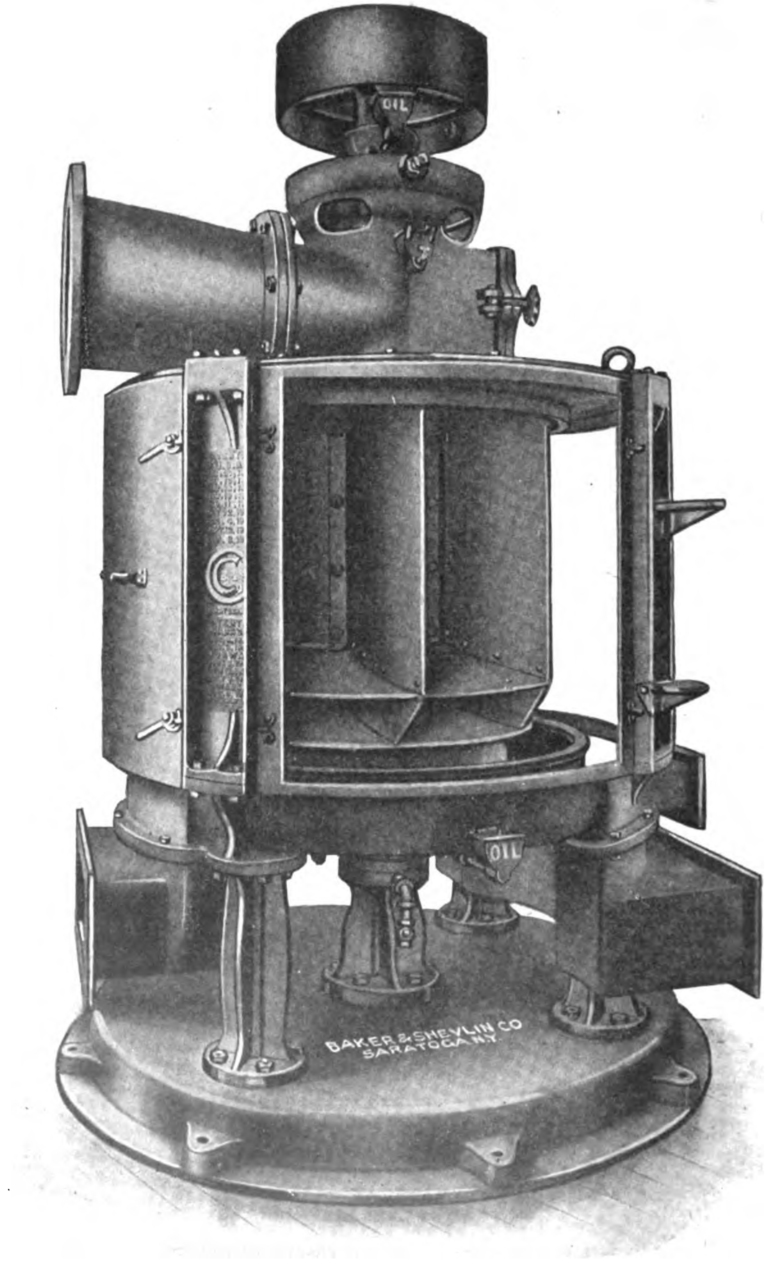
passes through what is called a riffler. This is a shallow wooden sluice about 6 or 8 feet wide, equipped with a set of baffles all along the bottom. The riffler is on a level, without any incline, so that the current is leisurely, being produced by the pump that draws the stock from the riffler. In this device the various impurities that may be in the stock sink to the bottom and are held by the baffles. The riffler should be about 18 inches deep and the baffles about 8 inches high and 8 or 9 inches from each other. The capacity of the riffler should be sufficient to take care of the output of the digesters and the length is governed chiefly by the amount of space able to be devoted to it, the longer the better.

The stock from the riffler is either pumped or gravitates to the screens. If it is pumped a centrifugal pump with wide impellers



Courtesy: Baker Manufacturing Corporation, Saratoga Springs, N. Y.

Fig. 52.—Centrifugal screen showing screen plates.



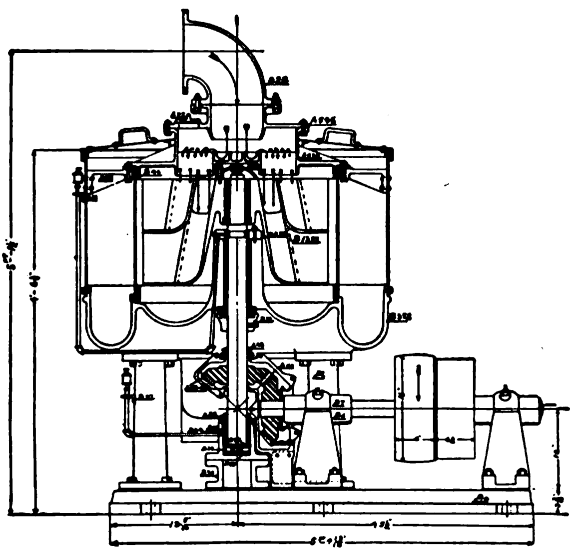
Courtesy: Baker Manufacturing Corporation, Saratoga Springs, N. Y.

Fig. 53.—Centrifugal screen with screen plates removed showing impeller.

specially designed for handling stock is generally used. For a 100-ton mill a 12-inch slow speed pump of the above kind will serve very well and will lift the stock from 40 to 50 feet, which is generally sufficient.

Screens.

The screens may be either centrifugal screens or diaphragm screens. For fine papers, such as book and writing, diaphragm screens are preferable. For papers such as wrappings, bag papers, newsprint, etc., centrifugal screens are quite satisfactory and their upkeep is much less troublesome and expensive.



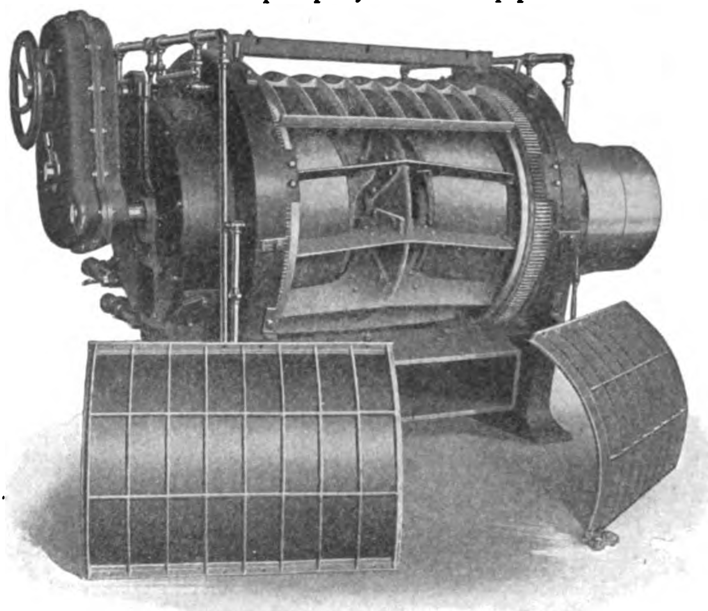
Courtesy: H. L. Orrman, Dayton, O.

Fig. 54.—Vertical cross section showing construction and operation of Ruth centrifugal screen.

The diaphragm screen is the same type of screen as is described in connection with the Fourdrinier machine in the chapter on the machine room. For details regarding their construction, operation and upkeep the reader should refer to that chapter.

The centrifugal screen consists of a runner or impeller surrounded by a cylindrical screen plate, this in turn being surrounded by a steel plate shell. The stock is urged against the screen plate through ports by the centrifugal force of the runner and the good stock passes through. The rejected stock passes out the base of the screen and goes to a secondary screen which is of the same construction, only coarser. The good stock from the secondary screen is usually put back through the system and goes again through the primary screen. The rejected stock from the secondary screen goes to the screenings chest. Another type of screen operates on the same principle but is of a horizontal design.

The entire battery of screens is supplied by a canal-like head box, with gates opposite each screen intake so that the flow to the screens can be regulated and any particular screen can be cut out at any time. In order to have the stock supply to the screens at a constant head there is an overflow from the head of the canal-like head box controlled by an adjustable dam. The overflow leads back to the riffler pump by a return pipe. The stock in



Courtesy: Improved Paper Machinery Co., Nashua, N. H.

Fig. 55.—Horizontal type of centrifugal screen.

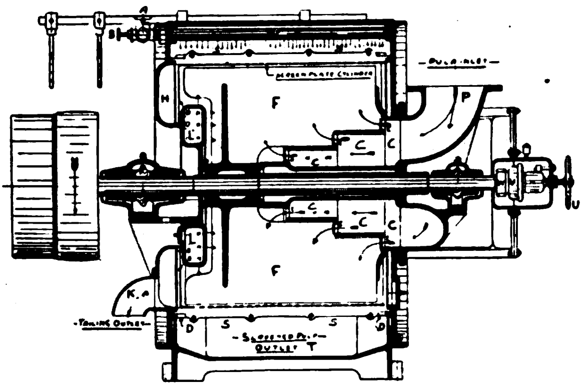
the screen head box is diluted with pure water to a consistency of about .5 per cent air dry.

The usual type of centrifugal screen runs at about 400 r.p.m. and has a power consumption of approximately 35 h.p.

Centrifugal screens are kept clean by means of a specially designed portable shower on the end of a hose which can be inserted between the screen plates and the outer shell. The pressure on this shower should be not less than 30 pounds, as keeping the screen plates clean is a very important factor in operating centrifugal screens. The size of the screen plate openings may vary from 55/1000 to 100/1000 inch, depending on the grade of stock being screened.

The rejected stock from the knotter screens gravitates, if possible, to a screenings or tailings chest from which it is pumped with a 6-inch fan pump to the screenings grinder. The power required to pump the screenings from a battery of screens in a 100-ton mill making sulphite, with a good arrangement of pumps and grinders, would be approximately 15 h.p.

The screenings grinder used is very often an old Jordan, although a number of special screenings grinders are on the market. However, the Jordan is generally satisfactory, especially when the stock is delivered to it with the pump pressure as in the layout described. The action of the acid in the stock on the Jor-



Courtesy: H. L. Orrman, Dayton, O.

Fig. 56.—Cross section of Westbye horizontal centrifugal screen. The pulp enters the cylindrical chambers "C" through inlet "P". From "C" the pulp is discharged horizontally through openings "E" to runner "F" and is thrown against the screen plates. The wings of the runner form a screw line and the tailings are thus gradually discharged to "H", where they are washed out through tailings outlet "K." Water under pressure enters "L" and is discharged through holes "N" to the runner wings and thrown against the screen plates diluting the tailings, while water discharged through holes "O" washes out the tailings. The good pulp drawn through the screen plates into "S" flows to the bottom and is discharged from the screen through outlet "T."

dan knives wears them away very fast and care should be taken to keep them in good shape.

From the screenings Jordan the stock is pumped with a fan pump to a screenings chest, into which the rejected stock from the stock screens is also run. From this chest the screenings presses, which are simply wet machines devoted to this particular duty, forms the stock into laps.

Deckers and Pulp Thickeners.

The good stock from the screens gravitates either into the vats of the wet machines, which form it into laps, or to the decker

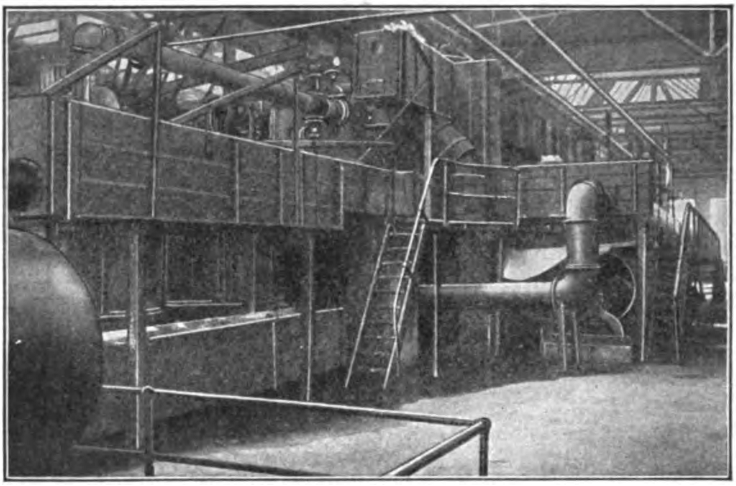


Fig. 57.—View in screen department of sulphite mill showing methods of installing centrifugal screens.

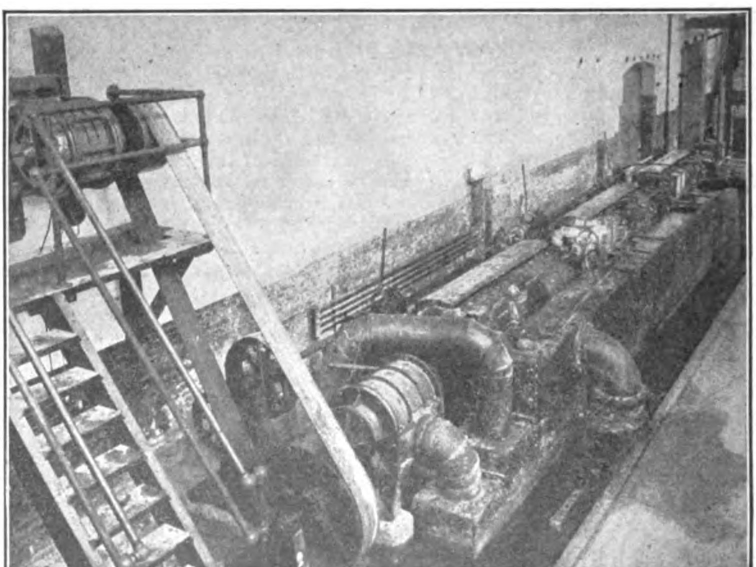
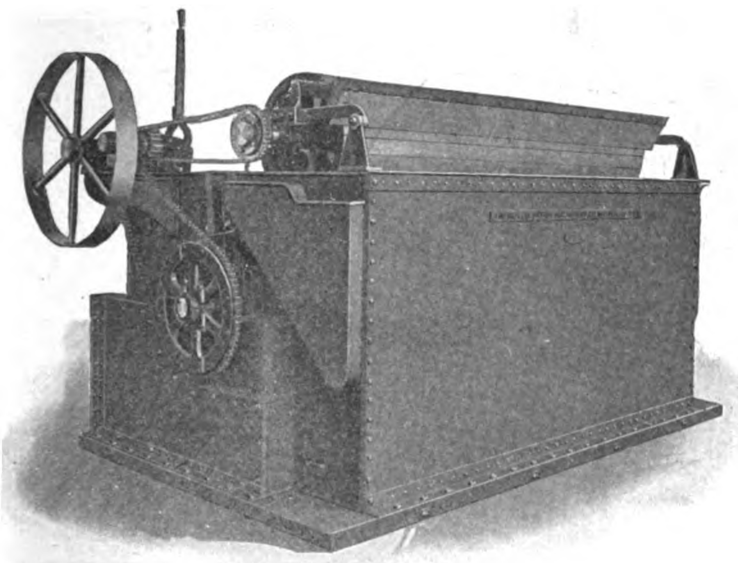


Fig. 58.—Pulp thickener installation in sulphite mill.

which thickens it enough that it can be used directly in the beaters.

The reader may wonder why the stock is formed into laps at all when these laps have later to be broken up and mixed with water in the beater. In other words, it may seem strange that all the stock is not simply run through deckers and then to the beaters. This latter plan is not practicable because frequently the sulphite mill is making much more pulp than can at that time be used in the paper mill. Every mill must carry a storage and laps are the most convenient form in which to store pulp. Moreover,



Courtesy: Improved Paper Machinery Co., Nashua, N. H.

Fig. 59.—Decker showing cylinder and doctor.

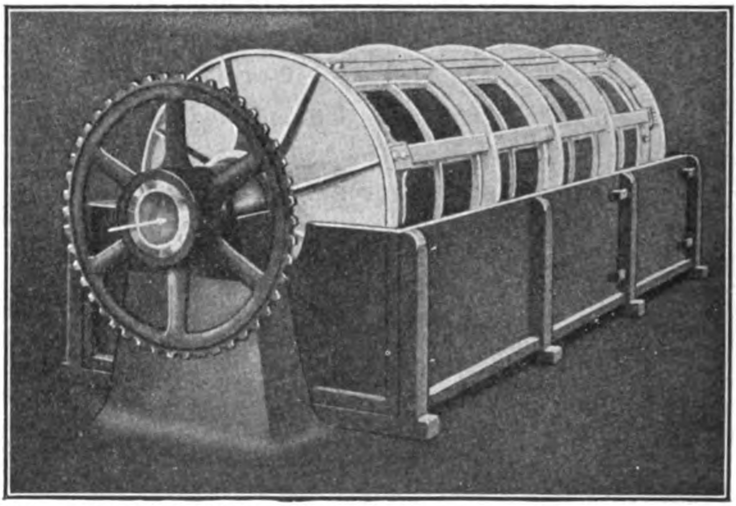
many mills sell pulp as such to other paper manufacturers and laps are the form in which pulp is shipped.

However, it is good practice to run as much stock as possible from the screens to the deckers, in this way eliminating the power required for pressing this portion of the stock, as well as the labor and upkeep on the presses that would be needed to handle it.

Various forms of pulp thickeners are used, of which the decker is the most usual. The object of all these machines is to reduce the water in the stock to a certain predetermined percentage.

The decker consists of a cylinder revolving in a vat of stock. The cylinder is first covered with a foundation wire (usually 14 wires to the inch) over which the finer outside wire is stretched. This outside wire is from 50 to 60 mesh and against it the pulp is drawn by the suction. Wire as coarse as 40-mesh can be used if the save-all equipment is sufficient to catch all the fibre let through by this coarser wire. On top of the cylinder is a couch roll covered with felt jacketing or soft rubber. Against this couch roll a doctor blade presses at such an angle that the pulp slides off it continuously and down into the stock chest at which stage it is referred to as deckered stock.

Another form of pulp thickener consists of a wire-covered drum against which the stock is drawn by vacuum. A mechanical arrangement shuts off the vacuum and applies pressure as the drum emerges from the vat of stock in which it rotates. In this manner the pulp is blown off the drum instead of being scraped



Courtesy: Moore & White Co., Philadelphia, Pa.

Fig. 60.—Horizontal screen type of pulp thickener.

off by a doctor. It is claimed for these machines that they give a greatly increased production together with a higher efficiency of water extraction, which is no doubt true, but the first cost is greater and the power required also greater on account of the vacuum pump required. (An illustration of this machine will be found on page 354 under "save-alls.")

The deckered stock chest should be equipped with an agitator running at a speed of approximately 8 r.p.m. in order to prevent settling and keep the stock of constant consistency until delivered to the beaters.

The pipe line from the deckered stock chest to the beaters should form a loop, i. e., the pump should be running and pumping stock all the time, returning the stock not used in the beaters back to the deckered stock chest. This eliminates the possibility of the stock draining and plugging up the system. A 6-inch fan pump with a 12-inch suction running at approximately 800 r.p.m. will furnish deckered stock for 6 beaters at a power consumption of approximately 15 h.p.

Wet Machines, or Presses.

The wet machine is used for that portion of the stock produced by the sulphite mill which cannot be deckered and used as deckered stock. It is practically a decker with a felt and press rolls added. The felt goes round the couch roll so that it comes in direct contact with the film of pulp that is picked up by the cylinder. This film is carried forward on the felt between the press rolls and allowed to wind around the top press roll. When

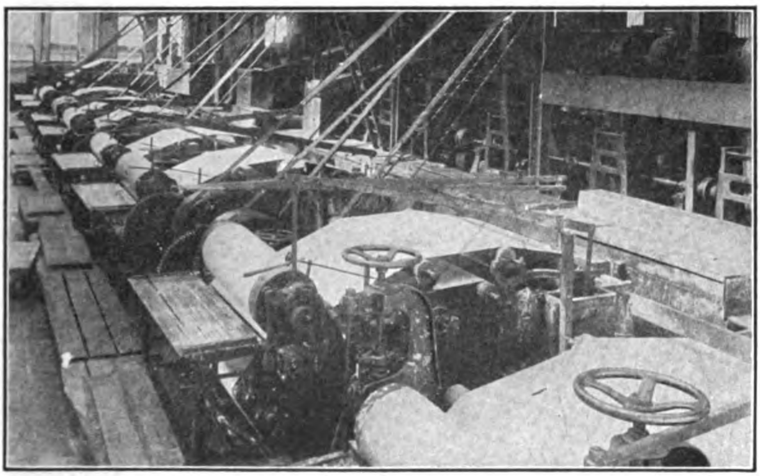
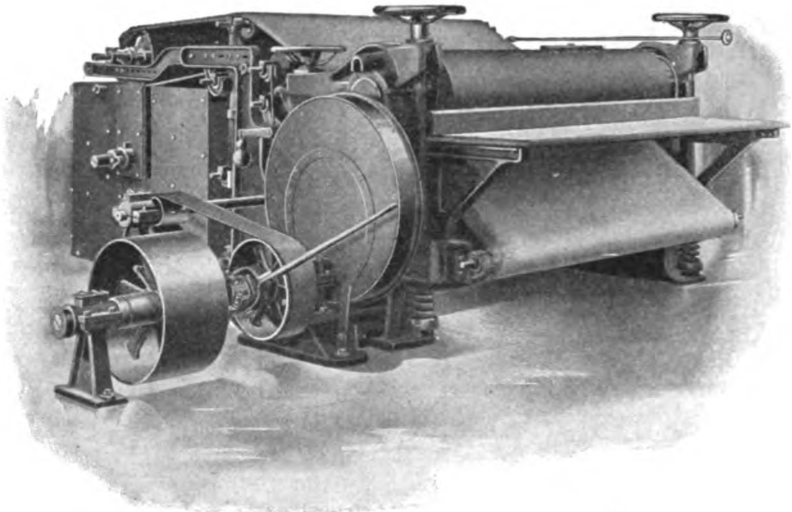


Fig. 61.—View in sulphite mill showing installation of wet machines.

it becomes thick enough it is cut off with a wooden pin. The size of the sheet thus made is governed by the circumference and width of the top press roll. This sheet is deposited on a folding table in front of the press roll and folded lengthwise twice and crosswise three times, making a sheet of pulp about 18 inches by 24 inches. These are called laps.

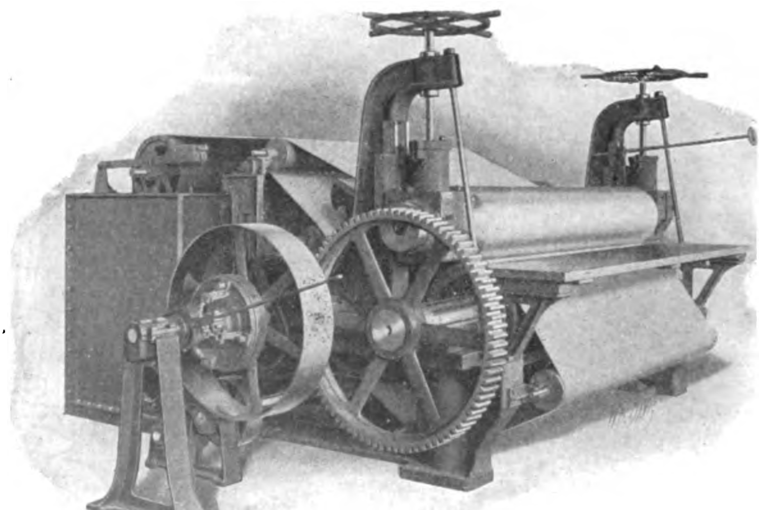
The machine is driven through the bottom press roll, the felt acting as a belt, driving the cylinder and the carrying rolls.

Pressure is applied to the top press roll by means of a system of compound levers with weights, or by springs, or occasionally by hydraulic pressure. Hydraulic pressure is used chiefly by mills which are preparing pulp for shipment to a distance, in which case it is desired to eliminate all possible water. In such cases the pressing on the wet machine is frequently followed by further pressing in a specially designed hydraulic press.



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

Fig. 63.—Typical wet machine arranged for spring and screw pressure.



Courtesy: Improved Paper Machinery Co., Nashua, N. H.

Fig. 64.—Wet machine arranged for hydraulic pressure.

Comparing levers with springs, the writer favors levers, because it is possible to note readily just how much pressure is being applied and because it is a check on the wet machine tender with reference to the moisture test of the pulp. The levers and weights are also a more yielding system and less likely to destroy a felt in case the layer of pulp becomes excessively thick or some foreign substance gets carried between the press rolls. The levers are more quickly disengaged and can be more accurately reset exactly at the pressure previously exerted.

The ordinary wet machine, equipped with levers or springs, can produce a pulp approximately 40 per cent dry.

If the mill is equipped with efficient save-alls, so that it is certain that all valuable fibre is caught in the white water, wire as coarse as 40-mesh can be used, allowing much more rapid production on the wet machine.

The help in charge of the wet machine should be made to keep the packings on the ends of the cylinders perfectly tight so that the stock does not leak through and go into the white water.

Should the pulp suddenly become full of shieves and dirt the trouble can usually be traced back to the screen plates of the centrifugal screens and it will be found, very likely, that a piece has broken right out of one of these, or that they have cracked. Another cause of dirty pulp suddenly appearing is a dirty vat. Pulp frequently shows dirt from this cause when a wet machine is started after having been shut down.

VII. The Acid Plant.

The function of the acid plant is to manufacture the solution used to digest the chips in the digesters.

Numerous forms of equipment for manufacturing this solution have been devised, a great deal of ingenuity having been devoted to this end since the early days of the sulphite process.

It is not our intention to devote space here to an account of the various systems that have been tried. The reader will find an excellent account of the development of such equipment in Griffin and Little.[1]

We will, however, explain the general principles of acid making and the forms of equipment in general use in America at the present time.

Chemistry of the Process.

Sulphur, when burned, unites with the oxygen of the air to form sulphur dioxide, SO_2, a gas which dissolves readily in water. There is always a tendency for this sulphur dioxide to take up more oxygen, becoming oxidized to sulphuric acid. In fact, this is the way in which commercial sulphuric acid is manufactured. In burning sulphur for the manufacture of sulphite pulp every precaution is taken to prevent the formation of sulphuric acid.

Sulphur dioxide in the presence of water and bases, such as lime or magnesia, forms solutions of lime or magnesia bisulphite. If more sulphur dioxide is added than the base will hold in combination, it goes into solution in the liquid, the amount depending on the temperature and pressure. The diagrams on pages 127 and 128 show the solubility of sulphur dioxide in water at various temperatures and pressures.

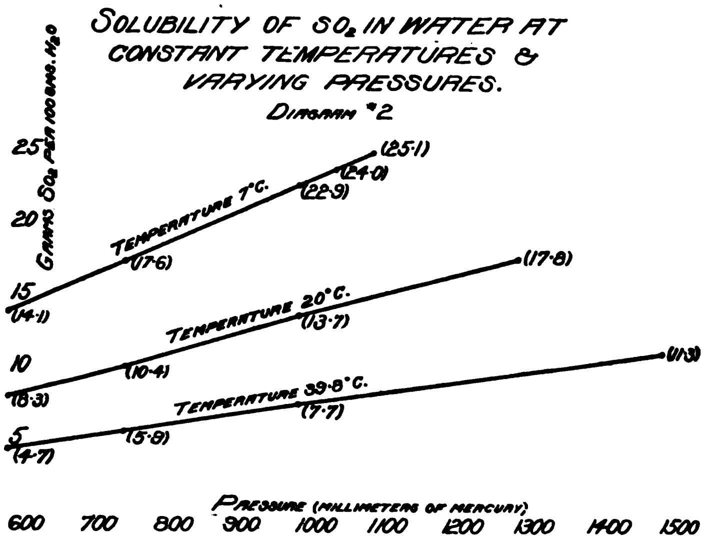
The liquid, generally called "acid," which is used in the sulphite digesters consists of lime and magnesia bisulphites in solution together with free sulphur dioxide in solution. The acid may also contain some sulphate and some monosulphite, but if the operation is properly conducted the amounts of these compounds will be negligible. Their presence is very undesirable.

This acid is distinctly corrosive and has to be handled in equipment constructed of materials selected to resist its corrosive action. All pipes, connections, valves, pumps, etc., with which it comes in contact must be of bronze, hard lead or some other acid resisting material.

[1] The Chemistry of Paper Making.

Raw Materials.

Sulphur: Sulphur is one of the chemical elements, being denoted in chemical symbolism by the letter S. Most American sulphur comes from Louisiana, where it is obtained in a high degree of purity from deep borings out of which it is expelled by superheated water, after which it is allowed to solidify in bins. It is a hard yellow solid which is crushed and pulverized to



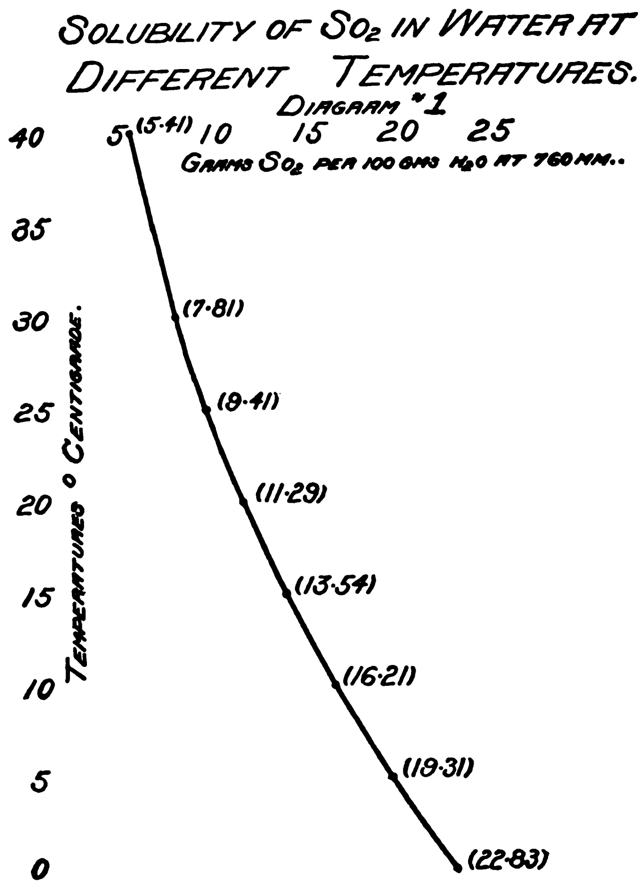
Courtesy: "Paper," New York.

Fig. 64a.

various degrees of fineness according to the use to which it is to be put.

Sulphur should be stored at the mill in bins, which may be of wood, concrete or metal. A number of bins of moderate capacity is preferable to one huge bin because it is easier to inventory the sulphur periodically and also the fire risk is less. The bins frequently have bands painted on them indicating various tonnages of sulphur so that it can readily be ascertained how much sulphur is on hand at any time. It is very important that the sulphur storage should be ample, and as this material does not deteroriate with keeping, a liberal supply should be maintained at all times. The sulphur is weighed as it is received at the mill and again when supplied to the burners. In this way an accurate check is kept on the sulphur consumption. Periodical analyses of the sulphur should be made by the laboratory, to determine the percentage of ash in the sulphur for the guidance of the acid and digester departments.

Limestone: The supply of limestone is usually obtained from the nearest location to the mill where it can be economically quar-



Courtesy: "Paper," New York.

Fig. 64b.

ried. Dolomite, or limestone with a high magnesia content, was formerly preferred by mills making strong sulphite such as that used for bag and wrapping papers, writing and book papers, etc. However, nowadays satisfactory pulp of this class is being made with acid from limestone analyzing 97 per cent lime and no magnesia present at all. Newsprint mills, the product of which does not require strength, and which is usually produced by a short cook with weak acid, prefer limestone as low as possible in magnesia. The reasons for the use of dolomite have largely disappeared with the substitution of towers for milk-of-lime systems.

Sulphur Burners.

Several different types of sulphur burner are in use. The older type, which has largely been replaced by more efficient de-

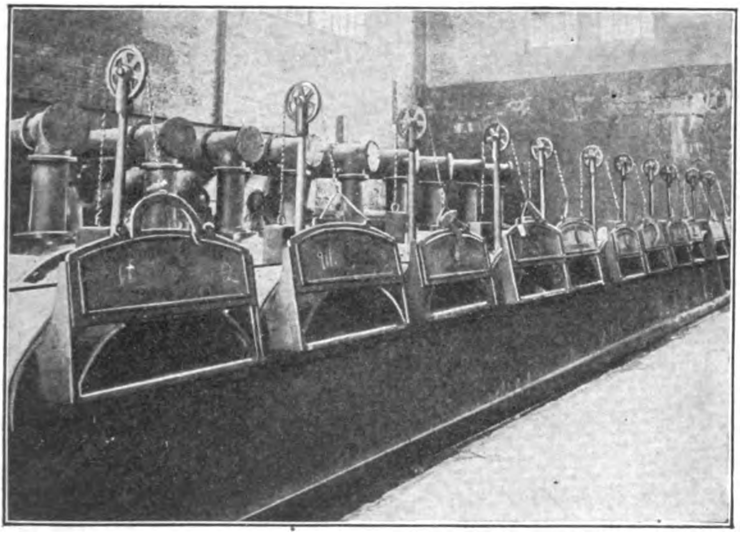
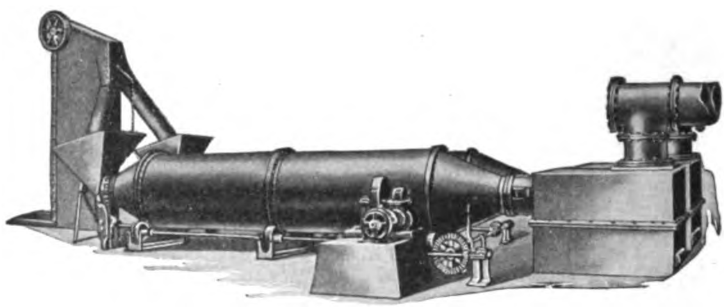


Fig. 65.—Installation of flat type sulphur burners.

vices, is the flat burner. These are essentially cast iron retorts, the body consisting of a single casting. The cross section is semicircular or "D" shaped. They are usually about 8 feet long and 2 feet wide on the outside and the maximum height on the inside is about 18 inches. These burners are set in banks in a brick setting, a sufficient number being installed to provide the amount of sulphur dioxide required for making the volume of acid needed by the mill. The doors of the burners are thus ranged in a horizontal row at a convenient height from the floor so that the sulphur can be charged into them with shovels. When once ignited, the sulphur maintains combustion if an adequate supply of air is admitted to the burner. This air supply is regulated by dampers in the doors and the regulation must be attended to by a careful and experienced man, because if too much air is admitted there is a tendency to form sulphuric acid which forms sulphates in the sulphite acid which are insoluble and cause trouble in the digester and in the washing of the pulp. Moreover, if too much air is admitted, this excess air dilutes the gas produced in the burners and cuts down the efficiency of the tower system. On the other hand, an insufficient supply of air results in incomplete combustion of the sulphur and this causes sublimation or deposit of unburned sulphur throughout the system, which is troublesome and cuts down the efficiency. The sulphur dioxide leaves the furnace through the pipe which is either bolted to the back of the furnace or else to the top of the arch near the back end.

Owing to the violent changes in temperature inseparable from the operation of sulphur burners of the flat type, there is a notable amount of expansion and contraction in the burner itself. Unless some provision is made to take care of this expansion and contraction, the whole system of pipes leading from the burner will be badly distorted. One device that can be introduced to lessen

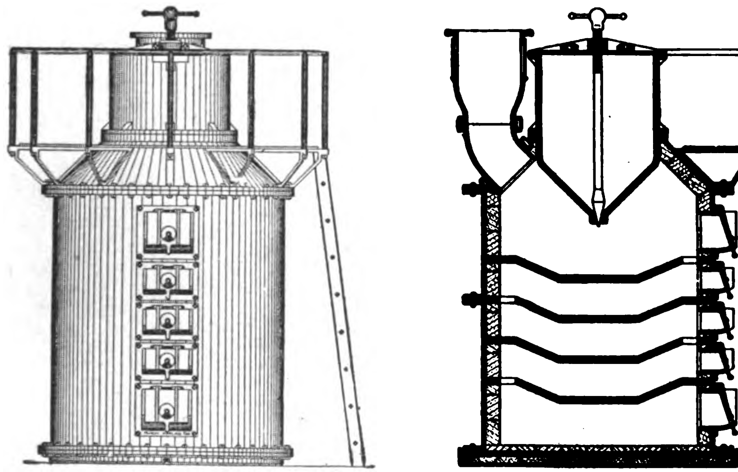


Courtesy: Glens Falls Machine Works, Glens Falls, N. Y.

Fig. 66.—Rotary type of sulphur burner.

this evil is to place the burner not directly upon the brick setting but upon rollers which will permit of a certain amount of motion as the burner expands and contracts. Another precaution is to have the flanged joint between the burner proper and the pipe through which the gas escapes more or less flexible. This can easily be done by not having this flange bolted. In this way the two surfaces can slide on each other with some degree of freedom. Of course the two surfaces will have to be practically air-tight as otherwise there would be considerable leakage or infiltration of air.

A more efficient type of sulphur burner is the rotary burner developed by Tromblee and Paull. This burner consists of a cast iron cylinder, usually about 8 feet long and about 2 feet in diameter mounted on brick settings and revolved slightly by means of gears. At each end of the barrel is a cone. The rear cone connects with the pipe which carries off the sulphur dioxide and the front cone contains the damper by which the air supply is regulated. The revolution of the burner constantly keeps a fresh surface of sulphur exposed to the air, thus giving very efficient combustion. The sulphur is fed to the burner from a small bin directly above the damper. A worm is generally used to facilitate steady and equal feeding of sulphur to the burner. The gases are conveyed from the burner proper into a comparatively large combustion chamber, provided with dampers through which air can be admitted to complete the combustion of the sulphur. In case any sulphur becomes sublimed, on account of insufficient air supply through the front damper, it is caught in this chamber where combustion is completed and prevented from getting into the cooler and the acid system.



Courtesy: Valley Iron Works, Appleton, Wis.

Fig. 67.—Exterior and cross section of Vesuvius sulphur burner.

Another type of sulphur burner is the Vesuvius burner which consists of a cylindrical steel shell lined with fire brick containing a number of shallow trays. These trays are so arranged that the molten sulphur will drip down from each tray to the one below, burning as it drips. The sulphur is placed in a melting pot at the top of the burner. This melting pot has a needle-point valve in the bottom. A fire is lighted in the top tray and as soon as the sulphur begins to melt the needle-point valve is opened and the sulphur drops down on to the first tray beginning to burn. The heat soon melts all the sulphur in the pot and gradually the valve is opened wider and wider and the burning molten sulphur drips down from tray to tray until it enters the bottom chamber where the ashes and impurities collect. Each of the chambers is provided with a door fitted with a damper for the admission of air. From the burner the gases pass to a combustion chamber wherein the sulphur fumes undergo a final combustion. One of the advantages of this type of burner is that it does not require any power to operate. Moreover, no hand firing is required. All ashes or impurities called "slag" are automatically carried to the bottom of the apparatus where they can easily be removed.

Coolers.

From the combustion chamber the sulphur gas is led to the coolers. It is necessary to cool the gas to about 25° C. before entering the towers. If the air supply has not been carefully regulated sulphuric acid will be formed in the coolers. The volume of air required to burn one pound of sulphur to 15 per cent SO_2 gas is 78 pounds or 9 cubic feet. The burner should be so

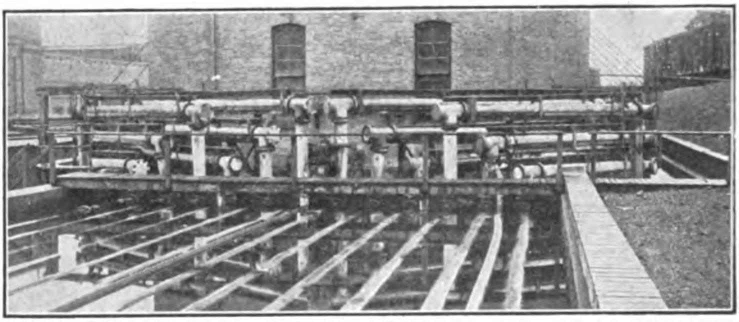
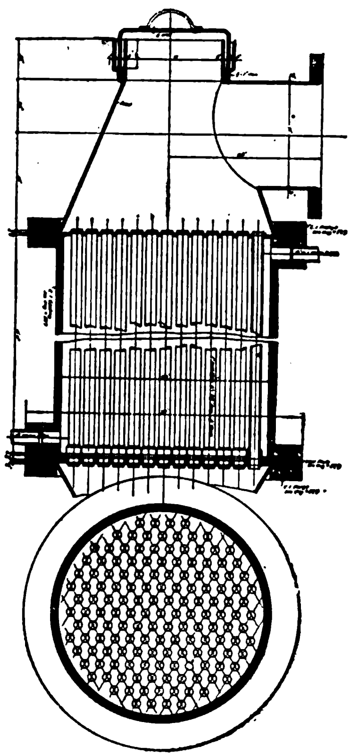


Fig. 68.—Installation of lead pipe coolers.

regulated that about 15 per cent SO_2 gas is formed in the burners. The combustion chamber should be as large as possible and should contain baffles to collect the dust and sublimed sulphur.

If the above precautions have been observed and the gas is properly made it will be cooled in the coolers without any considerable contamination with sulphuric acid and will also be free from sublimed sulphur.

There are numerous types of coolers in use. One type consists of a system of lead pipes flanged to lead headers. The gas enters at one end of the header and passes through the pipes and out through the header at the other end. This whole system of pipes is contained in a vat or pond and the water supply is arranged so that the water enters at the end opposite to the gas entrance. In some cases the system of pipes is only partially immersed in water and is showered with water from sprays. This is much better practice than merely depending on the water in the tank to cool the pipes. On account of poor circulation the water nearest to the pipes will become heated and remain so and the maximum cooling effect will not be obtained, whereas with the spray system fresh water is constantly dripping over the pipes and is also being cooled by evaporation owing to the finely divided water being constantly brought in contact with the air. A very efficient form of cooler is the Sandberg cooler furnished with the Jenssen acid system. This cooler consists of a header and a series of lead pipes placed in a concrete tank filled with water. The gas enters the header and passes through the pipes which stand horizontally and are connected at the top by U bends. Water is sprayed into the top of the cooler and flows down the



Courtesy: G. D. Jenssen Co., New York.

Fig. 69.—Diagram showing the construction of Sandberg cooler.

pipes and out through the concrete tank into the sewer or for further utilization. If the lead pipes are kept in a good state of repair, this water will be perfectly pure and can be used for washing purposes or as boiler feed water, thus utilizing the heat given up by the sulphur gas. This type of cooler is not only very efficient but is easily cleaned as the top of the cooler is readily accessible and the U bends can be taken off and the entire system of tubes cleaned whenever necessary.

The cooler should be as near the combustion chamber as possible so that the cooling of the gas will be rapid. Slow cooling tends to produce sulphuric acid. This is on account of the fact that the best temperature for the formation of sulphuric acid is from 200° C. to 900° C., and on this account the gas should be produced as at high a temperature as possible in the sulphur burner, and then cooled as rapidly as possible in the coolers, so that there is never at any time any considerable volume of gas within the range of temperature favorable to the production of sulphuric acid.

Absorption Equipment.

There are two chief classes of equipment in which the sulphur dioxide gas is brought into contact with the lime and thus converted into acid for use in the digester.

One form of equipment is generally known as the milk-of-lime system. In this system the gas is brought into contact with water containing the lime in suspension. The second and more modern system of acid making is known as the tower system. In this system the gas is brought into contact with limestone, not lime, in the presence of water.

In the milk-of-lime systems the gas first dissolves in the water and the solution immediately reacts with the lime to form monosulphite which is quite insoluble and separates from the solution. The formation of monosulphite goes on in the tank until all of the lime is precipitated in this form. As the addition of gas continues, the monosulphite gradually takes up more sulphur dioxide gas forming bisulphite which, unlike the monosulphite, is readily soluble in water. Unfortunately sulphur dioxide gas in solution tends to form sulphuric acid and in practice there is always formed, together with the bisulphite, more or less sulphate which is insoluble and remains in the acid as a white precipitate, commonly called "gypsum." This precipitate gives a great deal of trouble in the acid and in the digesters. Although it is generally regarded as insoluble, it is not absolutely so and a sufficient amount of it dissolved in the acid afterwards separates out in the digester, where it frequently plugs up in the bottom connections of the digester causing trouble when the digester is to be blown. The removal of this gypsum is a matter of great difficulty, as when it is allowed to accumulate it has to be chipped out with a hammer and chisel. This is troublesome and expensive and involves shutting down the digester, and also is hard on the lining. Sometimes the gypsum will close up the outlet from the digester to such an extent as to make it very slow and difficult to blow out the stock. From the above considerations it will be realized that every precaution should be taken to prevent the formation of sulphate or gypsum in the acid. This can only be guarded against by accurate chemical control of the acid plant and by constant watchfulness on the part of the entire operating force. The cause of sulphate or gypsum in the acid may, as can be seen from the above considerations, lie with the operation of the sulphur burners or the coolers or the milk-of-lime or tower system. If difficulty is found in keeping the acid free from sulphate all of the above possible causes should be carefully investigated.

Milk-of-Lime Systems.

The best known milk-of-lime systems are the Stebbins System and the Barker System.

Stebbins System: This is a three-tank system, the tanks being placed one upon the other. The system can be intermittent or continuous but the continuous systems are preferable. The gas is drawn through the system by a vacuum pump which exhausts the excess gas from the highest of the three tanks.

In the continuous Stebbins system, milk-of-lime is supplied to the top tank and flows through the two lower tanks. The gas enters the lowest tank, passes through the solution, is piped from this tank to the bottom of the second tank, through which it then bubbles in the same manner, and finally through the upper tank. The milk-of-lime is prepared by agitating the lime with hot water in an iron tank provided with an agitator. This tank discharges into a large wooden tank also provided with an agitator in which the milk-of-lime is diluted with fresh water to a density of 1° Baume. From this tank it is passed through a filter into a storage tank where it is held until required for the absorbing system. Provision is made for drawing samples from the lowest tank.

The Stebbins system is passing out of use on account of the invention of more efficient equipment for producing acid.

Barker System: This system is the most generally used of the various tank systems. It is a four-tank system, the four tanks being placed one above the other. The milk-of-lime is pumped into the top tank and overflows in succession into the second, third and fourth tanks. From the bottom of the fourth tank is pumped to the top of a recovery system to be described later. The gas enters the bottom of the lowest tank, passes through the solution into the bottom of the second tank and in the same manner into the third and fourth tanks. Just as in the Stebbins system, the gas is drawn through the system by means of a vacuum pump connected to the pipe by which the excess gas is removed from the highest tank.

In the Barker system the tanks are placed one directly above the other in a tower. In actual practice four tanks are not used, but one tall tank divided into four compartments by means of partitions. The recovery or reclaiming system used with the Barker milk-of-lime system is practically the same as that used with tower installations to be described later.

The advantages of the Barker system over other milk-of-lime systems are compactness, lessened expense for repairs and greater ease of cleaning. It is also easier to operate the Barker system in a continuous manner than other milk-of-lime systems. However, while probably the best of the milk-of-lime systems, this system exhibits a great many disadvantages when compared with tower systems. These disadvantages will be more readily understood after the tower system has been discussed.

Burgess System: In this system the gas is admitted through hollow agitator arms which are rotated in the tanks.

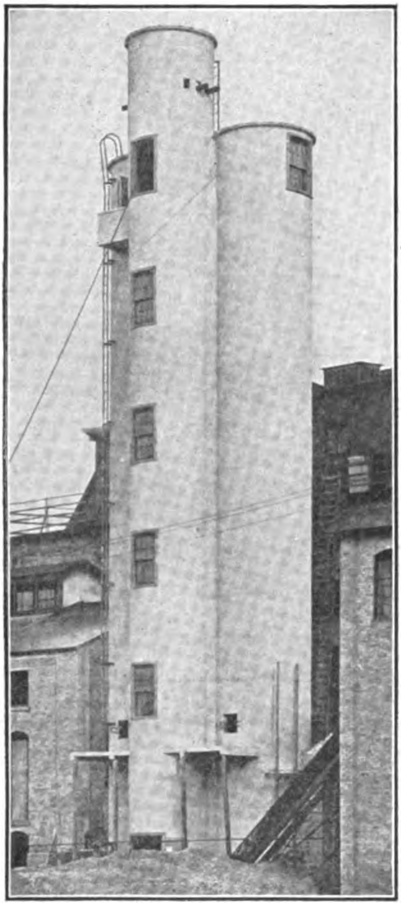
Tower Systems.

The earliest forms of acid making equipment were tower systems, the towers consisting usually of high wooden columns of circular cross section. The towers were filled with lumps of limestone or dolomite, the latter mineral being a limestone which contains a high percentage of magnesia. The gas from the sulphur burner entered the bottom of the tower and rose in an irregular manner, its passage upwards being intercepted and broken by the limestone. Water was sprayed into the top of the tower in such a manner that it would flow down through the tower, covering all the pieces of limestone with a film of water as it flowed.

The engineering difficulties connected with the construction and maintenance of towers were so numerous and so formidable that the earlier types of towers, such as those designed by Mitscherlich, Ritter and Kellner, etc., were largely abandoned in favor of the milk-of-lime systems previously described.

However, with improved facilities for constructing towers, the system has come back into favor to such an extent that it has largely supplanted milk-of-lime systems in the majority of sulphite mills. The most efficient tower system is the Jenssen, the towers of which are constructed of re-enforced concrete, lined with acid resisting tile.

The following is a description (for which we are indebted to the G. D. Jenssen Co.) of a typical installation of this kind. A hard lead fan, directly connected to a variable speed motor so as to allow the capacity of the plant to be carried at any desired point, blows the sulphite gas through the concrete towers which work in series. After the gases have passed through the first tower, they enter the second tower at the bottom through a tile pipe. The unabsorbed gases (carbonic acid, nitrogen, oxygen) pass out into the air through a pipe on top of a second tower. The feed water is distributed from the top of the second tower in which it forms a very weak acid, which is pumped into the first tower where the finished acid is made. The grates on which the limestone rests are elevated from 17 to 20 feet above the gas inlets and the space between the gas inlet and these grates is filled with a wooden checker work fixture. The reason for this arrangement is to allow the acid to be saturated with free SO_2 before the gas strikes the limestone. Careful experiment has shown that from 17 to 20 feet of wooden checker work is sufficient to bring the acid to the point of saturation. Raising the grate still higher would not influence the content of free SO_2 to any extent. By arranging the towers in this way, it has been possible to produce with 15 to 16 per cent gas and a water temperature of 5° C. a tower acid containing 4.5 per cent total SO_2, 3.1 to 3.2 per cent free SO_2 and such an acid in connection with a proper reclaiming



Courtesy: G. D. Jenssen Co., New York.

Fig. 70.—A recent installation of Jenssen towers.

system and proper operation of the digester relief, brings the percentage of total SO_2 in the cooking acid up to 7 per cent or higher.

When the towers have been in operation two or three days they are reversed, the second tower being used as the first and vice versa. This allows the first tower to be charged with limestone as the cover on top can be removed after creating a slight vacuum with a steam jet, the gas in this way being prevented from entering the charging room. The high efficiency of this system is demonstrated by the fact that over 90 per cent of the gas is absorbed in the first tower, the towers being operated under forced draft and with a large volume of water. For this reason it has been found that cleaning the limestone grates is a thing of the past. The system can be shut down on Sunday morning and started up on Monday without any cleaning whatever.

With this system the regulation is very simple, there being only one water valve to attend to, and the system is frequently run from ten to twelve hours without changing the water valve.

The flexibility of the system is as great as any milk-of-lime system. If a higher content of combined SO_2 is desired in the acid this can be done in two ways, either by heating the feed water so as to accelerate the chemical actions in the towers or by recirculating some of the acid from the first tower back to the top of this tower again which will raise the lime content to any desired point.

The above arrangement of the towers is used where a straight calcium limestone not exceeding 8 to 10 per cent magnesium carbonate is at hand.

Where a limestone or dolomite containing as high as 40 to 45 per cent magnesium carbonate is to be used, tower construction has to be changed. It is well known that calcium carbonate is easier to dissolve than magnesium carbonate, and due to this lack of uniformity in the solution of magnesium and calcium carbonate, the latter is first attacked by the gases with the result that the surface of the stone crumbles and a sludge is formed. In order to dissolve this sludge the grates, when a limestone high in magnesia is being used, should be elevated 40 feet above the gas inlets and four towers should be used in order to obtain sufficient capacity to cover the slower absorption ability of the high magnesia stone.

Until recently, it has been the opinion of many that acid high in magnesia was to be preferred. The explanation of this has been that magnesium bisulphite is decomposed easier by steam in cooking than calcium bisulphite and that the sulphates of magnesia are soluble whereas the sulphates of calcium are insoluble. Possibly these facts had a bearing on the quality of pulp produced in former days when sulphite mills used acid low in free SO_2 and high in lime. Today, however, with excellent means of reclaiming the digester gases and obtaining cooking acid containing from 5 to 7 per cent total SO_2, the preference for magnesia over calcium has, in the writer's opinion, absolutely disappeared. Mills having changed from milk-of-lime to a straight calcium limestone have confirmed the above experience.

One of the advantages of the tower system is lower sulphur consumption. The tower system is very flexible compared with the milk-of-lime system. The output or the composition of the

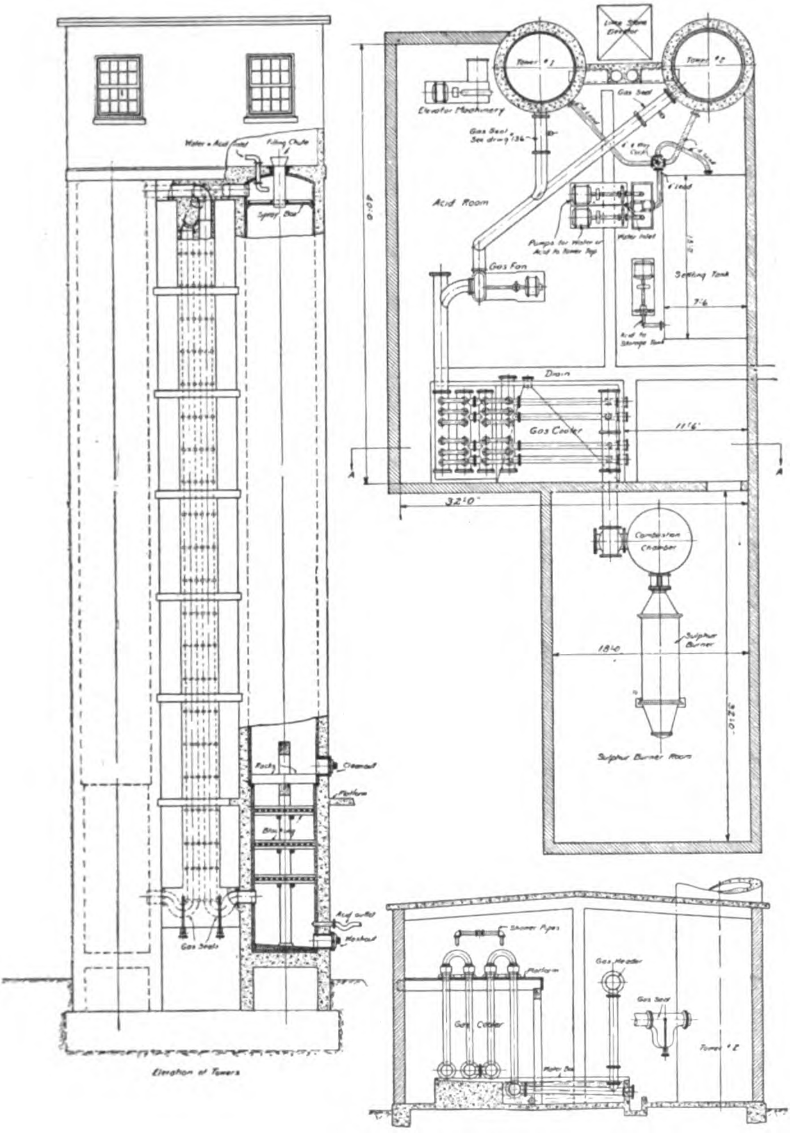


Fig. 71.—Diagram showing construction and operation of Jenssen tower system.

acid can be changed easily by any one of a number of means such as changing the volume of water admitted to the towers, altering the temperature of the water, increasing or decreasing the speed of the fan or vacuum pump, etc. The upkeep of the tower systems is much more economical than that of milk-of-lime systems. In the milk-of-lime systems sulphate or gypsum forms quickly and plugs the holes in the bottom of the tanks, the connecting pipes, etc. Acid of much higher strength can be made in the towers than is possible with the best milk-of-lime systems. Moreover, the cost of lime is high compared with that of limestone. Furthermore, limestone is not subject to deterioration while lime slacks, especially in the summer time, and requires special storage facilities. Also, whereas the limestone is constant in chemical composition, the lime is constantly changing and it is impossible to estimate the quantity of lime to use in a milk-of-lime system without making new calculations on the basis of frequent and careful chemical analysis of raw materials.

Efficiency of Tower Systems.

The tower system offers the great advantages of economy in power and materials, ability to adjust itself quickly and easily to changes in manufacturing conditions and reliability in operation.

It is stated by Henry F. Obermanns[1] that in changing from a three tank milk-of-lime system (five of which systems were required for a 100-ton mill) to a tower system the following advantages were derived: "Each tank system had its own vacuum pump requiring about 35 h.p. or a total of 175 h.p. for vacuum pumps alone. To this is to be added another 150 h.p. for agitators for the various tanks. On the other hand, the entire power necessary for the operation of the tower system amounts to about 50 to 60 h.p. for the operation of the fan and water pumps. This means a saving of from $10,000 to $12,000 per annum. With the old system operating continuously sulphur consumption ran about 15 per cent on basis of bleached pulp, or about 300 pounds of sulphur per ton. With the towers the consumption is from 11¾ per cent to 12 per cent. Further saving is in the substitution of limestone for burnt lime. Wear and tear is very small as compared with constant repairs and replacements with the old system. In labor there is no particular saving, as no men could be eliminated with the introduction of the towers, but the acid-maker was left with no manual labor to perform, thus being free to devote all his time to proper supervision."

Proper Strength of Acid.

Very divergent views are held as to the proper strength of acid and the proper proportions of free and combined. It used to be thought that acid should have a high combined. A usual analysis in the old days was 4.00 per cent total, 2.75 per cent free

[1] Technical Association Papers, 1918, pg. 28.

and 1.25 combined. In such an acid only 70 per cent of the total is free. Modern acid makers like to have anywhere from 78 to 88 per cent of the total acid in free form.

The writer, after lengthy experimentation, has come to use an acid, with wet wood and a cook of ten to ten and a half hours duration, analyzing 4.65 per cent total, 3.50 free and 1.15 combined; for dry wood, total 4.39 per cent, free 3.25 and combined 1.10 to 1.15. By wet wood we mean wood containing approximately from 40 per cent to 50 per cent moisture and by dry wood we mean wood containing 27 per cent to 35 per cent moisture. The above strengths are the strengths of the cooking acid. The strength of the raw acid is about 3.60 per cent total, 2.18 per cent combined and 1.42 per cent free in the case of the wet wood; and 3.86 per cent total, 2.37 per cent free and 1.49 per cent combined in the case of the dry. This acid is made at about 4.5° Be. the strength being brought up to the total mentioned with reclaimed acid. For cooking bleached stock stronger acid with a total of about 6 per cent is preferable. The above figures are for unbleached stock. The above figures are all based on the use of ¾-inch chips which run from 55 to 60 per cent within this specified length and it is also assumed that dry steam is supplied, generated at 150 pounds boiler pressure and with a pressure of from 60 to 68 pounds of dry steam on the digesters.

However, the above just applies to certain grades of sulphite requiring definite strength and quality. The writer would not hesitate to use stronger or weaker acid were the conditions different. Newsprint can be made with weaker acid, particularly if the wood is dry. R. E. Cooper states[1] that an acid (raw) analyzing total 3.50 to 4.00 per cent, free 2.40 per cent and combined 1.30 to 1.60 per cent is satisfactory for newsprint. This acid when strengthened with reclaimed acid analyzes from 5 to 6 per cent total, 4 to 5 per cent free and about 1 per cent combined. Robt. B. Wolf[2] states that one summer the acid in the plant he was operating dropped from 6 per cent to 4.25 per cent and the decrease in the strength of the pulp was so noticeable as to cause several of the mill's customers to inquire as to the cause. When a refrigerating plant was installed and the acid went up to over 5.5 per cent the strength test of the paper immediately increased from 65 to 85. Mr. Wolf explains these results on the grounds of the higher maximum temperature and increased cooking time needed with the weaker acid. He states, moreover, that the consumption of wood per ton of sulphite was markedly affected. With the strong acid it took 1.65 cords of wood to make a ton of bleached sulphite, whereas with the weaker acid it took 2 cords.

The combined should be kept above 1 per cent if possible, certainly above 0.9 per cent. A lower combined will mean using

[1] Guide to Sulphite Pulp Manufacture. Paper, Inc., New York, 1918, pg. 26.
[2] Technical Association Papers, 1918, pg. 62.

much more bleach in making bleached sulphite and also the pulp will be of poorer quality. It has been stated by Prof. McKee that letting the combined drop to below 0.8 per cent will double, or even treble, the bleach consumption.

Strong acid means a higher sulphur consumption. Modern reclaiming systems make possible the maintenance of acid strengths that would have been out of the question before such systems were used, but with the best reclaiming systems there is a direct relation between the sulphur consumption and the strength of the acid. For one thing, it is not always possible to relieve all of the gas to the reclaiming system before blowing. In one mill the conditions are such that the digesters have to be blown very light to keep the temperature down. This involves blowing at a time when the acid tests 1.6 per cent free, which means blowing sulphur into the air at the rate of about 150 pounds per ton of pulp. Systems for reclaiming the fumes from the blow pits have been devised to take care of just such cases as this.

Theoretically 190 pounds of sulphur should be required to make 1 ton of spruce sulphite pulp. Most American mills use much more, some as much as 300 pounds. E. R. Barker states that certain Scandinavian mills make good pulp using less than 190 pounds.

Superheated Steam.

Some pulp makers favor the use of superheated steam in the digesters. It is certain that its use facilitates the maintenance of the strength of the acid, but on the other hand there are num erous disadvantages. Further comments on this subject will be found in the chapter on the power plant.

Reclaiming Systems.

Recovery towers are the chief feature of the reclaiming system. These are usually of concrete and may be filled with wooden checker work or with logs or with chemical stoneware rings. Dilute acid from the tower system is pumped into the top of the reclaiming tower and flows down it, meeting and absorbing the gas from the relief lines of the digesters. The liquid never absorbs all the gas and the unabsorbed gas fills the space in the tower above the liquid. This makes a pressure of gas on the liquid which enables it to hold more gas in solution than if air were present above the surface of the liquid, which is an

The reclaiming of the relieved liquor is very simple, as it is simply run to tanks, from which it is mixed with the raw acid.

The gas, however, has to be cooled before going to the reclaiming towers. The coolers are similar to those used for the cooling of the gas from the burners. The effect of temperature on the strength of the acid is very marked. Reference to the diagrams on pages 127 and 128 will show how rapidly the solubility of sulphur gas in water decreases as the temperature rises. Whereas at 0° C. 1 volume of water will dissolve approximately 80 volumes of sulphur gas, at 40° C. it will only dissolve about 19 volumes. Consequently cold water should be used in the towers, the reclaiming system should be kept cold and all pipe lines containing raw or cooking acid should be laid out with this in view. In some mills refrigerating systems have had to be installed to keep up the strength of the free acid in summer.

Pressure and Vacuum.

The milk-of-lime systems were worked under vacuum. That is, the gas was drawn through the system, not forced through it. One milk-of-lime system was introduced operating under pressure (that of Francke) but it had other drawbacks that prevented its wide application. Theoretically the tower systems are pressure systems, but the pressure is so low that it has no effect one way or the other on the strength of the acid. With milk-of-line systems, however, pressure is much preferable to vacuum as it will permit of an acid much higher in free SO_2. Pressure systems are more used in Europe than in America.

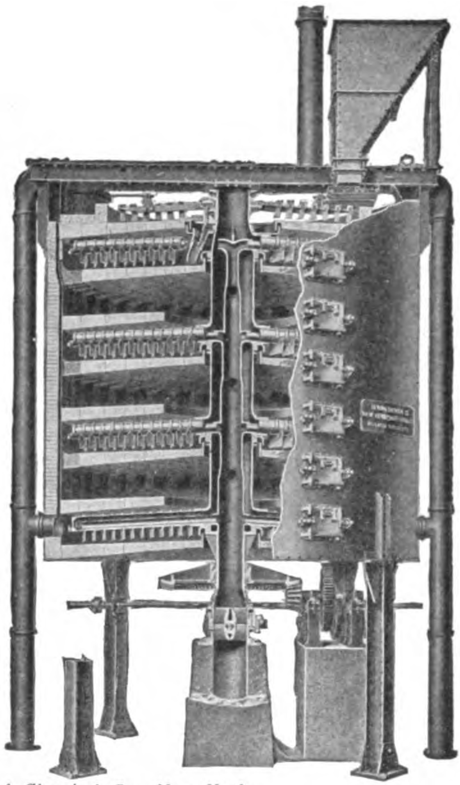
Burning Pyrites instead of Sulphur.

Pyrites is sulphide of iron, containing about 54 per cent sulphur and 46 per cent iron, when pure. Commercial pyrites is rarely pure. The mineral pyrite is mixed with other sulphides and with ordinary rock. However, in most parts of the United States and Canada, supplies of pyrites can be obtained yielding from 33 per cent to 48 per cent sulphur.

The possibility of burning pyrites instead of sulphur in pulp mill acid plants is probably chiefly interesting in Canada, since there are no deposits of sulphur in that country and the pulp mills there secure all their sulphur from the deposits of the southern United States. However, as the practice develops it may become very interesting to mills located in those portions of the United States remote from the sources of supply of sulphur and near satisfactory pyrites deposits. Several Scandinavian mills use pyrites with excellent results.

The manufacturers of sulphuric acid have developed the art of burning pyrites to a high degree of efficiency. However, several conditions enter into the burning of this material for pulp mill purposes that are not met with in the sulphuric acid plant. The manufacturer of sulphuric acid is pleased rather than otherwise if some of the sulphur burns to SO_3 in the pyrites furnaces. The pulp manufacturer has to avoid that condition. Temperatures have to be carefully regulated. Some pyrites ores contain a metal known as selenium and the presence of this in even very small proportions is detrimental as it causes the SO_2 to oxidize to SO_3, thus forming sulphates in the digester acid. The presence of copper is also undesirable.

There are a number of pyrites burners on the market, possibly the best known of these being the Herreshoff Furnace and the Wedge Furnace. Both of these are mechanically operated furnaces with circular hearths on which the ore being roasted is stirred with rotating arms. It is not necessary to describe these furnaces here in detail as anyone interested in the possibilities



Courtesy: General Chemical Co., New York.

Fig. 71a.—Herreshoff furnace for burning pyrites.

of pyrites in the pulp mill will find detailed information on such equipment in standard text books on metallurgy and the manufacture of sulphuric acid.

Furnaces of the rotary kiln type have also been used, the best known of these being the Jones furnace which has been used in a sulphite mill in Canada.

Pyrites burners will not yield as rich a gas as sulphur burners. About the best they will yield is 12 to 16 per cent SO_2. On the other hand, there is less free oxygen in the gas, which is an advantage. A mill contemplating using pyrites should have a large tower capacity, since about 30 per cent more gas will have to be passed through the towers to produce acid of a given strength. Also very cold water for the towers is a requisite. Granted these conditions good pulp can be made using pyrites in the acid plant. It is all a matter of comparative costs. The first cost of the equipment is high.

According to Dr. A. W. G. Wilson,[1] of the Canadian Department of Mines, a pyrites burning equipment for a 100-ton sulphite mill would consist of:

Two mechanical roasters, provided with hopper feeds, belt conveyors for charging ore to the hoppers and removing cinders to the cinder bin.

Main flue, with dust discharge hoppers.

Dust chamber, with dust discharge hoppers.

Auxiliary cooler, with dust discharge hoppers.

Fan, driven by variable speed motor.

Scrubbers, with liquor tank and centrifugal circulating pump, and driving motor.

Assuming three shifts per day, three furnace men and three laborers will be required in constant attendance. In addition the mechanical equipment will require daily inspection by a machinist and occasional repairs and adjustments.

Dr. Wilson makes some careful calculations of the cost of pyrites burning as compared with sulphur and comes to the conclusion that for Canadian 100-ton mills, paying $30 or more per ton for sulphur, that a daily saving of $163 would be possible. This would pay the interest and depreciation on the plant and yield a very satisfactory profit.

[1] Paper read before the Technical Section of the Canadian Pulp and Paper Association, Montreal, Jan. 30, 1918. Reprinted in "Paper," Feb. 13, 1918, pgs. 102-134.

VIII. The Soda Process.

The soda process for the manufacture of chemical wood pulp depends on the chemical fact that alkali at high temperatures will dissolve all the other constituents of wood except the cellulose, leaving the latter in a form suitable for paper manufacture.

The soda process is much older than the sulphite process and is, of itself, simpler. However, in order to be carried on at a profit, it is necessary to recover the soda and most of the problems of soda pulp manufacture are connected with the operation of the recovery department.

Not only is soda pulp necessary for certain varieties of paper, but the soda process will serve to utilize many kinds of wood that cannot profitably be dealt with by the sulphite process.

Poplar is the principal kind of wood used for soda pulp, but some spruce, pine, hemlock, cottonwood, etc., are also worked up by this process.

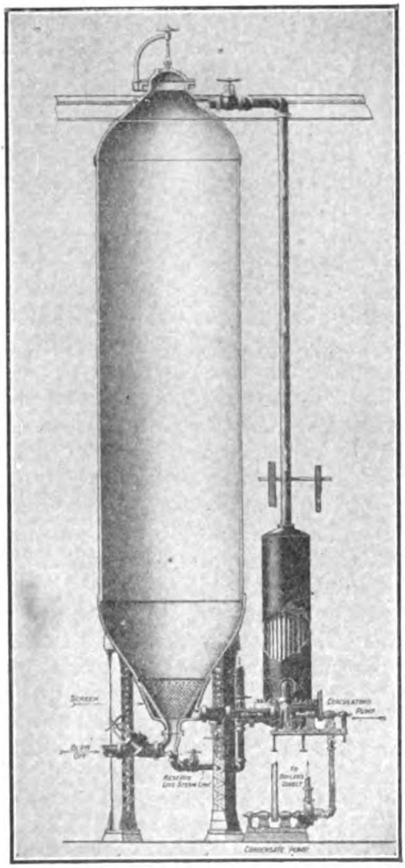
It is not necessary to prepare the wood so carefully for the soda process as for the manufacture of sulphite pulp. The bark is removed, but it is not generally considered necessary to exercise the extreme care to get rid of all the small particles of bark that is usually exercised in making good sulphite. No attempt is made to eliminate knots or decayed wood. The more drastic solvent power of the soda lye readily reduces even knots and bark.

The wood is chipped just as for the sulphite process, except that the chips are usually a little smaller, being from 3/8 inch to 1/2 inch in length. The chips are screened in exactly the same manner as for sulphite pulp and are then conveyed to chip bins ready to be placed in the digesters.

In the older soda mills rotary digesters, either horizontal or spherical, similar to those used for boiling rags, were extensively used. These digesters were heated with steam coils, the steam entering through the trunnions and the coils rotating with the digester. These digesters were of small capacity and the cost of upkeep was high. The digesters were constructed of steel plate without any special lining as steel plate resists the action of alkali about as any metal.

These rotary digesters have largely been replaced by stationary vertical digesters, similar to those used for the sulphite process, but usually somewhat smaller, although some soda pulp mills are now using very large digesters, even larger than the usual sulphite digester. In most cases the direct cook is used in these digesters, live steam being introduced at the base of the digester. However, in a few cases jacketed digesters have been employed.

A great deal of trouble has been occasioned by the impossibility of keeping ordinary riveted steel plate digesters tight when filled with soda lye. Although steel plate resists the soda lye very well, leaks develop where the shells are riveted, presumably because of electrolytic action set up between the shell



Courtesy: Fibre-Making Processes, Inc., Chicago, Ill.

Fig. 72.—Soda digester arranged for indirect cooking.

and the rivets, the composition of the two being sufficiently different to cause this effect.

With a jacketed digester, if the steam pressure is kept in excess of the pressure within the digester, any leaks will be inwards and comparatively harmless.

Welded digesters are now on the market and are being used by some of the large manufacturers of soda pulp with conspicuous success. These digesters provide entire freedom from leakage. The size in which such digesters can be furnished is constantly increasing, as the art of welding advances, and some have been made sufficiently large for use in the sulphite process.

Systems for circulating the liquor have been employed a good deal in connection with the soda process. One important mill uses steam injectors for this purpose. The Morterud process, whereby the liquor is heated in a separate heater and pumped through the digester has been used for the soda process with considerable success in Europe and is now being introduced in America. This process has the advantage that the liquor is not diluted and consequently the evaporating problem in the recovery plant is simplified.

A digester of the stationary type 7 feet in diameter and 29 feet high holds about 3½ cords of chips and 4,200 gallons of liquor. This would be a small digester. Soda process digesters as large as 19 feet by 65 feet have been used. This liquor is caustic soda solution usually 11.5° to 12° Baume at 60° F.

When the digester is full the lid is bolted on and the steam admitted. The pressure is brought up to maximum as quickly as possible and maintained until the end of the cook. In this regard this is a much simpler process than the sulphite cook. Pressures over 90 pounds used to be unusual and in the older accounts of the process pressures from 60 to 90 pounds are spoken of as good practice, but in the modern soda mill the pressures are much higher, 125 or 130 pounds being quite ordinary.

The length of the cook depends chiefly on the dryness of the wood. The dryer the wood, the more rapidly it absorbs the caustic soda solution. Usually the cook is completed in from 6 to 8 hours. In order to circulate the liquor, the pressure is relieved from time to time. This causes dilution of the liquor from the new steam entering and loss of heat units and is one of the arguments against the direct cook as compared with the indirect methods where forced circulation is used, because in the soda process there is no reason apart from promoting circulation for relieving the pressure until the cook is completed, i. e., no gas is generated during the process which has to be relieved as is the case in cooking sulphite pulp.

When the cook is completed the valve at the bottom of the digester is opened and the contents blown into a receiving tank. This tank is usually elevated above the wash pans, in which the liquor is eliminated from the pulp, as the digester pressure is sufficient to elevate the pulp to the height of the receiving tank. The steam escapes through a vent at the top of the tank, this vent usually being provided with baffles to prevent any pulp or liquor being blown or splashed out.

The contents of the receiving tank are next run into the first of a series of wash pans which are provided with perforated false bottoms through which the liquor drains from the pulp. Dilute hot liquor from a certain portion of the recovery system is then sprayed on the pulp in the first pan, which it frees from alkali to a certain extent, at the same time becoming fortified itself. Following this operation more and more dilute liquor and finally clean hot water is sprayed on the pulp for long enough to remove the last traces of dissolved intracellular matter and alkali. This water goes to the recovery system also as it drains from the pulp.

The contents of the digester when blown are of quite a different appearance from the contents of a sulphite digester, being dark brown and in some cases black, and having a distinctive empyreumatic odor.

The pulp, when the liquor is washed from it, is of a gray or brown color which it does not lose until it is bleached.

The whole principle of washing the contents of the soda digester is to thoroughly get rid of every last trace of alkali and dissolved intracellular matter without diluting the wash liquors any more than is absolutely necessary, as all these liquors have later to be evaporated to recover the soda. Very small traces of liquor left in the pulp render bleaching very difficult and seriously impair the value of the product. Excessive use of wash water makes recovery too costly.

For these reasons the pulp, at each stage of the washing, is washed with the liquor from the pan just before it in series, and the small amount of fresh water used for the final washing of a lot of pulp passes in succession through the whole series of washing pans or tanks (usually four or five in number) in each succeeding one of which the percentage of black liquor retained by the pulp is greater. At the end of the operation the liquor is used to wash the pulp fresh from the digester, as mentioned above, and as a result of this operation is brought up to a concentration approximating, in properly conducted plants, about 55 per cent of the original strength. The capacity of the wash pans should be sufficient that no liquor will ever have to be drained to waste. Of course, some soda is unavoidably lost, but if less than 95 per cent of the soda goes to the evaporators from the pans there is something wrong in the system.

The completely washed pulp is hosed out of the washing pan in exactly the same manner that sulphite pulp is hosed from a blow pit, which has been described in the chapter on the sulphite process. A pump elevates the stuff to the screens. The remainder of the treatment of soda pulp is exactly the same as already described for sulphite pulp. However, diaphragm screens are almost altogether used for soda pulp. The reader will probably recollect that when discussing the screening of sulphite pulp we described both diaphragm and centrifugal screens and stated that although centrifugal screens were more efficient, where the quality of the paper being produced would tolerate their com-

COOKING CONDITIONS EMPLOYED AT SPECIFIC AMERICAN SODA-PULP MILLS [1]

Reference No.	Date of report	Digester: Kind	Digester: Size	Digester: Wood capacity	Digester: Manner of heating	Quantity of chemicals charged: Actual caustic soda (NaOH)	Quantity of chemicals charged: Total soda expressed as carbonate	Quantity of cooking liquor charged: Per cook	Quantity of cooking liquor charged: Per cord
			Feet	*Cords*			*Pounds per cord*	*Gallons*	*Gallons*
1	1909	Cylindrical, stationary, vertical	....	3	Live steam or steam jacket.	....	1,000	2,800–3,000	[2]930–1,000
2	1909	....do	28 by 7	3–3.5	Live steam	720–860 pounds per cord.[2]	1,030–1,300[2]	3,400–3,500	[2]975–1,150
3	1909	....do	....	3	Steam jacket / Live steam	....	1,000	2,500	[2]830
4	1907	....do	49 by 10	15	Live steam	625 pounds per cord.	....	13,000	[2]870
5	1907	Cylindrical, rotary, horizontal	20 by 7	3.5	....do	25 per cent =650 pounds per cord.	....	[2]2,750 3,100	[2]780-900
6	1907	Cylindrical, stationary, vertical	30 by 8	5.5	....	....	....	....	....
7	1907	....do	40 by 9	....	Live steam	....	....	....	....
8	1907	....do	30 by 8	5.5	....do	....	....	....	....
9	1907	....do	42 by 9	12	....do	....	....	9,300	[2]775
10	1904	....do	27 by 7	4	....do	....	885	3,600	900
11	[3]1909	Cylindrical, stationary, vertical (welded)	29 by 7	....	....do	2,792 pounds per charge.[2]	....	4,200	....
12	1910	....do	29 by 7	3.5	....do	610 pounds per cord.	....	2,930	840
13	1910	....do	30 by 7	4.0	....do	650 pounds per cord.	....	3,200	800

[1] Each report represents a single mill except as specified for reference No. 11.
[2] Calculated from other data given.
[3] Statement by A. G. Paine, jr., in United States House of Representatives Doc. 1502, 60th Cong., 2d sess., 1909. Conditions employed by mills of the New York and Pennsylvania Co.

COOKING CONDITIONS EMPLOYED AT SPECIFIC AMERICAN SODA-PULP MILLS—*Continued*

Reference No.	Cooking liquors at start of cook: Density, Baumé	Density, Twaddell	Density, Specific gravity	Concentration of NaOH	Causticity	Cooking pressure per square inch	Durations of cooking: Total	From start till cooking pressure is reached	At cooking pressure	Blowing pressure per square inch
					Per cent	*Pounds*	*Hours*	*Hours*	*Hours*	*Pounds*
1	7–12°	[1] 11–18°	[1] 1.05–1.09	Equivalent of 1 pound soda ash per gallon..	92	110–120	8–12 (8 for poplar).	2–3	5–10	
2	14°	[1] 22°	[2] 1.11	9 per cent [2]........................	88–92	110	10–12	1.5–1.8	8.2–10.5	
3	10–15°	14.24°	[1] 1.07–1.12	5–10 per cent [1]........................	....	110–120	9.5–10	1–2	7–5.9	
4	7.5°	[1] 10°	[2] 1.05	Equivalent of 0.96 pound total alkali per gallon.	82	75	5.8	1	4.8	75.
5	13–14°	[1] 20–22°	[1] 1.10–1.11	8.5–10 per cent........................	....	110	7.5	....	....	Not blown.
6	14–16°	[1] 22–26°	[1] 1.11–1.13	....	....	100	6–8	....	....	
7	14–16°	[1] 22–26°	[1] 1.11–1.13	....	....	100	6.8	....	....	
8	[1] 11–12°	17–18°	[1] 1.08–1.09	....	....	110	5.5–6	....	....	
9	10.5°	[1] 16°	[1] 1.08	....	....	105	10	....	....	
10	11°	16.4°	1.081	6 per cent Na_2O........................	....	110	....	....	8	
11	11.5–12°	[1] 18°	[1] 1.09	8 per cent [1]........................	98	125–130	[3] 6–8	....	....	
12	12°	18°	1.091	8 per cent........................	90	110	8	2.5	5.5	110.
13	12°	18°	1.091	9 per cent........................	92–95	110–120	4.5–6	1.5–2	3–4	75.

[1] Calculated from other data given.
[2] Statement by A. G. Paine, jr., in United States House of Representatives Doc. 1502, 60th Cong., 2d sess., 1909. Conditions employed by mills of the New York and Pennsylvania Co.
[3] Not specifically known whether time is total duration or duration at maximum pressure.

COOKING CONDITIONS EMPLOYED AT SPECIFIC AMERICAN SODA-PULP MILLS [1]

Reference No.	Date of report	Digester				Quantity of chemicals charged		Quantity of cooking liquor charged	
		Kind	Size	Wood capacity	Manner of heating	Actual caustic soda (NaOH)	Total soda expressed as carbonate	Per cook	Per cord
			Feet	*Cords*			*Pounds per cord*	*Gallons*	*Gallons*
1	1909	Cylindrical, stationary, vertical	....	3	Live steam or steam jacket.	....	1,000	2,800-3,000	[2]930–1,000
2	1909	....do	28 by 7	3-3.5	Live steam	720–860 pounds per cord.[2]	1,030-1,300[2]	3,400-3,500	[2]975–1,150
3	1909	....do	....	3	Steam jacket; Live steam	....	1,000	2,500	[2]830
4	1907	....do	49 by 10	15	Live steam	625 pounds per cord.	....	13,000	[2]870
5	1907	Cylindrical, rotary, horizontal	20 by 7	3.5	....do	25 per cent =650 pounds per cord.	....	[2]2,750 3,100	[2]780-900
6	1907	Cylindrical, stationary, vertical	30 by 8	5.5	....	....	....	....	....
7	1907	....do	40 by 9	....	Live steam	....	....	....	....
8	1907	....do	30 by 8	5.5	....do	....	....	....	....
9	1907	....do	42 by 9	12	....do	....	....	9,300	[2]775
10	1904	....do	27 by 7	4	....do	....	885	3,600	900
11	[3]1909	Cylindrical, stationary, vertical (welded)	29 by 7	....	....do	2,792 pounds per charge.[2]	....	4,200	....
12	1910	....do	29 by 7	3.5	....do	610 pounds per cord.	....	2,930	840
13	1910	....do	30 by 7	4.0	....do	650 pounds per cord.	....	3,200	800

[1] Each report represents a single mill except as specified for reference No. 11.
[2] Calculated from other data given.
[3] Statement by A. G. Paine, jr., in United States House of Representatives Doc. 1502, 60th Cong., 2d sess., 1909. Conditions employed by mills of the New York and Pennsylvania Co.

COOKING CONDITIONS EMPLOYED AT SPECIFIC AMERICAN SODA-PULP MILLS—*Continued*

Reference No.	Cooking liquors at start of cook: Density: Baumé	Density: Twaddell	Density: Specific gravity	Concentration of NaOH	Causticity	Cooking pressure per square inch	Durations of cooking: Total	From start till cooking pressure is reached	At cooking pressure	Blowing pressure per square inch
					Per cent	*Pounds*	*Hours*	*Hours*	*Hours*	*Pounds*
1	7-12°	[1] 11-18°	[1] 1.05-1.09	Equivalent of 1 pound soda ash per gallon..	92	110-120	8-12 (8 for poplar).	2-3	5-10	
2	14°	[1] 22°	[2] 1.11	9 per cent [2]........	88-92	110	10-12	1.5-1.8	8.2-10.5	
3	10-15°	14.24°	[1] 1.07-1.12	5-10 per cent [1]........	....	110-120	9.5-10	1-2	7-5.9	
4	7.5°	[1] 10°	[2] 1.05	Equivalent of 0.96 pound total alkali per gallon.	82	75	5.8	1	4.8	75.
5	13-14°	[1] 20-22°	[1] 1.10-1.11	8.5-10 per cent........	....	110	7.5	....	....	Not blown.
6	14-16°	[1] 22-26°	[1] 1.11-1.13	....	....	100	6-8	....	....	
7	14-16°	[1] 22-26°	[1] 1.11-1.13	....	....	100	6, 8	....	....	
8	[1] 11-12°	17-18°	[1] 1.08-1.09	....	....	110	5.5-6	....	....	
9	10.5°	[1] 16°	[1] 1.08	....	....	105	10	....	....	
10	11°	16.4°	1.081	6 per cent Na_2O........	....	110	....	....	8	
11	11.5-12°	[1] 18°	[1] 1.09	8 per cent [1]........	98	125-130	[3] 6-8	....	....	
12	12°	18°	1.091	8 per cent........	90	110	8	2.5	5.5	110.
13	12°	18°	1.091	9 per cent........	92-95	110-120	4.5-6	1.5-2	3-4	75.

[1] Calculated from other data given.
[2] Statement by A. G. Paine, jr., in United States House of Representatives Doc. 1502, 60th Cong., 2d sess., 1909. Conditions employed by mills of the New York and Pennsylvania Co.
[3] Not specifically known whether time is total duration or duration at maximum pressure.

Cooking Conditions Employed in the Soda Process of Wood-Pulp Manufacture

Reference No.	Practice followed	Digester				Quantity of chemicals charged		Quantity of cooking liquor charged	
		Kind	Size	Wood capacity	Manner of heating	Actual caustic soda (NaOH)	Total soda expressed as carbonate	Per cook	Per cord
			Feet					*Gallons*	*Gallons*
1	Watt and Burgess process								
2	do								
3	Sinclair's process	Cylindrical, stationary, vertical.			Direct fire				60 per cwt. dry wood
4	Houghton's process								
5	European practice (1870)					336 lbs. per ton green wood.			
6	American practice (1870)	Cylindrical, stationary, vertical.	16 by 5	1 cord	Direct fire or steam jacket.				
7	American practice (1880-1890)	do	27 by 7	4.3 cords	Live steam	444 lbs. per cord [1]		3,400	[1] 765
8	do								
9	do	Cylindrical, stationary, vertical.			Jacket, coils, or direct fire.				More than 700
10	do	Rotaries			Live steam				700
11	Modern practice								
12	Modern practice (American)	Cylindrical, stationary, vertical.	27 by 7	4.5 cords	Live steam	450([2])-920 lbs. per cord.[1]	635([2]) to 1,320 lbs. per cord.[1]	4,000-5,000	[1] 900-1,100
13	do	do							
14	Modern practice (Canadian)						800-950 lbs. per cord.		
15	Modern practice					12-20 per cent of weight of wood.			
16									
17									
18									
19	Modern practice	Stationary or revolving			Live steam	16-20 per cent			
20	Modern practice (American)				do				
21	Modern practice	Stationary			do				
22	Modern practice (Swedish)			8.5 cu. meters (=300 cu. ft.)[1] of chips.		637 kilos (=1,400 lbs.)[1] Na_2O for charge.		6,000 liters (=1,321 galls.) [3]	

[1] Calculated from other data given. [2] Strong solution of caustic soda.

[3] In addition to the total time of cooking Congdon reports: Time required for charging digester, 30-45 minutes; for relieving pressure and blowing, 45-60 minutes; total period for a cook, 11-11¾ hours.

Reference No.	Cooking liquors at start of cook: Density: Baumé	Density: Twaddle	Density: Specific gravity	Concentration of NaOH	Causticity	Cooking pressure per square inch	Cooking temperature	Durations of cooking: Total	From start till cooking pressure is reached	At cooking pressure	Blowing pressure per square inch	Authority [1]
					Per cent	Pounds	° F.	Hours	Hours	Hours	Pounds	
1	12°	18°	[1] 1.09	6 per cent [1]	.....	60	.....	.....	.....	.....	.....	Griffin and Little, 1894.
2	(2)	(2)	(2)	.....	.....	90	.....	.....	.....	10–12	.....	Clapperton, 1907.
3	.....	.....	.....	.....	.....	180–200	.....	.....	.....	0.5 or less	Not blown	Watt, 1907.
4	4°	[1] 6°	[1] 1.03	2 per cent [1] (?)	.....	180	.....	.....	.....	.....	.....	Houghton; Griffin and Little, 1894.
5	.....	.....	.....	.....	.....	150–180	360–375	.....	.....	.....	.....	Silcox, 1875.
6	12°	[1] 18°	[1] 1.09	7 per cent [1]	.....	65 or more	.....	6	.....	.....	65 or more	Hofmann, 1873; Watt, 1907.
7	11°	[1] 16°	[1] 1.08	7 per cent [1]	.....	110	.....	[3] 9¾–10	2¾–3	7	45	Congdon, 1889; Watt, 1907.
8	8–15° at 60° F.	[1] 12–24°	[3] 1.03–1.12	.....								
9	11° for poplar	[1] 16°	[1] 1.08	.....								
	12–14° at 60° F.	[1] 18–22°	[1] 1.09–1.11	6–9 per cent	.....	90–110	.....	[4] 8–10	.....	.....	.....	Griffin and Little, 1894.
10	(5)	(5)	(5)									
11	.....	.....	.....	.....								
12	10–15° at 60° F.	[1] 14–24°	[1] 1.07–1.12	6–8 per cent	.....	90–110	.....	.....	.....	8–10	.....	Cross and Bevan, 1900.
				5–10 per cent [1]	92–94	100–120	.....	[1] 8½–13	2½–3	6–10	75	International Library of Technology, 1902.
13	(2)	(2)	(2)									
14	.....	.....	.....		.....	100–110	.....	.....	(6)	(6)	.....	Clapperton, 1907.
				.....	.....		.....	.....	.....	.....	.....	De Cew, 1907.
15	10–14°	15–22°	[1] 1.07–1.11	5–7 per cent Na_2O	.....	130–160	360	[4] 6	.....	.....	.....	Stevens, 1908.
16	10°	[1] 14°	[1] 1.07	.....	.....	132–147						
	12°	[1] 18°	[1] 1.09	.....	.....	88–118	.....	[4] 6	.....		.....	Schubert; Stevens, 1908.
17	12–14°	[1] 18–22°	[1] 1.09–1.11	7–9 per cent [1]	.....	73–147	.....	[4] 5–6	.....	.....	.....	Ernst Muller; Stevens, 1908.
18	10–14°	[1] 15–22°	[1] 1.07–1.11	5–7 per cent [1]	.....	73–176	.....	[4] 5–6	.....	.....	.....	Klemm; Stevens, 1908.
19	.....	.....	.....	.....	.....	70–80	.....	8–9	.....	.....	.....	Sindall, 1908.
20	.....	.....	.....	.....	.....	100–130	338–355	.....	.....	.....	.....	Beveridge, 1911.
21	13° [1]	20°	[1] 1.10	.....	.....	100–150	.....	.....	.....	6–8	.....	Cross, Bevan, and Sindall, 1911.
22	.....	.....	.....	.....	.....	125	353	.....	.....	1–2	.....	Hennefeld, Beveridge, 1911

[4] Not specifically known whether time is total duration or duration at maximum pressure. [5] Stronger liquors than Ref. No. 9.
[6] Less than 10–12 hours. [7] See Bibliography at end of appendix, for more detailed references.

paratively incomplete screening action, the manufacture of fine papers required diaphragm screens. Soda pulp is used chiefly for good book and writing papers, hence the use of diaphragm screens in such mills in preference to centrifugal screens.

Recovery Systems.

Early in the development of the soda process it was realized that it would be necessary, in order to make the process attain maximum economy, to recover and re-use the alkali in the waste liquor. This development was urged forward in many localities by litigation with a view to preventing the waste liquors from being run into flowing streams.

To clearly understand the recovery process, the reader should remember of what the liquor is composed. It holds two main ingredients, organic matter in solution and carbonate of soda. Now, when sufficiently concentrated, the organic matter will burn, yielding a considerable amount of heat which can be utilized in the first stages of concentration of the liquor. At the end of the process we will have a mixture of carbonate of soda, unburned carbon and incombustible mineral matter from the wood (ash) and this mixture goes by the name of "black ash."

The specific gravity or density of the liquor at the commencement of the recovery process depends on the strength of the original liquor charged, the moisture in the wood, whether the cook was with direct steam or by the indirect method and the efficiency of the washing system. In one American mill operating the soda process on a large scale the density is 9.5° Baume at 60°F. According to Griffin and Little "it is possible to bring the mixture of waste liquor and wash water up to a gravity of 6° to 9° Baume at 160°F. The higher gravity is very rarely reached, and in some mills the liquors going to the evaporator do not stand over 3° to 4° Baume at the same temperature." Griffin and Little's remarks were written in 1894 and in the period since then considerable development has been made in the efficiency of the soda process and their figures would be considered rather too low now.

The first attempts at recovery utilized open evaporating pans. Such inefficient equipment was soon abandoned in favor of multiple effect evaporation in suitably designed equipment.

Multiple Effect Evaporation

The theory of multiple effect evaporation is a vast and complex subject, but the following brief explanation of the principle may be helpful. The boiling point of water becoming lower as the pressure is decreased (i. e., the vacuum increased), it is possible to make water evaporate from a solution being concentrated at a lower temperature by decreasing the pressure. When water is boiled at atmospheric pressure it boils at 212° F. and the vapor given off has also this temperature. In addition to the heat units it possesses simply by virtue of being at 212° F.,

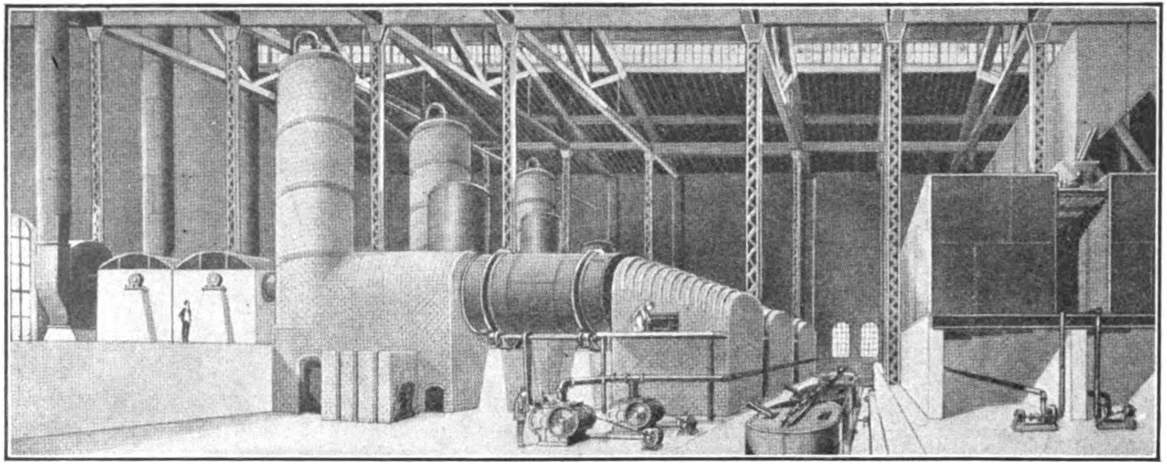
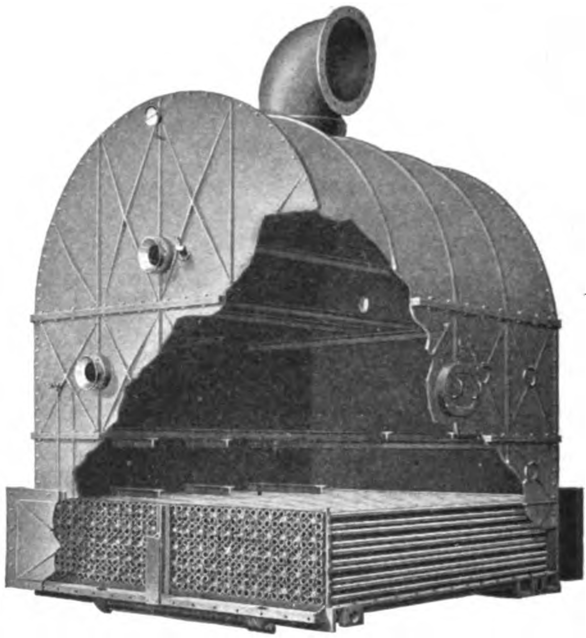


Fig. 73.—Recovery system for soda mill showing rotary furnaces.

it also possesses a large additional number of heat units that have been put into it in converting liquid water into water vapor, or steam. This heat will again be given up when the steam is



Courtesy: Swenson Evaporator Company, Chicago, Ill.

Fig. 74.—Typical modern evaporator.

This is a rectangular evaporator with horizontal tubes located near the bottom of each effect. It is made up in sections of heavy cast iron plates with machined and drilled faces and flanges. The assembled castings are bolted together with a suitable packing material—usually sheet asbestos—making a vacuum type joint. There is a steam chest at each end cast as an integral part of the vertical tube sheet. Each tube passes through both tube sheets and is packed by special packing plates and rubber gaskets, thus insuring vacuum tightness and resistance to high temperature.

condensed. It is called the latent heat of steam. A pound of steam at 212° F. will have about 1146 units of heat, of which about 964 will be in the form of latent heat.

Now, a multiple effect evaporator is really a series of boilers, so arranged that the steam from the first boiler, or "effect," will be carried over and used as the heating agent in the next effect. The second effect is able to boil at a lower temperature than the first owing to the maintenance of a partial vacuum. The steam from the second effect goes to a third, which operates at a still greater vacuum and thus to a fourth, and perhaps even fifth and sixth effects. Four effects is a usual number in practice. Finally the steam from the last effect goes to a condenser.

Equipment utilizing this principle has been designed with such engineering skill as to make almost perfect utilization of the heat supplied to the machine. The first multiple effect evaporators used in the paper industry were of the well-known Yaryan type, and although these evaporators have largely been replaced in recent years by equipment of improved design (such as the Scott, Swenson, Zaremba, Buffalo, Badger-Webre and Kestner evaporators), there are still a good many of them in use and a description will not be out of place.

Yaryan Evaporator.

Each effect of this evaporator is like a boiler with a number of horizontal pipes arranged in coils parallel to the shell. A supply pipe feeds the liquor into a header at the back of the machine from which the coils lead. The steam is admitted into the shell surrounding the coils. At the front of the machine the coils end in a header which serves as a separator, separating the vapor from liquor and foam, and in which a partial vacuum is maintained. The difference between the pressure at which the liquor is supplied and the partial vacuum in the front of the machine keeps the liquor constantly moving forward, forming a film on the surface of the tubes, and in this way a new surface of liquid is constantly exposed to the action of the steam. The liquor from the separator of the first effect is pumped into the second effect and the vapor from the first effect is supplied to the shell of the second effect to give up its heat, and the operation is repeated for as many effects as there may be. The liquor is usually concentrated from its original density to from 32° Be. to 40° Be. at 60° F. Of course, the concentration could be carried much higher in modern evaporators, but this is not done because of the difficulty of pumping such very thick liquors. Moreover, the further evaporation of such liquors is not necessary as from 37° Be. to 40° Be. has been found a good strength for burning.

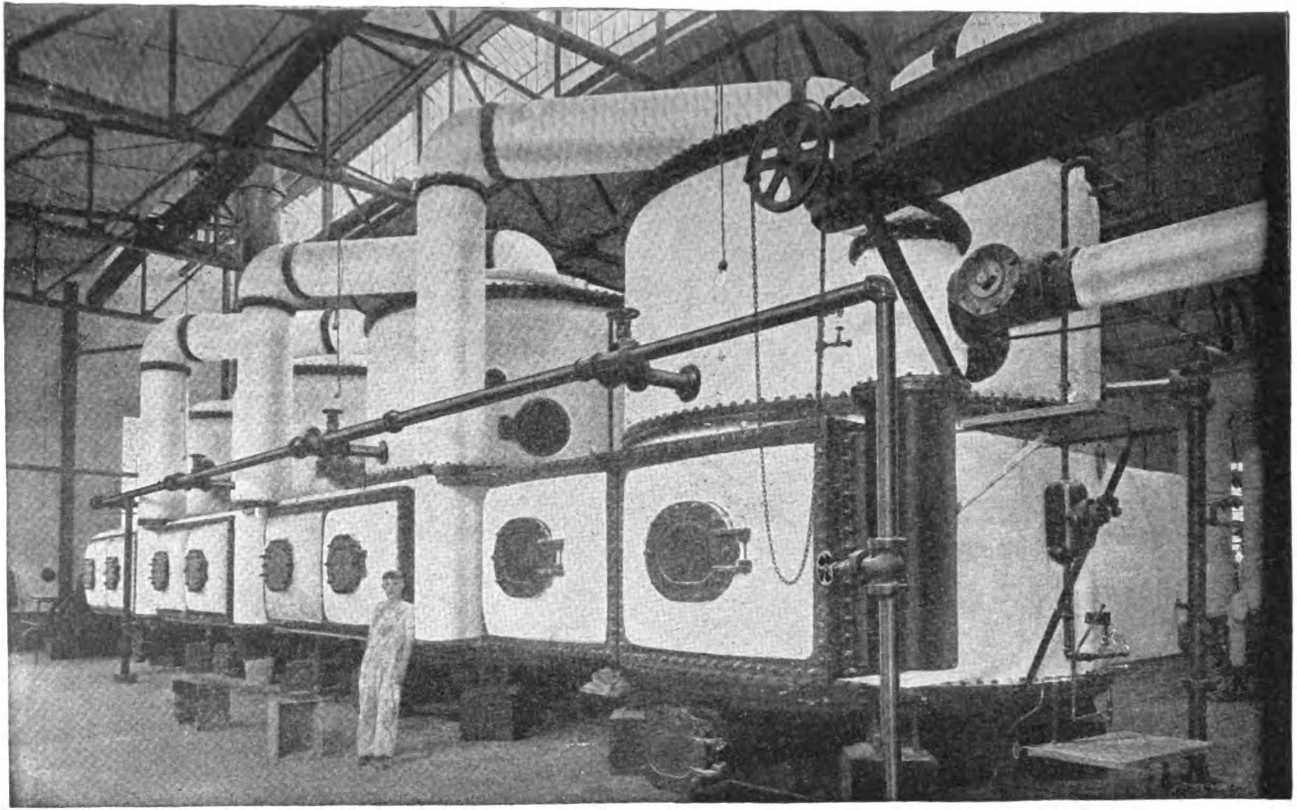
Disc Evaporators.

Sometimes only part of the water is driven off in multiple effects, the remainder being removed with disc evaporators. One of the best known disc evaporators for use in the evaporation of waste liquor is the Carlson and Waern evaporator. This machine employs the principle of exposing a thin film of liquid to direct heat over a large area. This is accomplished by rotating a wheel, or series of wheels, made up of thin steel plates, so that the plates are alternately dipped in the liquid and then exposed to the hot gases which pass through the evaporator in such a manner that they come in contact with the exposed surfaces of all the plates or discs. The moisture is absorbed from the film of liquid and passes in the form of vapor to a stack, or to a reclaiming apparatus, as the case may be. While these evaporators are frequently used alone, they can be used most efficiently to follow a preliminary evaporation in some form of multiple effect evaporator. In the sulphate process they are usually used alone as the liquors are usually not so dilute as in the soda process owing to the greater use of indirect cooking in sulphate mills. These evaporators have the advantage that they will handle thick, gummy liquors that would clog tube evaporators.

Rotary Furnaces.

The liquor from the evaporators is sufficiently concentrated that it will support its own combustion when introduced into the rotary furnace. A storage tank heated with a steam coil should be placed in the system between the evaporators and the rotary furnace, and a by-pass should be installed so the liquor can go direct from the evaporators to the rotary when circumstances permit. In this way the maximum amount of heat can be conserved. These furnaces consist of two parts, the rotating part and the stationary part. The stationary part is a fire-box, constructed either of steel-plate lined with fire-brick, or of fire-brick held in place by iron bands. It is fitted with a grate for burning coal or wood, or with equipment for burning gas or oil. It opens into the rotating part of the furnace. The rotating part is a cylindrical steel-plate shell, lined with fire-brick. It is usually from 8 to 9 feet in diameter unlined and from 14 to 30 feet long. The lining decreases the diameter about 1 ft. According to Spence[1] it requires about 1 lb. of coal burned in the fire-box to produce 6 lbs. of ash in a 14-foot rotary, while 1 lb. of coal will produce 12 lbs. of ash in a 30-foot rotary. When burning liquor from cooking of hard-wood, 70 lbs. of ash per sq. ft. of burning surface per 24 hrs. is considered good and this is increased about 10 per cent for more resinous woods such as spruce, pine, poplar, etc. However, the larger rotaries cause more loss of soda up the stack owing to the increased draft required. The furnace is caused to rotate slowly. This is usually accomplished by iron rings which rest on flanged wheels, the axles of these wheels resting in journals supported by masonry. The rotation is accomplished with a worm drive and a gear and pinion. The liquor is run into the end of the rotating cylinder farthest from the

[1] Report of the Committee on Soda Pulp, T. A. P. P. I., 1919. "Paper," Feb. 12, 1919, pg. 619.



Courtesy: Zaremba Company, Buffalo, N. Y.

Fig. 74a.—A Modern Multiple-Effect Evaporator Installation in a Large Pulp Mill.

fire-box and gradually runs forward, burning as it moves, and the black ash falls out of the cylinder through an opening located just back of the fire-box. The heat produced in this furnace is generally utilized, either in the disc evaporators or for operating a boiler which supplies steam to the multiple effect evaporators, of for a preheater for the liquor going to the evaporators. The black ash used to be conveyed, either by trucks, or by a conveyor to the leaching and causticizing department, but is now more usually discharged into a tank situated in a pit under the discharge of the rotary.

Causticizing.

The black ash is leached in a system of leaching tanks so as to effectually wash out all the soda, leaving only black, finely divided carbon, which is a by-product. Some modern soda mills work this up into a salable substance used for filtering and decolorizing purposes. Sufficient new carbonate of soda is added at this stage to bring the liquor up to the required strength. As a rule from 10 to 30 per cent of the soda used is lost at every operation and this soda has to be replaced at this stage in the process. The soda has to be causticized before it is added to the liquor. The chemistry of the causticizing operation consists in converting carbonate of soda into caustic soda, or sodium hydroxide. This is done with freshly burned lime. Equipment for causticizing has been developed to a high degree of efficiency by chemical engineers because this operation is important in other industries as well as in paper making. It is a necessary part of the manufacture of soap, the refining of oils and of many other lines of manufacture.

The standard system of causticizing is to add the lime to the solution of soda ash in a tank fitted with an agitator and a false bottom full of perforations. Freshly burned lime is added to the liquor in the proportion of about 60 pounds of lime for every 100 pounds of carbonate of soda (soda ash) in the liquor. The lime mud produced is thoroughly washed to remove all traces of caustic soda. This is done by repeating the process of washing, settling and decantation until the sludge is as free from alkali as circumstances will permit.

Variations of the causticizing tank have been devised. In some forms there is a suspended basket for the lime. The causticizing tank is provided with steam connections for heating the contents.

In some mills the lime mud is recovered by burning in a rotary furnace to form lime again. This requires a huge furnace, expert attention and a lot of fuel, and has not generally been considered practical, at least where good lime can be obtained at a reasonable price.

The labor cost of the causticizing process is high and it requires a lot of floor space, tanks, piping, steam connections, etc.

Causticizing Processes Employing Filtration: Owing to the length of time required for ordinary settling and decantation, filter presses have been introduced in some causticizing plants. The ordinary plate and frame filter press is too well known to require detailed description here. It has the drawbacks of small capacity and requiring a great deal of labor.

Improved forms of filter press, such as the Kelly press and the Sweetland press have endeavored to overcome these defects by giving an increased capacity for the space occupied and the time required in the operation.

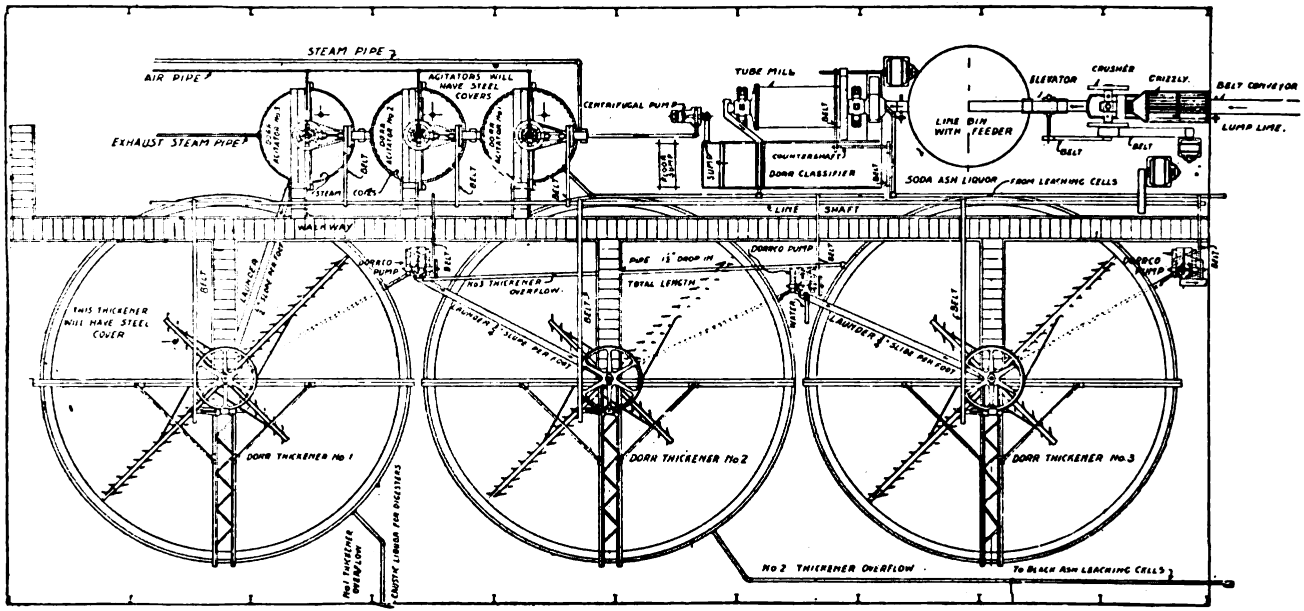
When filter processes are used for causticizing in soda mills the sludge-containing liquor from the causticizer should be sent to a settling tank, from which one decantation of the strong liquor is made. The sludge from this tank is sent direct to the filter presses and the filtrate from the presses is mixed with the decanted liquor. The filter press cake is then washed and the wash water united with the strong liquor to whatever extent may be advisable.

Rotary continuous filters are much more efficient tnan filter presses for this sort of operation. These consist of a tank in which is suspended a revolving drum, the surface of which is composed of a number of compartments, covered with a wire cloth or other filtering medium. Each compartment is connected to a trunnion fitted with an automatic device so suction or pressure can be applied to each compartment at the particular stage in the operation where it is required. When the drum is immersed in the tank, that portion is supplied with suction and the sludge is drawn against the filtering surface. When that portion comes out of the bath of liquor in the tank, pressure is applied and the film of sludge is forced off, this action frequently being assisted by a doctor blade. These machines are not unlike pulp thickeners or wet machines, used in the pulp industry, in their general principle.

Dorr Causticizing System.

The Dorr Continuous Cauticizing System embodies an attempt to avoid the evils of the ordinary system of causticizing by intermittent agitation and successive washings and decantations. This system applies to the problem principles long recognized as sound in the washing of precipitates and employed in metallurgical plants. It makes the whole process continuous, effecting a marked saving in labor and power and reduction to a minimum of the losses in charging, agitating, decanting and washing, due to elimination of the personal element which is such a big factor in intermittent work. This system is now installed at a recently erected soda pulp mill in the South. The causticizing plant produces 50 tons 100 per cent caustic soda per twenty-four hours in the form of either a 10° Baume or 14° Baume liquor.

The illustration shows a plan of a complete Dorr causticizing



Courtesy: The Dorr Co., New York.

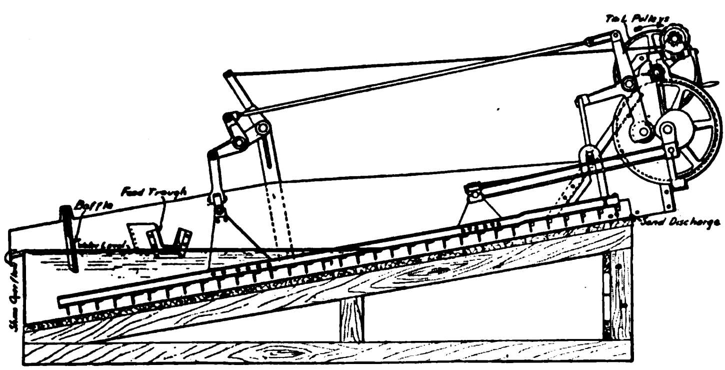
FIG. 1

Fig. 75.—Plan of complete Dorr causticizing plant.

plant and a convenient arrangement of the mechanical equipment used. Before going into details regarding the flow of liquor, etc., through the plant, a description is given of the individual machines used.

In the lime slacking circuit a standard tube mill and Dorr classifier are used. This latter machine, a cut of which is shown, consists of a settling tank in the form of an inclined trough open at the upper end. The feed enters near the center and the liquid and the slow settling solids overflow at the closed end while the sand or quick settling solids are conveyed along the bottom by mechanically operated reciprocating rakes and after emerging from the liquor are discharged at the open end.

The tube mill and classifier as shown on the plan are laid out to operate in closed circuit, which system consists of connecting a grinding mill and a classifier, so that the mill discharge goes to



Courtesy: The Dorr Co., New York.

Fig. 76.—Dorr Classifier.

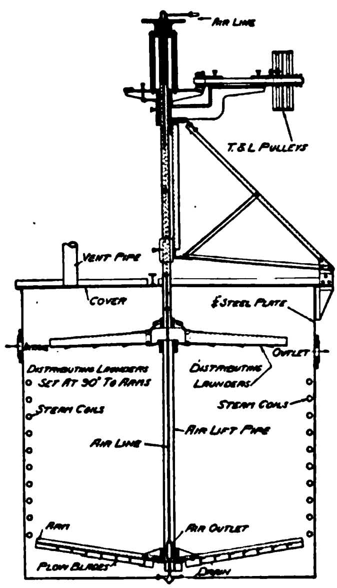
the classifier and all finished product is overflowed, while the unfinished product from the sand discharge end is returned to the mill. In this way the circulating load may be several times the tonnage being ground but the finished material is removed from the circuit as fast as made.

Owing to the fact that all parts of the classifier moving one on another are suspended above the liquor and that the average speed at which the rakes are operated is approximately ten strokes per minute, the upkeep of this machine is very light. The horse power required to operate a classifier of this type is less than ⅛ horse power.

The reaction between the soda ash or soda ash liquor and lime takes place in agitators, a cut of one of which is shown.

As will be noted, these agitating tanks are equipped with a central vertical pipe carried by a shaft supported from the top of the tank and equipped with two arms to which are attached plow blades which travel around the bottom of the tank and move the lime mud to the center. Air is introduced at the bottom of the vertical pipe, making it can air lift, so that the solids which are plowed to the center are raised and distributed by means of the launders which are attached to the pipe just above the liquor level and which rotate with it. The reaction agitator tanks are equipped with covers and steam coils, a temperature of about 95° C. being maintained for causticizing. The mechanisms are belt driven through bevel gears and make about three revolutions per minute; this slow speed and the fact that no submerged bearings are used tend to a minimum of attention and repairs.

Owing to the fact that the whole agitator mechanism can be



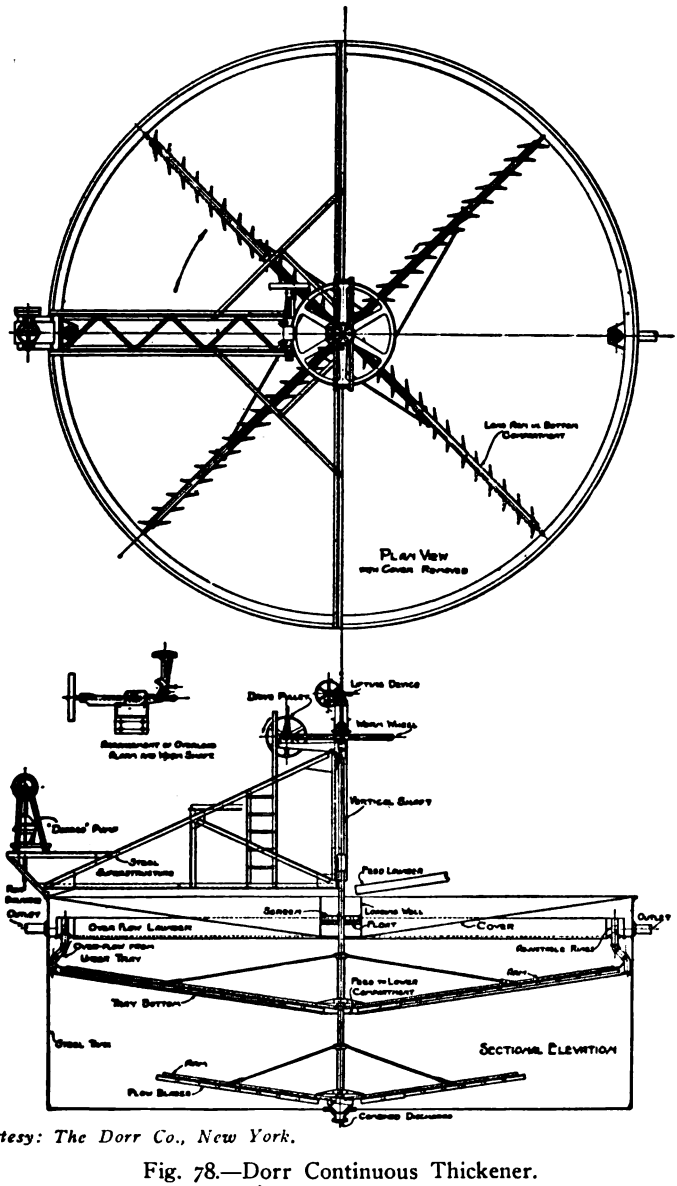
Courtesy: The Dorr Co., New York.

Fig. 77.—Dorr Agitator.

readily raised, no difficulty is encountered in starting up after a shut down. The horse power will, of course, vary with the size of the agitator used, but can be taken at approximately ½ horse power to rotate the arm. Approximately 10 cu. ft. of free air per minute at 15 lbs. pressure will be required for the air lift.

To collect the caustic liquor and wash the lime mud formed, Dorr Continuous Thickeners are used.

This machine consists of a slow moving mechanism set in a tank and is made up of a central vertical shaft driven by a worm wheel and worm, the shaft having radial arms attached to its lower end. These arms carry plow blades set at an angle which, through the rotation of the mechanism, move the settled material to a discharge opening at the center of the tank.



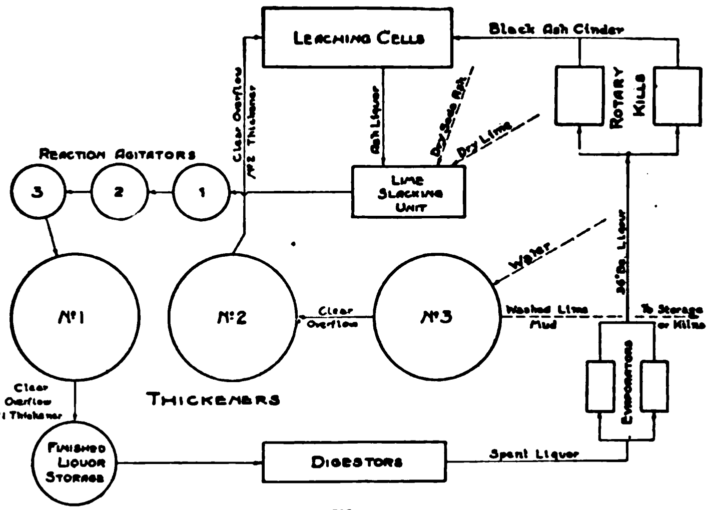
Courtesy: The Dorr Co., New York.

Fig. 78.—Dorr Continuous Thickener.

The average speed at which a thickener mechanism is operated is about one revolution in six minutes, the horse power required being approximately ⅛ horse power. Here again, due to the slow speed and the fact that there are no submerged bearings, the upkeep and operating cost is extremely low. The slow stirring action produced by the rotation of the arms causes some condensation of the lime mud by squeezing out a part of the water entrained in the flocs so that a denser underflow can be obtained than is possible in the case of undisturbed settling.

To control the underflow of the thickeners and to raise the lime mud to a sufficient height to discharge it into the next thickener in the series, Dorrco diaphragm pumps are used.

This pump is a form of diaphragm pump with flat valves which has been designed to give continuous operation with minimum repair costs. It is entirely self-contained, a heavy frame being used to support the eccentric shaft and drive pulley. The



Courtesy: The Dorr Co., New York.

Fig. 79.—Diagram illustrating flow of liquor in soda mill through digesters, recovery, and causticizing plants.

eccentric is adjustable so that the length of stroke can be set from 0" to 3". The speed at which these pumps are operated vary from 20 to 40 strokes per minute.

The density of the thickener underflow is controlled by the number of strokes per minute, the length of these strokes, and by allowing air to enter the bowl compartment of the pump. Once a plant is tuned up, this type of pump requires but little attention. There is no upkeep cost except for an occasional change of diaphragm. The rubber diaphragms are readily replaceable without dismantling the pump, the average life being about two months.

The discharge pipe of each thickener tank is directly coupled to the suction of one of these pumps and usually two valves are placed in this line. A high pressure water pipe should be connected so that in case this suction pipe becomes choked one of the valves may be closed and the water turned on to flush it out.

Now, referring to the drawing on page 166 which diagramatically portrays the flow of liquor through the digesters, soda ash recovery, and causticizing plants. It will be observed that all of the water entering the system is introduced at No. 3 thickener where the pump discharges its mud drawn from No. 2 thickener to the mixing launder. This launder is a steel trough with baffles laid in the bottom so that the lime mud and water are thoroughly mixed to form a uniform feed for the thickener.

The clear liquor overflowing No. 3 thickener joins the lime mud from No. 1 thickener and is mixed with it in like manner to form a homogeneous feed for No. 2 thickener. The clear liquor overflowing No. 2 goes to the black ash leaching cells and the effluent from these, after being built up with dry soda ash, is partially used in the closed circuit lime slacking system, the balance going direct to the reaction agitators.

Again referring to the plan it will be seen that the slime slacking operation is carried out by means of a standard tube mill working in closed circuit with a Dorr classifier as described. A small crusher is provided to reduce the lump lime to a maximum of 2 inches, after which it is elevated to a lime storage bin as shown.

A mechanical feeder, adjustable to close control, delivers the crushed lime from the bin to the grinding mill. By the operation of this continuous system of making milk of lime, all handwork is eliminated, the waste of lime and the labor required for cleaning out sand from slacking tanks is obviated and absolute uniformity of the milk of lime is assured.

Any unburned lime rock or silica is taken care of, as they are ground to such a fineness before leaving this system that they pass through the reaction agitators and thickeners mixed with the lime mud formed and so cause no trouble.

By the use of a classifier working in closed circuit with a tube mill, the grinding efficiency is raised to a maximum and small mills which require little power can be used so that continuous lime slacking by this method means a saving of power over slacking in tanks with paddle agitators.

The percentage recovery of caustic soda by the washing process will depend upon the number of thickness used and the amount of wash water that may be added, the latter depending upon the density of finished liquor that is required. When producing a 15° Be. liquor and using three thickeners, a 99.7 per cent recovery of caustic soda is assured.

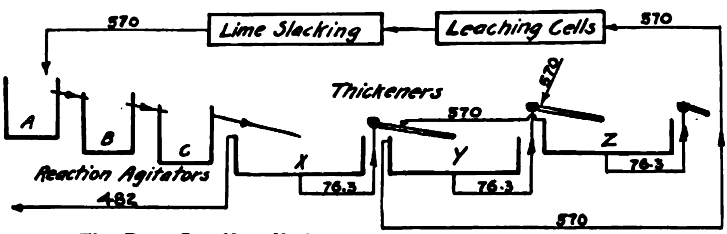
One drawback of the Dorr system is that it must be wasteful of heat as the thickeners are extensive and shallow. Not only will this cause heat losses but the room will tend to be very humid, especially in cold weather.

Efficiency of Causticizing Systems.

The following comments on the relative efficiency of the various systems discussed above is largely taken from an article in "Paper" for October 3, 1917.

Taking as a basis a mill producing about 100 tons of soda pulp from poplar wood, the actual alkali required daily would approach 100,000 pounds of caustic and be contained in about 160,000 gallons or 21,040 cubic feet. The amount of calcium carbonate resulting from the chemical reaction would be about equal to the amount of alkali.

To install the usual sedimentation and decantation process would require a tank floor space of 15,000 square feet provided only one tank volume is turned out every twenty-four hours. A tank should make two complete cycles daily and in this event the floor space would be reduced half or 7,500 square feet. This alone would call for a building 75 feet by 100 feet allowing no



Courtesy: The Dorr Co., New York.

Fig. 80.—Conventional flow sheet of a continuous counter-current causticizing plant.

room for operating. Additional tanks for weak liquors and storage or mixing of cooking liquor must be provided and means for the final disposition of the sludge.

The building should be of good height, not less than forty feet, and all above ground to secure a good light, ventilation and drainage. There should be an upper enclosed deck or gallery to contain the causticizers and a storage of lime conveniently located.

These tanks must all be equipped with agitators and power to drive them. It would probably require an equipment of 100 h.p. capacity to operate such a system, though the actual power required for some of the time would be less. It would require at least three men to operate this part of the plant.

A causticizing plant according to the Dorr System is built in ten ton of caustic soda units. Each unit requires a floor space 75 feet by 26 feet. It would require five such units for a production of 100 tons of poplar pulp daily. This would call for a floor space of 75 feet by 130 feet. It is possible to reduce this floor space by using the tray type of thickeners. No additional space would be required for weak liquors since the counter current system provides for this, and no pumps other than the small diaphragm pumps are required. The total power required for each unit is 5 h.p. One man only would be required to operate the whole five unit plant.

In a system where a filter forms an essential element, the capacity of the filter must be the basis. Choosing the Kelly press as one type, two single units, or one twin unit, would be required.

The floor space occupied by the single press is 5½ by 23 feet each. Additional space must be provided for tank supplying the presses, for pumps, air compressor and operation.

The presses must be situated at an elevation which will permit of automatically discharging the cake into a hopper and thence to a conveyor beneath. Probably 50 h.p. and two men would be ample to operate.

It will thus be seen that the building and floor space for such a plant would be relatively small, the idea being to make complete separation of solids and liquids by forced filtration of the original liquor rather than by a progressive separation by dilution of the residue which requires large tank capacity.

The rotary continuous filter operating on strong caustic sludge would receive the sludge from a continuous settling tank as described above. Two of these filters would be required and should be placed with their discharge sides facing each other so that the cake may pass to a common conveyor. Filters of this type of suitable capacity occupy a space 8x8x8 feet and weigh about 11,000 pounds each.

The filtering drum revolves about ⅓ r. p. m. The only power required for this work would be for an exhaust pump which would act as a blower at the same time, and for the conveyor. Practically no labor is required as the process is automatically continuous.

In discussing the relative merits of the different causticizing processes used in soda pulp mills and their efficiency as regards steam consumption and alkali accounted for, it is necessary to form some basis of efficiency. In the older decantation process, in most general use, time and capacity are the principal efficiency factors.

An alkali room (causticizing room) having ten pans (each of such capacity that when charged with liquor, causticized, properly settled, drawn off and mixed with a properly settled first wash, there will be enough liquor for two digesters) is capable of furnishing liquor enough for twenty digesters in 24 hours. In other words, each pan should be allowed 24 hours for one complete cycle in order to obtain good economical results. This will allow the strong and first wash each 4½ hours and each of the other three washes 3 hours to settle before syphoning off the clear liquor. When handled in this way, the lime sludge discharged will contain about 85 per cent weak liquor and 15 per cent solids by volume, or 68 per cent weak liquor and 32 per cent solids by weight. The loss of soda in this sludge discharge will be from one-half to three-quarter per cent of the total soda used.

Thorough agitation is also a necessary factor in causticizing soda efficiently. If the agitator shaft is provided with one set of wings near the bottom, it should make at least 30 r. p. m.; but provided with three sets of wings at three different heights, the speed of the shaft can be cut to 16 to 18 r. p. m. and give equally good results. Of two mills using the same size alkali pans, the same quality of lime, and all other conditions the same, excepting the speed of the agitator shaft, the shaft in one mill made 20 r. p. m. and in the other 30 r. p. m., with the result that the former was obliged to use about 8 per cent more lime than the latter; and, on account of using extra lime to get the same causticity, 6 per cent less liquor was syphoned from the strong pan in the former mill, after allowing the pans to settle the same length of time.

When using a lime containing 94 per cent active calcium oxide, it is customary to use from 550 to 600 pounds of lime for each 1,000 pounds of sodium carbonate causticized, in order to get a strong liquor having 92 per cent of the total soda causticized. This strong liquor when mixed with a first wash of 97 per cent causticity, will furnish liquor of about 94.5 per cent causticity for the digesters. The lime when slacking in the pan of liquor heats it and will furnish about 480 B. t. u. per lb. or 268,800 B. t. u. for every 1,000 pounds of sodium carbonate causticized. This will raise the temperature of the liquor about 30° F. If the liquor from the leachers tests 160° F., the lime added will raise the temperature to 190° F. so that it is only necessary to add enough steam to raise the temperature 27° higher to reach boiling point. It is only necessary to boil the pan of liquor about 15 minutes, when the agitation is good, but agitation should be continued from 20 to 30 minutes longer.

The influence of quality of lime on time necessary to boil the liquor is important. The calcium oxide content of a lime, as found by analysis, very often comes far from representing the active content of the lime. Samples of lime with a total calcium oxide content of 85 per cent have shown an active content as low as 72 per cent. The principal cause for the difference between the actual and active calcium aside from that present as carbonate, is due to presence of an excessive amount of silica and alumina in the form of silicates, which has been fused by overburning in the kiln, and encloses some of the active lime, making it difficult for the slacking water to reach it. Lumps of this lime will stand in hot water as long as 25 minutes without breaking down, while a lump of good slacking lime will break down completely in about one minute. It will be found advantageous to make a rough slacking test in the alkali room, when a car of lime appears refractory; and if it requires much time for the lumps to break down better results can be obtained by boiling the pans of liquor an additional half hour. By the old process, allowing 24 hours for one complete cycle, eight pounds of soda ash can be causticized per cubic foot of pan capacity in 24 hours. Many soda pulp mills have increased their production to such an extent that the alkali room is worked far beyond its capacity; and the result is inefficient operation in this department. The original ten pans are trying to do the work of fifteen, which results in cutting the cycle of time 16 hours in place of 24, and causing a loss of from 3 per cent to 4 per cent of the total soda causticized.

The newer processes cannot be considered substitutes for the causticizing process, as the first step in the operation is the same in every case. The soda ash must first be causticized by boiling with lime. It is from this point on that improvements have come to the assistance of the soda pulp manufacturer. By a small addition to his alkali room he is able to secure, with the same number of pans, an increase in capacity of 100 per cent to 150 per cent. The improvements consist in new methods of separating the liquor from the sludge after the causticizing process is finished, effecting a saving of time and space, and cutting down the loss of soda in the sludge discharges.

Percentage of Recovery.

Throughout the recovery plant in a soda mill everything must be reduced to standard methods and accurate records must be kept, otherwise there is sure to be a steady loss in soda which cannot be explained by any one factor. Such a loss is usually the sum total of a great many things that are not being done as they should be. When the standard amounts of liquor or water to be used for washing, the standard time for washing, etc., have been worked out on the basis of tests made by the laboratory, strict adherence to these standards should be insisted on and a system of records devised to show how well the system is working out. Just as in the sulphite process, accurate records should be kept of each digester cook. Then the time consumed in washing each charge in the washing pans should be recorded. The records of the evaporator department should show the concentration of the liquor from the washing pans, the density and temperature of the concentrated liquor produced (these measurements should be made hourly) and the pressure maintained on each effect of the evaporator. The concentration and temperature of the evaporated liquor should not vary perceptibly from hour to hour. If it does, a thorough investigation should be made of the working of the evaporator system. The liquor going to the rotary furnaces should be tested several times each day and the total amount of this liquor should be known. A careful record should be kept of the amount of fresh soda added.

In making up the liquor for use in the digesters a hydrometer should be used to determine whether the liquor is up to standard or not, and the degree of causticity should be determined by the laboratory. The help in the alkali room can easily be trained to make the causticity tests which can be checked from time to time by the chemist. Needless to say, the digester liquor must be absolutely uniform. If abnormal amounts of soda have to be added to bring the liquor up to strength it is evidence that some detail of the recovery system is not in proper working order. Although the operation of this department should be checked by chemical tests in the laboratory from time to time, the actual work is done by men who must be instructed simply in terms of so many pounds of lime and soda and so many inches of liquor.

To calculate the percentage of recovery in the mill it is only necessary to know the number of pounds of soda in the liquor charged to each digester, and the weight of new soda used each day. The new soda added is deducted from the total soda and in this way the percentage of recovery worked out.

There is no reason why, with efficient equipment and intelligent, careful supervision, the percentage of recovery should not be in the neighborhood of 95 per cent. This, however, is unusual and the writer knows of two mills, which are usually considered very good soda mills, where the management is satisfied if the percentage of recovery exceeds 85 per cent although it frequently is as high as 90. Probably the average throughout the country would be much lower than this, in all likelihood not higher than 75 or 80 per cent. The chief factors which make the actual percentage recovery lower than the theoretical are:—(1) the pulp is not washed long enough or carefully enough in the wash pans; (2) the draft in the rotary furnace carries away some soda mechanically (modern mills are installing devices to recover this soda); (3) some soda is left in the lime sludge after causticizing; (4) some soda is retained by the carbon of the black ash through incomplete washing; (5) poor or improperly operated evaporators will allow some of the soda liquor to escape with the condensate; (6) leaks, spilling, inaccurate weighing and general carelessness. It is usual to charge all losses not otherwise explained to losses "up the stack." The following remarks are from a paper on this subject by George K. Spence.[1]

One of the biggest problems confronting the soda pulp mill superintendent today is that of recovering the black ash passing out of the rotary stack.

Some have tried to do so in a wet way by spraying the stack with weak liquor or water, but so many products of combustion and destructive distillation are reclaimed with the ash, that it forms a dirty conglomerate mass, difficult to handle. It is too dirty to send to the leachers, not strong enough to burn without evaporation, and contains too much suspended solid matter to send to the evaporators. The washing has been accomplished

[1] Report of the Committee on Soda Pulp, T. A. P. P. I., 1919. "Paper," Feb. 12, 1919, pg. 619.

very efficiently; but, as stated above, it has been a very difficult matter to prepare the resultant liquor for use.

Attempts have been made to separate the solids from the liquor by passing it through a plate and frame filter press; but this process is very slow and unprofitable. We give below a partial analysis of solids removed by the press and the liquor from solids.

SOLIDS

Water	= 54.65%		
Organic Matter	= 19.22%		
Mineral Solids	= 26.13%	Insoluble.........	= 1.00%
		Sodium Carbonate	= 23.94%
		Sodium Carbonate	= .688%
		Sodium Sulphate..	= .49%

LIQUOR

Water	= 72.23%		
Organic Matter	= 9.64%		
Mineral Solids	=	Insoluble.........	= .02%
		Sodium Carbonate	= 12.41%
		Sodium Chloride..	= 1.90%
		Sodium Sulphate..	= 2.51%

A centrifugal apparatus has been used, and the resultant solids and liquors showed about the same analysis as the foregoing; but the results of the experiment were not very satisfactory. It does not seem possible to reclaim the rotary stack losses satisfactorily in a wet way.

There have been several methods suggested for collecting this dust in a dry way, the most feasible of which appears to be the Cottrell electrical precipitation process. By this method the dry dust is collected, while the moisture and gases pass out, owing to the high temperature in the stack.

This is an expensive installation as the units are small, requiring 360 collecting electrode pipes 15 feet long and 8 inches in diameter to handle 50,000 cubic feet of gas per minute. Moreover special generating, transforming and controlling equipment is required. The operating expenses, including interest, depreciation, royalty, power, labor, etc., would be a little less than $20,000 a year on such an installation. If by draught control it is impossible to keep the stack losses below 7,000 lbs. of soda a day in a rotary department sending 50,000 cubic feet of gas per minute up the stack, it is advisable to use this or some other dry dust saving system. The Cottrell electrical precipitation system has been installed in the rotary department of several pulp mills.

While it may not seem advisable to install an expensive system to reclaim this ash, this important point in the recovery department should not be overlooked. It should be under efficient control at all times, and the speed of the flow of gas so regulated as to produce the best burning results, with the smallest possible loss of soda.

In order to determine the loss of black ash from any one or from all rotaries, it is necessary to pass a measured volume of gas through a filtering medium, enclosed in a sampling tube, after which the volume of the gas is reduced to dry gas at standard conditions (32° F. and 29.92 inches of mercury) by means of the following formula:

$$V = V' \times \frac{459 + 32}{459 + T} \times \frac{B - S - P}{29.92}$$

V = volume of dry gas at standard conditions.
V' = volume of gas as registered on meter.
T = temperature of water in meter in degrees Fahr.
B = barometric pressure at point where sample is taken.
S = suction in inches of mercury as read from meter gauge.
P = aqueous tension at meter temperature (taken from psychrometric tables).

From this corrected volume and weight of dust caught in the filter, the amount of dust per cubic foot of dry standard gas can be calculated. By means of the wet and dry bulb readings in the flue a correction is made for the aqueous vapor pressure in order to bring results to flue conditions. The amount of soda in the dust is determined, which multiplied by the volume of gas passing through the flue, will give the amount of soda lost during any specified time.

It is first necessary to take a Pitot tube traverse of the flue in order to determine the average velocity of the gas throughout the cross-section of same.

A convenient station can be then selected at which to take Pitot tube readings, while samples are being taken, and use a correction factor for the average velocity. For example, if the average velocity is 21 feet per second, and the station selected showed 21.6 feet per second when the traverse was taken the correction factor for this station is $\frac{21}{21.6} = .972$, which should be used to multiply all succeeding Pitot tube readings by in order to obtain the average velocity through the flue.

The velocity of the gas is determined by means of the following formula: $V = 2.9 \sqrt{T.\,H.}$

V = velocity of the gas in feet per second.
T = absolute temperature in degrees Fahr.
H = velocity head in inches of water.

The volume of gas passing through the flue is determined by multiplying the velocity in feet per minute by the cross-sectional area of the flue in square feet, giving the result in cubic feet of gas per minute.

The velocity of the gas entering the nozzle of the dust collector should be the same as that in the flue. In order to measure the gas at the proper velocity it is pulled through a water filled gas meter by means of a steam or an air syphon. The dust can be caught in paper thimbles when the temperature is under 450° F. If the temperature exceeds this, alundum thimbles should be used.

1.—Meter reading in cubic feet.

2.—Temperature of water in meter in degrees F.

3.—Suction (negative pressure) on meter in inches of mercury as shown on gauge.

4.—Temperature of gas in the flue in degrees F. (with pyrometer).

5.—Velocity of the gas in the flue in feet per second.

6.—Static pressure in the flue in inches of mercury.

7.—Wet bulb reading in the flue in degrees F.

8.—Dry bulb reading in the flue in degrees F.

It is also necessary to know the barometric pressure at the point where the sample is taken.

By tests made in the above manner it has been found that 14-foot rotaries lose from 450 to 1,000 lbs., 16-foot rotaries from 650 to 1,300 lbs., and 30-foot rotaries from 2,500 to 4,000 lbs. of soda up the stack in twenty-four hours.

Many varieties of dust collecting chambers have been constructed between the rotary and the stack, some of which are fairly efficient; but, as a general rule, the ash collected represents only a small percentage of the amount of ash passing up the stack.

IX. The Sulphate Process.

The sulphate process is a modification of the soda process in which sulphate of soda is used to replace soda ash. This process was invented by Dahl in Europe about 40 years ago. The Scandinavian pulp makers were finding it hard to sell their soda pulp in competition with the then recently introduced sulphite pulp and welcomed the sulphate process for which they obtained sodium sulphate cheap from England, where it was a by-product of the chemical factories. The first introduction of the sulphate process in America was at the plant of the Brompton Pulp & Paper Co. in Canada in 1907, since which time the industry has developed rapidly, the U. S. and Canada today producing about 2,500 tons per day. It was originally used for making a pulp which was subsequently bleached yielding a very fine grade of stock from which excellent soft pliable papers suitable for book and other purposes, could be made. A considerable amount of sulphate pulp is still prepared which is subsequently bleached, especially in Europe, but the greatest application of the sulphate process today is in making what are known as Kraft papers. Kraft paper is an exceedingly strong, tough paper, ideally suited for wrappings and bags. It is not bleached, having a natural brown color which is characteristic of this variety of paper. As there is a great demand for this product and as a number of woods can be reduced to pulp by this process much more economically than by any other, manufacture of Kraft paper by the sulphate process has assumed very large proportions in the paper industry.

Originally Kraft paper was made by only partially digesting the pulp and subsequently completing the process by mechanical means such as grinding in a kollergang or edge-runner. This procedure required a great deal of power and also gave a very limited output as the capacity of the kollergang was comparatively small. In the modern production of kraft pulp, the cooking is more thorough, and the subsequent disintegration of the pulp is accomplished in the beaters and Jordans.

The sulphate process costs more to operate than the soda process, especially as concerns the recovery system.

The Cooking Liquor.

Although the process is known as the *sulphate* process because sodium sulphate is used in making up the liquor, a number of other compounds of soda are present in the liquor as used. The liquor as actually used contains in solution:

Sodium Hydroxide	($NaOH$)
Sodium Sulphide	(Na_2S)
Sodium Carbonate	(Na_2CO_3)
Sodium Sulphate	(Na_2SO_4)

The actual digestion of the pulp is mainly effected by the sodium sulphide in the liquor and it has been suggested that "*sulphide process*" would be a more correct name than "*sulphate process*" for this method of making pulp. A high percentage of sulphate or carbonate in the cooking liquor is undesirable.

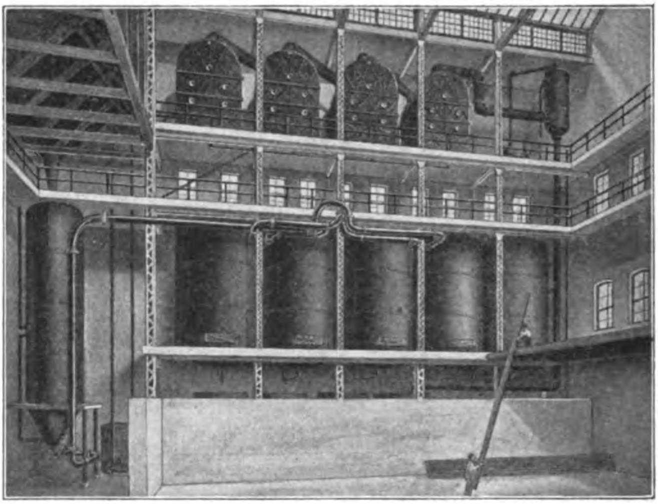
Equipment.

The digesters used for the sulphate process are practically identical with those previously described in connection with the soda process. They must be well insulated to avoid heat losses and excessive condensation. Just as in the soda process no special lining is required, such as is used in the sulphite process, because the cooking liquor does not attack the metal of the digester. Direct cooking such as is used in the sulphite process is extensively employed. However, recently various systems of indirect cooking, the digesters being equipped with a system of forced circulation, have been successfully applied. The Morterud process, previously described in connection with the cooking of sulphite pulp, is typical of these systems. It is claimed by the proprietors of this system that it will reduce the cooking time to one-third of that required by the direct cook, that it will save chemicals, and that it will render the evaporation problem in the recovery of the liquor much simpler, owing to the fact that in the indirect cooking process the liquor is not diluted by steam. It is stated that the actual saving for a three-ton digester based on six cooks daily will amount to 1,500 tons annually. The objection to the indirect process in the past has been based on the difficulty of keeping the equipment in good order. Great attention has been paid to the details of the design of the heaters and pumps in this system and it is in successful operation in many sulphate mills today.

Details of the Process.

The wood is prepared for the sulphate process exactly as for the sulphite process excepting that it is frequently not considered necessary to exercise such extreme care to eliminate all bark and unsound wood as is desired in the case of the sulphite process. This is because the cooking liquor used in the sulphate process will dissolve any particles of bark or unsound wood and they will not be found in the finished pulp.

The above remarks should not be interpreted as meaning that unbarked and dirty wood can be used in the sulphate process to produce the best quality of pulp. The wood is barked for use in the sulphate process just as in the sulphite, but the extreme care which the best manufacturers of sulphite pulp use to prevent particles of bark at all getting into the digesters is not necessary in the sulphate process. For instance, if a block happened to have a few shreds of bark adhering to it after leaving the barking drum, it would hardly be necessary to remove this bark by hand as should be done in making sulphite pulp.

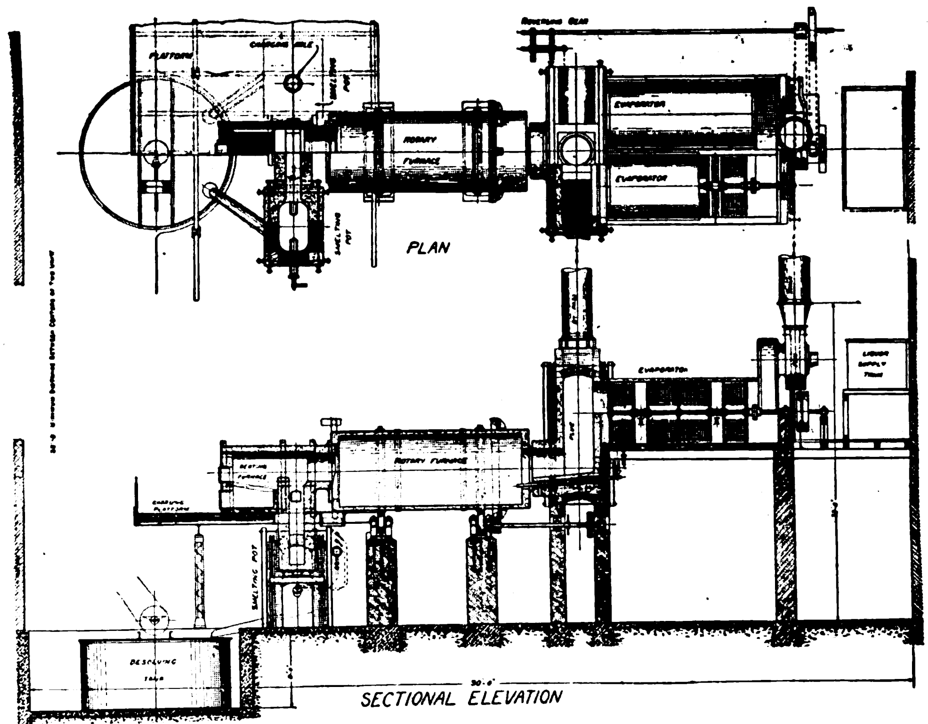


Courtesy: Swenson Evaporator Company, Chicago, Ill.

Fig. 81.—The interior of sulphate mill showing digester, diffusing tanks and evaporators from which the liquor is pumped direct to the rotary furnaces.

The wood is chipped just as for the sulphite process and the chips stored in bins from which they are run into the digesters. After the required amount of chips has been placed in the digester, the liquor is run in and the digester closed. The pressure is brought up to 20 or 25 pounds at which point the cold air present in the charge is relieved. Immediately thereafter, the pressure is brought up to maximum which is usually about 100 pounds and no relieving is necessary from that point on as, unlike the sulphite cook, no gas is formed during the cooking. There is no top pressure and the temperature and pressure will correspond right up to the end of the cook.

The duration of the cook depends on the quality of pulp to be produced and also on the percentage of moisture present in the wood, and other factors. From 2½ to 6 hours, depending on conditions, is usual; and short cooks, say 3½ hours, predominate. When the cook is completed, the pulp is blown into the blow pit, just as in the sulphite process. In making the sulphate



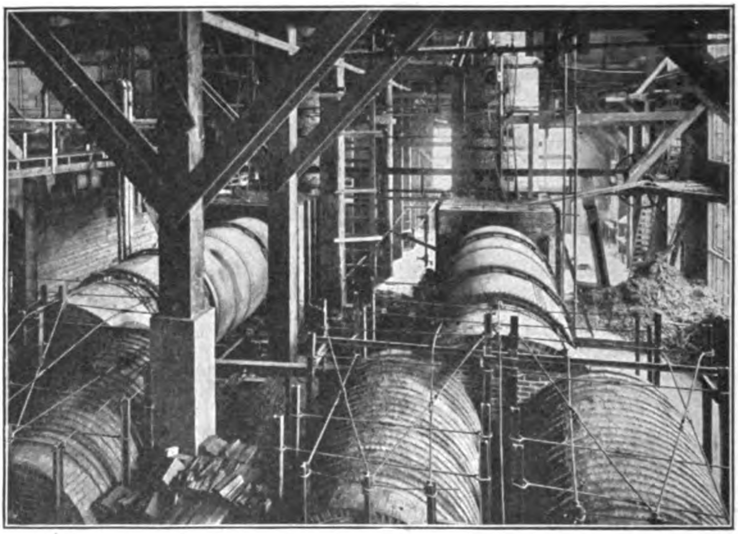
Courtesy: *International Process Co., New York.*

Fig. 82.—Diagram showing plan and elevation of recovery plant for sulphate mill using disc evaporators. No multiple effect evaporators are called for in this design, the liquor being delivered to the disc evaporators sufficiently concentrated that they can complete the work of concentration.

pulp it is customary to blow the digesters at a somewhat lower pressure than is usually the case with sulphite digesters. This is done by relieving the pressure just preliminary to the blow. It is claimed that blowing at low pressure will yield a better quality of pulp in addition to making the washing of the pulp in the blow pit an easier matter.

The steam blown off is passed through a separator which eliminates liquor and turpentine which is always formed in connection with this process. The steam is used to heat some of the water used in washing the pulp.

A very thorough washing is necessary for this class of pulp



Courtesy: Swenson Evaporator Company, Chicago, Ill.

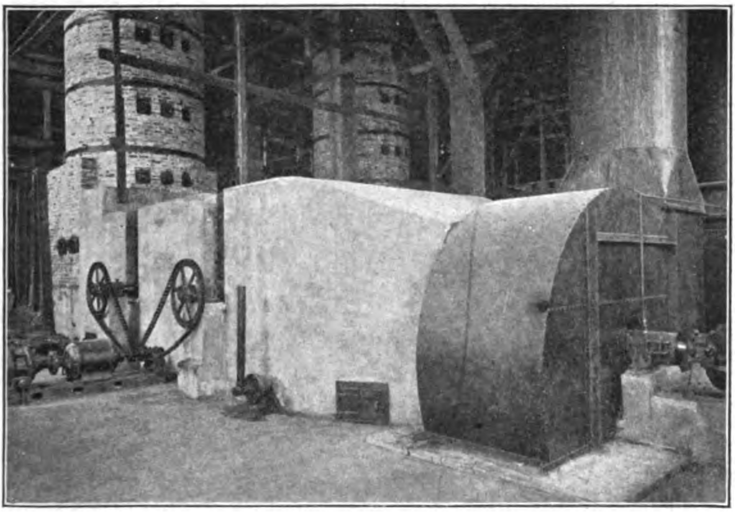
Fig. 83.—Recovery equipment being installed in large sulphate mill. The vertical structures in the background are waste heat boilers.

not only to give a pure stock, but also to recover the highest possible percentage of chemicals used in the process. As a general rule the pulp is washed in series of diffusing tanks. The diffusing tanks are closed as the vapors given off in the sulphate process are malodorous and noxious. In the first of these tanks it is washed with waste liquor and in each of the succeeding ones with more and more dilute liquor until it is finally washed with pure water. By this process, the percentage of soda in the liquor is systematically concentrated.

The waste liquors all go to a recovery system and the efficient operation of this recovery system is the most important detail in connection with a successful operation of a sulphate mill.

The recovery system consists of evaporators and rotary furnaces quite similar to those already described in connection with the soda process. Where the indirect cook is used multiple effect evaporators are sometimes dispensed with, the liquor being sufficiently concentrated to go direct to the disc evaporators.

However, the latter stages of the recovery are somewhat different owing to sulphate of soda being substituted for soda ash in this process. The black ash from the rotary furnace is mixed with sulphate of soda and sawdust and thrown into a smelting furnace lined with soapstone (alberene stone), or refractory brick. Air is forced into the furnace and the black ash is burned, during which operation part of the sulphate of soda is reduced to sulphide of soda. Some carbonate of soda



Courtesy: Swenson Evaporator Company, Chicago, Ill.

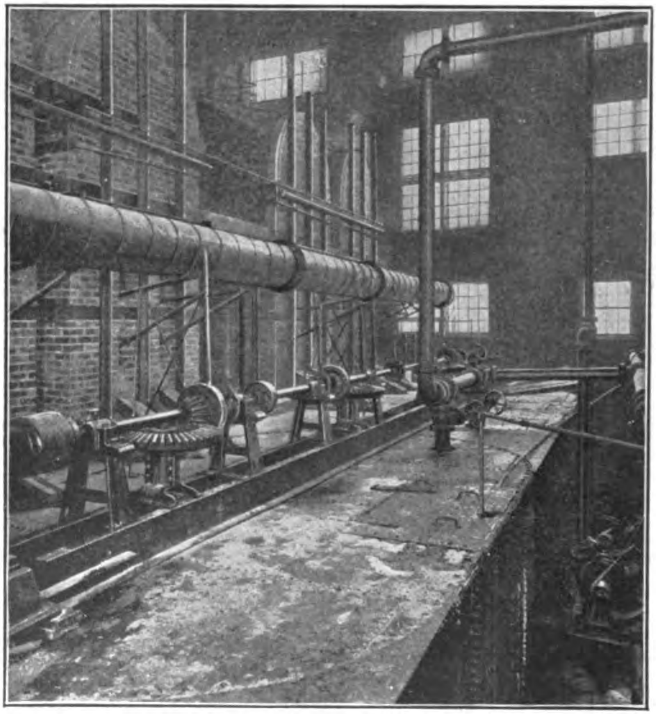
Fig. 84.—Part of recovery system in sulphate mill showing disc evaporator and waste heat boiler.

is also produced and some of the sulphate of soda passed through this process unaltered. The hot gases from this furnace are used to heat the rotary furnace in which the final concentration of the waste liquor has previously taken place. The fused alkali from the smelting furnace runs into a dissolving tank set in a concrete pit and filled with an agitator where it is dissolved with the proper quantity of water or weak liquor from the washing of the lime mud in the causticizing department. It is then pumped to the cauticizing system. The causticizing system and the general arrangements for preparing the liquor for charging the digester are not materially different from those used for the soda process.

The fresh liquor from the causticizing department, usually known as "white liquor," is generally made stronger than is intended to be used in the digesters, and is subsequently diluted with black liquor, thus making up the volume and concentration required for the digester.

This is generally done with tanks provided with floats. The tanks have previously been calibrated, i. e., the operator knows how many gallons are represented by an inch of height on the tank.

The composition of the cooking liquor depends on many factors such as the nature of the wood, the duration of the cook,



Courtesy: Swenson Evaporator Co., Chicago, Ill.

Fig. 84a.—View in recovery department of sulphate mill showing leaching tanks and discharge end of smelting furnace.

etc., but in general it should analyze about 40 to 65 grams per liter of caustic soda and about 15 to 40 grams per liter of sodium sulphide. The total amount of mixed caustic soda and sodium sulphide will be about 16 to 23 pounds per 100 pounds of wood to be pulped, on a bone-dry basis. The sulphate and the carbonate should be kept low in the cooking liquor, as neither of these chemicals has any active part in the pulping process. The sulphate will be high if the reduction in the smelting furnace is not properly conducted. Incomplete causticization is the chief cause of an excess of carbonate. Even if the reduction should be complete in the smelting furnace, there will be some sulphate in the liquor as sodium sulphide will always gradually oxidize to sulphate in solution. In actual practice the liquor contains small amounts of many other compounds of sulphur and soda.

The success or failure of a sulphate mill depends largely on the efficiency with which the recovery system is operated and very accurate chemical control is necessary if the best results are to be obtained in this department. Much that has been written on this subject relates to European conditions which are not identical with those in America and much money has been wasted in attempting to import Scandinavian sulphate practice bodily to this continent. New and improved methods of recovery are constantly being devised by American chemical engineers and evaporator builders which are based on actual knowledge of American conditions. Any of our readers who wish to go into detail on this subject would be interested in the bulletins issued by the Swenson Evaporator Co., Chicago, also in a paper by Hugh K. Moore, published in "Chemical and Metallurgical Engineering," August 1, 1917, pages 117 to 125. In this paper, Mr. Moore outlines the drawbacks of the recovery process for sulphate mills as ordinarily operated and describes various improvements which he introduced in remodeling a large sulphate mill in Canada. The ideas advanced in this paper are very novel as the author does not hesitate to depart radically from the previously established systems in plants of this kind. However, his proposals seem to have worked out well in practice and the article makes profitable reading for any one interested in this particular branch of the paper industry. It is, however, doubtful if sulphate mills in general will abandon, as Mr. Moore has done, tested methods until the newer practice has been in use long enough for its own shortcomings to become apparent.

X. The Ground Wood Mill.

Ground wood pulp constitutes the lowest class of pulp because of the inferior strength, length and stiffness of its fibre. As a result of these characteristics it is almost impossible to obtain a sufficiently strong sheet on the machine by the use of ground wood pulp alone, but it has, when mixed with a certain percentage of chemical pulp, a wide application in the manufacture of paper.

Making ground wood, as the term implies, is purely a mechanical process—the essential feature of the process being the placing of a log under pressure against the surface of a revolving stone. There are, however, some slight modifications of this process, the products of which are called semi-chemical pulps, wherein wood before being ground is submitted to a steam treatment.

There are many items to be considered in the manufacture of ground wood the most important of which are: (1) Power; (2) Quality of wood; (3) Preparation and handling of wood; (4) Burring of the stones; (5) Temperature and pressure; (6) Speed of stone; (7) Organization; (8) Good mechanical equipment.

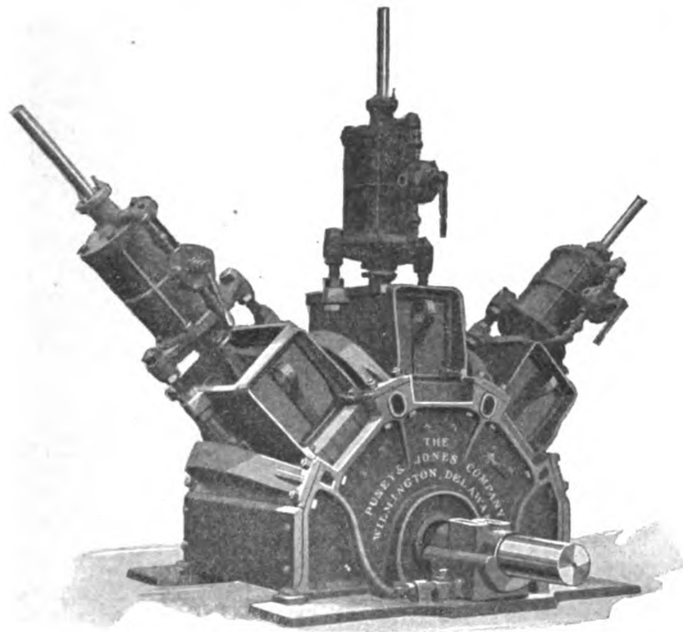
Power.

Ground wood mills are ordinarily located where there is plenty of available water power; otherwise steam or electric power is used. Up to within a few years ago practically all pulp grinders and other motive power for running screens and presses, etc., was supplied by water wheels, but today the motor driven ground wood mill is finding an increased field. In this branch of the industry the total horse power used has grown from 10,000 to something around 70,000 and this figure is steadily increasing as manufacturers are beginning to realize the efficiency of motor driven grinders. If sufficient water power were available the year round there would be no necessity for motor driven grinders, but it is due to the fact that uniform water power is not always available that the water wheel is being supplemented by the motor. When water is low a certain number of grinders or of pockets are withdrawn to lessen the load. Some mills find it necessary to make all of their ground wood pulp during that period of the year when water power is uniformly available, but this handicaps other operations at such times when the ground wood mill is not in operation; for during these times the paper mill constantly calls for a variation of free and slow stock which cannot be supplied by the ground wood mill as a result of insufficient water power.

Quality of Wood.

The quality of mechanical pulp is determined to a large extent by the texture of the wood, the age and the seasoning. Wood for grinding must be sound, that is to say, the interior must not be reddened by disease, neither blue nor black owing to the felled trees being left too long exposed to the damp air. The moisture in the air permits slow decomposition of the ligneous fibres, attracts insects, and develops mould.

The best wood is that which, after the trees have been felled, has been preserved on a dry and very airy spot, stacked consecutively so as to allow active circulation of air, and which is used



Courtesy: The Pusey and Jones Co., Wilmington, Del.

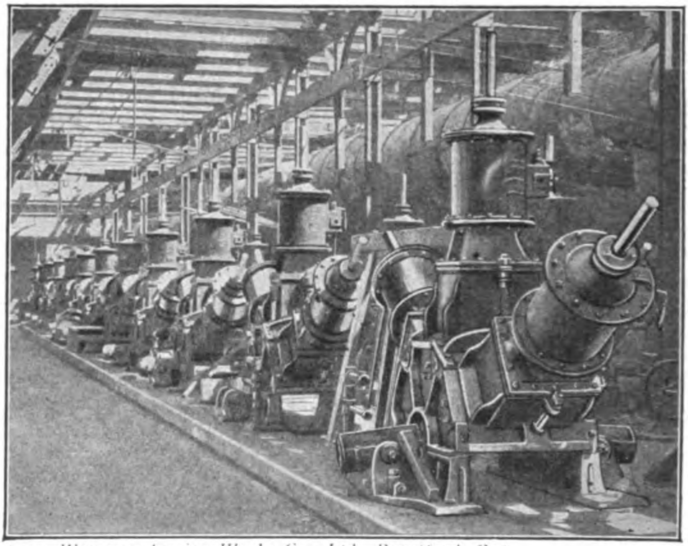
Fig. 85.——Typical pulp grinder.

within six to twelve months after cutting. The fresher and greener the wood the more easily will it grind, the yield will be higher and less power will be consumed. It is more difficult to secure a long, free stock from wood that is dried and has been seasoned than from good fresh material. Pitchy wood should not be used for making ground wood pulp unless previously treated by steam.

Equipment.

The equipment of the ground wood mill includes grinders of various types, all of which are efficient under proper management, grind stones with proper burring facilities, silver screens, stock and pressure pumps, pulp screens, flow boxes, wet machines, stock tanks and hydraulic presses. We must also include generators whether they are run by water, steam or electricity. With the above equipment and with intelligent supervision ground wood pulp can be economically and efficiently made.

Grinders: The type of grinder universally used consists of a large grindstone usually about 54 inches in diameter and wide enough to accommodate 16-inch or 24-inch blocks. There are



Courtesy: Waterous Engine Works Co., Ltd., Brantford, Ont.

Fig. 86.—Battery of grinders being installed in ground wood mill.

some grindstones in operation that are 54 inches wide which accommodate 4-foot wood. The grindstone is mounted on a shaft and revolves inside an iron casing which usually has three compartments. At the upper extremity of each of these compartments are hydraulic cylinders fitted with piston heads and as the wood is fed into the compartment the head forces the wood against the revolving stone. The pressure is furnished by either a close fitted centrifugal pump or a duplex or triplex plunger pump. The pump is usually driven from the grinder spindle. The friction between the stone and the wood causes an intense heat which necessitates the use of a large stream of water the object of which is to clear the stone and also reduce the temperature of the operation. Failure to keep the temperature sufficiently low causes the stone to become glazed and the stock is burned lifeless and short. The capacity of the grinder depends on the nature of the wood and the power available, but it usually runs from two tons to seven tons per 24 hours and requires approximately 200 to 600 h.p. per grinder.

As the ground wood pulp reaches the grinder pit, it falls to the silver screens, a series of iron plates perforated with ⅜-inch or ½-inch holes that remove the larger bull slivers, knots, etc., which are carried off from the surface of the screens by a drag conveyor, dumping the bull slivers in a receptacle at the top of its course. The screen and conveyor is constantly showered with water to wash off any fibres adhering to the large slivers. These bull chips are in turn sent to a sliver grinder or else burned as fuel in the boiler house. Either flat or rotary screens can be efficiently used for the removal of these large bull slivers.

The stock freed from these large slivers is pumped to a centrifugal or diaphragm pulp screen, which removes the last traces of slivers and coarse stock. This stock pump is either a slow speed fan pump or a plunger type pump. It is very good practice to design the pipe suction from sliver screen to suction of pump of ample size to handle stock without unnecessary friction. An 8-inch fan pump will handle the stock from four 3-pocket grinders under ordinary conditions and will pump the stock to the screens with approximately 20 h.p. This figure is for a stock line of 8 inches diameter and approximately 150 feet in length. Through these screens only the finest fibres are permitted to pass, the rejected coarser particles being passed through a Jordan or some other machine for reducing and refining them, after which they are again passed over the screens. The construction and operation of these screens is described in detail elsewhere.

. At this point in the process the consistency of the stock is about one-half of 1 per cent, as a large amount of water is required for disintegrating and washing and screening—approximately 150,000 gallons of water per ton of air dry product.

The removal of a certain percentage of water from this very dilute mixture is ordinarily performed by means of a pulp thickener which is a cylinder revolving in a vat of stock, the cylinder being fitted with a wire netting of about six meshes to the inch, which supports a finer wire cloth. The top of the cylinder is above the contents of the vat and as it revolves the water passes through to the inside and leaves a thin layer of pulp on the outside. At this point the machine resolves itself into either one of two types depending on whether deckered stock or pressed stock is to be made. If stock is to be used in the mill direct, it can be scraped off from the top of the cylinder with a doctor and then pumped to the beater as required. This operation is that of deckering while the machine consisting of vat, revolving cylinder and doctor for removing the stock is termed a decker. The other type is that of the wet machine or press. This has already been described in the chapter on the sulphite mill. Where the paper mill is isolated from the pulp mill the stock is prepared in this lap form.

Under ordinary conditions where stock is to be shipped to a short distance the ordinary wet press previously described gives a lap of stock sufficiently dry for transportation. From an economical standpoint where stock must be shipped a long distance it is advisable to submit the laps from the regular wet press to the action of a hydraulic press which leaves only 40 per cent of water in the stock. There are theories to the effect that pulp containing 70 per cent moisture will not decay as rapidly as the hydraulically pressed pulp. In the case of a law test pulp when a certain amount is piled, the weight exerted presses the air out and results in the canning of the pulp, leaving a wet mass which preserves the ground wood just as wood which has been sunk in a river is preserved.

Water Supply.

The water supply for the ground wood mill is usually furnished by a pressure pump of either centrifugal or plunger type. The water is taken from a water screen of revolving cylinder type, the size commonly used being 42 inches diameter by 84 inches long, the capacity of this size being 750,000 gallons for 24 hours. This size will supply a 4-grinder mill of approximately 8 ton capacity and will require 12 h.p. to drive both water screen and pump, provided the pump is not pumping against a head greater than 50 feet, and through a discharge pipe of 8 inches diameter, with 10 inches suction on the pump.

Operation of the Ground Wood Mill.

In the manufacture of ground wood pulp one of the most essential factors, so far as cost is concerned, is that of handling the raw material. All modern plants have studied this question and have arranged their plants so that waste of material and unnecessary handling of material shall be reduced to a minimum, since the raw material itself is the most expensive item. The wood in its course from the wood yard through the mill up to the grinders should not be touched by hand but should be conveyed by a system of conveyors that will eliminate costly hand manipulation.

The question of barking and cutting and preparing the wood has already been taken up in the chapters on the sawmill and the wood room and therefore calls for no further discussion.

Burring: Closely allied in importance to the choice of raw materials is the question of the burring of the stones as the surface of the pulp stones has an extremely important effect upon both the quality and the quantity of pulp, that the grinder will produce. Stones suitable for grinding pulp for wall board and various bag papers would not be suitable for making a light weight Manila sheet containing from 40 to 60 per cent of ground wood. This necessitates, consequently, the selecting of grindstones properly surfaced for the particular grade of pulp desired. A coarse stone should be used for coarse pulp while a stone with a finer grit should be used for fine pulp. Since stones vary in texture to a large extent, these natural variations must be regulated by proper burring of their surface so that this irregularity will not show up in the finished pulp.

The object of burring is to expose new sharp particles of grit and at the same time provide depressions in the stone. The operation is performed by means of a burr placed against the revolving stone. There are many different types of burrs on the market all of which differ slightly in pattern on the outside circular circumference. Tests have been made which show that, if two types of burr are taken and the stones ground to the same

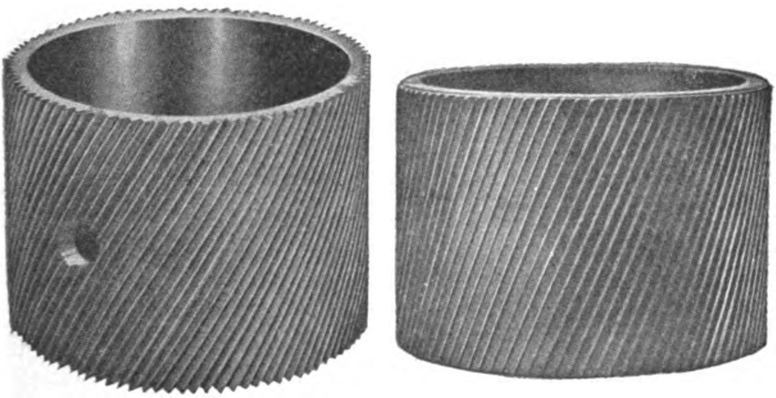


Fig. 87.—Two typical forms of burr.

depth in each case, the resulting product will be similar indicating that if the stone is properly dressed the product will be good. regardless of the type of burr. However, there are some types of burr whereby it is easier to maintain a desired surface and which eliminate a large amount of the personal element in so far as dressing is concerned.

There are many different conditions that influence the burring, for instance, whether the burr is held at one arm of the lever and fed across the stone by hand or whether it is held by tool posts and automatically fed across the stone by a screw device, where the pressure of the burr against the stone is entirely a matter of the operator's judgment.

When the grinder pressure and speed are held constant the effect of sharpening the pulp stone is to increase the production and produce a pulp of a coarser quality.

Influence of Temperature: Temperature conditions greatly influence the quality of the final product. The pulp of most value to the paper maker is that which has the best felting properties.

To obtain this, the pulp should not be ground too cold, for under these conditions the stones are kept clear of pulp and have a much greater cutting action, resulting in pulp that consists of small bundles of fibres instead of single fibres. This causes it to have no felting properties. On the other hand grinding pulp too hot results in the so-called worthless flour pulp, which is of no value to the paper maker as the fibres are practically dead and inert. Too hot grinding also causes an excessive wear on the surface of the stone.

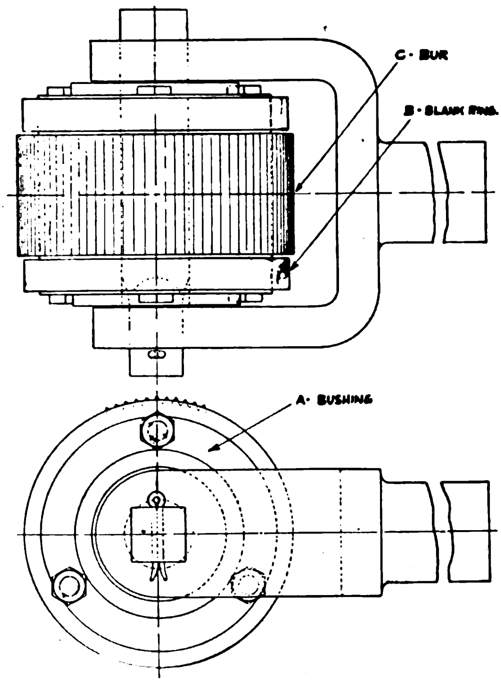


Fig. 88.—Diagram showing construction of a typical automatic burr.

It has been found that a temperature of 140° F. is a good average temperature at which to obtain a mechanical wood pulp approaching as nearly as possible the quality of a chemical wood pulp.

Pressure: Other variables remaining constant, the production varies directly with the cylinder pressure. The quality of the pulp is determined by the unit pressure with which the wood is forced against the surface of the stone. In grinding a round stick ten inches in diameter, the pressure on the stone will be one-tenth as great when the greatest diameter is reached as when the stick presented a width of one inch near the beginning of the operation, with the ultimate result that the product contains a mixture of fibres produced under a continuous change of unit pressure.

The speed of the pulp stone has a greater influence on production than upon the actual quality of the stock itself, in that the production increases directly with the peripheral speed. But in electrically driven installations the fluctuation is very slight. This variation in speed applies more to water driven units.

In the production of mechanical pulp the human element is an important factor. As a result of the slight readjustment of pressure, temperature, speed and burring the slightest change of workmanship from man to man will have its effect not only on quality but on production. Within certain limits this factor can be controlled by careful supervision, by periodical checks on the mill's operations. It is a well established fact that production will be lowered during night shifts which is easily accounted for. The decrease is caused by the manner in which the pulp wood is fed into the cells of the grinder. This can be so arranged that a block can be wedged between two others, producing a resultant of pressure on the perpendicular sides of the pocket instead of transmitting the pressure to the stone. The stick does not grind away so fast and the operator gets a chance to take a rest. Such factors cause many times decreased production as a result of inefficient workmanship and lack of supervision.

Between the power from the motors or waterwheels, condition of stone surface, cylinder pressure, speed of stone and the human factor there is a very intimate relation. None can be altered without having an effect upon the others.

In ground wood mills operated by water power, when the speed of the stones rises too high production suffers. Some of the most frequent causes for a rise in speed are (1) binding of the wood on the sides of the wood compartments, (2) withdrawal of pressure from one or more grinder cylinders, (3) not replenishing a pocket immediately after it has become empty of wood, (4) drop in pressure in the pump line, and (5) freshly sharpened stones. It will be observed that many of these causes can be traced directly to the operator.

The quality can be controlled within certain limits for different degrees of sharpness of stone by manipulating the cylinder pressure and using lower pressures on a sharp stone and higher ones on a dull stone. Lowering the cylinder pressure for sharp stones causes the speed to rise and if the gate opening is decreased production suffers excessively. Increasing the pressure with a view to increase production requires an increase in power delivered to the pulp stone in which case all of the installation may not be operated.

Grinders have been developed with specially adapted pockets to eliminate the binding which is one of the causes of rise in speed and loss in production, but apparently did not meet with any marked success. Centrifugal pumps have been belted to grinder shafts in order to increase the cylinder pressure with rise in speed of the stone and in this manner restore the speed to normal. Their action is rather sluggish, beside producing large variations in pressure which decreases the uniformity of the pulp. Governors attached to the grinder shaft control the speed successfully but do not permit the water wheels to operate at maximum capacity, since the cause of the decreased load is not removed, and the grinderman can not readily notice faulty performance. Relief valves at the pressure line at each grinder permit adjustments of cylinder pressure to keep the turbines properly loaded but require considerable attention.

As a means of controlling the speed between fairly narrow limits the method of using fewer than the total number of pockets on any line of grinders should give good results. By this method the surplus pockets are kept filled with wood to which the pressure is applied when the load is withdrawn from other pockets for purposes of replenishing or rearranging the wood. The period of increased speed ordinarily accompanying these latter operations is eliminated, and at all times a maximum load may be maintained upon the turbines.

The control over speed should be primarily to maintain production, while quality is probably best controlled by the condition of the surface of the pulp stone. It has been pointed out that the dressing or burring of the pulp stone involves to a very great extent the human factor, and does not permit an exact duplication of treatment.

Each superintendent or manager has his own theories about the method of grinding, and as a result, scarcely any two mills operate under the same conditions, even when grinding the same species and turning out similar products.

For example, one mill producing newspaper has 135 h.p. applied to each grinder; the pressure computed to the basis of a 14-inch cylinder is 17.5 lbs. per square inch, and the peripheral speed of the stone is 2,660 feet a minute. In another mill, with the same size installation and making the same class of paper, each grinder has 625 h.p. applied to it, uses a pressure of 72 lbs. on a 14-inch cylinder, and a peripheral speed of 3,540 feet a minute. A variation of from 135 h.p. to 625 h.p. to the grinders is seen in the example cited.

Reports of power consumption per ton of pulp in twenty-four hours show a range of from 65 to 100 h.p. In view of the extreme variation in the conditions of manufacturing mechanical pulp, it is no doubt true that some mills are operating under conditions of very low efficiency. From experiments it has been determined that the utilization of a considerable amount of power is necessary to obtain a strong paper. It has been noted, however, that paper increases in strength with the power consumption only up to a certain value; above this value the strength will decrease. Maximum efficiency in the production of a mixed ground wood and sulphite paper of a given strength requires the proper adjustment of both the power consumption of the grinder and the percentage of sulphite in the mixture. For instance, it might be desirable to use a small amount of power per ton of pulp and a relatively high proportion of sulphite, rather than a higher power consumption and lower proportion of sulphite. The proper adjustment would depend, of course, on the relative value of ground wood produced by high and lower power, and sulphite fibre.

In electrically driven mills many attempts have been made to control the pressure in the cylinders of the grinders so that nearly constant full load would be carried by the motor. This is desirable, of course, from an electrical standpoint, because by holding constant full load on an electric motor, advantage is taken of its highest operating efficiency. Furthermore, it will be readily appreciated that by maintaining conditions at their full load value, the output of ground wood will be very much increased over a condition where the load falls below normal.

The earliest form of regulation, consisting of belting the pressure pump to the shaft of the grinder, so that when the grinder increased its speed the pump would do likewise and deliver a greater pressure on the cylinder, thereby reducing the speed of the revolving grindstone, is useless on an electrically driven grinder, since the motor speed is practically constant.

A form of regulation better adapted to electrical installations consisted of a throttle operated by the grinder man, who, between his duties of filling the pockets with wood, was supposed to watch an indicating meter and adjust the pressure according to the load as shown by the meter. This method, however, had its shortcomings, for a heavy load would always seem to appear when the grinder man was otherwise occupied.

Electrical Pressure Regulators.

Other systems of regulation have been tried, among which is a solenoid connected to the throttle valve so fluctuations of load on the motor would actuate the solenoid and raise or lower the valve stem. It was found that regulation was not very close and fluctuations in the water system would occur with such rapidity as to cause a pumping action and inability to control the load with any degree of reliability or accuracy. This would cause excessive peaks and high power cost, particularly where power is purchased from a power company.

An electrical automatic pressure regulator has recently been invented and is now in successful use in a number of mills for which the following advantages are claimed:

1. Prevents peak load charges.
2. Prevents overload on motors.

3. Eliminates underloads so motors may operate at practically 100 per cent load factor.

4. Increases the production of ground wood.

5. Improves the quality and uniformity of the pulp.

6. Reduces the amount of splinters or shives.

7. Reduces the amount of short fiber which is carried away in the white water.

8. Reduces the maximum demand horse power where power is purchased and allows, when desirable, all motors to be operated at the exact value of the generator capacity where a mill has its own power plant.

9. Improves the service rendered by the power company by maintaining constant load and better power factor and voltage regulation.

10. In installations involving several grinders, the number of grinder operators can be reduced, as supervision over the load taken by the grinders is not required.

11. Increases materially the electrical performance of the motors and transformers by maintaining them at their full load efficiency.

12. Prevents shutdowns on account of overloads and consequent loss of production.

13. Is absolutely "fool proof" and cannot be interfered with the grinder operators.

14. The regulator can be adjusted to control the grinder load only or the entire mill load.

15. Small amount of power required to operate the regulator —less than 1-6 h.p.

16. Although the grinder operators have to handle considerably more wood, due to the increased production, yet the elimination of responsibility for peak loads and the relaxation from constant attention usually required has been welcomed by the men in charge of grinders.

17. The regulator allows the power station to figure on the exact maximum demand of a paper mill, and where several mills are on one line, the sum of the individual maximum demands will be the exact capacity necessary to be furnished, no extra allowance being necessary to take care of the overloads.

18. The regulator is easily adjustable for load setting in case the demands of the power station or mill vary.

The installation of such a regulator does not involve changes in the system of piping, and pumps used in mills can be used without any extensive alterations, a positive pressure or centrifugal type of pump acting equally well.

Regulation is obtained by automatically varying the water pressure in the cylinders of the grinders so as to obtain constant load upon the motor driving them. Variations in load take place when the pressure is taken from a cylinder preparatory to charging a pocket and again when the pressure is reapplied; also during grinding, since less power is required when the circumference of a log is in contact with the stone than when a greater area of contact is presented when a log is partly ground away.

All the above variations produce a fluctuating load and resultant loss in production, as is obvious by an inspection of the curves taken from a graphic meter chart.

It is seen that without the regulator, as the area of wood in contact with the stone varies, the power taken by the motor varies, since constant pressure is usually maintained in the cylinders of the grinder. In other words, there is constant pressure in the cylinders, but not constant unit pressure on the wood, since its area is varying continually. In order, therefore, to obtain constant pressure per square inch of wood, it is necessary to vary the cylinder pressure a few pounds from normal to secure this, and also to maintain constant load on the motor.

Since pressure per square inch and power variations can be kept constant by controlling and varying the normal water pressure by a few pounds, it has also been desirable to provide means whereby the slight pressure changes are brought about gradually so as to prevent the formation of splinters and shives, as now occurs when the wood is brought in contact with the stone after pressure is applied to a pocket. As a result of this and the constant unit pressure, not only an increased production is secured, but a more uniform grade of pulp is obtained.

The system of regulation most suitable for a particular application is determined largely by the operating conditions which obtain and the class of product manufactured. In two mills having all conditions the same, that which would be suitable for one would be wholly inadequate for another. The proper installation to be made in a given case, however, can readily be determined by a casual inspection.

In carrying out the installation of the regulator, a series or current transformer of suitable ratio is placed in circuit with the motor driving the grinders and connected so that fluctuations of load will cause the moving element of the primary regulating relay to respond therewith. This moving element operates either up or down, depending upon whether the load is above or below the predetermined value, said value being obtained by balancing the movable arm equally between the contacts by a screw adjustment when the indicating meter registers the desired load. As the primary regulating relay element moves upward or downward beyond a certain adjustable distance, a set of contacts is closed, causing the secondary relay or magnet switch to operate, thereby energizing one of the solenoids of an hydraulic regulator valve. Instantly, the core of the solenoid is raised to its extreme position, opening both ports, which were previously closed, thereby admitting hydraulic pressure to the upper end of the cylinder through the other pilot valve port, the piston in the cylinder is thereby forced downward, opening to a larger extent the balanced regulating valve. This permits an increase in pressure in the grinder cylinders, thus increasing the load on the motor driving the grinders.

As soon as the electric load has reached the point for which the primary relay is set, the primary circuit will be broken, causing the secondary relay to break the secondary circuit, and the core of the solenoid immediately drops, forcing the pilot valve pistons to the lower position, which closes both ports, thereby preventing the admission or escape of water from the hydraulic cylinder, and consequently locking the piston of the hydraulic cylinder in the exact position which it occupied between one valve closed. This is usually in some mid position between one end of the other of the cylinder. The piston in the balanced regulating valve controlling the admission of water to the grinder cylinders will, of course, occupy a corresponding position to that of the piston in the hydraulic cylinder, which would be partly open.

Now, as long as the load remains constant, a state of equilibrium will exist in the system; but if the load should increase above the point for which the primary regulating relay is set, contact would be made in that direction, causing the other switch of the secondary relay to close its secondary circuit, energizing the other solenoid, and opening the other pilot valve. The opening of this pilot valve opens both of its ports, admitting hydraulic pressure to the lower end of the hydraulic cylinder through one of its ports and exhausting water from the upper end of the cylinder through its other port.

The piston in the cylinder will then be forced upward and the balanced regulating valve piston correspondingly raised, thereby shutting off some of the pressure applied to the grinder pockets and reducing the load on the grinder motor. As in the first instance, when the load reaches the value for which the primary regulating relay is set, the circuits will be opened, the pilot valve returned to its normal position at the lower end of its stroke, closing both ports and locking the piston hydraulically in some mid position of its stroke at whatever point it happened to be when the correct load value is reached.

The primary regulating relay can be adjusted for any degree of load by simply raising or lowering a screw, so that in localities where the power company changes the available demand from day to day, it will be found very easy to make the desired adjustment and so prevent the occurrence of peak loads.

In order that there may be stability in the operation of this regulator, as in the operation of any governor, there must be a certain limit between the contacts of the primary regulating relay, where the regulating valve will be inactive. One of the most vital points to be met with in the successful operation of the regulator is the length of the time between the change of the load on the grinder motor and the change of water pressure in the cylinder of the grinder. Between these limits, a number of operations are performed, and in accomplishing the proper results, we have given considerable attention to the most efficient speed of operation of the regulator; that is, the ratio between the speed travel of the solenoids and the distance of travel of the valve piston controlling the admission water to the grinder cylinders. This time ratio is adjustable from .2 second and up, so that an exact point for an installation can be set.

There are several limiting points from a practical standpoint that must be considered, among which is an unnecessary operation of the regulator, preventing close regulation, because the time element of the sequence of operations taking place when the pressure is to be regulated has a direct effect upon the hydraulic equilibrium of the system. This condition should not produce hydraulic oscillations or severe shunting will result, causing surges and inability to regulate with any degree of accuracy.

In order to dampen any irregularities in the hydraulic system, use is made of a surge tank of suitable capacity and connected with a by-pass check valve between the main regulating valve and the grinders. This surge tank acts in somewhat similar capacity to a surge tank in a penstock line of power plant.

When the balanced regulating valve controlling the entrance of water to the grinder cylinders is suddenly opened a certain amount of increasing pressure on the side toward the grinders is dissipated into the surge tank, cushioning the effect and preventing an abrupt seizure of the wood upon the grinding stone, thereby reducing the formation of splinters and shives. When the balanced regulating valve is suddenly closed, to a certain extent reducing the pressure at the grinders, a certain amount of pressure is admitted from the surge tank, thereby eliminating any tendency for the regulator to shunt when the by-pass check valve is properly adjusted.

The object of the by-pass check valve is to prevent a large and rapid delivery of pressure from the surge tank to the grinders, but yet be able to absorb considerable excess pressure when the balanced regulating valve is suddenly opened. To secure positive operation, compressed air is maintained in the top portion of the surge tank.

As a further refinement, the gate or piston of the balanced regulating valve is so designed that in opening it the area of port opening increases as the square of the degree of raising of the piston from its seat. By this means a heavy inrush of water is prevented when the valve is first opened, but an increasing amount is allowed as the opening increases. When the valve closes, the amount of water is reduced speedily at first, but tapers off to a minimum as the piston approaches its seat. This gradual change of water will not be slow enough, however, to allow a drop in load on the motor, but by this charactertistic, abrupt changes in pressure are prevented and smoother operation secured.

In addition to a regulator for motor operated grinders, there is also a regulator for waterwheel-driven grinders. The apparatus comprising this type is similar to the regulator for motors, except that a centrifugal governor belted to the grinder shaft is substituted for the actuating solenoid of the primary regulating relay. This arrangement maintains constant speed and constant load, so that the gate opening of the waterwheel may be fixed at the best position to permit the most efficient operating speed of the wheel.

On account of the class of labor usually employed, the apparatus has been made as near "fool proof" as possible, so that the operation of the regulator cannot be interfered with by the grinder men.

How to Tell Good Ground Wood.

A man accustomed to the manufacturing of ground wood can usually very closely determine the quality of the pulp by observing a few simple rules. The flow of the pulp over the grinder dams, the speed of grinders, pressure gauge, the heat of the pulp (judging from steam arising from casing of grinders caused by friction), the size of cylinders, color of pulp, the sound of the grinders, the amount of slivers running into the sliver screen, etc., all these points can be observed in passing through the grinder room without a close inspection of the pulp. A skillful ground wood pulp maker can casually walk through a grinder room and tell very closely the condition without closely inspecting the pulp or asking questions.

First—The pulp should be a rich creamy color; this indicates that the grinders are not allowed to run toc hot, sc that the pulp is not burned.

Second—The flow of the pulp over the grinder dams should reveal to the experienced eye the texture of the pulp. Coarse pulp will fill up to the top of the dam and break over it in chunks instead of flowing over smoothly.

A piece of blue glass set in a small wooden frame is very useful for testing ground wood. A sample of the ground wood is taken and diluted with water. If the frame is now held against the light, the fibres being white and the light blue, the size, nature and uniformity of the fibres can be seen very clearly. If chips, shieves, slivers or unseparated bundles of fibres are present, they will be revealed.

Another useful device is the use of a long, sharp-pointed stick for detecting the presence of holes and uneven spots on the surface of the stone. If such a stick is held against the surface of the stone as it revolves, being gradually moved across the surface, any irregularities in surface will reveal themselves by making the stick vibrate. The sense of touch will soon learn to detect even very slight defects in the surface of the stone. This device obviates the necessity of shutting down the grinders to find out if the stones need burring, etc.

TYPICAL SPECIFICATIONS FOR GRINDER.

To be latest design and finish, having..................pockets and taking a stone 54" in diameter, 27" face for 25" wood.

Base Plates: The Base Plates are of cast iron 6' long, in the form of an angle plate, the vertical part forming part of the grinder side up to the shaft center. Top of upright is planed to receive the sides. At each end of the base plate will be a socket suitable for the boss on the side frames, the two together forming the hinge of the side frames, when they are lifted. The base plate is 2¼" thick on the horizontal part and 1¼" thick on the upright and is heavily ribbed to insure rigidity.

A pad is case on the base together with lugs. The pad is machined to receive main journals and lugs are fitted for the adjusting screws.

Four 1¼" holes are bored in the plates for the anchor bolts.

Sides: The Grinder sides to be made of cast iron, heavy in design with strengthening ribs under each pocket and to be machine finished where all connections are made. These frames to be made of our latest pattern which is thoroughly well suited to its duty. The side of each frame will be slotted for the adjusting bolts which secure the pockets in position; the slots to be reinforced with strengthening ribs. On the inside of the grinder case there are to be three 2" ribs for each pocket; the center ribs to be planed to extend ¼" higher than the ribs on either side of same. On the end of each pocket there is to be a groove planed to correspond with the extended ribs in these grinder sides. The bottom of the flange of the grinder side where it connects with the base plate is machine finished and to have slotted holes for the six through bolts, 1" diameter. To the grinder sides around the shaft is fitted a case to be packed with rubber packing to prevent the stock running out. These sides when placed in position stand 37" apart.

Pockets: The Pockets are 1½" thick, made of cast iron and each in one casting. Length of pocket inside 25½". The pocket doors will take wood 14" in diameter. Three strips are cast on both sides of inside of pockets to assist in the alignment of the piston rod, and reduce friction of the wood. The ribs extend from top to bottom. The working side of the pocket at the bottom, which extends across the face of the stone, is fingered also the ends. The pocket can be so adjusted that this face will just clear the stone largely preventing slivers. The opposite side of the pocket is cut out at the bottom, to give ample room for possible slivers. Provision is made to prevent accumulation of slivers between pockets. The ears on each side for supporting the pocket in the proper position are 3¾" deep, through which the adjusting bolts pass. A strong ribbed foot extends at each end of the pocket for connecting same to the sides. Can adjust the pockets from the 54" diameter stone to 58" diameter stone. The top and ends are machine finished. The top of pockets are completely covered by the bottom head of the hydraulic cylinders, preventing any pulp flying out. The pockets at each end or side where they come against the frame are machined, provided with a groove in which the raised rib on frame of grinders forms a guide, which is machine finished to size 2" wide ¼" thick, so that whether the pockets are up to a 54" stone, or down to a 38" stone, the pockets always maintain the same position in these guides and cannot move out by the center line of machine in either direction. The adjustment is given to the pockets by two large bolts, 2" diameter with double jam nuts on each side of pocket wings. To further insure the pockets from shifting their position and partly to relieve the adjusting screws of the tension imposed on them, bolts passing through the side frame and sides of pockets are provided. The position of the pockets on the grinders are at such an angle that the pulp after being ground will not hang up in the pockets. On the bottom of three sides of the pockets are 2" fingers for discharge of the pulp, which will prevent larger slivers from working out.

Pocket Doors: The Pocket Doors are made of soft steel ⅛" thick. Size of door 14x14½". These doors slide in a groove and are held in position by a guide which is connected to the pocket. Fittings for guide pieces are brass. The handles for doors are cast iron.

Pillow Blocks: The Pillow Blocks or main bearing are to be heavy cast iron boxes having a bearing for the shaft, 18¼" long. The boxes are to be { babbitted / wood lined }

Our babbitted box is of a water-cooled oil ring type, so designed that a water-circulation is kept up in each box thus keeping it cool. Our best copper hardened babbit is to be used, the box then bored and fitted to the shaft.

Our wood lined boxes are lined with blocks of maple after being boiled in tallow. The box is then bored out to fit shaft.

These boxes are adjusted by means of the two wedges on which they rest. The wedges in turn are adjusted by two screws with lock nuts fitted to the two lugs on the base plate.

These wedges are planed on the face thereby rendering adjustment easy.

Yokes or Bridgetrees: The Yokes are of cast iron 44" long. 5" wide, one on each side of the pocket. They are heavy and heavy ribbed from the ends to the center. A pocket is bored in each to receive the adjusting screw nut. The top is flanged to receive the two adjusting screws which support the grinder pockets. The yokes are machine finished where they connect to the grinder sides.

Bottom Cylinder Heads of Saddles: The Bottom Cylinder Heads are accurately fitted to cylinder and cover the entire pocket. Bored for brass gland and piston rod. A brass ring is fitted in each head under packing gland. This brass ring will take all the wear of the piston rod. It can be removed and a new one put in its place, thereby saving the lower cylinder head. The brass gland is split and made heavy and deep, insuring a good packing. The head has a door, front and back, which can be quickly removed when gland requires readjusting or repacking. This head is heavily ribbed; is machine finished where it connects to top of grinder pocket, and is held in position by eight stud-bolts, hex nuts. The brass gland is held in position by three ¾" brass stud-bolts and hex brass nuts.

Hydraulic Cylinders: The Hydraulic Cylinders are 22" long, ⅝" thick with flanges on each end ¾" thick. The face of flanges are machine finished; also outside diameter of lower flange, which is made to enter lower cylinder head, insuring perfect alignment. The cylinder is bored to receive a hard-drawn seamless brass tubing...........inches inside diameter, ⅛" thick. This tubing is forced into place under pressure and rolled. The side of the cylinder shell is fitted to receive the hydraulic valve. There is no piping between valve and cylinder. Cylinder and valves are all tested before leaving the factory.

Top Cylinder Head: The Top Cylinder Head is nicely fitted to the cylinder, and made to enter inside diameter of cylinder, making perfect alignment. Fitted with heavy brass gland using ½" square packing. This gland is also made deep, insuring ample packing for the work. The glands are held in position by three ¾" brass stud-bolts with hex brass nuts. All cylinder heads connect to cylinder with seven ¾" bolts with hex nuts.

Hydraulic Piston Rods: The Hydraulic Piston Rods are made of soft steel 5' 8" long, 2-15/16" diameter at the lower end, and 2⅜" at the upper end, which passes through the top cylinder head. The Piston Head and follower are held in position on the piston rod by two brass hex nuts, one being a jam nut.

Piston Head and Follower: The Piston Head and Follower are 1/16" less in diameter than the bore of the cylinders. The heads slip against a shoulder bearing on piston rod. The follower is ¾" thick and 1¾" thick through the hub and held against the packing and head by two brass nuts on the piston rod. These heads are packed with six rings of flax packing ½" square. The piston is fitted with a cast iron spring ring, 2¾" wide.

Pocket Follower: The Pocket Follower is made of good strong gray iron from a straight pattern and having the ribbed surface where it comes in contact with the wood. It is 24" long, in width just clearing the sides of the pocket. Diameter of the hub 5½". Heavy ribs extend from the hub to corners. This follower is pressed and bolted on piston rod.

Shafts: The Shafts are made from steel forgings............inches in diameter in the bearings and............inches in the stone. Threads for flanges are cut so both flanges slip off same end of the shaft. Two half "V" threads to the inch to receive the flanges, cut right and left hand. End of shaft fitted to large wrench for removing stone.

Grinder Flanges: The Grinder Flanges are made from steel castings 38" diameter, 6½" through hub. Machine finished where face of flanges come in contact with stone. Four 1⅞" holes through flanges in which are fitted two steel pins for removing flanges from shaft. Threads are cut right and left hand to fit grinder shaft.

Couplings: (Flange) Couplings made of good strong gray iron.
(Compression) Outside diameter............hub diameter ....length of coupling. Couplings lock on face.

Tools: One large wrench for removing flanges from shaft, also set of steel wrenches for nut on the grinders. One stone trueing tool with disc holder and six discs; one burr holder and six cast iron burrs.

Fittings and Piping: Each grinder fitted with three improved 4-way valves.

Packing: All cylinder heads are put on with sheet packing 1/16" thick.

Painting: All grinders to be painted with good durable paint.

XI. Bleaching

Wood pulp, regardless of the process by which it is made, requires to be bleached if it is to be used in any of the finer varieties of light colored paper.

Rag pulp, straw pulp and pulp made from esparto, jute, etc., and most of the other miscellaneous materials from which paper of any kind is made, require bleaching in order to enhance the value of the product.

The bleaching of rag stock is a comparatively simple matter owing to the comparative freedom of such stock from colored impurities which have to be eliminated by the bleaching agent. It should be borne in mind that most rag stock of the better grade is made from material which has already been submitted to bleaching in the processes of textile manufacturing, and any coloring matter which may be present is in the form of dyes which have been added by the textile manufacturer or finisher, and which are relatively easy to remove when compared with the coloring materials embodied in wood pulp which are an integral part of the fibre itself.

Wood pulp, no matter how carefully made, and whether produced by the sulphite or soda process, always has associated with the cellulose a portion of the lignin or incrusting matter ordinarily present in the raw fibre and this lignin carries with it certain colored bodies of highly complex chemical composition. These colored impurities cannot be removed by any amount of washing or mechanical treatment. They are united in a chemical manner with the fibre or cellulose and a chemical process is necessary for their removal.

In addition to the colored materials that are ordinarily present in the fibre, other dark colored substances are produced during the process of digesting the pulp, by the chemical action of the acid or alkaline liquids on the various complex substances contained in natural wood.

Wood pulps and pulps made from esparto, straw, jute, etc., require, as pointed out above, a much more drastic bleaching than rag pulp, resulting in a much larger consumption of the chemical used for bleaching purposes and a much greater proportional loss in weight through the bleaching process.

The object of all successful bleaching practice in the paper industry is to thoroughly bleach the pulp so as to turn out a product of maximum whiteness and purity, which will remain white indefinitely, and, at the same time, not to impair the strength and natural properties of the fibre, not to cause too much shrinkage in weight and volume, and not to have an excessive consumption of the bleaching agent.

Naturally, as in any other process, it is also desirable to reduce the labor employed in the process to a minimum and consequently whereas bleaching was formerly carried out in simple tanks provided with more or less crude agitators, at the present time numerous highly efficient special forms of bleaching equipment are on the market, all of which are designed with the idea of making the process as largely automatic as possible.

Rag pulp is frequently bleached in a Hollander or washer in which the boiled rags are given the preliminary treatment which converts the stock into what is known as "half-stuff." As a rule, in bleaching this kind of stock, no special bleaching equipment is provided, the bleaching agent being added to the Hollander towards the final stages of the operation and washing being continued sufficiently long after the bleaching effect has been accomplished to wash out the impurities and the surplus bleach.

Bleaching Agents.

Bleaching is essentially an oxidizing reaction. This is shown by the fact that many materials will become bleached when simply left exposed to the wind and weather. All of the various chemicals used for bleaching purposes are used with the idea of oxidizing the colored materials and, of all these bleaching agents, the commonest are certain of the compounds of chlorine. Chlorine, when brought in contact with water, releases the oxygen of the water and it is this freshly released oxygen that exerts the decolorizing action on the fibre.

The commonest bleaching agent is bleaching powder, a white substance having a distinct odor of chlorine. It readily absorbs moisture from the air and for this reason must be kept in covered drums or other vessels which will exclude air. The chemical composition of bleaching powder is not very definite, but the formula $CaOCl_2$ is generally accepted. The material is bought and sold on the basis of the amount of "available chlorine" present in the bleaching powder. Good commercial bleaching powder or chloride of lime, as it is frequently called, should contain from 35 to 37 per cent available chlorine.

Bleaching powder is usually shipped in steel drums or wooden barrels. The steel drums weigh from 100 to 800 pounds including the weight of the drum, and the wooden barrels usually weigh from 350 to 415 pounds including the weight of the barrels. An 800-pound steel drum such as is ordinarily used for the shipment of bleaching powder measures 30x39½ inches. Where it is necessary to use this material in small quantities it is usually purchased in 5- or 10-pound cans and this is frequently a convenient way of buying and storing the material as the slightly increased cost on account of the containers will be more than offset by the prevention of deterioration in the material.

In Europe bleaching powder is frequently sold on a degree basis, the degrees representing the volume of chlorine which will be liberated from one kilogram of the bleaching powder at standard temperature and pressure. The following is a table of the relation of French degrees to "available chlorine" as given in Griffin and Little.[1]

RELATION OF FRENCH DEGREES TO PERCENTAGE OF AVAILABLE CHLORINE

French Degrees	Percentage Available Chlorine	French Degrees	Percentage Available Chlorine
65	20.65	100	31.80
70	22.24	105	33.36
75	23.83	110	34.95
80	25.42	115	36.54
85	27.01	120	38.13
90	28.60	125	39.72
95	30.21	130	41.34

Bleaching powder requires great care in shipment and storage. If the powder is allowed to become wet, or even damp, it will rapidly deteriorate and lose a large percentage of its available chlorine. In case the powder should become actually wet, as might happen in a leaky ship or a bad car exposed to the weather, the decomposition may be so rapid as to cause explosions.

Griffin and Little mention a series of experiments carried out by Pattinson regarding the rate at which bleaching powder deteriorated in storage. Pattinson took three 600-pound barrels of bleaching powder; 12 bottles of the same powder were filled at the same time. The barrels were sealed and both the barrels and bottles were stored in a cellar. A maximum and minimum thermometer was placed near them, and a careful record of the temperature made for each working day of the year. The record shows the temperature to have been uniform and comparatively low during the entire year, the highest being 62° F., and the lowest 38° F. One bottle from each of the three sets of twelve was opened and tested each month, and a sample was also withdrawn and tested from each of the three casks. The results of the experiment shows a gradual and regular loss of available chlorine during the time over which the tests were made. The average loss in the barrels was about one-third of one per cent greater than in the bottles and the barrels were not necessarily air-tight. A complete analysis of each of the barrel samples was made at the beginning and also at the end of the experiment. These analyses are given in the table below:

[1] The Chemistry of Paper Making.

Composition of Bleaching Powder

	January 29, 1885			January 5, 1886		
	A	B	C	A	B	C
Available chlorine	37.00	38.30	36.00	38.80	35.10	32.90
Chlorine as chloride	0.35	0.59	0.32	2.44	2.42	1.97
Chlorine as chlorate	0.25	0.08	0.26	0.00	0.00	0.00
Lime	44.49	43.34	44.66	43.57	42.64	43.65
Magnesia	0.40	0.34	0.43	0.31	0.36	0.38
Silicious matter	0.40	0.30	0.50	0.50	0.40	0.50
Carbonic acid	0.18	0.30	0.48	0.80	1.48	1.34
Alumina, perioxide iron, oxide manganese	0.48	0.45	0.35	0.40	0.40	0.37
Water and loss	16.45	16.33	17.00	18.18	17.20	18.89
	100.00	100.00	100.00	100.00	100.00	100.00
Total chlorine	37.60	38.97	36.58	36.24	37.52	34.87

The small quantity of chlorine found as chlorate at the beginning of the experiments ceased to exist in this combination at the end, and from tests made it was found that all the chlorate had disappeared about four months after the barrels were filled. The amount of chlorine existing as chloride had slightly increased. It is not often that bleaching powder can be stored where so low a temperature as 60° F. can be maintained for any length of time, especially in the summer months when, as previous experiments have indicated, the greatest loss of available chlorine takes place.

Bleaching powder should be stored in as dry a place as possible, or, better, in one that is both dry and cool; and if any of the containers are damaged, they should be the first ones selected for use.

According to Griffin and Little, the rate at which the bleaching powder deteriorates is influenced by the kind of container in which it is packed. Soft woods are considerably affected by the action of the powder, and shrink badly when exposed to the sun. If such containers are subsequently exposed to rain, water readily finds its way into the barrels. Ash and other hardwoods can be used for such barrels, but the best barrels are built of oak staves one inch in thickness.

The leading companies manufacturing bleaching powder have given very careful atteniton to the containers in which this material is shipped and if it is purchased from a reliable concern, little trouble will probably be experienced with deterioration in shipment or storage.

Preparation of the Bleaching Liquor.

The usual method of preparing bleaching liquor is to place a suitable quantity of bleaching powder in an iron tank provided with an agitator. These tanks are usually painted with red lead ground in oil. The mixture is agitated thoroughly and the agitator then stopped, allowing the mud to settle. The liquid is then drawn into a second settling tank in which the finer sediment settles out. The slime remaining in the agitator is again treated with a fresh quantity of water and the weak solution thus obtained is drawn off into a storage tank from which it is taken for the treatment of a new lot of bleaching powder. In this way the utmost economy in the use of material is obtained. The slime should be sampled and sent to the laboratory from time to time so as to determine if the washing is being carried out in a sufficiently thorough manner to extract the maximum percentage of available chlorine.

The bleaching liquor should be very thoroughly settled and decanted before being used in the Hollander or special bleaching equipment. Not only is the muddy bleaching liquor less efficient than a pure solution, but it also contains dirt which will cause black specks in the paper.

A hydrometer is usually used for testing the strength of the bleaching liquor. This is a very inaccurate method of testing this liquor because there is not necessarily any definite relation between the density of the solution and the amount of available chlorine present. If the mill has adequate laboratory facilities it would be much better to take samples at regular intervals and have these sent to the laboratory for a determination of the available chlorine present. However, the hydrometer test is better than nothing, and in many mills is the only practical method that can be used. According to Griffin and Little it may be accepted as a rough rule that 1° Be. on the hydrometer averages about 0.47 per cent available chlorine in the solution.

Chlorine Bleach.

Recently, since highly purified chlorine gas has become an article of commerce, being sold in liquefied form in steel cylinders, considerable work has been done on the bleaching of pulp (and also textiles and other materials) with liquid chlorine instead of bleaching powder.

Very pure liquid chlorine is now being placed on the market by several firms at a reasonable price. It is shipped in steel cylinders containing from 100 to 150 pounds and can also be shipped in tank cars containing 30,000 pounds. The cylinders measure 53 in. by 8½ to 10½ in. The following is an analysis of the chlorine sold by one of the leading manufacturers of this product:

Chlorine........................	99.80 per cent to 99.99 per cent
Carbon Dioxide..................	0.01 per cent to 0.20 per cent
Air and Oxygen..................	0.00 per cent to 0.10 per cent

The use of liquid chlorine obviates all the labor, trouble and uncertainty of making up bleaching liquors from bleaching powder and water. Highly efficient special proportioning valves have been devised that will automatically admit enough chlorine to the water to make the solution up to any required percentage of available chlorine. The convenience and simplicity of this method is rapidly becoming more and more appreciated and undoubtedly will be used to an increasing extent in the future.

The Bleaching Process.

We are indebted to an article by James Beveridge in "Paper" for Oct. 30, 1918, for much of the following information concerning the bleaching process. The bleaching properties of a pulp depend upon the process by which it is prepared. As a general rule vegetable fibre when prepared by the sulphite process bleaches more readily than that prepared by the soda or sulphate process.

Also sulphite pulp made with an acid high in magnesia usually bleaches more readily than a pulp made with an acid prepared from straight limestone.

The quality of the water used for cleaning the pulp also has an influence on the bleaching process, especially if the water contains lime in any form. In the sulphite process the lime salts precipitate insoluble resin soaps on the surface of the fibre which absorb chlorine in proportion to their presence, and in order to avoid such precipitation the water is sometimes heated to boiling or chemically treated for the removal of lime before it is used. A similar precipitation of lime salts takes place when water containing lime is used for washing soda or sulphate pulp, the lime being precipitated either as carbonate or sulphate by the alkali present. Both of these substances cling to the fibre and carry down with them organic coloring matter which renders the process of bleaching even more difficult and costly than is the case with sulphite pulps.

The loss of weight in bleaching pulp, together with the cost depends on many factors, the most important of which may be enumerated as follows:

1. The raw material from which the pulp is prepared.
2. The process employed for manufacturing the cellulose or fibre, whether this be alkaline or acid, i. e., soda or sulphite process.
3. The purity of the pulp obtained, controlled largely by the conditions under which the fibre is prepared, such as the amount, character and composition of the chemicals used in cooking; the temperature employed; the time given to complete the process; the purity of the water used for washing.
4. The dilution of the pulp with water, or density of the stock, during the bleaching operation, which insures a more intimate and closer contact of the bleaching agent with the fibre.
5. The temperature at which the bleaching is carried out and the consequent acceleration of the chemical action between the chlorine and the coloring matter.
6. The time allowed for bleaching, controlled by the temperature and density of the stock under treatment.

With regard to these factors, it has been found in manufacturing practice that the greater the yield of fibre from unit weight of raw material, no matter by what process the pulp has been made, the greater is the loss of weight of pulp bleached and the amount of bleaching agent required. It has also been found that the dilution of the fibre with water or density of the stock, and the temperature employed for bleaching, are most important since the first manifestly results in great economy of steam and the second in economy of bleach.

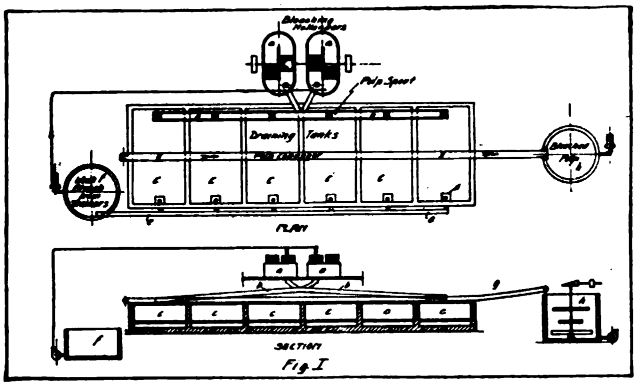
Bleaching Equipment.

In the following paragraphs describing bleaching equipment we have drawn liberally on the information in Mr. Beveridge's excellent article in "Paper" for Oct. 30, 1918.

In the older methods of bleaching, the Hollander with a paddle wheel to throw the pulp over the backfall instead of a roll, and sometimes called a "pocher" was used, the fibre being allowed to circulate either cold or hot until the required degree of whiteness was attained. The stock at first was washed in the Hollander after bleaching with drum washers, the washings containing the excess bleach being thrown away. Or, instead of washing, a quantity of antichlor or sodium hyposulphite was added to destroy the excess of hypochlorite present. This was obviously a very wasteful method and a distinct improvement was the introduction of a special draining tank, usually built of concrete and provided with a perforated false bottom of earthenware tiles, into which the pulp was emptied and drained, the liquor being pumped back again to the "pocher" to be mixed with a quantity of fresh unbleached pulp, so as to exhaust any available chlorine it contained. These draining tanks are in use today in many paper mills.

A still further advance was made when a series of open concrete tanks was put down to bleach and store large quantities of pulp, the main principle being to thoroughly mix the bleach liquor and pulp together in a suitable Hollander or "pocher," and after steaming to the required temperature running the whole charge into a tank, there to remain till the fibre came up to the requisite degree of whitness, a slight excess of bleach liquor being added for this purpose. The liquor was then drained off into a well and from there pumped back to the "pocher" to meet fresh unbleached pulp, thus becoming exhausted of its available chlorine. The density of the stock was in all cases, attained with the drum washer.

An arrangement of the kind described above is shown in the illustration. The fibre direct from the screens flows into the "pocher" a, and after the desired density has been obtained with the drum washer, the bleach liquor is added and the whole circulated for a couple of hours or so, steam being injected meanwhile till the temperature reaches 100° to 110° to 120° F. The charge is then run off through the chute b, into any one of the series of tanks c, where it remains at rest for twelve or sixteen hours. By this time the pulp will have reached a good color. The liquor is then drained off through the plug hole d, into the pipe e, which conveys it to the well f, from whence it is pumped back to the "pocher" again. The drained and bleached fibre is afterward conveyed to the beater floor in trucks, or thrown on the traveling belt g, and conveyed to the stuff chest h, mixed with water and pumped partly to a wet machine on the beater floor, to be made into laps, and partly direct into the beating engines. Such a system manifestly involves much labor, plant and floor space, not to mention a somewhat large expenditure of steam for heating, when hot bleaching is carried on. As a rule not more than 2.5 to 3 per cent density of stock is obtained from the "pocher."



Courtesy: "Paper," New York.

Fig. 88a.—Tank system of bleaching.

Bleaching apparatus was next designed fulfilling more perfectly the conditions for economy. The vessels or "pochers" were built of tile, or reinforced concrete, and the mixture of pulp, bleach liquor and water, kept in continued motion by means of a screw or propeller, until the process of bleaching was practically completed.

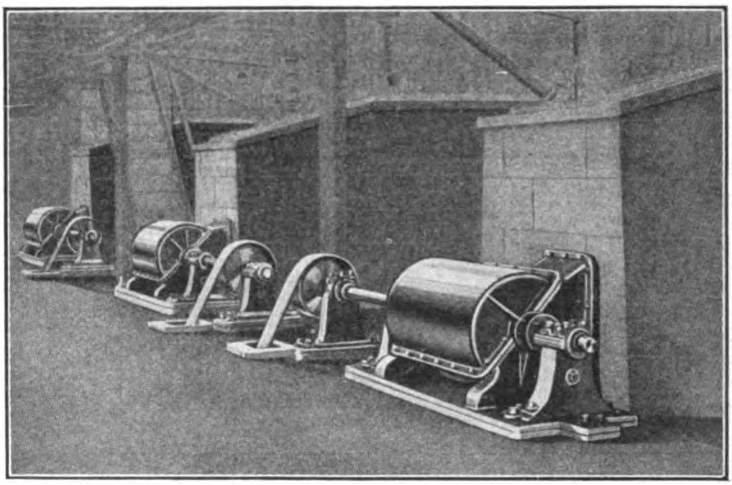
The propeller is placed at one end, and in this particular case causes the stock to travel in the direction of the arrows. These bleaching engines are built to hold from one to ten tons of air-dry pulp per charge, and are operated with from four to six per cent stock. Such a degree of concentration insures fair economy in bleach and steam, but they are intermittent in their action, and, in consequence, there is considerable loss of time in filling and emptying. The stock, after it has acquired the right degree of whiteness, is emptied into the chest beneath, from whence it is pumped to the washing and drying machines. The names of

Kellner, Partington, Bellmer, Hromadnick, and others are identified with bleaching engines and systems of this kind.

Bellmer Bleaching Process.

Probably the most successful of these systems is the Bellmer Bleaching Process. The following description of this system is furnished by the makers: The propellers are erected outside the bleaching engines on a cast iron foundation plate. They are connected with the engine tub by means of flanges and enclosed funnels projecting in the walls of the tub.

The propellers are driven by a simple open belt running from above or below the floor. When electric motors are used the propeller axle is direct-connected to the motor. The frame can easily be opened at any time by removing the top, and all parts can be easily removed for cleaning or inspection.



Courtesy: Moore & White Co., Philadelphia, Pa.

Fig. 89.—Bellmer bleach tanks showing propellers.

The tub is generally made of concrete or brick and is lined inside with tile, these tiles requiring little cleaning and protecting the inside of the tub from the injurious action of the bleaching fluid. Moreover, the tile lining reduces the friction of the material against the sides and bottom and helps to keep the bleach liquor clean. The tub has no dead points and is designed with enough bottom fall to insure perfect circulation. The dimensions of the tubs can be altered to suit local conditions and they can be installed singly or in batteries.

Double acting propellers with three running channels are best, but single acting propellers can be installed when desired for installations handling less than 8,000 pounds and are very useful for connecting up with already existing bleaching tubs of the usual form.

The advantages of this system are claimed to be as follows: The propeller admits the thickest material and will move the contents sufficiently rapidly to be economical. The mixing of the bleaching liquor with the stock is thorough. Formation of scum and knots is avoided. No separate stuff pump is required. Various kinds of stock can be mixed while the bleaching operation is going on.

It has always been the aim of pulp bleachers to invent a continuous system, or one that is nearly so, and quite a number of such have been constructed and operated for many years in Europe and America. Such plants are known in Great Britain as the "tower system" and in America as the "continuous tank system." Neither of these fulfills the most perfect conditions for bleaching, although the tower system is thought to be the better of the two. The towers are usually concrete tanks, with or without conical bottoms, connected together by channels or passages.

Continuous Tank System.

This consists of six or more circular concrete tanks 12 feet in diameter by about 20 feet deep, connected together with passages or pipes, at top and bottom alternately. These tanks have flat bottoms and agitators driven by spur gearing at the top, which keeps the pulp in continuous motion. The pipes or passages connecting the tanks at the bottom, are all on the same level, but those for the overflow from 2 to 3, 4 to 5, 6 to 7, and so on through the series, are all on different descending levels, in order to permit the pulp to flow by gravity from the first to the last tank in the series in the direction as shown by the arrows.

Instead of the stock flowing by gravity, it is sometimes pumped from one tower to the next in series. This obviously is forced circulation, and has certain advantages over circulation by gravity, but can scarcely be called a continuous system. It permits of greater concentration of stock, a stronger bleaching fluid in intimate contact with the fiber, and economy of steam for heating when hot bleaching is employed, but under the best conditions, seldom more than 4 to 4.5 per cent stock can be handled, which in the opinion of many is too dilute to yield the most economical results in any continuous system.

Skjold[1] describes a method of continuous bleaching in which he employs a series of flat-bottomed upright circular tanks, built of concrete and containing agitators, four or more tanks being employed in the series, connected by an arrangement of pipes, so that the pulp can be pumped from one to the other continuously, or circulated at will from the bottom on the top of each tank; a mixing tank is provided between the wet machine and the first bleaching tank, for mixing the sheet of wet pulp with water of

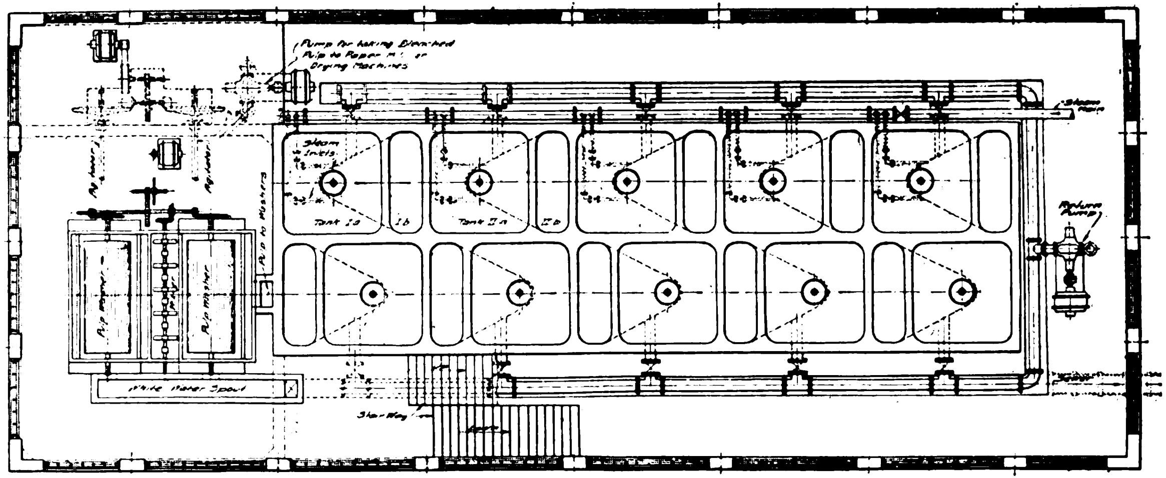
[1] Svensk Pappers-Tidning, 1905, No. 15, pg. 85.

50° C. (122° F.) and bleaching powder solution of 3.5° Be. The bleached pulp leaving the system is washed on wet machines before it is dried. The tanks in this system are each 4.9 meters in diameter by 8 meters deep, giving a total capacity for the four, of about 600 cubic meters, and it is stated, that from forty to forty-five tons of air-dry pulp can be bleached in twenty-four hours, equivalent to nearly 500 cubic feet of tank space a ton a day. This is a large output, which is made possible, perhaps, by the high temperature employed—viz: from 130° to 140° F. The operations of this system are somewhat broken, and Beveridge states that it is doubtful if these conditions as to output could be maintained in constant practice, unless the stock treated were of the easiest bleaching character.

J. E. Heiskanen, in his apparatus (U. S. Pat. 1,277,926), has overcome certain difficulties and has greatly simplified the continuous system. All stock pipes, centrifugal pumps and agitators, are eliminated, the inventor substituting for these propellers for mixing, agitating and circulating the stock through the whole system. These propellers are driven by small motors and as he attains a density of 6 to 8 per cent stock he fulfills the best conditions for economy of bleach liquor and economy of steam for heating. The floor space occupied by the plant is about half of that required for the "continuous tank system" mentioned above.

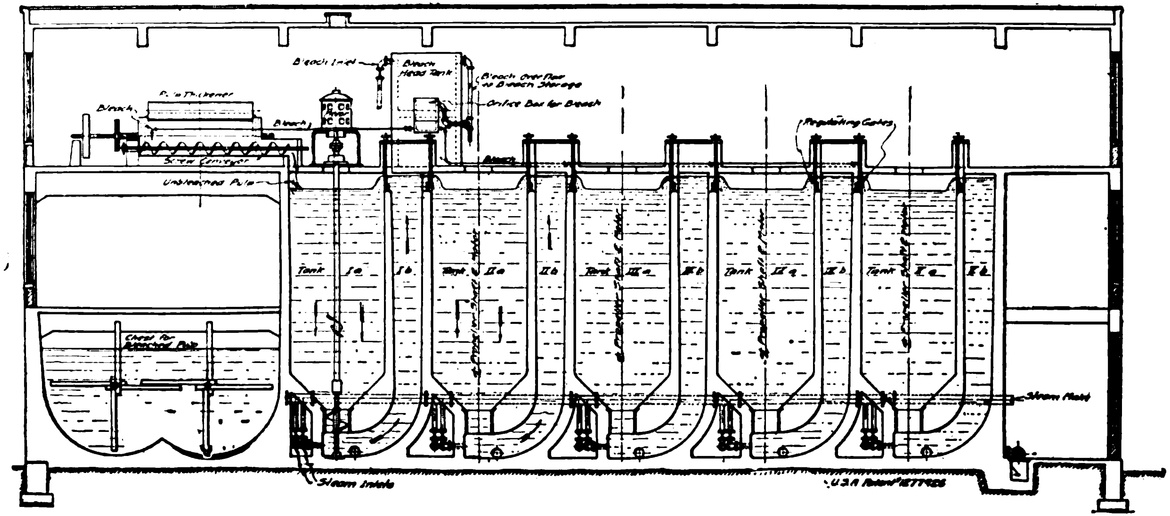
The unbleached pulp falls from the pulp thickener into the screw conveyor where it is mixed with the necessary quality of bleach liquor and hot water, the mixed stock being conveyed automatically into the first bleaching tank Ia. The fiber in this tank is forced upwards by the propeller to the top of Ib, where the stream is divided by the regulating gates into two parts, one part giving back into Ia, while the other part flows into IIa. The proportion going forward into IIa varies from one-tenth to one-fifth of the total volume passing the propeller, so that the stock in Ia is kept circulating vigorously and is in continual motion. These regulating gates are placed at the top of Ib, IIb, IIIb, and so on through the whole series, the flow forward from one tank to another being adjusted by them in accordance with the amount required, and kind of pulp to be bleached. Steam is introduced at the bottom of each tank imemdiately below the propeller to maintain a uniform temperature throughout the apparatus. After the pulp has traversed through the series of tanks it is discharged into the chest at the end, from whence it flows by gravity, or it is pumped, to washers and finally to the drying machine. The return pump is not essential and is seldom or never used, but is added to enable the operator to pump the stock a number of tanks back, if by accident insufficient bleach liquor has been added.

Heiskanen represents that his plant occupies half the floor space of the ordinary "continuous tank system"; that he can attain a density of 7 per cent stock on an average; and that by so



Courtesy: "Paper," New York.

Fig 89a.—Diagram showing plan of continuous tank system of bleaching.



Courtesy: "Paper," New York.

Fig. 89b.—Diagram showing elevation of continuous tank system.

doing the consumption of steam and bleach is reduced to a minimum. The consumption of power and labor is extremely low; for in the first case there is very little weight to be moved by the propellers, the columns of stock in Ia and Ib equalizing themselves, while in the second one man is sufficient to run the tanks from the first tank to the pulp chest. He also allows eight hours or so for bleaching and completes this with a total tank capacity of about 200 cubic feet a ton of pulp a day.

The plant as shown is capable of handling 100 tons of pulp a day, is well designed, and as it is constructed of concrete, lined internally with glazed tiles if so desired, and fitted with bronze working parts in contact with the fiber, the risk of iron spots appearing in the dried pulp is avoided.

Bleach Consumption.

The amount of bleach required for any particular lot of stock depends, as previously explained, on many factors. We are of the opinion that the majority of mills use more bleach than is necessary. There is a tendency to use bleach liberally, getting rid of any excess of bleach with antichlor. This is wasteful and expensive.

Griffin and Little give the following figures for the amount of bleach required for 100 lbs. of different fibres:

Rags	2 to 5 lbs.
Straw	7 to 10 lbs.
Esparto	10 to 15 lbs.
Soda (poplar)	12 to 15 lbs.
Soda (spruce)	18 to 25 lbs.
Sulphite (poplar)	14 to 20 lbs.
Sulphite (spruce)	15 to 25 lbs.
Jute	10 to 20 lbs.

Use of Steam in Bleaching.

Raising the temperature hastens the bleaching process, but it considerably increases the consumption of bleach as chlorine is less soluble at the increased temperature and tends to boil out of the solution. Moreover, too high a temperature causes the bleach to attack the cellulose of the fibre itself, giving rise to compounds which cause a yellow color and a lessening of strength in the paper.

Any economical system of bleaching must involve a high density of stock, primarily to economize steam for heating. This is a very important factor. The following is Beveridge's formula for calculating the amount required, which is applicable to every case of hot bleaching:

$$\frac{(W\,S + W'\,S' + W''\,S'' + \ldots\ldots)\ (tf - ti)}{T - tf} = S$$

in which

S = Lb. of steam required.
W = Wt. of air-dry pulp in the charge, in lb.
s = Sp. heat of air-dry pulp (0.65).
w′ Wt. of water associated with the pulp in lb.
s′ = Sp. heat of water (1.00).
w″ = Wt. of vessel in which pulp is bleached, in lb.
s″ = Sp. heat of material of which w″ is constructed.
ti = Initial temperature of stock in degrees Fahr.
tf = Final temperature of stock in degrees Fahr.
T = Total B. thermal units in 1 lb. of steam used for heating.

From this formula the following quantities of steam required for different densities of stock bleached at different temperatures have been calculated, taking the initial temperature t, as 60° F., the final temperature tf, as 90, 100, 110 and 120° F., and the total British thermal units in one pound of steam T as 1,190, i. e., steam at 110 lbs. pressure above atmospheric.

Density of stock		Water associated with 2000 lb. air-dry pulp	Lbs. of steam required to heat the mixture containing 2000 lb. air-dry pulp to			
Pulp	Water		90° F.	100° F.	110° F.	120° F.
3%	97%	64,666 lb.	1881	2421	3053	3699
4%	96%	48,000 lb.	1427	1809	2282	2764
5%	95%	38,000 lb.	1154	1442	1819	2203
6%	94%	31,333 lb.	972	1197	1510	1830
7%	93%	26,571 lb.	842	1023	1290	1562
8%	92%	23,000 lb.	745	892	1125	1269

Note: This table is based on the above formula but the weight of the apparatus w″ has been eliminated. Three per cent should be added to the above quantities of steam in cols. 4, 5, 6 and 7 to allow for loss of heat by radiation.

Antichlors.

The complete removal of surplus bleach by washing being a very slow operation, many mills remove the last traces of bleach with an antichlor. The ordinary antichlor is hyposulphite of soda or sodium thiosulphate (which are just two names for the same chemical). Sodium sulphite, calcium sulphite and sulphite waste liquor have been used also as antichlors.

Blueing.

A small amount of blue (ultramarine or some other blue) is frequently added to offset any slight yellowness that may be left after bleaching. Sometimes this is done with pulp that is to be offered for sale to cover up imperfect bleaching. The addition of even very little blue soon becomes apparent to the eye of the expert. It can best be detected by rolling a lap of the pulp into a tube and looking into it by a clear north light, or by looking into a folded lap as into the pages of a half open book.

Use of Acid in Bleaching.

Some paper makers add a little sulphuric or other acid in bleaching. This is often alluded to as "souring." The acid is generally added towards the latter stages of the bleach when the stock has almost reached the required degree of whiteness. The action of the acid is that it neutralizes the lime salts and facilitates the liberation of chlorine. Probably the chemist would consider the above explanation inadequate, but the chemistry of this process is really quite complicated. The above is, however, the general effect. Acetic acid is considered less harmful to the stock than mineral acids, and for that reason is favored by some paper makers.

Electrolytic Bleach.

Many paper mills have introduced electrolytic plants for the production of their own bleach. It is beyond the scope of this work to explain in detail the construction and operation of such plants, which is really more a matter for chemical and electrical engineers than for paper makers. However, very simple and efficient installations have been designed which, when once installed, can be operated by the usual force of a paper mill without any special skilled attention.

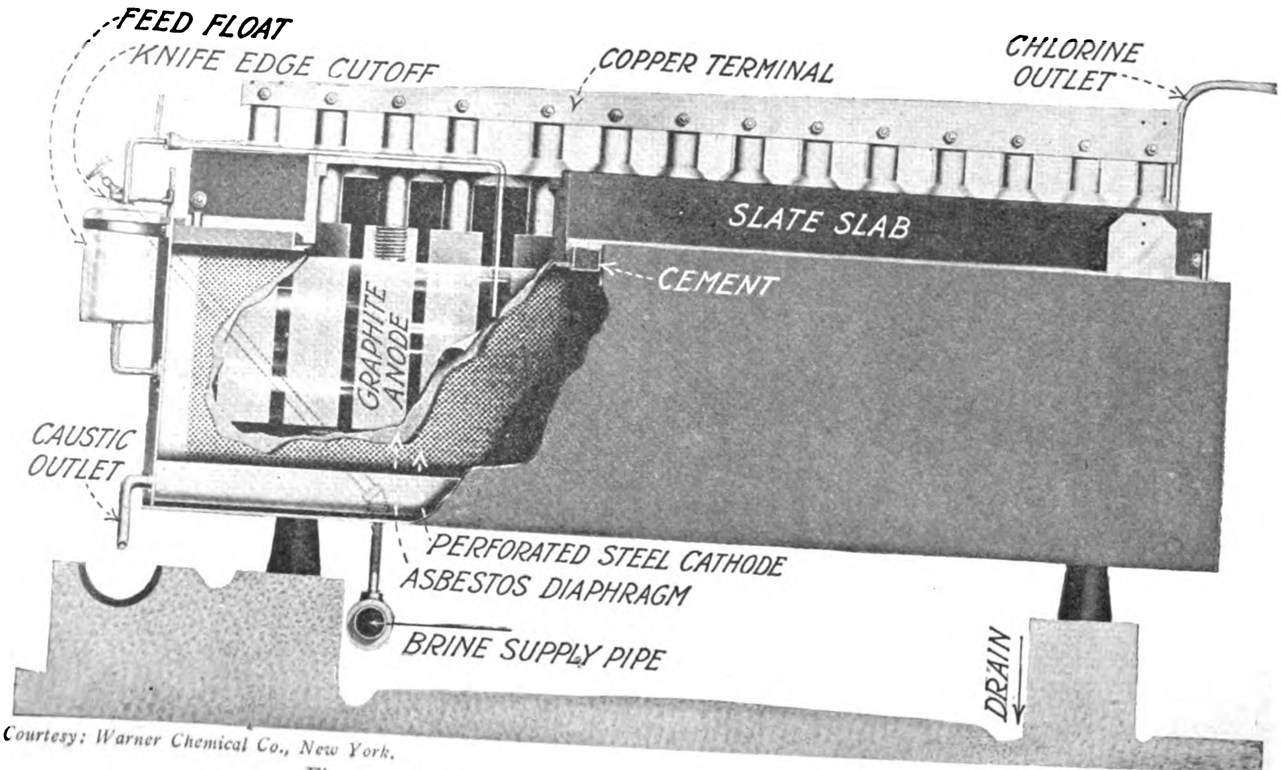
There are a number of cells on the market for this purpose, of which the Allen-Moore, Nelson and Wheeler are excellent examples. They all operate by allowing an electric current to pass through a solution of common salt, decomposing it into chlorine and hydrogen. In all but a few very large plants the hydrogen is allowed to go waste. One large paper mill in New England uses the hydrogen to hydrogenate oils and to make hydrochloric acid which they sell. This is an example of what can be done in the way of utilizing by-products. The chlorine is led into vessels where it reacts with milk-of-lime to form bleach liquor which is used directly in the bleaching process. Caustic soda is also produced as a by-product, and if no use can be found for this in the mill it can be concentrated and sold.

Another type of cell does not separate the products of the electrolytic action and produces sodium hypochlorite liquor, which is used as bleach instead of bleaching powder solution.

Many pulp and paper mills being located where water power is plentiful and, in consequence, electric current comparatively cheap, and being distant from points where bleaching powder is manufactured, find the manufacture of their own bleach a very profitable proposition.

Bleaching Ground Wood.

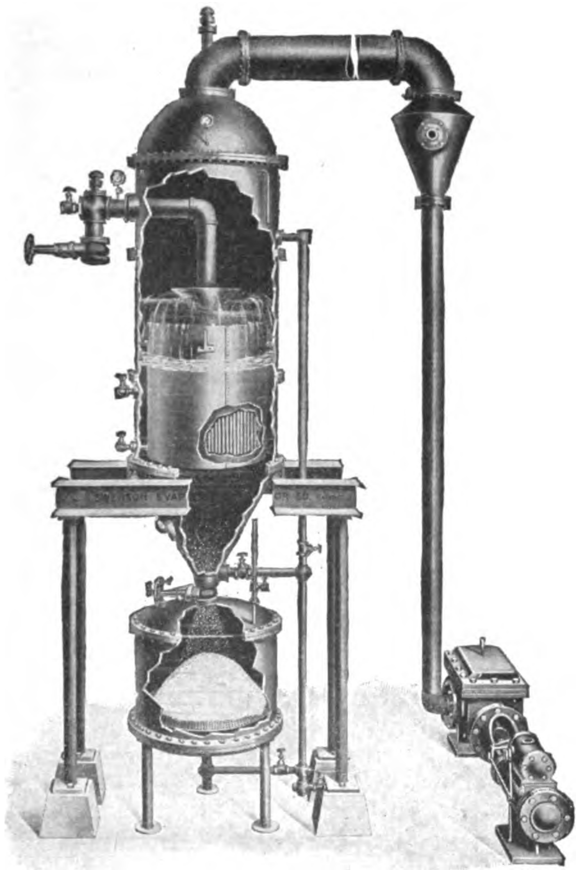
The bleaching of ground wood is a very difficult matter as this class of pulp contains all the intracellular matter of the original wood. Moreover, there has been little demand for this product



Courtesy: Warner Chemical Co., New York.

Fig. 90.—Typical cell for manufacturing electrolytic bleach.

in America. In Europe, however, the bleaching of ground wood has developed to quite an extent. The bleaching agent is sodium bisulphite and the operation is carried out on a wet machine, the top press roll of which is equipped with two small felt covered rolls. Above the upper roll is a hard lead spray pipe. The



Courtesy: Swenson Evaporator Company, Chicago, Ill.

Fig. 91—Type of evaporator used for concentrating caustic soda produced as a by-product in the manufacture of electrolytic bleach.

bleaching solution is sprayed by this pipe evenly on the upper roll, from that it is transferred to the lower of the two small rolls, the intention in this arrangement being to equalize the distribution of the bleach, and from the lower small roll to the sheet of pulp that is winding up on the top press roll. Difficulty has been met with owing to the perforations in the pipe clogging up. A patent distributing box intended to overcome this difficulty has been invented by Schutz (U. S. P. 1,208,670). The sodium bisulphite is used in 2 or 3 per cent solution.

Bleached ground wood is never as bright and white as bleached sulphite. It can always be detected in paper very easily as the bleaching does not prevent the fibre from showing the usual deep red coloration characteristic of ground wood with phloroglucinol.

Bleached ground wood has found its chief application in light weight papers where opacity is desired. It will increase the opacity without decreasing the tensile strength as much as a sufficient quantity of filler to produce the same result would.

For ground wood for bleaching dull stones and high pressure should be used, but this should not be carried so far as to unduly decrease production. In Austria excellent tissue paper is being made from 30 per cent bleached rag, 30 per cent bleached sulphite and 40 per cent bleached ground wood. It has also been used for cheap book and magazine papers.

XII. The Beater Room.

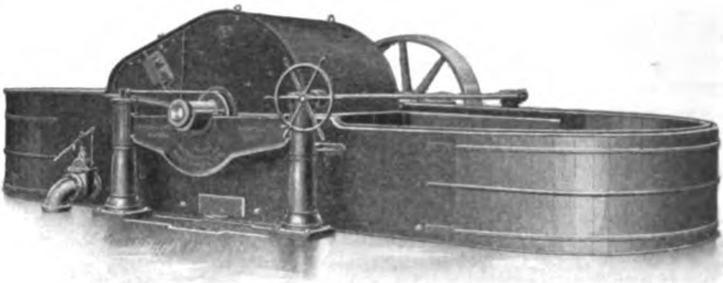
The manufacture of paper, as distinct from the manufacture of pulp, starts in the beater room. In studying the preceding sections, dealing with the various processes for making pulp, it should always have been kept in mind that pulp is not paper—it is merely one of the raw materials of paper, of which there are a

Fig. 92.—Typical beater room.

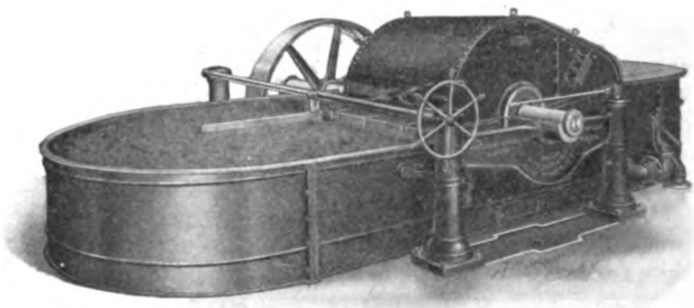
number of others of lesser importance, e. g., clay, size, colors, etc. There are many large paper mills which do not manufacture any pulp at all, buying all their raw material from other plants which stop with the manufacture of pulp and do not proceed to make it into paper.

Beaters.

The beaters, or beating engines, are large, oval, tank-like machines constructed of 3 or 4 inch cypress or other suitable planks.



Courtesy: E. D. Jones & Sons Co., Pittsfield, Mass.
Fig. 93.—Wood tub beater.



Courtesy: E. D. Jones & Sons Co., Pittsfield, Mass.
Fig. 94.—Iron tub beater.

The dimensions vary according to the requirements. The following is a table of the sizes and dimensions of the beaters made by one prominent American manufacturer of these machines:

APPROXIMATE DIMENSIONS AND CAPACITIES OF BEATERS

Length	Width of Tank	Size of Roll	Capacity lbs.	R.P.M.
15' 6"	6' 6"	36" x 34"	300	165
17' 6"	6'11'	40" x 36"	500	148
17' 6"	6'11"	54" x 36"	500	110
18' 0"	7' 8"	40" x 40"	600	148
17' 6"	7' 8"	54" x 40"	600	110
18' 0"	8' 3"	44" x 44"	800	135
19' 6"	7'11"	58" x 42"	800	102
21' 7"	8'11"	48" x 48"	1000	124
21' 7"	8'11"	62" x 48"	1000	96
21' 7"	8'11"	54" x 48"	1200	110
23' 0"	9' 7"	65" x 52"	1200	91
23' 8"	10' 5"	58" x 56"	1500	102
24' 8"	10' 9"	67" x 58"	1500	88
24' 2"	10' 5"	62" x 56"	1600	96
24' 8"	10' 9"	72" x 56"	1600	82
25' 8"	11' 2"	60" x 60"	1800	99
26' 2"	11' 2"	72" x 60"	1800	82
26' 8"	11' 6"	62" x 62"	2000	96
27' 9"	12' 2"	72" x 66"	2000	82

A usual size is about 25 feet long by 11 feet wide. Such a beater will hold about 1,500 pounds of completed stock. The usual height of the walls of the beater is about 3½ feet.

Some beaters are constructed of iron, having cast iron or steel plate sides and ends, and a bottom of wood, cast iron or concrete. Concrete beaters are also used. In such cases the customer furnishes the concrete construction and the roll, bearings, bed-plate and various fittings are supplied by a manufacturer.

Extending through the middle of the tank, parallel with the sides, but stopping short of the ends by about three feet, is a sturdy fence-like partition called the midfeather. The mid-

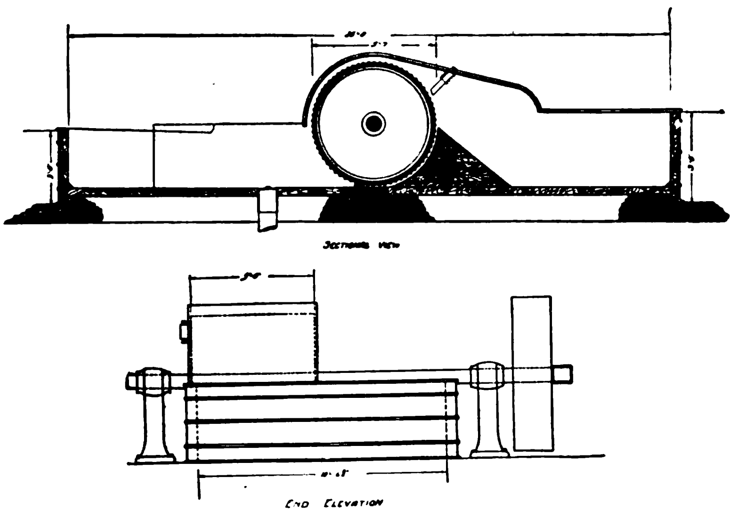


Fig. 95.—Diagram showing side and end elevation of typical beater.

feather may be of either wood or iron. On one side of the tank, filling the space between the midfeather and the wall, is a cylindrical beater roll. This roll is so proportioned that its diameter is about equal to its length, the exact dimensions varying with the size of the beater, an idea of this being given by the preceding table. This roll is equipped with 78 steel bars or knives, each about 8 inches wide and ¼ to ½ inch thick. At the bottom of the tank, directly under this roll is a bed-plate, extending the full width of the roll and shaped so that its upper surface is parallel with the surface of the roll. The bed-plate is usually about 16 inches wide and 5 inches high and it contains 42 knives. These knives are not set exactly parallel with the knives of the roll. They are usually arranged at an angle or in a V-shaped arrangement, as shown in the illustration.

The details of the construction of the roll and bed-plate will be dealt with later in this chapter under the heading "Maintenance of Beater Room Equipment." Such a beater as we have described is frequently spoken of as a Hollander or Holland type beater. Other special types of beater departing widely from the above description, but intended for the same purpose, have been designed. A few of the more important of these will be described later, but the above description covers the usual type of beater in paper mills throughout the world.

When the beater roll revolves each of its 78 roll bars or knives comes in contact with each of the 42 knives of the bed-plate, so that the roll will give 3,276 cuts for each revolution.

With the roll running at a speed of 100 revolutions per minute, it is apparent that there will be delivered 327,600 cuts per minute to any material forced between the roll and the bed-plate.

The beater-roll weighs several tons and may be raised from, or lowered upon, the bed-plate by "Lighter-Bars," which carry the roll in strong journals. Such movement is rendered very accurate by having a hand wheel geared to it in a pretty large ratio. Thus the roll may be changed in its relation to the bed-plate a very small fraction of an inch. These fine adjustments are frequently necessary.

Into the beater the beater help feed the various ingredients of the paper as determined by the "Formula." When it has been found by experience that a certain percentage of sulphite pulp, a certain percentage of Kraft (sulphate) pulp or of ground wood, so much coloring matter, so much "fixing" solution, size, filler, etc., is required to produce a certain definite grade of paper, these percentages are rigidly adhered to every time a run of this paper is made.

Naturally, such measurements and chemical treatment cannot be carried out by guesswork. The percentage of the various ingredients are reduced to terms of weight (the various pulps, sulphite, sulphate and ground wood being fixed on a "5 per cent air-dry" basis) and the "Furnish"—this being the phrase by which the exact formula of a given *grade* of paper is known—is built up accurately on exact scales.

When a large mass of pulp is placed in the vat (which is capable of holding 1,500 pounds of completed paper-stock) the revolving of the roll will draw the material between itself and the bed-plate and cause a general circulation of the material, around and around the tank, since the midfeather gives us a perfectly oval path for the "stuff" to travel in.

Sand Trap: A short distance in front of the roll, a small box or trough extending from the side of the beater to the midfeather is set in the floor of the beater. This trough is covered with a screen plate. It is known as a sand-trap and it serves to eliminate small particles of grit and dirt which, on account of their weight, stick to the bottom of the stock as it circulates around the beater. This is used only for fine papers.

Backfall: As the beater-roll turns up the material rather sharply behind it, a cover or decking is necessary at that part, and a little beyond, to hold the mass down to its proper level and prevent its being thrown out of the beater. Immediately behind the beater-roll is a device known as the "Backfall." This is a hump or elevation constructed of wood covered with steel plate, the side of which nearest to the beater-roll conforms in shape to the roll. The pulp is propelled upwards between the beater-roll and the backfall and strikes the cover of the beater which gradually smooths out the flow so that the pulp again becomes level in its travel around the beater before coming under the beater-roll the next time. The tendency to mount up and overflow behind the beater-roll is much more marked in the case of the heavy viscous stocks—such as those containing a high percentage of Kraft pulp.

Doctor: Immediately above the backfall and behind the roll is a doctor consisting of a heavy board with a cast iron edge. This doctor is arranged so as to just clear the surface of the roll and prevent any stock being carried around with the roll, deflecting it back over the top of the backfall.

String Catchers: In beating certain classes of stock such as waste paper, jute, etc., strings, rope, wire, etc., are frequently present. The string catcher is a device consisting of a series of bars or fingers secured to a steel shaft which extends over the path of the stock in the beater. The shaft and fingers form a sort of fork or rake which will catch any pieces of string or rope without seriously impeding the flow of the stock. A hand wheel is provided by means of which the device can be raised or lowered, as required. This device not only prevents string and rope from being mixed with the stock but also prevents such material from winding around the beater shaft where it would cause a great deal of trouble.

Emptying and Wash-Out Valves: Various arrangements are used for emptying the stock from the beater. One of the commonest is an iron disc resting on a circular seat. In the center is a depression spanned by a cross-bar by means of which the disc is lifted out of its seat, allowing the stock to flow out of the beater. This device has the objection that the opening is relatively small, thus increasing the time necessary to empty the beater. Moreover, if any pressure is created in the stock chest, for instance, when one or more other beaters are being emptied, the disc may be forced up, allowing the contents of the beater to be prematurely dumped. This is guarded against sometimes by a lock type of valve, as illustrated. However, this is no more rapid in operation than the ordinary type and involves fumbling with a locking device at the bottom of a beater full of stock.

Much better are special quick-emptying valves, which are operated by a lever outside the beater. The disc is carried on a riser operated by a series of levers. A spray of water is also provided with this type of valve which assists in the rapid removal of the stock and also keeps the valve seat clean and free.

A still further improvement is a patented stock emptying valve of oblong shape about 6 inches wide located in the bottom of the engine just in front of the roll, extending right across from the midfeather to the side of the beater, its top being flush with the bottom of the inside of the engine. The valve cover lifts up along the side furthest from the roll, and when raised to a vertical position becomes a dam, aiding in forcing the stock out of the beater. It is operated by a shaft extending through the side of the beater and having a lever at its outer end. A shower of water is provided to help the stock out of the beater and to keep the valve seat clean. With an adequate

Courtesy: Noble & Wood Machine Co., Hoosick Falls, N. Y.

Fig. 97.—Disc type of emptying valve for beater.

discharge pipe (not less than 18 inches diameter), the stock can be removed from the beater almost instantly without using any rakes and with a minimum of labor. With the ordinary disc valves the use of rakes is generally imperative.

Function of the Beater.

Referring to the roll and bed-plate of the beater as containing "knives" may possibly have caused the reader to think that the main purpose of this machine is to cut the fibres to a given length. While the machine admittedly is used for this purpose, this is not its only function—or its most important one. No less vital than the cutting of the fibres to a certain length is the separating of the *bundles* of fibres (which will exist to a certain extent in even the best grades of sulphite and kraft pulps) and to *brush* or *stroke* the fibres into greater flexibility.

The tiny fibres are *stroked out* by the blunt knives of the beater, in somewhat the same manner that a hairbrush strokes out human hair, and moreover the fibres are caused to *curl at the ends.*

Upon the ability of these fibres to curl and connect with each other, when allowed to "bond" (by removal of the surrounding liquid) depends the strength and toughness of the resulting *paper*. If these fibres are not drawn out to the correct degree, they will not grasp and entwine with each other in the manner which we denote by the term "felting."

It will readily be appreciated that not only must the fibres be "brushed out" and made flexible, but—in order to obtain a sheet which will have strength and thickness—*the fibres must be kept long in the beater.* This applies with particular emphasis to papers of light *basis-of-weight*, of which a great deal is expected—as, for example, fine writings, ledger and bond papers and 28- and 30-pound kraft wrapping and bag papers.

Now, if we are to have a consistent length maintained, it will be seen that (whatever its shape and size) a beating engine must be smoothly constructed so that no stuff can lodge and stay in any part of it, but must circulate uniformly around and around, and beneath the roll again and again. Fillets are provided in the angle between the sides and bottom of the beater so that no stuff can lodge and remain in a position where it does not come under the action of the beater-roll, as might be the case if the sides and bottom of the beater joined at a sharp angle.

Moreover, the roll must be heavy enough to soften thoroughly all pulp and keep it in constant motion. Another great desirability in a beater, is to be able to adjust it so minutely as to give us the exact length and quality of fibre we desire—and to maintain the entire output completely uniform.

While we have stated that *long* fibres are vital in certain classes of paper, it is equally important that we must not have them *too long.* Else the paper produced will actually possess less firmness and tensile strength than if the fibres had been a little shorter. This is true because of the paper machine's inability to mesh and quickly drain paper-stuff containing fibres that are beyond a certain length. This point will become clearer after we have discussed the construction and operation of the paper machine.

But, whether the fibres are to be long or short when they reach the paper machine, the basic properties of the paper will depend on the treatment they receive *during the first hour and a half* in the beater. If the roll be put down sharply on the plate at first, the fibres may retain their length, but they will be considerably weakened, and the sheet will have a raw, soft feeling. Such stuff is generally termed "fast" or "free."

In brief, the beater is not an automatic machine. It is an instrument—and one that requires intelligent and experienced control. An inexperienced or careless operator can easily ruin an entire charge of material—especially during the first hour and a half.

The "rawness" alluded to above as caused by putting the roll too sharply down on the plate at first, is often quite noticeable in papers made from kraft pulp. In the *thin* papers of this class, the idea that length of fibre necessarily means ***strength*** is so often over-stressed that, when the pulp reaches the paper machine, a considerable portion of it refuses to drain properly. The whole matter (as intimated above) lies in the fact that a great part of the worth of the resulting sheet of paper is contingent upon the behavior of the fibres in meshing readily on the paper machine.

Under a microscope, a sheet of thin paper will often exhibit *spaces* between the long fibres, which seem to be filled with a transparent, non-fibrous material. The longer the fibres, the more apparent these spaces will be—and, however minute, their presence must tend to *weaken* the sheet. With fibres just a shade finer, the finest of all will, on the paper machine, tend to settle into these spaces, more closely felting the whole sheet.

So that, while as a general proposition the long fibre does lend the sheet its great strength, it should be borne in mind that this is not the entire value—and that good stock for light, strong papers requires a certain free fibre to be present as well. This will be explained in greater detail when we come to talk of the paper machine, but it is necessary to allude to the fact now in order to illustrate the problems that arise in the proper handling of the equipment of the beater room.

On the other hand, in preparing stuff for *thick* papers, the roll can be put down much sooner after the beater has been furnished. This is so that the stuff may be fine and free, parting with water readily on the paper machine, and giving a close, easily felted sheet. But there is danger here in going to extremes and making the stuff too soft and fine, so that we must not run it too long in the beater.

Blunt plates and rolls are used for stock intended for thin, strong papers which must be kept in the beater for at least six hours, during which time sharp knives would cut it up altogether too much (making it too free) and preventing it from felting properly on the machine. For preparing such stock the Jordan and other engines, subsequently to be described, are very useful, the stock being beaten a shorter time and finished in the Jordan. In the thick, heavy papers sharper plates and rolls may be used, and the stock is not held nearly so long in the beater. For instance, stock for blottings is frequently only kept in the beater an hour and a half.

From the above considerations the reader will be able to understand why the beating time varies over such a wide range in preparing stuff for different grades of paper, ranging all the way from merely mixing the stock and color and then dumping in thirty minutes, to combing out and beating for eight hours or more.

When a large proportion of ground wood is involved, (as is the case with some of the cheaper varieties of bag paper, etc.), the beaters must not be heavily loaded (that is, only a comparatively small amount of stuff can be handled in one batch), nor allowed to run very long, since this class of fibre is naturally reduced very quickly, and soon arrives at the state known among paper-makers as "slow stuff"—that is, not draining quickly and properly on the paper machine, which is conducive to poor quality and cuts down the productive efficiency of the paper machines seriously.

When excellent folding qualities are especially desired—for instance, in paper to be used for the manufacture of bags—the beating time is protracted, but under these circumstances the roll is lowered only enough to give a *very gentle rub*.

It is always preferable to use separate beating engines for the extremes of adjustment illustrated above. Or, in other words, the beater that is used for greasy slow stuff should not be used for short ground wood fibres. With even the most careful manipulation and adjustment, there is a certain range over which a beating engine operates most efficiently.

Notwithstanding the degree of nicety with which (by means of the hand-wheel geared to the lighter-bars), the roll can be raised or lowered, regulating very minutely the superficial pressure exerted on the ultimate fibres, the stuff produced with sharp bars is inevitably weaker (even if the ultimate fibres be of full length) and it will lack the greasy, well-beaten feel, indispensable in the production of thin, tough papers.

Moreover, long experience has demonstrated that a light beater-roll will draw out fibres much better than a heavy one, even though it takes longer to do it. The crux of the whole matter is the superficial pressure exerted on the fibres by the beater-roll—since, with sharp bars, *the pressure is increased in proportion as the area of the bearing-and-cutting surface is reduced.*

Consequently, it is necessary to determine the type of the beater engine in accordance with the special requirements of the paper it is desired to produce, whether this be newsprint, writing paper, bag paper, etc.

In the manufacture of some grades of newsprint, with a large percentage of ground wood, a treatment in *agitators* sometimes precedes the treatment in the beater. These agitators are simply large tanks provided with mechanically driven stirrers to keep the stock in circulation. The pulp is treated with size and alum, and held in the agitator sufficiently long for the size and alum to penetrate the fibres. This is called "soft stock" as opposed to sulphite, which is "medium stock," and kraft would be a good example of "hard stock."

Numerous forms of testing instruments have been devised for determining the control of the beater operation, but the human element still governs it to a high degree. The appearance of the stock in the beater and the feel when a handful of it is picked up are the chief points on which the experienced operator relies.

Even the novice, if of an observing nature, will notice that when the stock is first admitted to the beaters, it is cold, bulky and fills the beater to the brim. This appearance will be kept up for some time, the stock breaking at various intervals, just before it passes under the beater roll. As the operation proceeds, however, there is a slight rise in temperature, the stock tends to sink more to the bottom, and at intervals it will *shine* on the surface.

After the stock has been worked in the beater it has a characteristic feeling, quite different from that of unworked stock.

Courtesy: Noble & Wood Machine Co., Hoosick Falls, N. Y.

Fig. 96.—Beater hydrant.

The hand will pass through it freely and it will be slippery and "greasy" so that it is practically impossible to retain any large amount in the hand when squeezed. An experienced papermaker, by taking up a handful of stock in a beater, can generally tell how long the stock has been beaten, and how long it will still have to go, from the feeling alone, even if he has no other source of information.

As the treatment the stock requires in the beater depends extensively on how it has been cooked in the digester, it is not possible for the workman in charge of the beater to operate under any fixed rule. Consequently, he must be a man of experience and good judgment. Procedure that may have produced good stuff from stock resulting from a certain digester cook would have to be altered materially to deal with the next cook produced under slightly different conditions.

Furnishing Lap Stock to the Beater: The beater should be filled up with water until the roll begins to circulate the water.

Assuming that the furnish is to consist of sulphite and ground wood, the sulphite should be furnished first, the laps being carefully opened before being placed in the beater. During the furnishing the roll should be away from the bed-plate sufficiently far to prevent it from jumping as the laps of stock go through. After the sulphite has all been furnished, the ground wood is put in. The roll should be kept up off the bed-plate until the laps are thoroughly disintegrated, then the roll can be lowered to the degree decided on by the beater engineer. Size, color and alum can then be added in the order mentioned. A sufficient interval of time should be allowed to elapse between the furnishing of each of these ingredients so that each will be thoroughly worked up with the pulp before the other is added.

In making paper from kraft and sulphite separate beaters should be used, as if it is attempted to beat them in one and the same engine, the sulphite will be overbeaten long before the kraft is properly worked up. The best way is to use two beaters, one for the sulphite and one for the kraft and to mix the stock in a chest after the beating is completed.

In making a paper 75 per cent sulphite and 25 per cent kraft, for instance, six beaters could be used, five on kraft and one on sulphite. The sulphite can be dumped after half an hour's beating whereas the five beaters working on kraft will be kept running six hours or more.

In making book and writing papers, the beaters must con-constantly be stirred, special attention being paid to the corners where, in spite of fillets, stock will accumulate.

The treatment the stock receives in the beaters depends to some extent on what is going to happen to it next. The next operation—treatment in the Jordan Engine or some other type of refiner—is generally co-related with the treatment in the beater, and the work of preparing the stock for the paper machine divided between them. Before treating of the Jordan Engine, however, we will discuss some of the materials which are ordinarily added to the stock in the beaters. The chief of these are, clay, size, alum, talc, coloring materials, etc.

Clay.

Paper made of fibre alone is more or less transparent, the degree of transparency depending chiefly on the thickness of the paper, but also on the nature of the fibrous material itself, some kinds of fibre being more dense and opaque than others.

In order to overcome the transparency of thin papers such as newsprint and also to give the paper other desirable qualities (such as a better printing surface and a lessening of the friction when in contact with the type on the printing press), it is generally advisable to load such papers with some inert material.

Such inert materials used for loading are known as "fillers." The commonest of these fillers is Kaolin or China clay.

This substance occurs naturally, being a hydrous silicate of aluminum, formed by the weathering and disintegration of certain kinds of rock. It occurs throughout the world but until recently clay for the use of the paper industry has been procured chiefly from Great Britain. Lately deposits of clay suitable for paper making have been opened up in the United States and Canada. The majority of clay deposits throughout the world are not suitable for the use of the paper industry because of the presence of impurities.

The composition of clay will always vary owing to the presence of impurities but a good average sample should run from 47 to 50 per cent SiO_2; 34 to 40 per cent Al_2O_3; 12 to 15 per cent chemically combined water. The usual chemical impurities are iron, calcium and the alkalies. Clay containing more than one per cent iron should never be used as iron will impart color to the paper. For making good white paper, clay should be perfectly white in color, very fine and free from grit.

The following table taken from Griffin and Little gives an analysis of four clays (presumably British), suitable for the use of paper makers:

ANALYSIS BY GRIFFIN AND LITTLE

	I	II	III	IV
Moisture, loss at 100° C.	0.30	10.15	7.09	9.10
Combined water, volatile at red heat	12.27	10.77	11.27	12.79
Silica (SiO_2)	47.56	42.72	43.50	41.16
Alumina (Ai_2O_3)	38.12	33.44	35.48	35.84
Sesquioxide of iron (Fe_2O_3)	0.08	1.04	trace.	0.67
Lime (CaO)	0.39	1.61	0.17	0.42
Magnesia (MgO)	0.00	0.16	0.41	0.02
Alkalis	1.28	0.11	2.08	....
	100.00	100.00	100.00	100.00
Specific gravity of dry substances	2.8625	2.5585	......	2.5451
Grit by flotation test (per cent)	0.65	6.83	......	0.10

On page 233 is the analysis of a clay mined in Quebec, Canada, which is being used with satisfactory results by Canadian paper makers and a clay from the Aiken district in South Carolina which has also been found satisfactory.

Whether a clay is suitable for paper making, or not, cannot, however, be decided by chemical analysis, although all clays considered for use should always be analyzed to prove the absence of chemical impurities in excessive amounts. The physical properties of the clay are equally as important as the chemical properties. These physical properties are the result of the geo-

ANALYSIS OF CLAYS FROM U. S. AND CANADA

	Aiken, S.C.	St. Remi d'Amherst Quebec, Canada
Silica	45.67	46.13
Alumina	37.86	39.45
Iron oxide	1.48	0.72
Lime	0.05	none
Magnesia	0.01	none
Alkalis	0.80	0.29
Combined water	13.22	13.81
Per cent grit	1.88	not estimated

logical history of the clay. A detailed discussion of this matter would belong more in a work on mineralogy than in the present volume. However, the chief point is the presence of what the chemist calls "colloids" in the clay. This means that the fine particles of clay will remain in suspension almost indefinitely when the clay is mixed with water. It is the presence of this colloid structure that gives the clay the greasy, slippery, tenacious consistency when mixed with a small quantity of water, which is characteristic of all good clays. Further on we shall give some simple tests by which the paper maker can determine whether a clay is suitable for his use from the standpoint of physical properties.

American Clays vs. British Clays: There does not seem to be any good reason why American clays should not be more used in this country than they are. However, trade tends to follow beaten paths, and even during the war when trans-Atlantic shipment was uncertain and expensive, large tonnages of Britisn clay were imported.

According to T. Poole Maynard,[1] a chemist with experience in the clay industry, American clays are available in immense tonnages of superior quality to any now imported from England.

The use of American clays is gradually increasing. In 1915 Georgia and South Carolina produced 92,000 tons of clay suitable for paper making, and in 1916 125,000 tons. In 1916 the total tonnage of such clays produced in the United States was 200,000 and in the same year more than 250,000 tons were imported from England. The production of clay for paper making in the United States decreased in 1917 and 1918 owing to lack of labor; it is now again on the increase.

Preparation of Clay: In preparing clay for the market, the crude product is thoroughly washed with water and the gritty impurities allowed to settle in large tanks. From these tanks the water is decanted off before the fine particles of clay have had time to settle. The clay is then allowed to settle in tanks

[1] Paper before the Technical Association of the Pulp and Paper Industry, 1919.

from which the clear water is siphoned off. The thick, creamy white sludge containing the pure clay is then dewatered in filter presses and the cakes dried and prepared for shipment.

Of course, the strength of any paper is weakened by putting in a filler with the fibre but since the surface, finish, feel and general characteristics of the paper are improved by the addition of fillers, it is generally advisable to do so. However, it requires experience and good judgment to determine in all cases just what proportion of filler should be used.

Clay is usually used as a filler in newsprint and the cheaper grades of writing and book paper. The better qualities of writing and book paper are usually loaded with special materials such as agalite, calcium sulphate, pearl hardening, barium sulphate, etc.

For use in the beaters, the clay is usually made into a thin cream with water, this generally being done in a small tank fitted with an agitator. Some paper makers mix the clay with rosin size before adding it to the beaters, it being believed that this procedure aids in the retention of the filler by the fibres.

A good clay should feel smooth and soapy between the teeth and should not scratch a finely polished metal surface. The best test for clay is to drop a few lumps of the dried clay into a glass of water and without stirring observe the behavior of it. A good clay will emit numerous bubbles with a slight buzzing sound and as the water penetrates, will gradually break down into a fine powder which rolls off from the surface leaving the lumps until finally it is all broken down into a powder.

Upon stirring up the mixture with more water, pouring off the fine milk, adding more water, stirring and pouring off, very few particles of clay will be left in the glass.

If instead of forming a fine powder which rolls off the surface of the lumps, the lumps crack into small pieces as the water penetrates them and these small pieces crack again and so on, the clay is not satisfactory and will give rise to "clay spots" in the paper.

Before adding clay to the paper it should always be screened through a wire cloth to remove any impurities that may have been left in the clay in manufacture or that may have got into it during shipment and storage.

The thinner the clay liquid is and the longer it can be stirred, the better it will be. There being fewer lumps to screen out, the screening will be more rapid and easy, a finer wire cloth can be used for the screening, and it will flow better through the pipes. A thick mixture of clay and water of this kind is called "slip."

A convenient strength of slip for furnishing to a beater is made by dumping a cask of about 2400 pounds of clay into a tank holding about 2400 gallons, partly filled with water, stirring and adding water until the tank is filled. This gives a "slip" each gallon of which contains one pound of clay. By this means, it is very easy to gauge the amount of clay being furnished to the beaters.

A good arrangement is to make up the "slip" in a small tank or box above the beaters. Hot water slacks clay more readily than cold water and it is of considerable advantage to warm the water especially in cold weather. When clay is slacked in the above manner, in small tanks or boxes above the beaters, and when any size is being used in the paper, it is a good plan to use hot water for slacking the clay and to dissolve the size at the same time.

The alkali of the size causes the clay to slack more readily to a fine slip. Alum, however, should never be added when slacking the clay as it makes the clay floculate together giving a slip of course consistency. Alum should, therefore, always be furnished separately and not mixed with the clay and water. Moreover, alum acts injuriously upon iron pipes, valves and agitators.

In mills where large quantities of clay are made into slip in large tanks and then pumped to the beaters, it is not advisable to mix the size with it, as it gives rise to much foam during the stirring and screening and when water is run into the tank for the next batch.

At frequent intervals samples of clay used should be sent to the laboratory, or to an analytical office, for chemical analysis and for physical and microscopical tests. Only in this manner can the mill be sure that the best quality of clay is being used and that too high a price is not being paid for the grade specified.

Soda pulp as a rule requires less filler than sulphite pulp because it is naturally bulkier and less transparent. However, with no kind of stock should excessive quantities of clay be used as it will dust off on the printing presses, contaminating the ink and giving poor results. The excessive use of clay is also a needless expense. as the fibre will only retain a certain amount and a great deal of clay will be wasted in the white water if too much is added. The proper amount to use for newsprint is generally about 5 per cent. The amount to be used with other grades of paper depends entirely on the effect it is desired to produce and must always be a matter of individual judgment and experience.

In making newsprint, when a mill is well equipped with save-alls and facilities for utilizing the white water, it is generally cheaper to use clay liberally and ground wood more sparingly. The exact balance betwen clay and ground wood in newsprint must, however, be worked out as a matter of practical experience. In ordinary news print about one-half of the clay furnished is retained, but this varies considerably according to local conditions. The amount of size used has a direct effect on the retention of the clay, but ordinarily in making the newsprint, no size is used at all except on special orders. Alum also has an effect on the retention of the clay but it is not desirable to use too much alum because it exerts a hardening effect on the paper. Moreover, it is not economical to use 2 cents' worth of alum in order to save 1 cent's worth of clay.

The only source of loss in the use of clay is in the white water which is allowed to run to waste, and if it were possible to re-use every gallon of white water and have none go to waste, there would naturally be no loss of clay or of fibre. Many efficient devices are on the market for recovering the clay and fibre from white water. See page 353.

Some paper makers object to the re-use of white water, liking to use plenty of fresh water because of a fear that white water causes slime to accumulate. Some paper makers go so far as to use fresh water exclusively, permitting all the white water to go to waste after passing through a save-all for removing the fibre. This is rarely necessary except in a few mills where exceptionally fine grades of writing paper, etc., are being made.

It is our opinion that the prejudice against the use of white water is largely unwarranted and instead of avoiding its use we believe that as much as possible should be used. There is an opportunity at almost every mill to effect considerable saving of clay and fibre by careful attention to the disposal of the white water.

The following is a table based on tests at certain mills showing the retention of clay in hangings and news-print:

Kind of Paper	% of clay furnished	% found	% retention
Hanging..........	13.00	7.81	60.08
Hanging..........	13.00	8.10	62.31
News.............	13.00	4.85	37.31
News.............	13.00	4.81	37.00
News.............	13.00	4.53	34.85
News.............	13.00	4.52	34.77
News.............	13.00	4.41	33.92

The hanging paper shows a fairly good retention but the retention in the case of the news is quite poor. We believe that a furnish of about one-half as much clay would give equally good results and would show a much larger percentage of retention.

In a certain mill the writer knows of 200 pounds of clay are used to a beater each round and out of each round they make 2150 pounds of paper. Consequently, 9.2 per cent is furnished, the per cent of clay found in the paper was 7.9, consequently the percentage of retention is 85.87 per cent. The cause of such a high retention was because this mill was very careful in the use of white water and in preventing clay going to waste. They also used quite a large amount of alum and the paper was very heavy.

Testing of Clay.

Moisture: Weigh from one to two grams of the clay in a clip of a watch glass and dry in oven at 120° C. until the weight is constant. The weight lost equals the moisture present in the clay.

Combined Water: Weigh from one to two grams of the clay in a crucible and heat over the highest heat in a blast lamp for about 15 minutes or until the weight is constant. The loss in weight equals the per cent of moisture equals the amount of combined water.

Total Silica: Weigh one gram of clay in a platinum foil and transfer to a casserole, add 20 cc. of sulphuric acid (1 to 1), 10 cc. of concentrated hydrochloric acid and 5 cc. of concentrated nitric acid. Cover with a watch glass and boil the mixture rapidly in gas plate until fumes of sulphuric anhydride are given off. Continue to heat just below the boiling point of sulphuric acid for two hours and add 55 cc. of water. Bring to a boil and then heat in the steam plate for 30 minutes. Filter off the separated silica and collect the filtrate in a 200 cc. graduated flask. Ignite the precipitate while still wet in a platinum crucible, completing the ignition by blasting for 20 minutes. Cool and weigh. Add a few drops of dilute sulphuric acid and a sufficient quantity of hydrochloric acid. Heat over a very low flame until the acids are volatilized and then ignite at full heat of burner. Cool and weigh. The loss in weight represents the total silica present in the clay. The residue rarely exceeds five milligrams and is, therefore, added directly to the weight of the iron and alumina precipitate.

Free Silica: Weigh one gram of the clay in a casserole and then treat in same manner as in the total silica. Filter off the silica and transfer paper and precipitate to a platinum dish. Ignite gently on a Brosson flame until the filter paper is entirely consumed, cool and add 50 cc. of a hot 15 per cent solution of potassium hydroxide. Boil for 6 minutes and filter off the free silica, which remains undissolved, washing with hot water slightly acidulate with hydrochloric acid and ignite. cool and weigh, treat with dilute sulphuric acid and hydrochloric acid and heat over a low flame until all acid is volatilized. Ignite, cool and weigh. The loss in weight represents the free silica in the clay.

Iron and Alumina: If the residue from the hydrofloric acid treatment of the total silica which is so small as to render fusion with acid potassium sulphate unnecessary, then cool the filtrate from the total silica, dilute to mark and shake well. Draw with a pipette 50 cc. of this solution, transfer to a 200 cc. beater and add about 5 cc. concentrated hydrochloric acid and a few drops of nitric acid. Heat to a boiling and add dilute ammonia until a slight excess is present, continue to boil until the odor of ammonia is only slightly perceptible. After standing a short time, filter off the precipitate by means of suction. Wash with hot water, dry the precipitate and ignite in platinum crucible. Finish the ignition by blasting for about 30 minutes, cool and weigh as Al_2O_3 plus Fe_2O_3.

Iron: Evaporate the filtrate from the silica, used in the determination of free silica, to about 100 cc. reduce the iron in the usual manner by means of a Jones Reducer, and filtrate with standard potassium permanganate. Express result as Fe_2O_3.

Alumina: Subtract the percentage of iron from that of the iron and aluminum combined. The result represents the percentage of Al_2O_3.

Calcium Oxide: In 100 cc. of the filtrate from the total silica, precipitate the iron acid and alumina with ammonia, filter and wash well. Heat the filtrate to boiling and precipitate the lime as calcium oxalite by the addition of a hot solution of ammonia oxalate. Filter off the precipitate, ignite to constant wt. cool and weigh as CaO.

Magnesium Oxide: Add a slight excess of hydrochloric acid to the calcium oxalate filtrate evaporate to about 100 cc. Add an excess of sodium ammonium phosphate, stir until dissolved and add concentrated ammonia drop by drop with constant stirring until a considerable excess is present. Cool in ice water for about two hours, filter, and wash the precipitate with ammonia wash water. Place the moist precipitate in a platinum crucible and carefully smoke off the filter paper. Finish the ignition over a hot blast, cool and weigh as $Mg_2P_2O_7$. Calculate to MgO.

Notes and Precautions: In the majority of cases the acid treatment of the clay gives as complete a decomposition as the sodium carbonate fusion, and the residue left from the hydrofloric acid treatment of the silica, should not amount to more than five milligrams. In case this residue is excessively large it then becomes necessary to fuse the residue with a small amount of acid potassium sulphate. This fusion is dissolved in hot water and solution then added to the 200 cc. flask containing the filtrate from the total silica, which is then diluted to the mark, and the 50 cc. portion taken for the determination of iron and alumina.

The determination of free silica is not an accurate one, when there is a large portion of the clay remaining undecomposed by the acid treatment, for the reason that no free silica can be obtained in the total silica derived from an alkali fusion.

EXAMPLE OF TESTS AND CALCULATIONS REGARDING RETENTION OF CLAY

Clay used, gave moisture and combined water.......	14.95%
Dry clay..	85.05%
	100.00%

Ash (Clay) in 4 Samples:

	(1)	2.700% ash
	(2)	3.123% ash
	(3)	3.366% ash
	(4)	3.420% ash
which averaged		3.152% ash

These results are figured on the basis of the paper containing 10 per cent moisture. Average percentage of ash in paper containing no filler was found to be 0.46 per cent. Hence percentage of dry clay in paper was 3.152 — 0.46 or 2.692 per cent. Calculating the dry clay to original clay used 2.692 ÷ 85.05 = 3.16.

Total production of paper was....................	5,980,430 lbs.
3.16% of which is clay 188,981 lbs.	
Returned waste was............................	29,740 lbs.
3.16% of which is clay 939 lbs.	5,950,690 lbs.

Hence the clay in the paper made was 188,339
Actual clay used in one particular month was, 365,974 lbs.
The percentage of retention was 51.46%

The following table shows the percentage of clay used, the percentage found, and the percentage retained in a number of different operations.

Per cent clay used	Per cent clay found	Per cent clay retained
12.57	9.11	72.5
12.00	6.05	50.4
11.72	7.66	65.4
11.40	7.24	63.4
10.02	7.06	70.3
9.29	4.58	49.1
7.38	4.55	61.8
6.03	3.23	53.6
5.99	2.91	48.7
5.57	2.34	42.2
4.87	2.63	54.1
4.43	2.26	51.2
2.96	1.56	52.4

Retention of Clay.

In order to determine the above values the following method was used:

1st. The weight of clay at each mill used for each month was reported and a sample sent to testing department.

2nd. The total weight of paper made each month and a sample of such paper taken every six hours was sent to the testing department.

3rd. The total weight of returned waste was reported.

4th. The total weight of paper made without clay, and a sample was sent to the testing department.

From this data the per cent retention was calculated as described above.

TESTS ON ENGLISH CLAY

First Test

3% of (finished product) of clay used.
Ground wood used (wet weight.)..83,976 lbs. (dry weight.)..26,872 lbs.
Sulphite used (wet weight.)......19,018 lbs. (dry weight.).. 6,846 lbs.

			———
			33,718 lbs. dry
Clay used 2.4% of 1 equals	812	(2 ⅛% of total wt. of stock)	
Alum......................	290 lbs.		
Size.......................	174 lbs.		
Total........	34,994 dry weight		
Paper made......	27,515 lbs.	33,718	
Waste and shavings.........	4,147 lbs.	1,276	
		———	
Sweepings (wet)..	95 lbs.	34,994 equals 110% of total stock	
	———		
Total........	31,757 lbs.		

Second Test

6% (finished product) clay used.

Ground wood (wet weight.)......	86,031 lbs.	32% dry.	27,529 lbs.
Sulphite (wet weight.)..........	22,148 lbs.	36% dry.	7,973 lbs.
			———
			35,502 lbs.
Clay used 5.2% of 1............	1,881 lbs.	(5% total weight)	
Alum...........................	320 lbs.		
Size............................	198		
	———		
Total..			2,899
			———
			37,901 lbs.
Paper made..............	31,365 lbs.		
Waste....................	4,126 lbs.		
Sweepings................	273 lbs.		
	———		
	35,764 lbs.		

These tests show a shrinkage of about 10 per cent. The per cent of clay in each case is figured on 2 different bases.

1st on the basis of total ground wood and sulphite used.

2nd on the basis of all the ingredients used, giving the clay added.

Presumably the loss in weight is due to alum and size.

This report is given to determine the retention.

To get the retention, we add to the ground wood and sulphite, the amount of clay used, and then divide by the amount of clay which gives the percentage of clay used.

This ignores alum and sizings. After obtaining the per cent of clay used as above, we divided the percentage of actual clay returned by this and thus obtained the percentage of retention.

The retentions in the two cases were 62.44 and 63.00 per cent.

Other Loading Materials.

Talc: A naturally occurring mineral found in almost every state and in Canada. Chemically it is a hydrous magnesium silicate. Its most conspicuous property is its soft, greasy feel. Its use is not confined to paper making, large quantities being used in the manufacture of talcum powder, rubber goods, etc. After being mined, the talc is pulverized so that it will pass through a 200-mesh screen and then bolted through fine cloth or graded with an air separator. Talc is not so much used as clay in paper but is necessary for some varieties of surface and is much used in paper coating mills.

Agalite: This is a filler chemically the same as ordinary talc, but of somewhat different physical structure, being prepared from a variety of talc that is more like asbestos. In fact, mineralogically the talcs and the various sorts of asbestos are very closely related. On account of its fibrous structure, agalite is a very useful loading material. Just like talc, however, it makes the paper loaded with it very greasy.

The terms agalite and talc are used very loosely and interchangeably by practical paper makers. Asbestine, French chalk, mineral pulp, etc., are all other names for the same thing.

Pearl Hardening: This is calcium sulphate (sulphate of lime, artificial gypsum, etc.), prepared artificially. It is much used as a filler in the better grades of paper. When properly prepared it is white and free from grit. The commercial article contains considerable mechanically contained water in addition to the combined water.

Crown Filler: This is another name for pearl hardening.

Ground Gypsum: Sometimes known as "terra alba." Chemically this is the same as pearl hardening, but it is made by grinding and bolting naturally occurring gypsum. It is not used so much as pearl hardening.

Satin White: This is an artificially prepared filler containing calcium sulphate and alumina. It is usually sold in casks or drums in the form of a paste. This filler gives a high percentage of retention owing to the alum it contains.

Size.

Size is any substance which is added to a porous or absorbent surface to render it less so. Sizing is by no means confined to the paper industry. A plastered wall is sized by brushing it over with weak glue or shellac, etc.

Paper needs to be sized to prevent the spreading of ink, to give it a good surface, to impart the proper degree of stiffness and rattle, etc.

The principle of sizing is to add some material that will fill up the pores between the fibres and the filler, thus preventing ink or moisture spreading by capillary action, just like oil spreads upwards in a wick.

Naturally, various degrees of sizing are required. Blotting paper and filter paper are not sized at all, as it is intended that they should soak up liquids. Newsprint is sized very little—

sometimes not at all—because the heavy viscid printing ink does not tend to spread much. Good writing papers require a lot of size because they are written on with fluid inks.

Several different materials are used for sizing. Rosin size, however, is at present by far the most usual.

Animal Sizing: This was introduced in the days when paper was still made by hand. It is still used in England and in certain mills in America making fine writing and drawing papers. This size is really a solution of gelatine, prepared by soaking hides in water. The size was applied to the paper after the sheets were made, by dipping the sheets in a vat of the size.

In America today so-called animal sizing is done with solutions of commercial glue and gelatine and the paper is led from the machine through a trough or vat containing the size. These machines are usually called size presses and are placed in the dryer part of the papermachine, the dryers being separated into two nests.

The drying of animal sized paper is an operation requiring great care. It must be carried out slowly and at a low temperature. Frequently such paper is "loft dried," i. e., the sheets are suspended on poles in a warm dry loft. This treatment brings out very fine qualities in the paper. When loft drying is not resorted to, sometimes special forms of mechanical dryers are used in which the paper is festooned in a blast of warm air, as in a coating mill.

Engine Sizing: This is the term applied to the addition of size to the beater where the stock is being prepared for the paper machine. This is the usual method of sizing. The size most usually added is rosin size.

Rosin Size: Rosin is a resin obtained in the manufacture of turpentine spirits from crude turpentine, which is a natural product obtained from pine trees. There are numerous grades of rosin, these grades being determined by the color. The grades are distinguished by letters of the alphabet. Rosin is graded B, C, D, E, F, G, H, I, K, L, M, N, W-G (window glass), W-W (water-white). B is the darkest and W-W the lightest grade. Ordinarily the first three grades B, C and D, are not separated. The grades E, F and G are the ones usually employed for making size in the paper industry. The other grades are used in other lines of manufacture. Rosin is sold in rather peculiar units of 280 lbs. This is derived from the English gross ton. However, the 280-lb. bbl. includes the weight of the container.

Provided that the darker color is not harmful, it is better to use E or even D rosin than the lighter F and G as the sizing value is higher. However, D and G are the limits and should not be exceeded in either direction.

Rosin is a weak acid and will combine with an alkali to form a chemical compound, known as a resinate. In making size the rosin is made to combine with sodium carbonate or soda ash. Usually 58 per cent soda ash is used. A table telling how soda ash is graded will be found at the back of the book. Rosin and soda ash do not react until heated. When mixed and heated they combine, carbon dioxide gas being given off, which gives rise to foaming.

The usual method of making the size is to dissolve the soda ash in water in a kettle heated by a steam coil or a jacket. Sometimes the kettle is heated by direct steam, but this is not good as it is necessary to make allowance for the dilution from the steam in weighing out the materials for the size. When the soda liquor is ready, the finely powdered rosin is stirred in and the whole boiled for some time, after which it is diluted with water.

The proportion of soda and rosin used varies. The maximum amount of free rosin can be obtained by using 9 pounds of soda ash and 100 pounds of rosin. Such size is rarely used. From 20 to 40 pounds of soda ash per 100 pounds of rosin is quite usual. The writer prefers 15 to 18 pounds soda to 100 rosin. The soda and the rosin never completely combine. That is, there is always free rosin and free soda in the size, even if just the right quantity of soda for the rosin is added. The amount of free soda and rosin decreases the longer the size is boiled. No rule can be given for the percentage of free or of combined rosin that a size should contain. It depends on the condition under which a size is to be used, the nature of the stock, the water, etc. A size that will work well in one mill may be useless for another.

After cooking until the lumps of rosin are dissolved and the batch is of a clear dark color, when the steam is turned off and the foaming subsided, a test is made as follows:

Take a ½ pint dipper, of hot size and add in a pail a quart of hot water and stir until well mixed; now add cold water till the pail is nearly filled and stir again. The resulting liquid should have a white or yellow color and dissolve to a thin milk free from lumps, grains or sticky pieces of rosin.

If it does not readily mix with water and dissolve to a milk, but forms grains like corn meal, it must be again cooked, but the cooking must again be stopped when the test shows it to be done as further cooking injures the size.

After it has stood for a day or two a black liquor separates which is brine and soda ash. This should be removed as it causes foaming on the screens, etc., and the running off of the black matter is of a great advantage. By longer standing and occasional poking with a stick more liquor can be made to separate from it and more should be worked off.

Notes on Making Size.

1—Caustic soda is not so good as soda ash and should not be used.

2—Lime is harmful rather than good.

3—Brine improves size by washing out the excess of soda.

4—Ageing size is good for it separates more black liquor from it and ageing can be hastened by using fresh brine.

5—Thick size should never be furnished to an engine. Thin size is made by dissolving one gallon thick size in four gallons water.

6—Heating size or the stock in the beater is detrimental to good sizing results and causes foaming.

7—Kerosene is bad for size and when used for keeping down foam should be used very carefully.

Process Where Direct Steam is Used.

The equipment consists of an iron tank heated by direct steam blown into it. In such a case there is water formed by the condensation during the cooking and care must be taken to use at first as little water as possible, for the reason that the weaker the solution of soda ash the longer it takes to cook the size. Therefore, only a sufficient quantity of water is run into the tank to just dissolve the soda ash used.

Soda ash must be dissolved: The water is first heated by steam by means of a steam pipe until the soda is completely dissolved and no undissolved lump should be left.

Rosin should be crushed fine: Rosin is next shovelled in, the finer it is crushed the quicker the cooking is completed. The cooking is continued as rapidly as possible without it running over the tank.

To prevent boiling water: It is a good plan to have a sprinkling can with cold water to stop the foaming and boiling water. After boiling until all the lumps are dissolved, try the Solubility Test.

Melted Rosin Process.

The following method of making size has proved very successful. The rosin is melted over night in a steam jacketed kettle. A strong solution of soda ash is made up and then added to the rosin a little at a time. At first the action is very violent, but it soon moderates. After all the soda is added the size requires very little boiling to be done.

When the rosin size is dissolved in water the free and uncombined rosin does not go into solution but forms a sort of emulsion in the water, this giving the whole a milky appearance. This uncombined rosin attaches itself to the fibres of the paper.

However, when making high rosin size great care must be exercised to have it exactly right, or sticky, tarry masses of rosin will separate out that will clog tanks, pipes and pumps, make size spots in the paper, adhere to felts and wires, and cause all kinds of trouble. Many of the ready made sizes are of this free rosin variety, but they are usually made with care so that the rosin stays in solution.

Ready Made vs. Mill Made Size.

Ready made size is undoubtedly more convenient than making size at the mill, but it is much more expensive and in spite of all the mystery surrounding the subject, any practical paper maker should be able to learn to make size suitable for his particular class of paper after a little experimenting.

Various Kinds of Rosin Size.

The following are descriptions of some of the kinds of size the paper maker will find, or will be given recipes for making, in many mills:

Highest Free Rosin Size: An example of this is one of the ready made sizes which contains so much rosin that, in order to get it into solution properly, 50 gallons of water must be used to dissolve 1 gallon of the size. One third of the 50 gallons is boiling hot and the hot size is sprayed into this water by means of a steam injector. The other 2/3 of the water is run in cold. If care is not exercised the result is a sticky, unmanageable mass. There is no doubt that such size gives good results and is economical of alum, but it is troublesome and in the long run the economy is doubtful.

Second-Highest Free Rosin: There is another group of sizes on the market containing less free rosin and capable of being dissolved without the need of special appliances, but still requiring great volumes of water for solution and being very troublesome to handle.

Most Popular Size: The most generally popular size is that which contains a large amount of free rosin, but not so much but what the size will dissolve in any quantity of water.

Old-Fashioned Size: Many old-fashioned size makers still adhere to the practice of using excessive quantities of soda ash and cooking the size so thoroughly that all the rosin is converted into soap and no "free rosin" remains. They test by dissolving in water, and if the size gives no "yellow milk color" they cook again. This is very wasteful of soda ash and alum. Old-fashioned size makers call modern high free rosin size, "raw size."

Adding Size to the Beaters.

The size should be diluted with water before adding to the beaters. The most convenient proportion is 1 gallon of size to 4 gallons of water, if ordinary size is used. If a high free rosin size is used correspondingly more water will have to be added.

Size should always be added to the beaters before the alum—never after, or at the same time. The size should be furnished when the stock is thin.

If any quantity of size is kept on hand, the tank in which it is kept should be provided with an agitator. It is advisable to keep enough size on hand that the beaters will never be furnished from too freshly made size. Moderately old size is better.

If clay is used, it is a good plan to mix together the size and clay before adding to the beater, and then to strain both. However, if the clay and water are mixed in a large tank and conveyed to the beaters by pipes this is not advisable. It works well when the clay is mixed with water in a small mixing tank above each beater.

Adding the alum before the size is properly dissolved is a frequent cause of size spots. These are frequently blamed on the composition of the size.

Foaming causes trouble if the stock is warm. Little trouble is experienced from this cause if the stock is beaten cold. In heavy sized paper it is sometimes advisable to mix a little tallow with the size during the cooking. This tends to prevent foaming. Some paper makers add kerosene to prevent foaming, but this is inadvisable.

Size in Newsprint.

Some paper makers claim that 1 pint of size to a 1,000 lb. beater is of advantage in making newsprint. It helps the fibre to lie down in moist weather. It is also claimed that it aids the retention of clay in the paper. This is undoubtedly true if a large amount of size be added, but experiments have proven that the amounts usually added in making newsprint have no effect on the retention of the clay at all. Alum has much more effect in this regard.

It is an undoubted fact that the use of size in news causes trouble with foam, slime, etc., and as very good news can be made without size, it would seem better practice to leave it out rather than to put it in on the supposition that it may do some good.

General Considerations about Sizing.

Many conditions influence good sizing results. It is well known that free stock is more difficult to size than slow stock. This is due because the finer meshes of the slow stock retain the particles of rosin almost completely while the coarse meshes formed by the free stock permit much of the size to pass through and be lost. *Sizing is quite a sensitive operation* and almost any change in the conditions under which a sheet of paper is made will produce some effect in the sizing.

We have observed that a sheet which has been running for some time with satisfactory results as to sizing became "slack sized" when the machine was speeded up. The amount of size had to be increased 25 per cent in order to get the same result as before.

Also we noted in making hangings out of a coarse pulp especially ground for the purpose that much more size was required to produce the same result than when "news pulp" was used for the hangings. Having run out of the special "hanging pulp" news pulp was substituted and it was apparent that the paper was too hard sized and the amount had to be cut down considerably. As soon as regular "hanging pulp" was again used more size had to be used.

Grinding, beating, Jordaning all have a decided influence on the quantity of size necessary to produce good results. It is also probable that *sizing* is influenced by the shake, suction, dryers, etc., and in fact almost by every step in paper making.

Alum.

Alum—in the usage of the paper maker—does not mean the alum of the chemist, which is the crystallized double sulphate of aluminum and potash. Paper makers use the term alum to denote aluminum sulphate, $Al_2\ (SO_4)_3\ 18\ H_2O$. The true alum was once used in paper making, but has been replaced by aluminum sulphate which is cheaper and stronger in alumina. The aluminum sulphate or paper makers' alum of commerce is not a definite chemical compound, different makers driving off different amounts of the combined water before the product is placed on the market. The best commercial product on the market today contains 22 per cent alumina, Al_2O_3 which is equivalent to 73 per cent sulphate of alumina, $Al_2(SO_4)_3$.

Commercial alum is generally prepared from bauxite, a naturally occurring hydrous oxide of aluminum. Pulverized bauxite is agitated with 50° Be. sulphuric acid in lead lined tanks. The mixture becomes very hot during the reaction, after which it is diluted with water, allowed to become cool and to stand long enough to deposit silica and other impurities. The clear liquor is then decanted off, concentrated with heat, and when thick enough, run out onto marble slabs, where it crystallizes in a mass which is broken up, packed and sold.

As bauxite always contains some iron, the commercial alum is rarely free from iron. The iron is frequently reduced to the ferrous condition with zinc before the alum is crystallized. but this proceedure is useless from the paper makers' point of view as the iron soon oxidizes up again and colors the paper in which it is found.

A good alum should contain very little insoluble matter, not over one-half of 1 per cent. More insoluble matter indicates that the alum has been made in a hurried and careless manner.

Free sulphuric acid is objectionable in an alum. It decomposes the size, corrodes the wire, disintegrates the felts and attacks every pipe and vessel it comes in contact with. It is possible to obtain from the manufacturers alum quite free from free sulphuric acid and this should be insisted on.

Other things being equal, the important point about an alum is the alumina content, although the efficiency of the alum cannot be absolutely judged by this factor.

ANALYSES OF ALUMS

SELECTED FROM GRIFFIN AND LITTLE (EXCEPT NO. 4)

	(1)	(2)	(3)	(4)
Insoluble in Water	10.61	0.67	0.11	0.02
Alumina (Al_2O_3)	14.96	22.37	11.64	22.02
Iron Oxide (FeO	0.13	0.46	0.06	none
Iron Oxide (Fe_2O_3)	1.08	0.08	1.17	0.01
Zinc Oxide (ZnO)	none	3.80	none	none
Soda (Na_2O)	0.57	none	4.75	0.72
Magnesia (MgO)	none	none	0.45	none
Combined Sulphuric Acid	37.36	45.28	35.98	45.36
Free Sulphuric Acid	1.08	none	5.13	none
Water by difference	34.21	27.34	40.71	31.87
Sizing Test (parts of neutral rosin size precipitated by one part of the alum)	3.47	3.64	3.19	....

Notes: In Sample (1) the high percentage of water insoluble material indicates that the raw material was not entirely dissolved by the acid. The free acid is also too high in this sample, and the iron. Such an alum is more suitable for water softening than for paper making. (2) is a better alum but the iron is too high. (3) is a very poor alum, the alumina being very low and the percentage of free acid being abnormally high. (4) is one of the best commercial alums on the market today. The alumina is high, the iron almost negligible and no trace of free acid present. It is interesting to note that apparently a higher alumina content than that required for the neutral sulphate has no effect on the sizing efficiency of the alum, as (2) in which the alumina is very high is not appreciably more efficient than (3) in which the alumina is very low.

Furnishing Alum.

Sometimes dry alum is put in the beater, but it is better to make up a solution of alum and use that. The solution can be kept in a measuring box above the beaters and connected below with a lead pipe leading to the beater. The alum solution is run into the measuring box and thence into the beater. The solution may be of any strength, but 1 pound to a gallon is a convenient strength.

Function of Alum in Paper Making.

It is frequently said that alum is added to size the paper. That is not correct. The true purpose of alum is to precipitate the dissolved rosin in the size on the fibres of the paper. This is sometimes called "setting" the size. It also "sets" or "fixes" certain colors, making them stronger and brighter, as certain reds and blues. However, it weakens certain other colors, such as yellows and greens. If it is necessary to make a heavily sized yellow paper it is best to experiment until the exact amount of alum to set the size is found and then use care not to add any more than that as it will weaken the color. The same hint applies to many other colors. However, many paper makers have the idea alum strengthens all colors, and will tell you it keeps the color from washing out of the paper, and when they are making any highly colored paper they will be very liberal in their use of alum. This practice is based on no scientific reason, and in many cases is absolutely wrong. The dealers in colors can usually provide information as to how they should be used, and unless the mill is provided with a chemist competent to work such things out on a truly scientific basis it is always better to follow the color dealer's instructions in detail.

Too much alum renders the paper brittle, causes it to loose moisture rapidly, and is a cause of rapid deterioration. Sometimes excessive amounts of alum are added to impart a stiffness and rattle to the paper but this is bad practice as it will cause the troubles described above and the desired effect can be secured in other ways— e. g., by the use of silicate of soda, starch, etc.

Excess of alum is also hard on the wire and felts, especially the dryer felts. The rottenness of felts, frequently attributed to burning or scorching on the dryers is due to a large extent to the accumulation of alum. The combined action of the alum and the heat of the dryer will soon destroy the felt.

In addition to setting the size, alum has a clarifying effect on the water. If water is turbid due to the presence of clay, etc., it cannot be filtered bright as this slime will either pass through the filter or else will completely stop up the pores of the filter so no water passes through at all. Alum causes the dirt in the water to coagulate so that it falls down in granules, leaving the water above clear and bright. Now, in paper making the alum exerts this same property and much clay and fine fibre that would otherwise be carried off with the water is coagulated and held in the web and is less likely to be sucked out by the suction boxes or to drain through the wire. This is why alum aids in the retention of clay, a fact that we alluded to when discussing the use of clay as a filler.

Hardening Action of Alum.

Alum tends to harden all organic substances. This is sometimes alluded to as the sizing effect of alum, but this is not correct, because sizing renders a paper impervious to moisture and while alum makes a paper hard and stiff it does not make it any more resistant to moisture than if none had been used. The general feel of such a paper is as if it had been sized, but it has none of the real properties of a properly sized paper.

It is sometimes desirable to make a very well sized soft paper, as for wall paper and hangings. In order to do this we use a liberal amount of size and less alum than is necessary to completely fix the size, letting some of the size wash out. This wastes some size and causes a little trouble with foam on the screens, but no other way of attaining the desired result has been devised. If enough alum is added to completely fix the size, the paper is too hard and brittle for satisfactory hangings.

Alum and Foaming.

Alum prevents to some extent the foaming caused by size, especially new size from which the liquor has not been well separated. In cases where an excess of alum is not objectionable this method of preventing foam may be permissible, but as a rule it is better to kill the foam with a spray of water or an air blast.

Alum and Pitch.

Alum tends to keep the wire of the paper machine bright. This is because of a slight corrosive action on the wire, which is increased if the alum contains any free sulphuric acid. A wire will last longer if excessive alum is not used, but when pitch is present to any extent the use of alum to prevent sticking seems an instance of permitting a slight evil to cure a much greater one. However, the use of alum for this purpose should be with discretion as too much alum will have a very bad effect on the felts.

Alum and Water.

If the water used in the mill is hard, i. e., if it contains salts of lime or magnesia in solution, a larger amount of alum than usual will have to be used to properly set the size. This is because some of the alum is used up in precipitating the lime or magnesia salts, as previously referred to in this chapter. Some paper makers add alum in excess of the amount required to set the size purposely to secure this effect, as if the lime and magnesia compounds are present in the water when the size is added they will precipitate the size as a flaky precipitate of resinates of lime and magnesia which has no sizing value and simply wastes that much rosin as well as precipitating an insoluble powder that is troublesome in the stock.

When alum is used in this way the general practice is to determine in the laboratory the amount of alum needed to soften the water, and then add that amount to the beater before furnishing the size. Then, after the size is furnished, the amount of alum necessary to set the size is furnished.

However, a much more modern and efficient way of producing the same results is the installation of a water softening plant, if the mill is located in a district where the water supply is at all hard. Such a plant furnishes perfectly soft water for the paper mill and also for the boilers and, in mills where varieties of paper are being produced where hardness of water would have a serious detrimental effect, will prove economical in the long run. Efficient water softening plants that require little attention are offered by a number of firms and we will describe some of the leading types of such plants in a subsequent chapter when speaking of water supply.

Caution Regarding the Use of Alum and Other Chemicals.

Paper making is largely a mechanical process and the quality of the finished product is dependent primarily on the character of the stock and the manner in which it is manipulated in the beaters and on the machine. The paper can be no better than the fibre (whether it be sulphite, ground wood, rag or anything else), which is put into it. Compared with these factors the quantity of chemicals added is insignificant.

When the quality of the paper is not what is desired the remedy will usually be found in the operation of the beaters or the machine (the shake, the dryers, the operation of the suction boxes, etc.), rather than in dosing the stock with chemicals or trying to make good paper out of poor stock by using clay, alum, silicate of soda, etc.

It is, of course, necessary for one to do everything possible to get the best results from a given stock and in some cases (e. g., where the wood pulp fibre is too coarse and hence the paper will not retain a good surface), it is all right to use chemicals liberally; but to make a regular practice of that, instead of getting to the root of the matter and finding out what is wrong with the stock or with the operation of the mechanical equipment of the mill, would be very bad practice.

It is a good rule that whenever the appearance of a sheet can be improved by mechanical means to do so rather than resort to the use of chemicals.

To Test How Much Alum is Necessary to Set a Given Quantity of Size in an Engine.

Furnish the engine as usual with everything except clay, color and alum. Have the stock rather thin, so that it will travel fast around the engine.

Dissolve 5 pounds of alum in hot water in a wooden pail, and pour the solution into the engine, allow it to mix for about 15 or 20 minutes and then test it as follows:

Have a small box made holding about a quart, and covered at the bottom with a piece of fine wire cloth. Fill this with some of the stock from the engine, and allow the water to run off till it looks clear, then catch about a half a tumbler full of it. Do not press the water out of the pulp, but let it drain off naturally, it will then be clearer. Add a little litmus solution to the tumbler, and if enough alum has been added the solution will turn red. If it is blue dissolve 5 pounds more of alum, add it as before and test at the end of another 15 or 20 minutes. Continue this until the clear liquid turns the litmus a distinct red.

When large quantities of size are used, testing after the addition of each 5 pounds of alum will be close enough. If only a little size is used, however, the alum should be added in portions of 1 pound at a time, in order to determine the proper amount with more accuracy.

The litmus solution is made fresh before the test, by dissolving a few lumps of the dry litmus in a half tumbler of hot water.

A piece of cheese cloth makes a good substitute for the wire screen. Do not squeeze the water out, however, but let it run naturally.

The amount of alum necessary to set a given quantity of size varies at different mills, owing to the different kinds of water. Also the quantity of alum necessary for 5 gallons of size is not five times as much as would be required for one gallon, because the water itself uses up some alum. Thus, for example, it might be found that when five gallons of size were furnished, 15 pounds of alum would be necessary, while when only one gallon of size was furnished, five pounds of alum might be required instead of only three pounds.

It will also be observed that when there is not enough alum to set the size, the water drawing away from the stock will have a milky appearance, while when enough alum has been added, the water will draw away quite clear. Clay would make the water a little milky, so it is best to leave out the clay in making these tests.

Two or three of these tests performed with different quantities of size will show once for all the quantities of alum required for different quantities of size at any one mill, and any more alum which might be added is wasted in case there is no other object in adding alum except that of setting the size.

Silicate of Soda.

This chemical is sometimes known as water glass. It is generally sold in solution in barrels or drums. A 50 per cent solution is ordinarily used, but any required concentration can be obtained from the makers, or the solid silicate can be obtained. This chemical imparts a hardness and rattle to paper that makes it valuable for use in certain writing papers. It tends to set size just like alum. It should not be used in conjunction with alum as the alum will yield a heavy precipitate with the silicate which will cause trouble. Silicate of soda is also used in making certain boards and paper specialties such as corrugated container board, on account of its adhesive and greaseproofing qualities.

Starch.

Various starches are used in the paper industry, such as corn starch, wheat starch, potato starch, etc. Starch is used for its hardening and stiffening action; also because it aids in the production of certain highly finished surfaces when the paper is calendered.

Some paper makers add the starch directly to the beaters and others mix it with the size. It seems to exert certain beneficial properties on the rosin of the size, enabling the particles of rosin to become better attached to the fibres of the stock.

According to J. Traquair[1] corn starch is not the best to use, a mixture of starches being better, and 1 lb. starch should be boiled with 2 gallons of water and the mixture kept at a little less than the boiling point for from 15 to 20 minutes, after which the starch is ready to be added to the beater. According to this authority the retention of starch is about 50 per cent.

However, starch is not much used in paper making, its use being confined to certain high class writing and book papers, also a little being used in cigarette paper.

There are various prepared starches in use made by treating ordinary starch with alkaline and acid solutions. Undoubtedly many of these are of use in making high grade papers, but in general their use is prohibited by the expense.

Colors.

It is hardly within the province of this book to deal at great length with so special and highly technical a subject as the coloring of paper. Also this is a branch of paper making where personal experience is specially necessary. However, some general remarks about the coloring of paper may prove helpful.

Color is almost always added to the stock in the beater, that being the chief time during the paper making process when there is an opportunity to color the fibres.

The coloring of paper has never received the same attention that the coloring of textile fabrics has. It is unusual to find men around a beater room who are as skilled and expert in the use of colors as the average textile dyer. The average paper maker regards color as a minor item in his responsibilities.

However, almost all paper has at least a little color added to it. The bleach is seldom relied on to give a satisfactory white color. Even newsprint has added to each beater usually a gill or two of blue and red to improve the appearance.

The color of the stock in the beater is usually deeper than it will be in the finished paper. One method of matching the

[1] Technical Association Papers, 1918, pg. 43.

color is to reduce the sheet to be matched to pulp, then making the pulp in the beater the same color. By squeezing dry a handful of stock from the beater some idea can be gained as to how the color will be in the finished sheet.

An experimental beater and a frame for making sample sheets by hand will be found useful in every mill where colored papers are being made. In general, the reliable dealers in colors and dyes can be depended on to give excellent help and advice in matching colors. Many of these firms maintain experimental paper beaters and machines for testing out their colors and solving their customers' problems.

The coloring materials used in the paper industry may be divided into *pigments,* or mineral colors (however a few pigments are non-mineral in nature), which are distinguished by being insoluble in water, and *dyestuffs,* mostly artificial in origin and usually spoken of by the general title of "aniline dyes."

Pigments color the stock by becoming enmeshed with the fibres in the beater. The size and alum helps the fibres to retain the pigments, which adhere in small particles to the surface of the fibre. Pigments do not penetrate the substance of the fibre as do dyestuffs. There is probably no chemical action between the cellulose of the fibre and the pigment, whereas in the use of dyestuffs the combination seems to be more chemical than mechanical.

The percentage of retention of a pigment, and therefore the degree to which the paper is colored, depends on the manner of sizing, the amount of alum used, the specific gravity of the pigment and the nature of the stock. Slow stock gives a higher retention than free stock. Also the operation of the paper machine, and whether or not suction couch rolls are used affects the retention of pigment.

Pigments, if used in any quantity, have exactly the same action as clay. In fact, they may be considered as colored clays. Just as too much clay will weaken the paper, so will too much pigment. Many pigments contain grit. All pigments to be used should be passed on by the laboratory to ascertain that they are free from grit, which will cause pin holes in the paper and also will injure the wire and felt and the calender rolls.

Some of the commonest pigments are ultramarine, Prussian blue, chrome yellow, red oxide, yellow oxide, umber, etc. All of these vary in their fastness to light and to alum. For the action of alum on colors, see the section of this chapter dealing with alum.

Owing to their being more powerful, more varied and easier handled, dyestuffs have largely replaced pigments. Moreover, they have no effect on the strength of the sheet.

Dyestuffs: Whether one speaks of aniline dyestuffs, synthetic dyestuffs or dyes, coal tar dyes or colors, etc., it is all the same product that is meant. They are all made from derivatives of coal tar by a series of complicated processes that is one of the triumphs of applied chemistry. The first such dye was invented by Sir William Perkin in 1856, since which date thousands of others have been invented.

Different manufacturers sell their dyes of different strengths. They are practically never placed on the market full strength. They are almost universally sold on the basis of samples. The names given to these dyes have no logical basis. Each manufacturer will give his dyes some individual name. Letters placed after the name of the dyestuff generally imply a certain shade, for instance R placed after the name of a blue means that it has a reddish shade.

Dyestuffs are divided into: (1) Basic dyestuffs, (2) Acid dyestuffs, (3) Direct dyestuffs, (4) Vat dyestuffs.

Basic dyes are not very fast to light and are hard to use unless perfectly soft water is at hand. With hard water they give the paper a spotty or mottled appearance. These dyes require no alum to set them. Auramine is a typical example of these dyes.

Acid dyes must be set with alum. They are faster to light than basic dyes. Unlike basic dyes they will resist comparatively high temperatures without change. They also work better if the water is at all hard.

Direct dyes do not require any alum or other chemical to set them. They do not work well with hard water. They enter into direct chemical combination with the fibre and so, are suitable for use with unsized paper, such as blottings. They are faster to light than either the basic or acid colors. These are the dyes that are known in the textile industry as cotton dyes.

Vat dyestuffs are little used in the paper industry. They are practically pigments of synthetic origin. So far few vat dyes have been made in America, whereas almost all basic, acid and direct dyestuffs are. Vat dyes are more expensive than the others.

Notes on Coloring Paper with Dyestuffs.

Test dyes to ascertain that a mixture is not being used. Mixtures do not give uniform and satisfactory results. A simple test for a mixture is to take a pinch of the dyestuff on a knife or coin and blow it sharply onto a piece of filter or blotting paper dipped in water containing a little acid. If the dye is a mixture usually spots of individual colors can be seen where the tiny separate particles fall.

It is better to dissolve the dyes to a liquid or to a paste before adding them to the beater. Dry dyes added to the beater are not so effective as some of the dyestuff is wasted and the effect is not so even.

Basic colors and acid colors should never be used together. They tend to coagulate each other.

Basic colors should not be mixed or used together with direct colors.

Acid colors can be used with direct colors, but not with basic colors.

Direct colors can be used with acid colors, but not with basic colors.

Excess of alum is bad for all colors. Just the right amount to use should be determined.

Good results can sometimes be used when a very full shade is desired by first dyeing the stock with an acid color and then submitting it to a second dyeing with a basic color. This will give a better color than could be obtained with an acid dye alone, and it will be faster to light than if a basic dye alone were used.

In coloring mixed stock, such as ground wood and sulphite, sometimes the ground wood will take the dye before any sulphite does, producing a mottled stock. This can be prevented by dyeing the ground wood first in a separate beater and then mixing it with the sulphite which has already been dyed.

Mottled papers, for instance, mottled blottings, are made by dyeing the stock strongly in two or more separate engines, then mixing just before the stock goes on the machine.

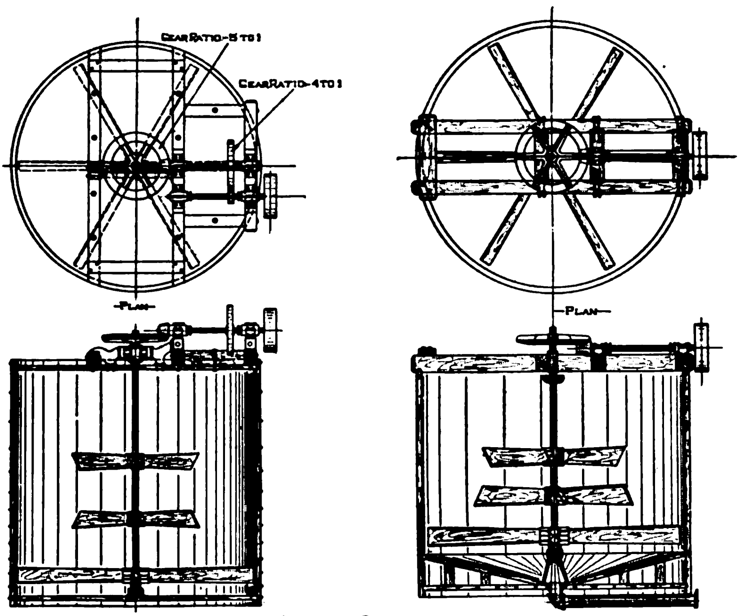
In purchasing colors adulteration should always be guarded against. Little risk is incurred if the colors are bought from reliable manufacturers, but as colors are extensively handled by jobbers, etc., large amounts of highly adulterated colors get on the market. This is possible because of the high concentration of the synthetic dyes and also because of the temptation offered by cheap colors. As a rule the best colors will be found the most efficient in the long run regardless of price.

The principal adulterants are dextrine, salt, sugar and Glauber's salt. None of these are harmful, except in that the customer is paying for their weight at the price of a dyestuff.

Several American firms are now manufacturing dyestuffs suitable for the paper industry quite equal to anything previously manufactured in Germany. In fact it is stated that as a result of tests some of these dyestuffs are better. It is not likely that American dyestuffs can be sold quite as cheap as German dyestuffs formerly were, and it is altogether likely that the German dye manufacturers will offer their products at a very low price in the attempt to regain their lost trade, the system known as "dumping." However, it is very essential that the American dyestuff industry should be supported and if the textile, leather, paper and other dye using interests will co-operate there is no reason why we should not soon have satisfactory domestic sources of every essential dyestuff.

Stock Chests.

In the basement of the beater room are a number of stock chests. These are for receiving the stock from the beaters preparatory to sending it to the Jordans or other refining engines, or to the paper machines. There are also other stock chests for receiving stock to be furnished to the beaters. Some of this stock is deckered stock received direct from the sulphite mill and some of it is stock produced by disintegrating laps of kraft or



Courtesy: Noble & Wood Machine Co., Hoosick Falls, N. Y.

Fig. 98.—Plan and elevation of two typical vertical stock chests.

other pulp with shredders and pulpers. Some lap stock is too hard and dry to feed to the beaters as lap stock and has to be mechanically disintegrated before being furnished. This is usually done with shredders and pulpers.

These chests vary in size according to the room available, or the size of the plant, but an average storage chest will hold approximately 2.5 to 3 tons of air dry stock. These chests are always provided with agitators to keep the stock of uniform consistency and to drive an agitator of the usual type in such a chest as we have described requires about 4.

The stock is pumped from the storage chests to the beaters by a centrifugal pump and it is generally advisable to get this pump down as low as possible so as to get all the head available and also to have the suction pipe as large as possible. A 6-inch

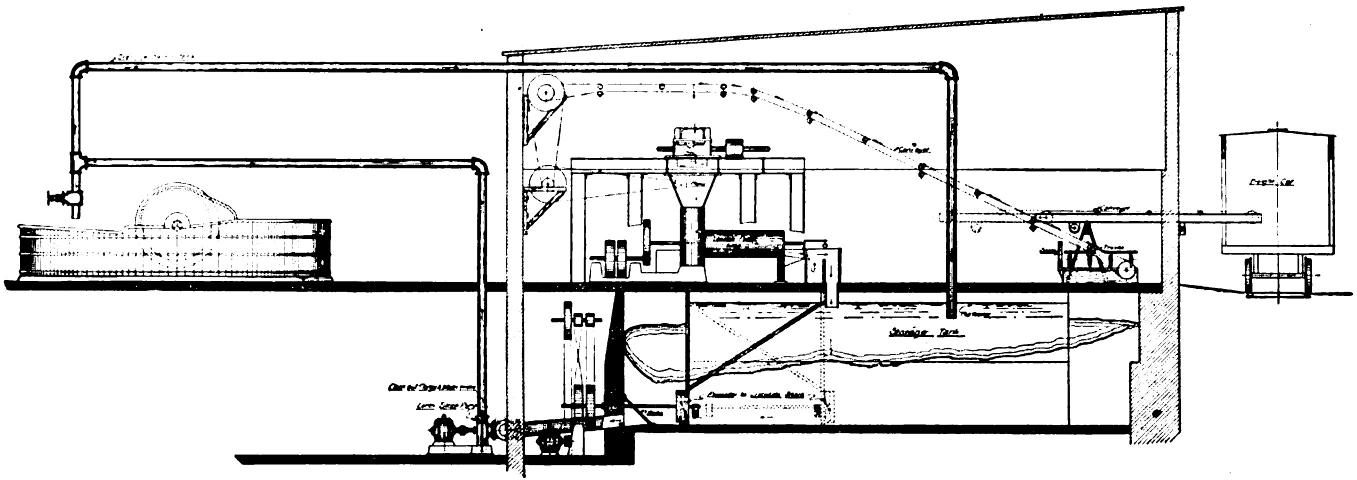
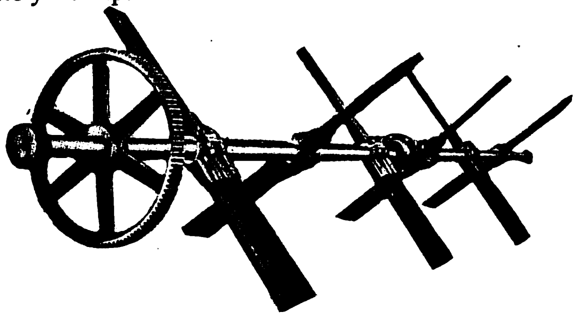


Fig. 99.—Diagram showing a complete installation for preparing kraft or dried or frozen pulp laps for the beater. The installation consists of a Mitts & Merrill shredder, Lannoye pulper and the necessary conveyors, tanks and pumps.

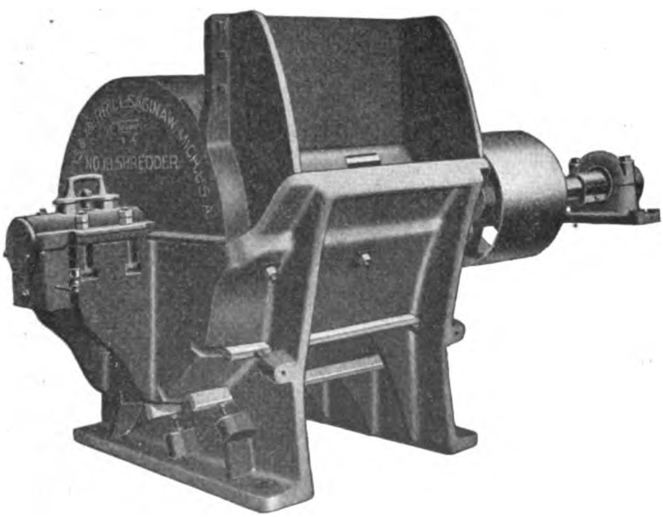
pump should have an 8-inch discharge pipe and, if possible, a 12-inch suction. The power required to drive such a pump with piping as described with a head of not over 20 feet will be approximately 20 h.p.



Courtesy: Noble & Wood Machine Co., Hoosick Falls, N. Y.

Fig. 100.—Type of agitator used in horizontal stock chest.

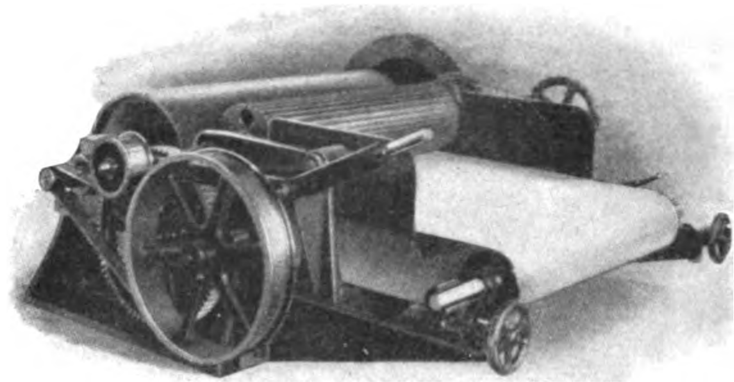
The stock usually gravitates from the beaters to the storage chests from which it is pumped to small chests located just above the Jordans. This is usually done with a duplex or tri-



Courtesy: Mitts & Merrill, Saginaw, Mich.

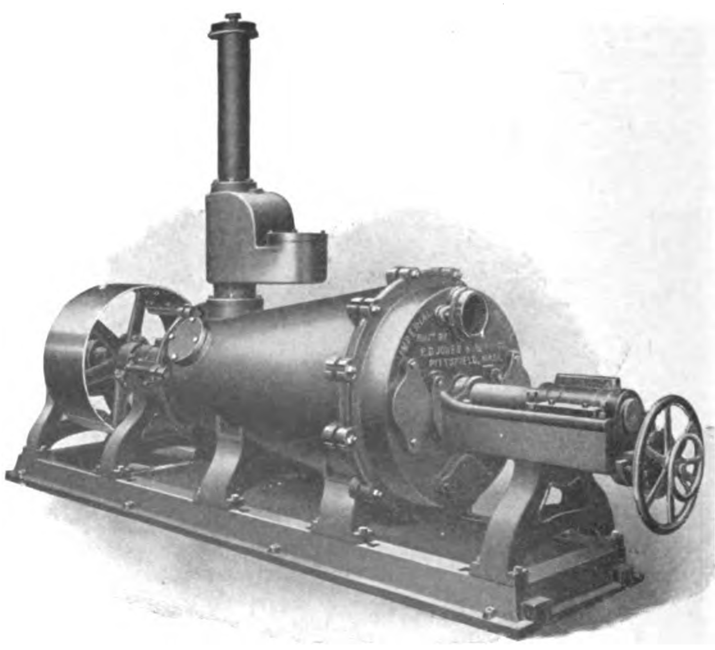
Fig. 101.—Shredder for disintegrating frozen or dried pulp laps.

plex plunger pump. It is good practice to have this pump of sufficient capacity to do the work at a low speed. For a machine of from 30 to 45 tons capacity a 12 x 12 triplex pump is a very efficient size. This pump running at a speed of ap-



Courtesy: Ryther & Pringle Co., Carthage, N. Y.

Fig. 102.—Belt feed type of shredder in which the stock is fed on to an endless belt and carried beneath serrated blades which, revolving in a manner peculiar to their arrangement, tear off the stock in small, irregularly shaped pieces and carrying same over a bed plate beneath the revolving blades which is provided with a number of serrated segments, serve to further disintegrate the stock and discharge same in front of the machine into a hopper leading to a chest or whatever other arrangement may have been provided to receive same.



Courtesy: E. D. Jones & Sons Co., Pittsfield, Mass.

Fig. 103.—Belt driven Jordan engine.

proximately 25 r. p. m. will deliver from 30 to 45 tons per 24 hours with a power consumption of about 15 h.p. against a 25 or 30 foot head. The suction pipe should be at least 14 inches in diameter with a stock gate in the line, also a "tee" placed near the pump to enable the operators to clean the suction in case it clogs.

The Jordan Engine.

This machine consists essentially of a conical cast-iron shell, the inside of which is fitted with long, narrow steel bars, and rotating inside this conical shell is a conical casting, called the "plug" or "runner," the outside surface of which is fitted with long, narrow steel bars, or "knives," each resembling, more or

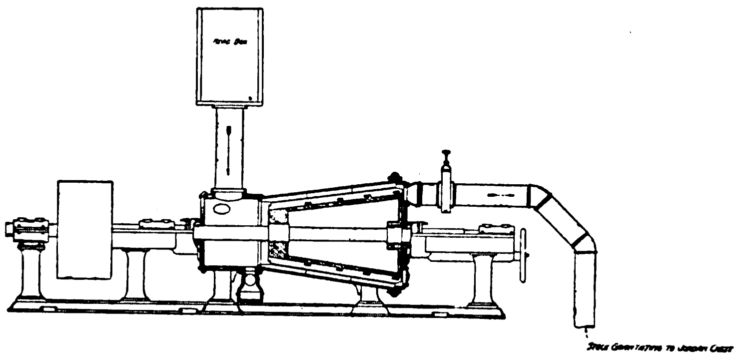


Fig. 104.—Diagram showing construction of Jordan engine.

less, the runner of a skate, although only about ¼ inch high and about of the same width.

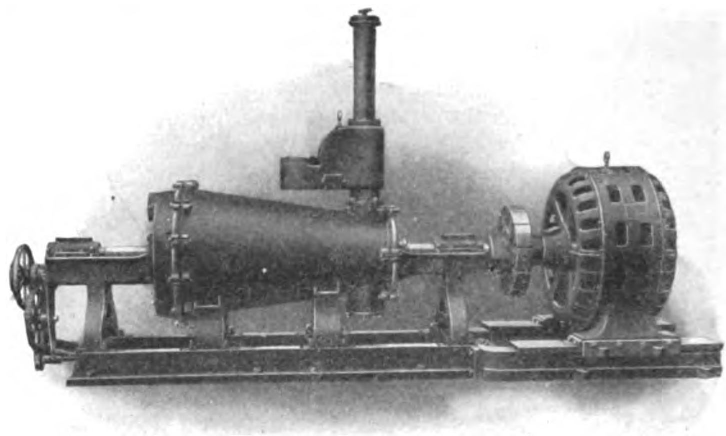
The runner is journaled to rotate about its long axis, and—like the beater roll—can be adjusted to clear the inside plates of the shell by a very minute distance. This adjustment is performed by means of a hand-wheel and screw. The runner makes from 300 to 350 revolutions per minute.

The bars, or knives, both on the shell and the runner are accurately ground, so that when the runner is properly adjusted, each knife cuts its entire length.

But this contact of the runner with the inside knives is not a direct or right-angle cut. The bars are so arranged as to deliver a *shearing* cut to the material, in somewhat the same fashion that the blades of a *lawn-mower* are obliqued against the bed-plate. These engines are massive affairs, weighing several tons, and requiring a driving-power of from 75 to 250 h.p., depending on the grade of paper being made. Kraft rag and jute stock take considerably more power than any other kind ordinarily met with, on account of their long fibre and heavy consistency.

The Jordan engine gives the paper-stuff the last refining touch before it goes to the paper machine. Each little bundle of fibres, which would otherwise clog and mar the final result, is separated and distributed throughout the material in such a manner as to make the whole stock consistent and homogeneous.

The material is forced into the small end of the cone, and out through the other end, having been compelled to pass



Courtesy: E. D. Jones & Sons Co., Pittsfield, Mass.

Fig. 105.—Motor driven Jordan engine.

through the very small space between the plug and the shell, and between the whirling knives. From the large end of the Jordan it passes down to a second stuff-chest, quite similar to the one that receives the stuff from the beaters, and is maintained in suspended state until the paper machine is ready for it.

Sand Trap.

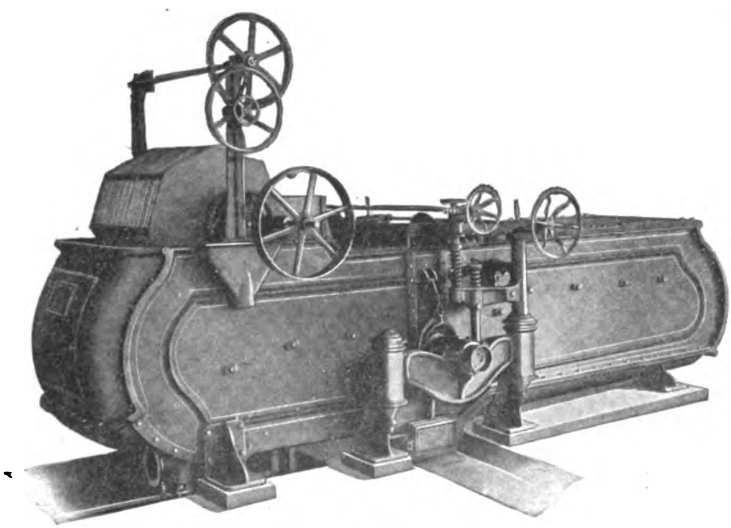
At the inlet to the Jordan a sand trap should be provided to keep sand and grit and also foreign matter such as nails, screws, pieces of iron, etc., out of the Jordan. On account of the nature of the Jordan such material would soon play havoc with the machine. It is important that these traps should be kept cleaned out, otherwise they are of no use. Sometimes a powerful magnet is built into the sand trap to retain pieces of iron. This is a very useful device.

Split-Shell Jordans.

A recent improvement in Jordan construction is making the shell in two halves, an upper and a lower, meeting along a horizontal line. The shell, heads and packing boxes are split, so that the top half of the shell can be lifted off when it is necessary to make repairs to the engine. In this way the plug can be refilled, without being removed, by merely rotating it. The top segment of the shell is provided with lugs and eye-bolts to facilitate lifting it. The two halves are carefully machined so that they come together with a water-tight joint and fasten with bolts. This type of engine is very handy when space is at a premium as it can be placed close to a wall or in any other position without allowing end room for drawing out the plug.

Marshall Engine.

The Marshall engine is another refining engine, more used in England than in America, but very useful for making certain classes of paper. It is especially good for preparing long, strong stock for thin, tough papers. It is quite similar to the Jordan, except that after the stuff has passed between the cone and the shell, it is caused to pass between a revolving and a stationary disc, both being provided with knives or bars. The revolving disc is attached to the end of the plug and the stationary disc is fastened to the inside of the shell head. The disc has a brushing action on the fibres much like the action of the roll in the beater, and the stock emerges from the machine free from chips and bundles of fibre and of uniform consistency.



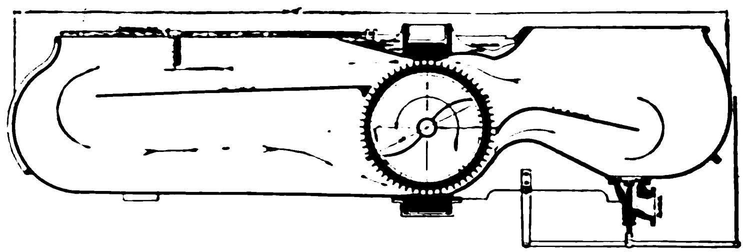
Courtesy: Downingtown Manufacturing Co., East Downington, Pa.

Fig. 106.—Miller duplex beater.

Miller Duplex Beater.

This beater is designed on the principle of effecting two beating operations for every circulation of the stock through the tub.

As the largest part of the power required in any beating engine is the power for circulating the stock, the above method would be a distinct advantage provided that it did not involve too complex a mechanism. The builders of the Miller beater seem to have

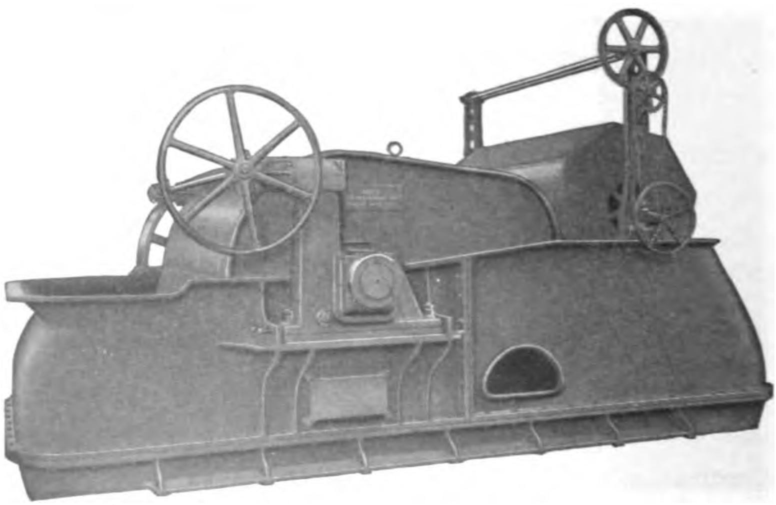


Courtesy: Downingtown Manufacturing Co., East Downingtown, Pa.

Fig. 107.—Diagram showing construction and operation of Miller duplex beater.

solved the engineering problems involved very nicely and numbers of these beaters are giving very good service.

The cut represents a section of the Miller beater, showing the submerged roll and the front and rear midfeathers dividing the tub into upper and lower sections, through which the stock is



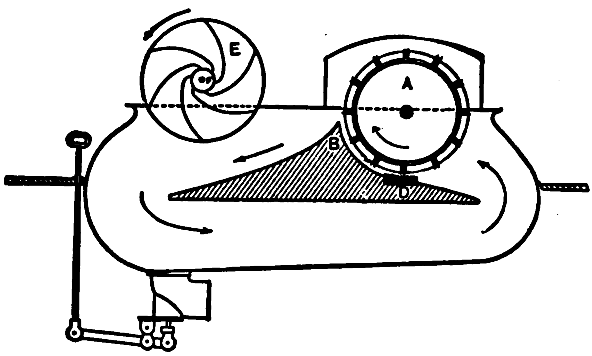
Courtesy: Holyoke Machine Co., Holyoke, Mass.

Fig. 108.—Umpherston beater.

circulated by contact with the roll in both sections, which greatly increases the rapidity of the circulation and makes it impossible for the stock to settle or lodge in any portion of the tub. The location of bed-plates both below and above the roll doubles the beating capacity of the engine. The roll is carried in double lighters in the usual manner. The top bed-plate is likewise carried on double lighters, which are connected to and controlled by the roll lighters in such a manner that the top plate is raised and lowered twice as fast as the roll, thus preserving an equal distance between the roll and both plates. In addition to being used for various sorts of paper stock, this beater has proven very efficient in beating cotton fibre for use in making smokeless powder. This beater can be equipped with one or more cylinder washers just as in the case of the usual type of beater.

Umpherston Beater.

In the Umpherston type of beater the stock is caused to pass below the floor and backfall on its return path to the front of the roll. This machine is very economical of floor space and it is



From "Outlines of Industrial Chemistry," Thorp, Macmillan Co.

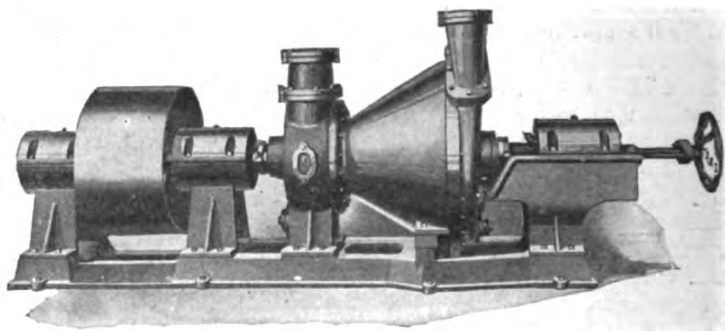
Fig. 109.—Diagram showing principle of Umpherston beater.

also supposed to give very perfect circulation with somewhat less expenditure of power than the usual type of beater. However, although many of these machines are in successful use, as is also the case with numerous other specially designed beaters, the ordinary type of beater will be found in the majority of mills. The Umpherston beater can be equipped with cylinder washers in the same manner as any other beater. The illustration shows an engine with one washer.

Continuous Beating.

The intermittent nature of the beating operation causes a certain waste of time, power and stock, as well as a duplication of equipment in some cases. Various efforts have been made to get around the filling and discharging of beaters and to devise a continuous beating process. Provided that such a system could be worked out in a practical manner many mills could reduce the amount of beating equipment required by a large amount since under the intermittent system the beaters are idle as far as production is concerned a large fraction of the time. Also in some operations, for instance the reduction of waste paper, owing to variations in kind of stock, strength and other conditions, some of the stock is reduced before other portions are ready to be discharged from the beater and the portions done first are beaten too much before the others are properly disintegrated.

The Bird Continuous Beater Attachment is typical of such appliances and is intended to enable any ordinary beater to be operated continuously. It consists of a specially constructed cylinder, which is placed in the beater like a cylinder washer, with holes of a proper size in the face and on the end next to the midfeather. The end next to the side of the beater is open for the



Courtesy: Claflin Engineering Co., Lancaster, Ohio.

Fig. 110.—Claflin Continuous Beater.

discharge of the beaten stock which has been extracted through the holes in the cylinder. A drain is cut into the side of the beater to which can be fitted a dam which will regulate the level of the stock.

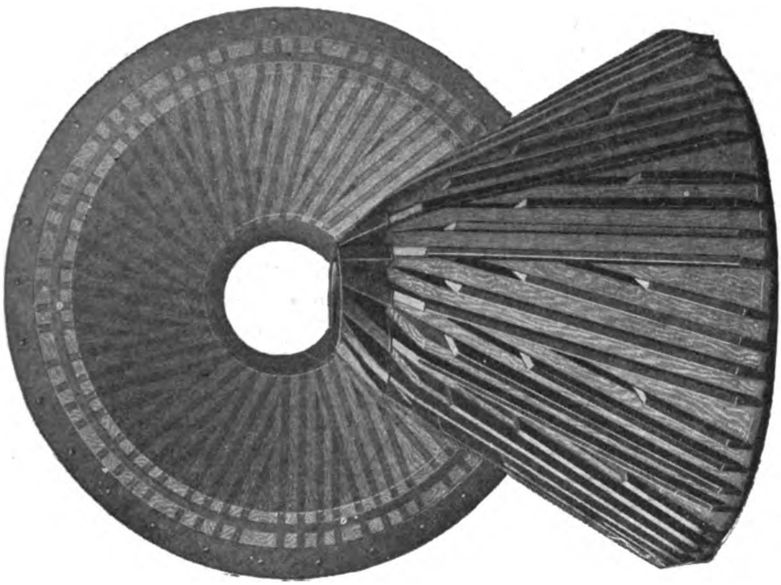
Various other devices of the same kind have been experimented with from time to time. They have found their chief application in working up waste paper, etc., for various kinds of boards. If the beating operation is to be rendered continuous it is more likely to be finally accomplished through the introduction of refining engines similar to the Jordan and Marshall engines than by adding attachments to ordinary beaters. However, under certain conditions such appliances as the one described above can prove very useful.

Claflin Continuous Beater.

The Claflin engine affords a means of making the beating operation continuous, which is an advantage from many points of view. At the same time the Claflin accomplishes everything that the Jordan engine can do. Consequently a suitable installation of Claflin engines may take the place of a combination of beaters and Jordans. This substitutes one type of machine for two, cuts down the power consumption (since the Claflins require less power than Jordans) and at the same time affords a continuous process.

Claflins are most usually installed for preparing stock requiring severe beating treatment, for instance kraft stock intended for the manufacture of high grade bag and wrapping paper.

The construction of the Claflin engine will be apparent from the illustrations. The cone is much more obtuse than in the Jordan engine, which accounts for the lower power consumption. The arrangement of the knives is also special with this engine and has been carefully planned so as to yield the same thorough brushing out of the fibres obtained in ordinary beating engines when operated in the proper manner.



Courtesy: Claflin Engineering Co., Lancaster, Ohio.

Fig. 111.—Internal view of shell and plug of Claflin Continuous Beater, showing arrangement of knives and fillers.

Power for Beater Room.

Proper drive for the equipment of the beater room involves quite a problem in mechanical engineering. With the success of the resultant sheet of paper depending directly upon correct pressure and duration of beating, and with a number of different grades of stock being carried to completion in a number of different beating and Jordan engines, it is impossible to use a centralized power-plant. The conditions are quite different from those in a factory where all the machines are driven all the time and are all shut down together when the whistle blows.

In the beater room machines are shutting down and starting at all hours of the day and night, and with a central source of power, a great deal of power would be constantly going to waste. The best procedure is to install a large electric generating plant and then drive the beaters, Jordans, agitators in stuff-chests, stuff-pumps, etc, by ***individual electric motors.***

Maintenance of Beater Room Equipment.

Beater Roll: The beater roll is made up of a number (generally four), of cast-iron discs arranged on a shaft. Two of these discs are at the two sides of the roll and the other two are near the center. The periphery of these discs is slotted straight across at stated intervals (usually about four inches apart), and into these slots the knives are driven. The knives have slots in each end, forming, when all the knives are in position, a complete circle of slots, one on each side of the roll. The outside discs have annular grooves located in a line with the base of the slots. The knives are driven in so that the lugs on the knives register with this groove. After the knives are all inserted a wrought iron ring, which fits the groove, is heated to redness and driven into this groove and allowed to cool and shrink, making a shrink fit, gripping each lug of the knives on both ends of the roll. After the knives are thus inserted and fastened, wooden filling pieces, with a driving fit, are put between each knife, and driven home by placing a wooden driver on the wooden fillers and hitting the driver with a sledge. Care must be taken to insert all of the wood fillers and to tap them down gently at first all around the roll. This is to avoid tipping the knives, and to bring an equal strain on each and every knife.

These knives (which are often called fly-bars or roll-bars), are slightly thicker in the center than at either edge, so that the swell in the center of the knife helps to hold the wood filling in place, since the wood is driven in beyond the swell. In addition to this the knives are scored slightly so that the wood when it becomes swollen with water fills the scorings. All this is done to prevent the woods from coming out and to hold the knives in an upright position.

After the knives are inserted, as above described, it will be seen that no matter how accurate the widths of these knives may be, that there is bound to be a slight variation in their height, making an uneven periphery. Thus when the roll is let down onto the bed-plate there will be found to be one or two high spots on the cutting surface and the roll will strike the bed-plate unevenly. As it is necessary to have the roll run absolutely smooth when resting on the bed-plate, the roll and bed-plate must be ground in to fit and produce smooth running. When the roll is on the bed-plate and in proper order it will hum as it revolves and there will be no knocking or rasping to be heard.

Bandless Beater Rolls: Several manufacturers of beating engines are equipping their beaters with bandless beater rolls. In these rolls the knives or fly-bars are held in position by a specially shaped slot. The knives are so made that the section in the head fits the dovetail slots. Between the heads the knives are of standard section. For this type of construction the following advantages are claimed: To fill the roll it is not necessary to take the roll out of the lighters; new bars are put into the slots with one end dovetail lug outside and next to an outside head, then with a hammer or a jack the bar is moved endwise into position. The wood filling is then put in and the roll is ready for use. However, there is some danger of the knives becoming rusted and stuck in the slots so that a great deal of trouble is had in getting them out.

Grinding a Roll In: To grind a roll in, a dam is erected of boards in front of the roll and in the space between this dam and the backfall water and sand are placed. The roll is lowered carefully onto the bed-plate and allowed to revolve so that the high spots will just touch the bed-plate. The roll is lowered as fast as the grinding proceeds, the progress of this operation being judged by the sound, which is helped by placing a smooth stick against the bed-plate and the other end against the ear. This makes it easy to tell if the grinding is going on in a satisfactory manner. When this grinding process is completed the roll is ready for use.

In running the beater extreme care must be taken that no foreign matter gets in with the stock, as even a nail would nick the knives and a bolt or larger object would seriously damage the knives and bed-plate.

When feeding laps the roll should always be raised from the bed-plate, about an inch, to avoid jumping the roll as the laps pass through. Laps should be opened out before being placed in the beater, as this makes it easier for them to pass the roll and also lessens the risk of foreign substances being put in with the laps. Also they disintegrate quicker.

Beaters intended for fresh stuff should never be used as broke beaters. The broke is hard to disintegrate and also is likely to contain pieces of metal such as bolts, nuts, tools, etc.

Beater knives should be inspected carefully to see if acid contained in the stock is wearing them thin. Sometimes beater knives are worn to a knife edge in this manner, under which circumstances they should be replaced.

In the course of time beater knives, bed-plate and the inside of the beater itself will acquire a certain smoothness from the constant polishing of the circulating stock. It is very valuable to preserve this and no scraping or rough handling of the interior of the beater or washing with strong alkali or acid should be permitted.

Bed-Plate: The bed-plate of the beater consists of a bank of knives and wooden fillers arranged alternately. The knives and fillers in the center are short and those at the two edges are longer, so that the top surface of the bank is a concave trough which is parallel to the bottom of the beater roll, so that every one of the knives in the bed-plate will cut. This bank is fastened together by bolts running straight through and fitted with nuts countersunk into the outside pieces of wook. Sometimes instead of being set parallel with the roll-bars, the knives are set at an angle so as to deliver a shearing cut when they come in contact with the knives of the beater roll. The whole bank of knives and fillers is set in an iron trough which has a lip perforated with a hole at its outer edge. This trough is set right across the path of the beater roll, its outer end coinciding with an opening in the shell of the beater. When it is desired to repair the bed-plate a bar is inserted through the hole in the lip of the iron trough and it is drawn right out, the beater-roll, of course, being raised during this operation. When the beater bed-plate knives wear down, the bed-plate is withdrawn in the above manner and shims inserted under the bank of knives and fillers, raising it the required degree. This operation can be repeated until the knives become worn down to such an extent that it is necessary to renew them.

Jordan Engine: Generally the first intimation that the knives of the Jordan plug are worn down appreciably, is the falling off in delivery of the stuff through the engine, owing to the loss of impelling effect on the stuff on account of the knives becoming flush with the wooden fillers. Also, the whining sound characteristic of the Jordan when the knives are in good order will be reduced. Also there is a characteristic sensation produced when the hand is placed on the shell of a Jordan, the knives of which are cutting properly, which is not met with in a Jordan, the knives of which are worn down. This can easily be ascertained by trial, and will assist materially in judging of the necessity for repair.

When the delivery of the Jordan falls below requirements, the plug has to be taken out. If it is found that the knives are in good conditions and that all that has happened is that the knives are worn down flush with the wood filling, then the wooden filling between the knives can be chipped out. This is done with a chisel. The shell of the Jordan is treated in the same manner as the plug. One chipping is all that a Jordan will stand, as if this operation were repeated so much of the wooden fillers would be removed that the knives would not have adequate support.

Owing to the acid in the stock, the knives will gradually wear very thin, and quite useless. When that stage is reached they must be replaced. Also they must be replaced if they have become hacked or nicked by foreign matter getting into the Jordan.

Jordan Outlets: There are three outlets on a Jordan—bottom, side and top. The outlets are situated on the big end. They are supplied with handhole plates when not in use. Only one at a time is used. Usually the top outlet is the one used. The lower ones would be used in the event of making free stock requiring little refining in the Jordan. The use of the upper opening backs up the stock in the Jordan, holding it in the engine for a longer time. This effect can be increased by having a valve on the outlet and throttling the discharge. If the plug is set so that the knives are not in actual contact and the stock is throttled so that it will pass through the engine very slowly it will be found that the fibers are rubbed against each other. This is what is called stuffing a Jordon. It is an excellent way to produce a long, strong fibre, such as is noticed in strong Kraft paper. When the Jordan is stuffed, it will be noted that the characteristic whining persists only so long as the engine is full of stock. If the stock is allowed to run out the whining will cease, showing that the knives are not actually in contact.

SPECIFICATIONS FOR BEATING ENGINE

from

(Name of Firm)

(Address)

Roll.

Of cast iron, ... diameter, ... face; to be balance, and the inside well painted. To have .... heads finished to an exact diameter, so as to give each bar a solid bearing on every head, accurately fitting slots to receive the bars and no wedges to be used for supporting or holding same in place. Each head to be bored a driving fit and firmly keyed to the cast iron shaft; the outside heads finished on their outer faces, provided with suitable "banger irons" made of wrought iron and fastened with countersunk head machine screws.

Shaft.

Of cast iron, ... diameter where the heads are located, finished the entire length, tapering towards the ends; provided with a finished brass cap on the front end. Wrought iron collars at the location of the back side and midfeather, and a .... collar at the location of the front side. .... for driving cylinder washers.

Bearings.

Front .... diameter, ... long; back .... diameter, ... long. Type, babbitted, water jacketed. Corners rounded.

Fly Bars.

Of ...., in number, ... wide, ...cut, ... shoulder, ... back, projecting .... beyond the filling, planed true on both edges, placed in position in the roll and securely banded with .... wrought iron bands shrunk on. The spaces between the bars to be filled with oak, carefully fitted and securely driven; then the ends of the bars, filling and the outer faces of the bands are to be finished true and the roll accurately balanced.

Pulley.

Of cast iron,............diameter, ...face, ... bore, of the double belt type, turned with a suitable crown and accurately balanced. Placed............from the inside of the tub. Speed.......... R. P. M.

Lighters.

Of cast iron, moulded from our heavy patterns, with steel shafts for operating both ends of the rolls simultaneously; the cross shaft passing above the tub. The posts supported by the harness or foundation, the bases............square, the chaps of......................and the hand wheel of............; the hoist of the worm and gear type. To have a quick lever relief hoist.

Bed Plate.

Elbow style, ...wide, ...sheet steel cuts, ... outside bars, ...hard wood filling, planed true on the bottom and firmly keyed into the plate box with hard wood keys.

Plate Box.

Of cast iron, finished all over, properly fitted to the bed, projecting outside of the tub sufficiently to admit of easily drawing the same.

Tub.

..............long, ...wide and ....deep at center, inside dimensions; side, ends and midfeather made of............ ...., bottom of ...., all dressed two sides, jointed, grooved and splined, staves hollowed and rounded. The top capped with a cast iron rim securely screwed to the woodwork with countersunk head iron screws; each end to have two flat wrought iron bands. The planks forming the bottom, sides and midfeather to be securely rodded and joint-bolted together. Back side supported by....... .... heavy cast iron braces; back end, front side, covered with 2" Gulf Cypress.

Rub Plates.

Placed on the front side and midfeather, extending from the high point of the backfall to the extreme front of the roll, from the top of the tub down to the bed, set into the woodwork flush, securely fastened with countersunk head .... screws and made of ...., ...thick.

Corners.

Of ...., located where the sides, ends and midfeather join the bottom.

Protecting Bands.

Of 1½"x¾" half round iron, fastened to the staves with countersunk head iron screws, located between the two regular flat bands.

Bed.

To have patented backfall; the bottom made of ....

timber; the crown of ....

Plating.

To extend from the extreme high point of the backfall to the back side of the plate box, from the front of the plate box to the low point of the apron (where there is an apron) otherwise for a distance of 18". To

be of ...., ...thick, securely fastened to the

woodwork with countersunk head ....screws.

Curb.

Heads of ...., packing boxes of ....,

cover of ...., fastened to the heads with

round headed .... Of our patented type, provided with adjustable Oak doctor, cast iron deflector and protector.

Spatter Boards.

Of ...., made in .... pieces, fastened together with heavy strap hinges of brass.

Valves.

Of cast brass; .... emptying, ... wash-up.

Hydrant Valves.

Of cast iron and brass; ....

Cylinder Washers.

.... in number, shape ...., diameter ....,

face .... Heads of ...., buckets of

........................., sash of ...., brass wire

cloth ...., reinforced by 3 mesh, No. 18 cloth; the edges and joints protected by strips of sheet brass, all fastened to the woodwork by copper tacks. The discharging, hoisting and driving apparatus complete, of cast iron, moulded from heavy and improved patterns. The shafting throughout of steel. The water-spout supported independently of the main shaft; the water box fitted to receive a 5" cast iron flanged drain pipe. The main driving gears 2½" face, ¾" pitch.

Patented Emptying Device.

Consisting of an invention for injecting a sheet of water under pressure between the stock and the bottom of the tub, thereby not only lessening the time and labor required for dropping, but also causing the stock and water to become more thoroughly mixed. Located in the backfall and equipped with a flanged end, iron body, bronzed mounted, single angle gate valve, with screws stem and hand wheel, angle end to turn down; you furnishing all materials and doing all the piping for connecting your water supply to the above.

Patented Stock Emptying Valve.

Consisting of an oblong rectangular valve and its cover, useo .n conjunction with our patented emptying device, of iron and steel throughout, located in the bottom of the engine and in front of the roll, extending between the front side and the midfeather, being so placed that its top is flush with the inside of the bottom of the engine. The lower end having a machine finished flange, the total depth being 14″ from the inside of the tub. The shaft operating the cover projects through the front side of the engine, is supported by proper bearings and has an operating lever on its outer end. The valve seat is provided with an automatically operated shower for removing the stock from it after emptying and before lowering the cover, we furnishing a 2″ iron pipe extending to the outside of the beater tub, with an elbow, nipple and a 2″ brass plug cock valve. When the cover is in its vertical position it becomes a dam, retards the flow of the stock and forces it down the valve opening, which latter is 6″ wide and of a length nearly equal to the face of the roll.

If the connecting pipe is of ample size, and we recommend not less than 18″ diameter from the bottom of the valve to the chest and sloping sufficiently so that the stock will flow freely, then the engine can be emptied almost instantly without using a rake and with no labor other than opening the water gate valve and raising the cover of the emptying valve to its vertical position.

Floor Plates.

Of cast iron throughout, for the support of the lighter posts, one single plate being required for each pair of posts, the raised surfaces at the ends for the support of the posts being machine finished, the intervening space between these raised surfaces having a drip pan bottom and ribbed edges, the bottom slanting to a 2″ drain hole located at the center; we to furnish the tap bolts, drill and tap the holes for fastening the posts to the plates, you to set the plates, furnish and install the bolts for fastening them to the floor system.

Stock Guides.

Of cast iron, fastened with brass screws to the midfeather and front side on the inside of the engine directly in front of the roll, for the purpose of guiding the stock away from the midfeather and front side.

Piping.

All piping of every name or nature not specified as being furnished by us is to be furnished and installed by the Purchaser.

Finish.

The woodwork throughout thoroughly..............................

outside, ...inside, with.................

coats of pure.................................. The iron work to have

...............coats of pure lead paint and oil on all unfinished exposed parts. Machined parts well slushed before shipment.

Workmanship and Material.

All workmanship first-class in every respect and materials of the best of their several kinds for the purposes intended.

Note.

The assembling and erecting of the tub and of the parts which attach thereto is to be done at the Purchaser's mill rather than at our shops.

The various parts of the complete engines are to be shipped in as much of a knocked-down condition as in our judgment may be best.

Conditions.

The date agreed upon for the shipment of this machinery is made in good faith; it is contingent, however, upon the non-occurrence of strikes, accidents and other delays unavoidable or beyond our control.

Title of Machinery.

The title to this machinery shall not vest in the purchaser until it is fully paid for; the fact that said machinery may attach to realty by any means whatever, shall not be considered as making it a part of such realty, but till fully paid for, the same shall be and remain personal property and the purchaser agrees to execute or cause to be executed, acknowledged and delivered to us, all legal instruments necessary and appropriate to preserve our title therein. If a note or notes of the vendee or any other person is or are accepted, the title to said machinery shall not pass from us until such note or notes, all extensions and renewals thereof and interest thereon, shall have been paid in full, and if default is made in payment of the contract price of said machinery, whether evidenced by note or otherwise, the right is expressly reserved and given to us to enter the premises where said machinery may be, and remove the same as our property. The taking of security other than provided for shall not operate as a waiver of our statutory lien, and consent is given, that we may, without notice, accept security and thereafter increase, diminish, exchange or release the same.

Acceptance.

Where the payments are contingent upon the dates specified in the contract for shipment, completion of erection or starting of the machinery, and should it be impossible or impracticable to ship, erect and start said machinery on these dates, owing to conditions over which we have no control, then shall this machinery and work be accepted and paid for as agreed in the contract, all providing that we are ready to ship, erect and start machinery on these dates, the payments being deferred or extended only by the additional time that we require to fulfill our contract.

Safe Keeping.

The purchaser shall become responsible for the safe keeping of this machinery and shall insure same for our benefit, as our interest may appear from the time it shall be shipped from our works.

Agreements.

There are no understandings or agreements not expressed herein and nothing is included that is not particularly mentioned.

Payments.

The contract price of any unpaid part thereof, shall draw interest after due, at a legal rate until paid, and when the time of payments extends beyond thirty days, such deferred payments shall be evidenced by a negotiable note or notes at our option.

Erection.

We will deliver F. O. B. cars..

.... (Address).............
you to unload same from cars and place in Engine Room of your mill, after which we will send...........competent........... to ....

the .... It is agreed that all labor and materials relative to the harness, floor system, leaders or pipes of any kind, pulley curbs, belts, grinding of rolls, holding-down bolts or any other kind of labor and materials which do not strictly belong to the engines, is not a part of this contract and is to be done and furnished by you, without expense to us. Price per day of ten hours for the Superintendent.............., for additional mechanics .... The charge to include time occupied going to and returning from your mill as well as while there. You are to pay all traveling expenses, board, lodging and transportation of tools both ways, also furnish all millwrights and laborers (without expense to us) that our superintendment may deem necessary in order to erect the machinery with the least possible delay.

JORDAN ENGINE SPECIFICATIONS

from

(Name of Firm)

(Address)

TYPE................ SPEED................ WEIGHT.................

R. P. M..............................lbs.

DIMENSIONS OVER ALL. 14'-10⅜"x3'9"   HEIGHT TO CENTER OF SHAFT. 2'-6"

Plug.

Of cast iron, 4'-3¼" long; 2'-10¾" and 1'-8" diameters, respectively, at the large and small ends, over bars. To consist of a taper shell, moulded from a heavy pattern, the center bored out and provided with a hub at each end. The casting to be trued up from the inside and machined to proper dimensions on its outer face; the hubs bored, splined and firmly keyed to the shaft by fitted taper keys, the latter being forced into position by hydraulic pressure. To have five (5) raised surfaces with finished slots to receive the bars. To be balanced.

Shaft.

Of hammered iron, turned all over true to sizes; 4 15/16" diameter at the pulley fit and bearings, bossed at the locations of the sleeves and plug. To have standard splines, provided with machine-finished keys for fastening the pulley and plug in position. At the back bearing there are to be five (5) taper grooves to take the end thrust.

Sleeves.

Two (2) in number, of seamless brass tubing, ¼" thick, shrunk on the shaft at the location of the packing boxes, extending from the ends of the plug to the nearest bearings and finished on their outer surfaces.

Plug Bars.

...........in number, of Open Hearth Jordan Steel; 2 11/16" wide,

............., 51¼" long, ...thick, ..., 28" long,

...........thick, planed to a width, placed in position in the plug and securely banded with five (5), ½x⅝" wrought iron bands shrunk on.

The spaces between the bars to be filled to the proper height with dry Oak; carefully fitted and well driven. The plug then to be accurately balanced.

Shell.

Moulded from heavy patterns, of cast iron, bored to a true taper inside and the ends squared up; the heads counter-bored to fit, drilled to interchangeable templates and fastened in position with standard tap bolts. To have four (4) wrought iron guide bars of 1"x⅜" iron, bent to proper shape, placed quartering and lengthwise and cap-screwed to the inner surface. To be provided with packing boxes and glands where the shaft passes through the heads; these to be finished in the usual manner. To have two (2) supporting brackets each side. The small end projecting beyond the plug about 14", having an 8" inlet at the top, a hand hole with cover on one side and a sand trap with clean-out hole and cover at the bottom. The outlets to be 6" in diameter and four (4) in number, three (3) to have plain caps and the fourth a 6" wrought iron pipe flange with standard thread.

Shell Bars.

Of Open Hearth Jordan Steel; type, ... in number,

16½" long, 1¾" wide, ... thick, planed to a width, placed in position in the shell, filled in between to the proper height with dry Oak, carefully fitted, each section being securely keyed. The filling to be made with two (2) chippings.

End Adjustment.

To be made in the usual manner by a hand wheel, screw and nut; the latter being fastened to the under-side of the back bearing.

Pulley.

Diameter............, face 18½". Of cast iron, split, of the double belt type, turned with a suitable crown, accurately bored, keywayed and balanced. To have two (2) set screws on top of the key; the latter to be of standard size and straight.

Bearings.

Three (3) in number, length 15", of the ring oiling, water-jacketed type, with slush cups and vertical adjustment; oil rings of composition, finished all over. The bases and sides machined and babbitted; one being fitted to the shaft grooves.

Guides.

Two (2) in number, of cast iron, fastened to the two (2) heads of the shell; the inner surfaces to be machine finished.

Stands.

Five (5) in number, of cast iron, two (2) each for the support of the guides and shell and one for the out-board bearing; all of the box type with machine-finished tops and feet, fastened to the base by tap bolts; the tops provided with clamping and tap bolts.

Base.

Of cast iron, moulded from a heavy pattern, thoroughly braced and cross-ribbed, provided with a solid top except where the pulley is located, sloping to a drain outlet at the back end, which is equipped for a 2" standard pipe flange. To have pockets on the ends, so that bars may be used for moving the engine, also, eight (8), ¾" anchor bolt holes. Both the top and bottom to be accurately planed.

Sand Box.

Of cast iron, of neat design, placed on top of and fastened to the shell at the feed end, provided with an 8" inlet and discharge and a cross partition or dam, dividing it into two (2) chambers; the first having a clean-out hole and cover on the side. To have a 6" vent pipe, 30" in length, equipped with a cast iron cap.

End Adjustment.

Made in the usual manner by a hand wheel, screw and nut; the latter being fastened to the under-side of the back bearing and the screw being connected through a train of machine dressed spur gearing, a shaft running lengthwise of the Jordan, supported by bearings attached to the base, the outer end being threaded and engaging a nut fastened to the bottom of the motor base, so that the same end motion which is given by the adjusting screw to the plug is also transmitted through the spur gearing, shaft and nut to the motor frame.

Couplings.

Of the flexible insulated type, one-half ...., bored, fitted keywayed and keyed to the end of the plug shaft; the other half whole, bored and keywayed to dimensions to be furnished by the Purchaser, we to furnish the key.

Motor.

Furnished by the Purchaser without expense to us and without pulley, outboard bearings or sub-base. The end of the shaft next to the Jordan Plug to project sufficiently to receive a one-half coupling; to be provided with a coupling fit and keyway. The base to have two planed surfaces in place of four; each of sufficient length and width to support the motor and to comply with our requirements. These to be finished on the bottom, outer edges and the ends. Holes to be drilled and tapped in the outer edges an the ends to receive ¾" tap bolts, to which will be attached castings which we will furnish. On the bottom of the frame there must be a raised flat surface, size about 5"x8"; to be planed, to have a counter-bore in the center 3¼" diameter, ¼" deep, to have four ¾" holes drilled and tapped to receive four tap bolts which, in turn, will fasten a nut to the frame. We will furnish the castings, the nut and all tap belts above referred to, but they will be attached to the motor base and frame by the Purchaser at his Mill.

This proposal is made with the understanding that the motor purchased

will not be higher than .... from the base to the center of the shaft, that the width from out to out of the feet will not exceed

............; otherwise an extra charge will be made and the amount of same will depend upon the increased dunebsuibs if the motor is over and above those specified.

Jordan Base.

Of cast iron, moulded from a heavy pattern, thoroughly braced, and provided with a solid top sloping to a drain outlet at the back end, which is tapped for a standard pipe. Top where the stands are located, the bottom and the ends to be accurately planed, one of the latter being drilled and provided with bolts for fastening it to the motor base.

Motor Base.

Of cast iron, moulded from a heavy pattern, thoroughly braced, and provided with a solid top. Top and bottom as well as one end to be accurately planed, the latter being drilled to receive the bolts which clamp it to the Jordan base. To be provided with our special arrangements for the support of the motor and easy adjustment thereof.

Notice.

The purchaser must advise the manufacturer of the motor and before contracting for same, in reference to all the special arrangements required and as outlined above.

Conditions.

The date agreed upon for the shipment of this machinery is made in good faith; it is contingent, however, upon the non-occurrence of strikes, accidents and other delays unavoidable or beyond our control.

Title of Machinery.

The title to this machinery shall not vest in the purchaser until it is fully paid for; the fact that said machinery may attach to realty by any means whatever, shall not be considered as making it a part of such reality, but till fully paid for, the same shall be and remain personal property and the purchaser agrees to execute or cause to be executed, acknowledged and delivered to us, all legal instruments necessary and appropriate to preserve our title therein. If a note or notes of the vendee or any other person is or are accepted, the title to said machinery shall not pass from us until such note or notes, all extensions and renewals thereof and interest thereon, shall have been paid in full, and if default is made in payment of the contract price of said machinery, whether evidenced by note or otherwise, the right is expressly reserved and given to us to enter the premises where said machinery may be, and remove the same as our property. The taking of security other than provided for shall not operate as a waiver of our statutory lien, and consent is given, that we may, without notice, accept security and thereafter increase, diminish, exchange or release the same.

Acceptance.

Where the payments are contingent upon the dates specified in the contract for shipment, completion of erection or starting of the machinery, and should it be possible or impracticable to ship, erect and start said machinery on these dates, owing to conditions over which we have no control, then shall this machinery and work be accepted and paid for as agreed in the contract, all providing that we are ready to ship, erect and start machinery on these dates, the payments being deferred or extended only by the additional time that we require to fulfill our contract.

Safe Keeping.

The purchaser shall become responsible for the safe keeping of this machinery and shall insure same for our benefit, as our interest may appear from the time it shall be shipped from our works.

Agreements.

There are no understandings or agreements not expressed herein and nothing is included that is not particularly mentioned.

Payments.

The contract price of any unpaid part thereof, shall draw interest after due, at a legal rate until paid, and when the time of payments extends beyond thirty days, such deferred payments shall be evidenced by a negotiable note or notes at our option.

Finish.

To be assembled in our shops and shipped whole. To have three (3) coats of pure lead paint and oil on all unfinished, exposed parts; machined parts well slushed before shipment.

Workmanship and Materials.

All joints machine-dressed and bolt holes drilled. Workmanship first-class in every respect and materials the best of their several kinds for the purposes intended.

XIII. The Machine Room.

The Machine Room is the name commonly given to the building housing the paper making machines together with the equipment for driving them and for supplying stock to the machines and steam to the drying equipment.

The machine ordinarily used for making paper is the Fourdrinier machine, and all remarks regarding paper machines in the subsequent paragraphs refer to that machine in its usual form.

Although there are numerous firms manufacturing Four-

Fig. 112.—View in typical machine room.

drinier machines of excellent design and construction, and although each of these firms has introduced certain special features which they think tend towards efficiency and perfection, yet the general principles are the same— i. e., the same essential parts are found in all the different makes—and the descriptions in this chapter will apply to any make of machine. Paper machines are not built standard and carried in stock like grinders or beaters. They are designed and built special for each case in accordance with specifications drawn up by the buyer, models for which will be found at the end of this chapter. Other machines sometimes used for paper making are the Harper Fourdrinier, the Cylinder Machine, the Flying Dutchman, Yankee Machine, etc. These forms of machine will be dealt with later on.

The Fourdrinier machine consists essentially of a device for allowing carefully screened pulp of constant consistency to flow onto a horizontal wire screen, made in the form of an endless belt and travelling constantly away from the point where the pulp flows on it. The water in the pulp drains through the wire, this drainage being assisted by suction boxes applied under the wire at certain points. At the end of the wire farthest from the point where the pulp flows on it, is a pair of rolls between which the film of fibres from the wire passes. At this point the film of fibres still contains much moisture, so it is passed through other felt covered rolls, which press more water out of it. Next it passes through a long series of steamheated iron cylinders, always supported by a layer of felt which travels with the paper, and these cylinders drive out all the remaining water except a small percentage always present even in paper commonly considered quite dry. Finally the paper passes through polished calender rolls to give it a "finish" and onto reels where it is wound up.

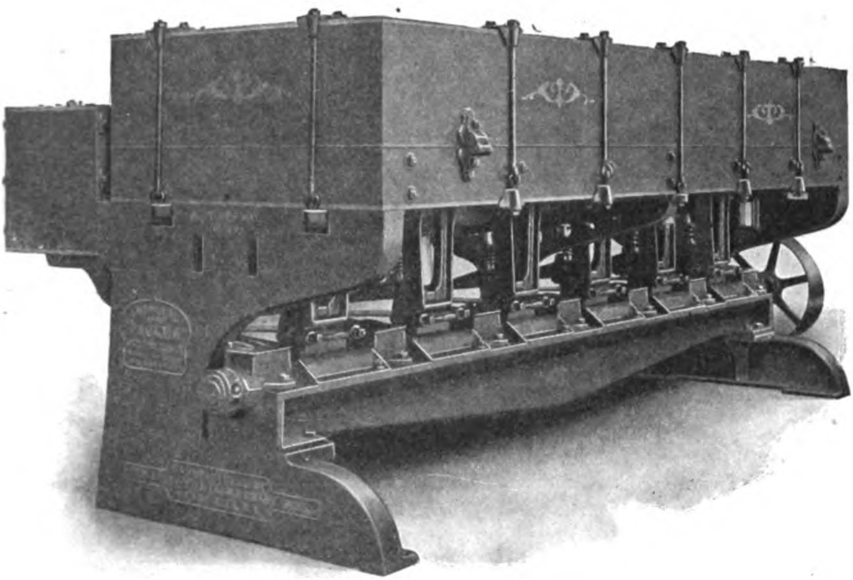
The foregoing description gives little idea of what a complex and intricate mechanism a Fourdrinier machine is, and of the necessity of having every part in perfect running order, and perfectly adjusted to every other part if satisfactory work is to be done.

Before reading the subsequent sections of this chapter, in which it will be attempted to outline the practical details of Fourdrinier machine operation, the reader is urged to study carefully the accompanying diagram of the Fourdrinier machine, learning carefully the name and location of all the various parts. After studying this diagram it would be highly advantageous, if opportunity presents, to study a machine in actual operation, identifying the various parts of the machine and carefully noting their functions.

Screens.

Before being allowed to flow onto the wire of the machine the stock is given a final screening, through screens much finer than any previously employed, in order to remove every possible trace of dirt, slivers, etc.

The screens (which in Europe are frequently called "strainers"), commonly used for this purpose are flat diaphragm screens (although rotary and other types of screens are sometimes preferred), the screening surface of which consists of a number (usually 12) of flat metal plates perforated with slits. These plates form the top of a shallow box, tray or vat, the bottom of which is made up of diaphragms which serve to suck the stock through the screens. These diaphragms are actuated by devices known in papermakers' lingo as "trotters." These trotters are simply arms attached to the under side of each diaphragm and bearing at their lower extremity a toe-block, usually of maple, which rides on a cam having three or four drops to the revolution. The cams are mounted on a shaft making about 125 revolutions per minute and are arranged so the diaphragms are not in step, i. e., so one is up when the others are down or in intermediate positions (like pistons in a four cylinder automobile engine). The toe-blocks are removable, as they wear out and have to be replaced. The diaphragms are attached to the frame of the screen by means of a leather or rubber flap which is



Courtesy: Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

Fig. 113.—Diaphragm screen, as used in connection with Fourdrinier paper machine.

sufficiently flexible to permit of the up and down motion of the diaphragm, and at the same time affords a tight joint.

The size of the screen is such that it takes regular size plates 12 in. by 43 in. The screen is so arranged as to have sufficient outlet for its capacity. The size of the slots in the plate is governed by the kind of paper being made, ranging anywhere from 8 to 18/1000 of an inch in width. Paper containing a large percentage of sulphite, Kraft or any long-fibered stock will naturally require a screen having larger slots than paper made from a shorter-fibered stock. Sometimes the screens contain two different sizes of slots.

For instance, if a slot 12 or 14/1000 is a little too small to pass the paper stock, three or four plates may be taken out and replaced by 16 cut plates, for instance, at the upper end of the screen where the stock enters the screen through a large pipe or flow-spout. This pipe is usually equipped with a quick opening valve so each screen can be operated exactly according to its capacity. The stuff goes into the upper end of the screen and flows toward the opposite end and the rapid action of the pulp when it

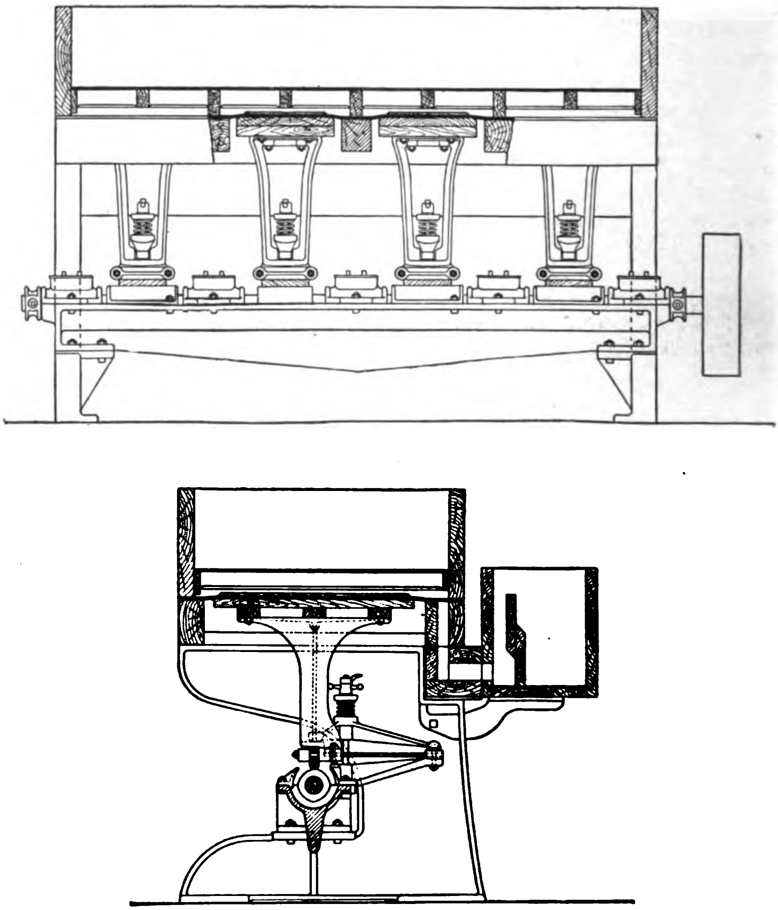


Fig. 113a.—Diagram showing side and end elevations of typical diaphragm screen.

strikes the screen does not permit of the stuff standing on the 16-cut plates. However, a good portion goes through, but dirt and shieves will not go through on account of the rapid stirring and agitation, so that the 16-cut plates help deliver the stock through without in the least increasing the dirt or shieves in the paper.

It is sometimes advisable to dam up the stock as it flows onto the surface of the screen plates by putting in cleats running crosswise of the screen, thus compelling the current as it flows over the dam, to zig-zag and retard. In these cases it is arranged to have the fine plates at the dry end of the screw, or zig-zag path, so that the large particles of dirt and shieves are carried forward with the flow of the stock and finally come to rest at the dry end. If these plates were coarse the dirt and shieves would finally jar through and get into the paper.

The screen is also equipped with adjustable dams at the outlet, so that the water and stock can be backed up under the plate at the desired distance from the plate. There is a point that is just right, which can be determined by experimenting a little with the dams. If the stock under the plates is kept at too high a level, i. e., too near the plates, the oscillation of the dia-

Courtesy: Union Screen Plate Co., Fitchburg, Mass.

Fig. 114.—Three types of plate used in diaphragm screens.

phragm will cause the stock to back up through the plates. Moreover, the long fibered stock might weave into cobweb-like particles. The slots in the screen plates are quite large on the bottom side and V-shaped, thus furnishing large grooves into which the stock would be continually beaten by the up-and-down motion of the diaphragm, and thus the process of weaving, alluded to above, set up. The cobweb-like accretions would finally get so large and heavy that they would drop off and float out through the screen outlet onto the wire. These larger particles are almost sure to break the paper down on the wire, but if any of the smaller of them do pass, they make a large blotch in the paper, which is usually wet and spoils that portion of the sheet. Consequently, great care must be exercised in adjusting the dams and thus regulating the height of the stock under the screen plates.

A good way to decide the adjustment of the dams when the screens are in use is to stand up above the screens and watch their operation, gradually and carefully lowering or raising the dam as may be required. Care must be taken during this adjustment not to flood the wire when lowering the dam, or to cause any considerable removal of stock when raising the dam. Either of these courses would result in breaks in the paper. If the lowering or raising is done ¼ inch or less at a time the adjustment can be made and the proper height of the dam arrived at without stopping operations and without any injury to the paper that is being made.

Screen plates should never be walked on, especially with hobnailed shoes, as the bars will become bent, thus opening the slots to an inordinate width, for instance, a slot intended to be 14/1000 of an inch will become possibly 24/1000 and will then let through coarse shieves and dirt.

If it is necessary to walk on the plates at all it should be done by stepping on the toes and soles of the shoes and not allowing the heels to touch, but it is much preferable that the plates be not walked on at all.

When the slots in the screen plates become filled with stock. the best way to clean them is to draw them out separately with a tool furnished by the screen plate makers, which is just small enough to go into the slot and pull out the fibres that have been caught in the slots and thus plug them up.

Some mills allow the machine help to use a wide, thin piece of rubber belting nailed to a handle, with which they clear the slots by pounding the belt on top of the plates. If this is allowed, great care should be exercised. Some predetermined thickness and weight of this slapper should be decided upon and the job should be entrusted to a careful workman. Otherwise the bars of the screen plate are sure to become bent just as if they had been walked on or bent in some other way.

The screens should be taken up and washed thoroughly as often as is necessary. It is usually customary to wash the screens once a week by rinsing and scrubbing off all the slime that may have accumulated under the vats during the week. If the slime is allowed to accumulate for any length of time, it gets so thick that it will drop off from the walls of the vat and come through on the wire. Slime has no fibre to speak of and consequently a hole is produced in the paper just the size of the slime spot. It may not actually make a hole until the paper reaches the calenders, but it is sure to spoil the paper. Furthermore, it is very likely to cause a break, and in addition, the slime spots often stick to the wire, causing a hole in the paper the size of the slime spot every time the wire makes a revolution.

The screens, in order to work properly, must be attended to just as faithfully as any other part of the machine. The toe-blocks of the trotters should always be kept tight and sufficiently long that they ride the cam, dropping into the depressions and riding over the top of the cam in a smooth way. Sometimes these toe-blocks get worn so short that only the very top of the cam touches the toe-blocks. Under these conditions no vibration is produced in the diaphragm at all. If one diaphragm is out of action in this way, it reduces the screening capacity of the equipment just 25 per cent, if there are four diaphragms to a screen.

In the event of there being more than one screen serving the machine (as is usually the case) it is necessary to watch carefully the operation of the screens with reference to the stock supplied them, and each valve should be opened or closed in proportion to the capacity of the screen it is feeding. If there is any difference in the capacities of the screens, it is probably due to the cams or toe-blocks being worn, or some other thing affecting the oscillation of the diaphragm. Always try to have the diaphragm operate with a smooth motion which will produce an intermittent suction under the screen plates. The suction is to draw the fibres through and the pressure caused by the upward movement of the diaphragm afterwards releases the fibres on top of the plates, so that the plates will not become sealed. This is why a steady suction down through the plate (such as that produced by a vacuum pump) would not do; a suction of this kind would soon seal the slots in the plate.

Another point worth bearing in mind is that large particles of fibre, dirt, shieves, and slivers are inclined to float, and if careful judgment is exercised, most of these can be floated to the dry end of the screens where they can be removed with a wooden pointed shovel.

The screen plates should never be scraped with metal harder than they are themselves. This produces rough, burr-like projections on the plates and prevents the fibres from dropping through the slots. In other words, clean, smooth slots of the right size should be maintained and care taken that nothing is done to get them out of this condition.

In taking up a screen for a general washing, if chain falls are used or rope tackle, care must be exercised not to drop any of these articles on the screen plates, for they are sure to be bent.

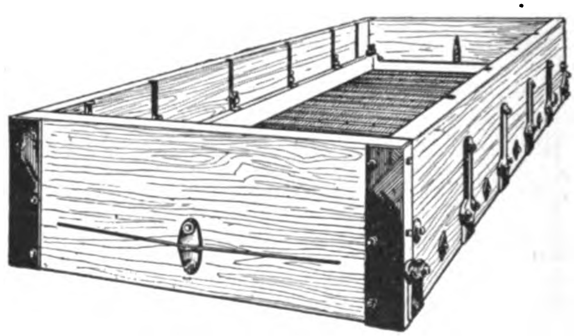
It is customary, and quite desirable, in almost all flat screens, to supply a shower of water to drive and float the material toward the dry end of the screen. These showers are usually provided by a shower-pipe extending crosswise of the screen at some advantageous point, and the needle streams that come from the shower-pipe are inclined at such an angle as to sweep the plates in the most efficient manner. With some grades of paper white water is used for the shower, while with other grades nothing but clear fresh water is used.

When the screen plates are put into a screen extreme care should be taken to see that they fit perfectly on the wooden sills of the screen body. Every screw should be driven home so that the plate will lie perfectly flat and be perfectly water-tight all around the edges. Where the sills have become worn, a thin sheet packing or gasket is sometimes used. The continued use of a screen vat necessitates screen plates being taken out and put in, time after time. The screws go back into the same hole every time, on account of the holes being drilled through the plate by a template. The holes in the sills will finally become so worn that the plates will rise or unseat every time there is an upward stroke of the diaphragm, thus letting through an immense amount of dirt.

The only cure for this worn condition of the sills is to renew them. Sometimes as a temporary makeshift, the holes can be plugged, but this it not generally recommended.

There are several screwless screen plate fasteners on the market. These have devices by which the plates can be clamped down and fastened in tightly without screw holes. The Witham Screwless Screen Plate Fastener is typical of these devices. The plates are beveled, and beveled cleats of special form hold them in position, obviating the use of screws, entirely.

Another point in connection with screens, worthy of consideration, is that the upper part of the screen body, carrying the plates, should always be carefully screwed or clamped to the screen vat and packing used to prevent this joint from leaking stock. The screens are sometimes placed in such a manner that it is hard for



Courtesy: Union Screen Plate Co., Fitchburg, Mass.

Fig. 115.—Vat of diaphragm screen showing Witham screwless screen plate fastener.

the workmen to get at the clamps to unscrew them, and in order to get them apart, the help sometimes use hammers, bars or weights. After releasing them a few times in this manner, the fastenings become useless. Good fastenings with proper packing will always keep the screen body tight, if treated with care. Leaks through the joint between the upper and lower parts of the screen body are bad because they reduce the suction under the plates, and maintain an untidy and wasteful mess of stock on the floor.

It may be that some machine tenders have the erroneous idea that by having the screen plates cut as fine as possible that it makes paper cleaner. The idea being that the finer the slot the less the large particles, such as shieves and dirt, will go through.

This idea of course is all right up to a certain limit, but where screen plates are so fine that they need constant stirring, it is very detrimental to making clean paper.

The slots in the plates must be large enough to permit of the stock going through readily without being stirred. For instance, if 14 cut plates were being used and it were necessary to stir the screens constantly to get the stuff through, it would be far better to change these 14 for 16 cut plates.

The exact limit must be determined by the kind of paper and the amount of work screens are required to do.

It is very poor judgment to equip any paper machine with a scant screen capacity, because the necessity of stirring the screens frequently not only delivers a lot of fine dirt through into the paper, but it also interrupts the weight of the paper. When the accumulated fibre in the screens is released by scraping, the weight of the paper increases. Since the drying is properly set for a certain weight of paper, the increase in weight will make the paper wet. When the screens are filling up the result following would be exactly the reverse. In other words the paper would bcome too light and dry. This would necessitate constant changing of the steam pressure in the dryers and would give all sorts of different weights to the paper, change its texture, change the moisture contained in the paper and cause no end of trouble. The screens must be adequate for the supply of the machine and the plates must be of such cut as will permit all of the stock to go through without constant stirring and attention.

As before stated, the best condition is to have the stock flow into the upper end of the screen and go through without stirring and have the large particles of dirt and shieves flow out onto the opposite end of the screen onto dry plates, where it can be carefully removed with a wooden pointed scoop.

Rotary Screens.

Some paper makers prefer rotary screens to diaphragm screens because they believe that the advantages of this type of equipment more than outweigh the somewhat increased complexity of the mechanism.

The advantages claimed for rotary screens over diaphragm screens are as follows: With a fixed flat bed screen plates cannot be maintained at a uniform or constant degree of cleanness for flat plates accumulate dirt; they fill up and foul until it becomes necessary to wash up. Consequently, there is a period just before washing up when the stock is dirty. By building the screen plates in cylindrical form, as in the rotary or revolving screen, it is possible to keep the plates clean all the time by a continuous shower.

In spite of these advantages, the universal introduction of the rotary screen has been delayed waiting for a rotary screen that would combine efficient service with simple and substantial construction, large capacity and long service.

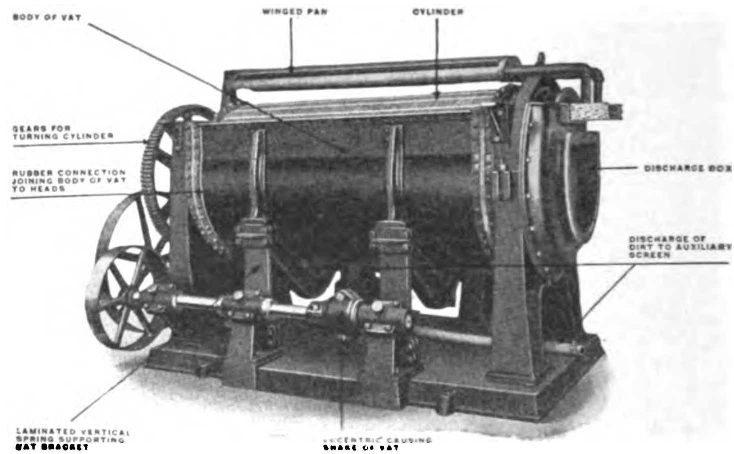
Several makes of rotary screens are now on the market which have proved very satisfactory in operation. These are mainly of two types: inward flow screens and outward flow screens.

Bird Inward Flow Rotary Screen: This is a very satisfactory screen for all grades of stock except those containing long, slow working fibres such as the stock for bonds, ledgers, writings, etc., which usually contain a large proportion of rag stock.

The inward flow type of rotary screen permits of greater capacity than the outward flow type and consequently is desirable wherever it can be used. It is suitable for newsprint, book paper, sulphite and mixed bonds, bag and wrapping papers, ground wood, and sulphite box board, chip board, roofing felt, rope, jute and sulphite specialties, etc.

The following is a description of the operation and construction of this screen:

Unscreened stock enters through flow boxes A and B, each placed above the vat and discharging downward against cylinder C. The stock is screened through the slowly revolving cylinder



Courtesy: Bird Machine Co., East Walpole, Mass.

Fig. 116.—Bird inward flow rotary screen.

and flows through the open end to discharge box R which is connected to the head box of the paper machine by a spout or pipe, as best suits the particular installation.

Impurities held back by the plates settle toward drain E, the down-coming, unscreened stock assisting gravity in this action, and are removed in a small, constant stream to the auxiliary screen. This auxiliary screen may be a flat screen already used in the mill, or a specially designed, two plate flat screen, equipped with cleaners, will have sufficient capacity to handle this tailing stock. Impurities are removed from the top of the auxiliary screen and disposed of as may be desired, while the screened stock from the auxiliary unit is returned to the flow box of the rotary screen to be rescreened before passing to the paper machine. It is usually possible to pipe the screened stock from the auxiliary screen to the white-water fan pump and use this medium for returning the stock to the rotary screen. Where this method is not possible, or convenient, a 1½-inch centrifugal pump may be installed as an independent unit.

The slots in the cylinder are cleaned by shower H. Winged pan I serves both as a guard against splashing and also as a tray to catch the water which is driven through. Tray J catches the water which strikes the cylinder and falls back.

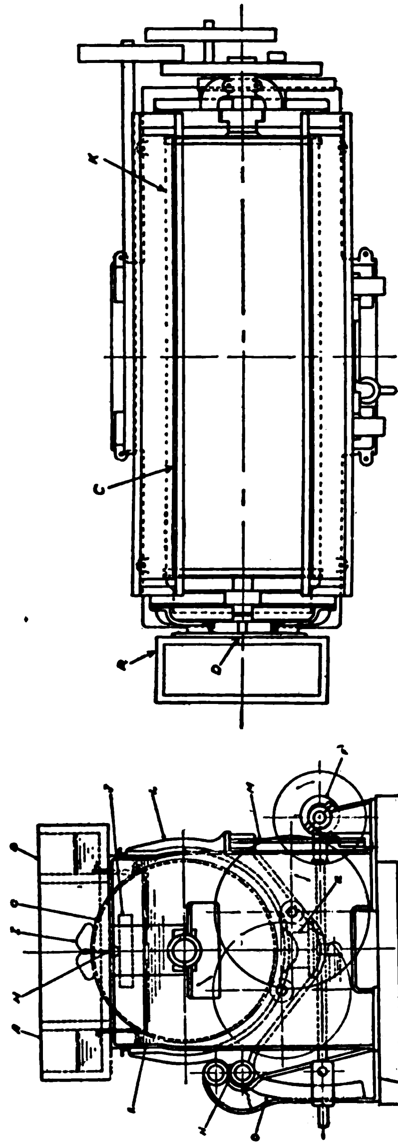
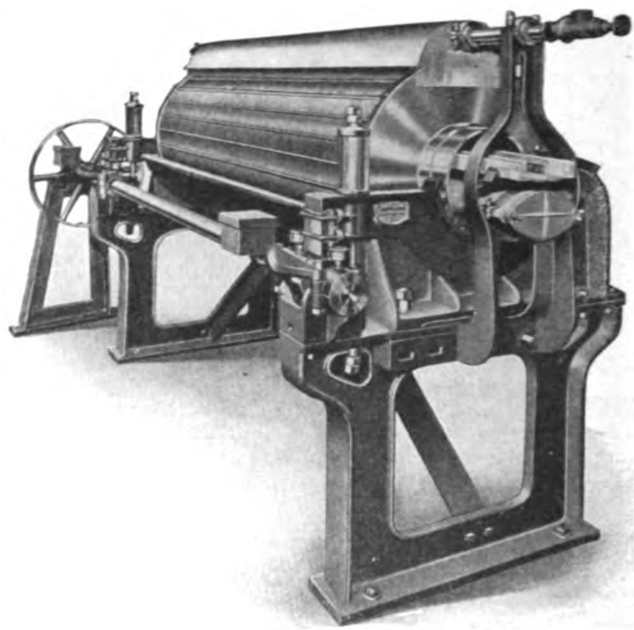


Fig. 117.—Diagrams showing side and end elevations of Bird inward flow rotary screen.
Courtesy: Bird Machine Co., East Walpole, Mass.

The body of the vat K is of 3-16-inch boiler plate, copper-lined, and rests in two semi-circular brackets L, one end of which is supported by two vertical, laminated springs M, similar to Fourdrinier supports, and the other by a double pivot N. From this pivot extends the shake arm O, connected by a rod to an eccentric P. Raising or lowering the position of the rod increases or decreases the length of the stroke. The eccentric is a 5-inch cast-iron cam running in a bronze-lined shell. The cam is bored off center 5-16 of an inch and, while running at a speed of 350 revolutions per minute, produces an easy but effective shake upon the vat. The vat body is connected to the fixed heads by strips of pure rubber. The cylinder itself is not shaken, nor is it subject to violent action as are the diaphragms in a flat screen.

One end of the cylinder is closed, and a shaft attached to the head passes through the vat by means of a simple stuffing box. The shaft is driven by heavy cast-iron gears (standard pattern) which reduce the speed from the driving shaft. These gears will last indefinitely, for they are easily lubricated and stock or water never reaches them.

The discharge end of the cylinder is carried in a bronze-lined ring bearing. A double set of packing strips makes a tight joint between the cylinder and the vat so that it is impossible for un-



Courtesy: Bird Machine Co., East Walpole, Mass.

Fig. 118.—Walpole outward flow rotary screen.

screened stock to get outside of the cylinder and leak into the screened stock flowing from inside.

It is claimed by the makers of this screen that only one-quarter as much power is required as for the operation of the diaphragms of flat screens. They also claim that plates cost less by the year when used in a rotary screen. The plates of this class of screen are interchangeable, reversible and easily replaced.

The Walpole Outward Flow Rotary Screen: This screen is specially adapted to stock containing long, slow working fibre such as is used for high class rag papers. It is an adaptation of the Wandel screen. The following is a description of the construction and operation of this screen: In construction the Walpole

Screen consists of a cast-iron vat and frames amply heavy to stand up and give long service. The vat is lined with copper, which prevents corrosion and discoloration of the stock. The cylinder plates are made of specially rolled phosphor bronze. The cylinder heads are of cast brass finished to offer a smooth surface to the stock. All fittings which come in contact with the stock are made of copper.

The stock is spouted into the cylinder through a hollow journal at the end; it drops to the bottom of the cylinder, passes through the slots into the vat, and thence to the paper machine. The rejections and impurities are carried up with the revolving cylinder and are washed out through the discharge pan by the shower. The cam shaft fitted with a six-pointed, round-faced cam at either end imparts an easy shake to the cylinder. This light, but positive vibration shakes out the massed fibers and effectively puts them through the screen plates well brushed out and ready for the paper machine. The only moving parts on a Walpole Screen are (1) the cylinder, (2) the pivoted bearings which support the cylinder, and (3) the cam shaft.

One pulley 24x4 inches constitutes the drive, which requires but 1 H.P. Oil and grease cups are provided for convenient lubrication.

Head Boxes.

The head box of a Fourdrinier paper machine is usually constructed of from three to four inches of hard pine or cypress plank, and perfectly tight. These boxes are usually strengthened with iron rods. The design of the head box should be such that it will deliver the entire flow of water and pulp mixture from the screens onto the apron and wire thoroughly mixed and not rushed on with any undue pressure which would create currents and boiling action. Also the stock should come up to the last opening and be delivered onto the apron in a smooth sheet of stock, the full width of the machine. This stock should be thoroughly mixed, the fibres drawn out and separated.

When a head box is so constructed that one can see streaks of water and streaks of stock flowing onto the wire, apparently separated, arousing the homely expression that one can see a streak of fat and a streak of lean, meaning by this that the stock is not thoroughly mixed. it is not of the right construction and should not be used.

A head box usually has two or more compartments. The stock is usually delivered at the back of the box, taking it directly from the screen spout. Sometimes it is put into the box at the top, and allowed to fill the first compartment, striking against the partition and coming up and over the edge of the last partition and onto the apron.

The size of this head box is determined entirely by the volume of stock and water that has to be handled. Different conditions require a little different construction to meet them. Sometimes it is necessary on account of the location of the screen to enter the stock down low where it first goes into the head box. In this case the first partition next to the intake goes clear to the bottom and the stock in this case has to flow over the top of the first partition and underneath the next one. All of this is meant to spread the stock, to produce the mixture uniformly or draw it out as mentioned above. There is also provided an overflow at the back side of the flow box so that in the event of a gush of water caused by the screens filling up, by the uneven flow of pumps or by opening valves at the intake of the screens, etc., this overflow will pass from the end of the head box around into the pump box and to the screens. A gush of water distributed in this way will not as a rule cause any breaks or trouble on the machine, if it is worked carefully.

If the wire should stop (from the breaking of a belt or the slipping of a couch roll or for any reason) so that the stock must be shut off suddenly before the machine can be closed down in the regular way, the outlet to the apron would have to be shut off quickly while the stock was still flowing into the screen and head box. This overflow would take care of the most of this violent gush of water and flood the wire but little. The head box is also usually equipped with a lip at the outlet where the stock is distributed onto the apron and this lip can be raised by means of hinges on the underside. This lip is called the apron-board and carries the apron across the breast roll. When a wire has to be put on, this hinge on the apron-board permits swinging it back out of the way, thus giving ample room to take out the breast roll without difficulty.

Apron.

The apron is a shallow, flexible trough, through which the stuff flows onto the wire, thus bridging over the open space between the breast roll and head box. The slices, which are metal dams with perfectly level under edges, set vertical to the surface of the wire, dam back the stock, filling the apron full of water containing pulp fibres and this is called the pond. The slices are raised one inch or less, from the wire so as to allow all the water and fibres to flow onto the wire. The force with which the stock comes out of the pond and under the slices is in direct proportion to the height of the water in the pond. This head is regulated by the supply of stock and also by the height of the slices from the wire. Without changing the stock supply, the slices can be lowered, reducing the area of the outlet, which results in backing up the stock in the pond to a greater height. This performance has the effect of giving the stuff more speed as it is delivered to the wire. Reversing this process gives the opposite results. These changes must be governed entirely by the kind of paper being made. The stuff must be delivered to the wire at as near the speed of the wire as possible. The slices, in conjunction with the shaking of the wire, are what spread the fibres evenly and uniformly.

The slices when set very low catch the fibres and turn them on end, causing the sheet to have a broken, unfelted appearance. This is more noticeable when working long stuff, and it is the cause of the wavy streaked appearance of thick sheets. The thicker the sheet the more shake is required to felt it and when making a thick paper, such as certain bag and wrapping papers, for which the stuff has been made long, the slices will have to be raised so that enough water may be worked in to assist in closing the fibres.

In starting a run the lower edge of the apron should be within about an inch of the first slice. This distance may often have to be varied later, depending on the particular kind of sheet being produced. When making a thin sheet from free stock, where there is difficulty in carrying the water nearly to the suction boxes, the moving of the apron clear down to the first slice will assist. Conversely when making a thick sheet from slow stuff the apron should be pulled back, possibly as much as two inches, depending on conditions to be met.

Slices.

The slices are sheets of brass, ordinarily from 6 to 12 inches wide and about ½-inch thick. They are placed across the wire vertical to the surface of the wire. They are made in two sections which slip by each other in such a manner that the length of the slice may accord with the width of the sheet of paper being made. When the length of the slice is determined, the sliding device is held firm by thumbscrews. A device is also provided for up and down adjustments so as to regulate the even distribution of the stuff on the wire.

As previously mentioned, when speaking of the apron, in making all grades and weights of paper, the slices should be so adjusted that the speed of the wire and that of the stock will be as near equal as possible. This result is obtained by the pressure of the head behind the slices (assisted by the pitch of the wire in some machines). Some machines, especially modern high speed news machines, give a high degree of pitch to the wire, sometimes the difference in elevation of the two ends of the wire being as much as 18 inches.

Slices are carried high on free stuff in order to supply the great amount of water needed in free stuff to properly close it on the wire before it reaches the suction boxes. On slow stuff the slices must be carried close to the wire in order to reduce the quantity of water. This is due to the comparatively small amount of water that will drain out of slow stuff on the wire. In most cases when making heavy paper, the slices are carried close to the wire, excepting when the stock is free, when they must be properly raised to close the sheet. The slices are a very important factor in making a paper that must be close and uniform (in looking through). Generally speaking, when making the lighter weights of paper, the best results are obtained by only using one slice, especially if the machine is running more than 200 feet per minute; otherwise the sheet is likely to be blemished with bar marks running across it. When using two slices, the first slice should be twice the distance from the wire of the second one. This causes a current between the two and insures a thorough mixing of the fibres just before they pass the last slice. The width of the deckle also influences the position of the slices. The slices on a narrow deckle must necessarily be carried higher than on a wide deckle; in fact, the whole matter may be summed up as a question of obtaining the proper head behind the slices to equalize as nearly as possible the flow of stuff with the speed of the wire.

Fourdrinier Wires.

The strands of the Fourdrinier wire are made of especially annealed copper or brass, very finely drawn and woven into a web usually from 60 to 70 wires to the inch, 60 being the most ordinary number as can readily be determined with an ordinary ¼-inch linen tester which should show 15 strands of wire to the square opening. Much finer wires are used for some special papers, such as cigarette paper. The wire is joined at the ends making an endless belt of wire cloth. Wire analyses show ordinarily 80 per cent copper and 20 per cent zinc.

The pulp fibres must be thoroughly crissed-crossed and interwoven on the wire while they are being formed into the film or web. This is the only place on the paper machine where the fibres can be interwoven and properly felted so consequently everything must at all times be in first class condition. To assist in interweaving the fibres a shaking or sifting motion is imparted to the shake rails which carry the tube rolls and wire. This is known as the "shake" of the wire. Assuming that there is only 15 feet to 20 feet of making up surface (this length depending on the machine), on the wire, and with the machine running, let us say five hundred feet per minute, it is evident that only a very small part of a minute is allowed for forming the paper. The speed at which the machine is to be driven, and the nature of the stock to be worked, must always be taken into consideration when specifying the length of the wire to be used. For the proper working of short, soft, greasy stuff at the correct speed, a long wire is an advantage, thereby giving more time to allow the water to be taken out; but for fine, long stuff, not too soft, worked at a moderate speed, a short wire will be best suited. The speed must also determine the amount of pitch or inclination to be given to the wire.

In the case of high speed news machines (as mentioned above) running constantly 600 feet a minute or more, the wire may be raised at the breast roll end as much as 16 or 18 inches to give the necessary speed to the stuff. If the stuff were moving

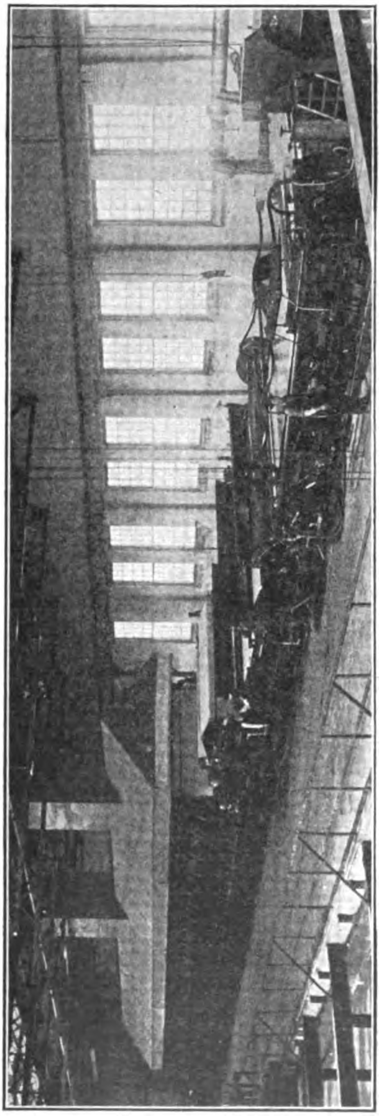


Fig. 119.—Typical Fourdrinier paper machine from wet end.

slower than the wire, the sheet would be rough and not properly felted and if the stuff should run faster than the wire it would accumulate in puddles causing streaks.

It will be noticed that when a wire after running, sometimes becomes slack on either of the edges, it is generally the back side, if the water for the wash roll enters at the front side, and vice versa if the water enters from the back. The reason for this is that the small holes in the water pipes are apt to become choked at the end farthest from the inflow, and the wire owing to its being much more dry is strained in its passage over the rolls. Apart from this the wash roll should have a suitable doctor and a good strong shower in order that any pulp, which would become lodged in the meshes, may be washed out.

Attention to this and also to thoroughly washing the wire, when shut down for any length of time, will keep the meshes clear, lessen the strain on the suction boxes, and improve the appearance of the sheet, in addition to prolonging the life of the wire.

Having the wire too slack is another very frequent source of "snap-offs" or crackings and breakings in the sheet between the dryers and calenders. When the wire is too slack the seam of it is apt to crease the paper when passing under the couch roll, but in such a way that it is scarcely noticeable, unless the machine tender knows where to look for it. This is most liable to happen when making a narrow sheet of heavy paper, and the first thing a machine tender should do when he is at a loss to account for such breaks, is to hold a light under the web between the under couch roll and the wet felt roll, so that he may make sure if any creases are there. If the wire is causing creases they will appear like small black streaks running a little way in from the edge. Tightening up the wire a few turns and putting more weight on the couch roll will cure this.

Causes of Wire Deterioration.

(1) The destructive action of the couch roll through actual wear.

(2) The pitch pressed into the wire.

(3) Foreign substances passing through.

(4) Cleaning the wire with acids.

(5) Breaking of jackets.

(6) Accumulation of stock on the wire, breast rolls and carrying rolls through the use of imperfect deckle straps and carelessness and above all the operation of imperfect shower pipes with inadequate pressure. This may be corrected by concave deckles and installation of shower pipes delivering a continuous and unbroken spray of water at from twenty to thirty pounds pressure.

(7) Improper bearings on rolls and unbalanced rolls.

(8) Rolls out of alignment.

(9) Imperfect guides and guide rolls.

(10) Deep pond over the apron and heavy load on the wire.

Except for high speed machines with inclined wire there seems to be no adequate means for relieving this load.

(11) Floods on the wire.

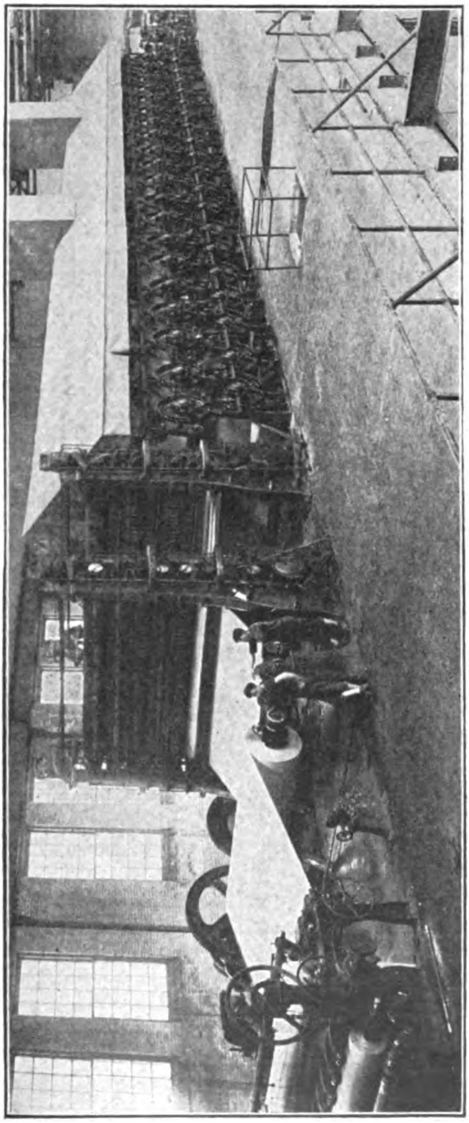


Fig. 120.—Typical Fourdrinier paper machine from dry end, showing two calender stacks.

(12) Improperly dressed suction box covers.

(13) Inefficient management has a direct bearing on shortening the life of the wire. Lack of inspection, lack of co-operation,

lack of incentiveness, contribute to a large extent to shortening the actual life of a wire.

(14) The importance of protecting the wire from injury in the store room until it is put on a machine is frequently underestimated. Unless there is a hearty co-operation and a real sense of responsibility there is likely to be trouble.

(15) Changing of wires. It is necessary that the proper facilities should be at hand when changing a wire. All parts of the machine should be thoroughly washed, cleaned and freed from slime and dirt. No foreign material or stuff should be left on the rolls, for this will cause ridges. Make sure before starting that the wire is perfectly straight, that the suction boxes are smooth, and that there is no greater tension on the wire than is absolutely necessary.

Putting on a new wire.

The wires necessarily being very fine and delicate, extreme care must be exercised in their handling, which should always be done by competent experienced workmen. A bruise or kink in these wires soon causes them to wear or break through, shortening their service to a great extent.

Defects in their manufacture should be observed, if possible, before they are put on the machine, and the wire should then be rolled back on the poles, boxed up and the manufacturer promptly notified of its non-acceptance. Slack edges, slack centers, poor seams and loops in the filling, known as slack shots, are all objectionable features. It is advantageous to have some smooth clean place in which to open up these wires, and have them inspected by a man who is competent to judge them, before they are put on the machine.

Wires should never be too tight when started, as they are thoroughly stretched before leaving the factory, and any undue strain on them shortens their service. On large machines the weight of the stretch roll is generally sufficient at the beginning, it not being necessary to screw this down.

It should be remembered that the strands of a Fourdrinier wire are not elastic, that is when once elongated by stretch they will remain so. Consequently, *the wire should never be stretched, when not in motion,* as this would lead to a permanent stretching locally whereas if stretch is applied slowly during one or more revolutions of the wire the stretching effect will be distributed evenly over the whole surface. Great care must be taken that the Fourdrinier part is thoroughly in line and level. If any of the rolls, especially the breast roll, is out of line a fractional part of an inch, a great deal of trouble is caused and the wire is liable to be run into a wrinkle. All the wire rolls should be of sufficient size and strength to prevent their springing at the center, as this usually results in a straight wrinkle in the wire which soon cuts through and destroys it.

Starting a new wire.

Great care must be exercised in starting a new wire, first being assured that everything is in proper condition before striking in the clutch, which operation should be performed very gently. A clutch should never grip so hard that the wire is started with a jerk. It is found to be a very good plan to turn the wire around slowly, at least once or twice, before the couch is set down, thus getting the wire in proper alignment before starting up. The stretch roll must not be fastened down until after the top couch roll is lowered into place.

Suction boxes should be thoroughly dressed (see page ...) so that the covers are smooth and level; all rolls should be properly cleaned; wire guides should be properly adjusted. The seam of the wire should be watched closely so that neither end will run ahead of the other, but should line up with the suction box or a parallel roll. If the apron is held in place by copper tacks it is very essential that no tacks should be left around in any place where they can get into the wire. All particles of hard material must be brushed and rinsed off before the wire is started up.

The breast roll should be supplied with a doctor, or shoe, which is simply a level edge pressing firmly on the roll, to prevent stuff collecting on it. In addition to this there should be a very strong shower of water passing through and in front of the roll and over the lip, so that all particles of stock may be washed away. There are different designs for these showers and doctors. In some cases a straight piece of square edged board covered with felt is wedged between the end of the save-all and the breast roll; in other cases a wooden doctor leans on the roll and scrapes off the stock, which collects and passes into the save-all, and under which is the shower above mentioned; anything which the doctor does not remove the shower will.

If for any reason the wire is stopped and the stuff shut off, the shake should also be stopped, as there is danger of shaking the wire into a wrinkle when it is not loaded with a sheet of paper and held down by the suction boxes. If anything happens making it necessary to strike the wire out immediately without first having a chance to shut off the stock, such stock should be thoroughly rinsed from the wire before attempting to start again. The weights should be removed from the couch levers, and by all means the suction should be broken, where the stock has sealed the wire over the top of the suction boxes. This can be done by rinsing, or by rubbing the fingers across the top to break the suction.

Care should be taken to let up on the guard-board screws before striking the wire in, as many times the couch roll jacket is torn off by neglecting to do this. The guard-board should never be let down onto the jacket until after the weights have been applied to the couch rolls, as there is always slack enough in the couch roll boxes so that if the guard-board is let down before the weights are applied this slack is taken up in the boxes and the guard box will necessarily have to carry the weight of the weights on the levers. In setting the guard-board, great care should be taken to lower it horizontally, never allowing one end to go down before the other, as in this way the jackets would be torn from the couch roll.

If the wire does not guide properly when started, there is sure to be some good reason for it, and the Fourdrinier part should be very carefully examined. No attempt should be made to guide the wire by weighting one set of the couch levers heavier than the other. It frequently happens that the suction boxes will control the guiding of the wire. It may run all right without any stock, but as soon as the sheet is put onto the wire and the suction boxes take hold, the wire may hang to one side or the other very strongly. Sometimes this can be averted by giving the suction box-heads a little air, or swinging one end slightly out of alignment.

A guide roll located between the last suction box and the couch rolls, and on a level with the suction box, is intended to keep the wire running in proper alignment. This guide roll is controlled by an automatic device called the wire guide, which tends to immediately correct any tendency of the wire to get out of alignment. The guide roll is rubber covered, and the wire makes quite a sharp bend from it down to the lower couch roll thus allowing the guide roll to get a good grip on the wire.

Care must be taken that good showers are furnished for the carrying or wash roll directly under the couches. The shower must strike the top side so that it will beat off the stock as it follows down around the wire. A good doctor also must be provided for this roll.

Stock should never be allowed to pile up in the save-all high enough to touch the wire. The cleaning of the stretch roll is another important feature. This should be well provided with good showers so that all particles of fibre may be rinsed away from the wire and the roll.

Deckles.

The Deckle Straps on a Fourdrinier paper machine are made endless, of soft rubber; 2x2½ inches square is a common size. They run over flanged pulleys like an endless horizontal belt, the upper strand being supported by the flanged pulleys, and the lower strand by the wire which carries the strap along with it caterpiller fashion by friction. These deckles are set at a width corresponding to the width of the pond, slices and apron, and on this depends the width of the sheet being made. The length of the deckle is from the pond to the third suction box. The flanged pulleys are made to move in or out—narrow or wide.

When they are moved the deckle strap moves with them. In this way the width of sheet is determined. These straps are very easily injured. The slightest crack or bruise on the edge will cause the paper to break at the couchers, presses, dryers and calenders.

The deckle straps, as they lie flat and square on the wire, prevent the fibres from spreading—they act as dams 2½ inches high, holding the stuff on the wire. The edges of the web are moulded against the straps as the straps, wire and stuff are all carried forward together. In order to mould a square and safe running edge, the water must be extracted so that the fibres are dry enough to stand up, after leaving the straps. It is for this reason that two or three of the suction boxes are placed under the straps. Modern high-speed machines have six suction boxes, three placed under the straps and three between the straps and the couch.

Deckle straps should be handled with extreme care when putting on a wire or making other repairs; avoiding having the strap come in contact with any sharp edges of any kind. They should never be tied up out of the way with a sharp string; a broad piece of wool felt should be used for this purpose.

Spare deckle straps should be kept immersed in water and never should be wound up in a tight roll. New deckle straps should be unpacked as soon as received and laid in a vat of water. If necessary for any reason to keep a deckle strap out of water for any length of time its position should be changed each day, as they rapidly harden and become rigid in whatever shape they are left in. Should a strap become nicked on the edge, or otherwise injured, it should be replaced and sent to the factory to be reground. No oil or grease should be allowed to come in contact with the straps as, like all rubber goods, they are easily ruined by oil or grease.

Tube Rolls.

The Tube Rolls are a number of parallel rolls of brass tubing designed to support the wire by forming a level table on which the wire runs. Hence they are often called table rolls. Those at the breast roll end, and under the pond and slices, should be somewhat larger than those forming the balance of the table to prevent springing under the excess weight of the pond. If a tube roll gets out of order it should be replaced at once, as the wire running over a stationary roll would soon wear a flat place on the roll. The machine tender should also look out for rolls with sprung journals, as these will cause the roll to be off center with the result that it produces an elevation in the wire, each revolution puddling the stock and causing thick streaks in the paper. If a roll can't be kept running it is always best to lower it out of touch with the wire until it can be replaced by another one.

Suction Boxes.

Suction boxes are long, narrow, brass boxes fitted with wooden covers, perforated with round, one-half inch holes or other openings, so arranged that every particle of paper that passes over them comes in direct contact with the suction without breaking the paper. In Europe these are often called pump boxes. The holes frequently flare a little from the under side so that accumulations of slime, etc., will tend to drop out. To the under side of each suction box is attached a set of pipes, leading to a vacuum pump regulated by valves, so that the vacuum can be regulated on each individual box. Furthermore, plungers are attached at the ends of these boxes which can be moved in and out in accordance with the width of the sheet. As the layer of fibres in water touches the machine wire there is approximately 99½ per cent water, but as the layer of fibres passes over the box on the top side of the wire, water is drawn out through the suction holes and pumped away, leaving about 85 per cent of water in the thin sheet before it passes between the couch rolls and on through the press rolls and dryers.

When a suction cover is dressed it should be done after the cover is screwed on the box, the whole box being removed and supported on two horses at each end, just as it is supported in the machine. Otherwise the top of the box will appear true until placed on the machine when it will be found to sag slightly in the middle. The millwright should use a jointer, not a jack plane, and an accurate straight edge.

Dandy Rolls.

The function of the dandy roll is to smooth down the surface of the sheet while it is still in formation and capable of being moulded. Moreover, the dandy roll is used to watermark the paper, in grades where a watermark is desirable, although recently other means of watermarking paper have been devised. However, watermarking with dandy rolls is still the general practice. The usual purpose of a watermark is to identify the paper of a given manufacturer. It is usually a name or a trade-mark, although watermarks for purely ornamental purposes are sometimes employed.

The dandy roll must be very light in construction and yet rigid enough not to spring. It must be sufficiently open in construction that it will not fill up, since if even a spot on the dandy is filled up it will lift the paper at that point. There is no shaft running through the center of the dandy. It is a fabricated roll, being made up of comparatively heavy wire, supporting lighter wire outside. The journals are attached to discs at each end.

The dandy roll is usually placed between the suction boxes. If a machine has six suction boxes under the wire, four are behind the dandy and two are ahead of it. The four behind prepare the sheet for the action of the dandy and the two following suck it dry ready for the couch rolls.

The dandy should never be placed right over a tube roll. It should be placed between two tube rolls, but the distance between centers should never be so great as to allow any sagging of the wire under the dandy.

The dandy is supported in "U" shaped bearings in such a manner that the weight of the dandy always rests on the paper. It must never drag on the paper.

The circumference of the dandy is so calculated that the watermark will register in just the right place on the sheet. That is, if one is making note paper or typewriter paper of a certain size it is desirable to have the watermarks come so that when the sheet is cut up the watermarks will be in the center of the sheets and not at the edges or chopped up by the cutting. It is possible to do this with wonderful precision. The paper on which the postage stamps of many countries are printed is so made that when the sheets are printed one watermark comes exactly in the middle of each stamp. Shrinkage of the paper has to be considered in this connection.

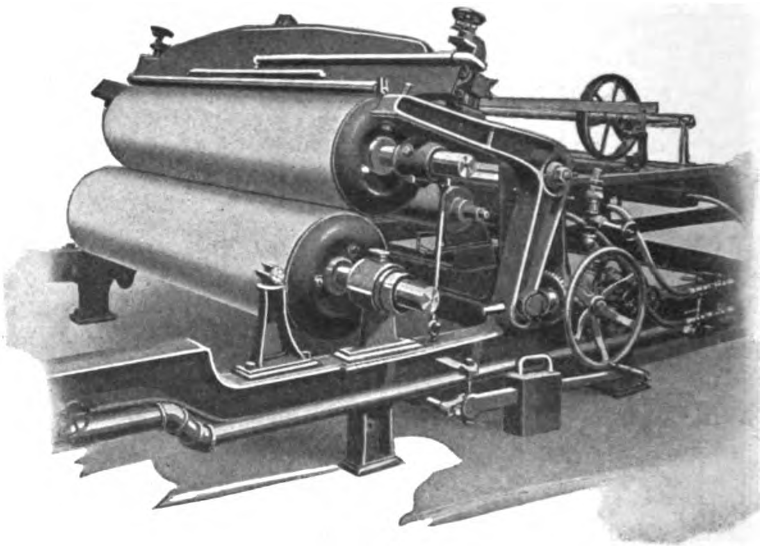
In a mill making fine writing paper or government papers for bonds, postage stamps, documents, etc., a large assortment of dandy rolls has to be kept on hand. Some of these rolls are very expensive, especially in connection with intricate watermarks (for instance the large coat-of-arms of the United States used on some government stationery) and this is an important item in such mills.

Of course, many mills not making any watermarked paper use dandy rolls for smoothing out the sheet, but such dandys are much simpler and less expensive than those used for watermarking.

If, on looking across under the wire, directly beneath the dandy, the wet streak always present under the dandy at the point where it touches the paper, does not run right across the sheet, it is an indication that the dandy is not pressing hard enough on the paper at the side where the sheet is dry, that is, it is riding in the journals, which must be adjusted to correct this defect.

The dandy is usually kept clean with a shower from a pipe supported by the supports of the dandy roll. Back of this shower is a wiper which keeps the dandy smooth and free from stock so that when it comes in contact with the paper it is perfectly clean. Some dandy rolls have internal showers, which is done by running a shower pipe through hollow journals.

It is easy to tell when the dandy needs a thorough cleaning, because it begins to pick up the sheet persistently. When this occurs the dandy must be taken off and cleaned. The right way to do this is for the machine tender to stand at the front end of the dandy and the back tender at the back end. They carefully lift the dandy from its bearings, and if this is done quickly and skilfully the paper will not be broken. Then the machine tender up-ends the dandy and places it on a pair of supports on the floor convenient to the machine. The roll is now scrubbed with dilute vitriol (sulphuric acid) care being taken that this acid is not too strong. A little acid should be added to water in a pail. It can then be tasted by sticking one's finger in it, and if it tastes about as sour as lemon juice it is all right to use. The acid is applied with a wire scrubbing brush in a thorough but careful manner. Finally, the dandy roll is thoroughly washed off with



Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 121.—Couch roll portion of Fourdrinier machine showing details of housing and adjustment by means of geared bevel and hand wheels. This illustration shows the old style of "plain" guard-board.

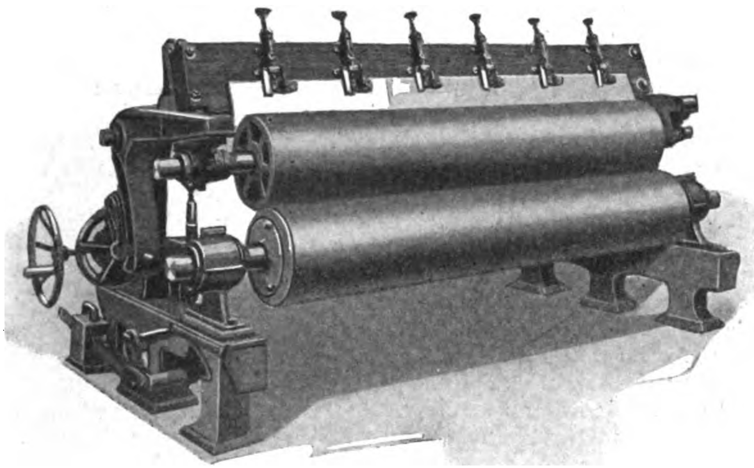
clean water. A steam hose is sometimes of benefit in cleaning a dandy roll.

When clean, the dandy is replaced in the same manner as when it was removed, care being taken to give it a little twirl in the direction of the movement of the wire when it is placed in the journals, and if this is done properly the paper will not be broken. Of course, it is always advisable to see that the dandy is clean before starting the machine, but if it becomes dirty while running the cleaning can be carried out in the above manner in about fifteen minutes.

Couch Rolls.

As the web of paper is carried with the wire after passing over the suction boxes, it passes between couch rolls where it is further squeezed to take out more water. The bottom couch roll is made of brass carefully ground to a smooth and true surface. The top couch roll is made of the same material but is supplied with a seamless tube made of wool called a jacket. A large amount of pressure is put on top of the couch roll by means of levers and weights. This jacket is put on dry, sewed around (generally with sisal cord) at the ends and shrunken in with hot water. The shrinking should be begun in the center working toward each end.

The bottom roll is connected with a clutch to a driving cone and serves to drive the entire Fourdrinier part.



Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 122.—Couch roll showing Gately patent spring guard-board.

The top roll contains numerous perforations through the shell which serve to let out any water, stock that may press through the jacket, and lint from the inside of the jacket which would otherwise create lumps which would be very harmful because of the pinching effect on the paper. These lumps would also be an obstruction to the guard-board lip as the roll revolves.

Guard-Board: The Guard-board is made from a heavy cypress or hard pine plank from 18 to 24 inches wide and 4 inches thick and trussed on the back side—also over the top. It is supported at each end by brackets extending from the upper couch roll housing. It bears a maple lip about one inch thick beveled down to about 1/4 inch on the lower edge. This lip is attached to the guard-board with iron brackets. Springs are provided between the lip and the brackets allowing for some up and down motion. This lip presses on the couch roll jacket at such an angle as to press out moisture and retard any pulp or particle of dirt, but not at such an angle as to chatter. Immediately in front of the guard-board lip is a shower-pipe extending across the couch roll to facilitate the removal of pulp and dirt, keeping the jacket clean. The lip touches the roll at a point back of the center making a shelf for water to rest in. Just in front of this shelf is a wiper consisting of a strip of felt hanging from a wooden bar extending right across the roll. This wiper assists in the maintenance of the pond of water.

Couch Roll Jacket: Either through faulty construction, pulling, shrinking or stretching, the couch roll jacket will sometimes give poor service in several different ways.

The most common of these troubles is for the jacket to stretch in the center, owing to the center constantly traveling faster than the two ends because of the slight crowning of the bottom roll.

If faults of this kind develop it does not necessarily indicate that the jacket is of faulty manufacture. The best possible jackets can give poor results if the weights on the couch roll are not kept even at the two ends, if the guard-board presses unevenly or for many other reasons.

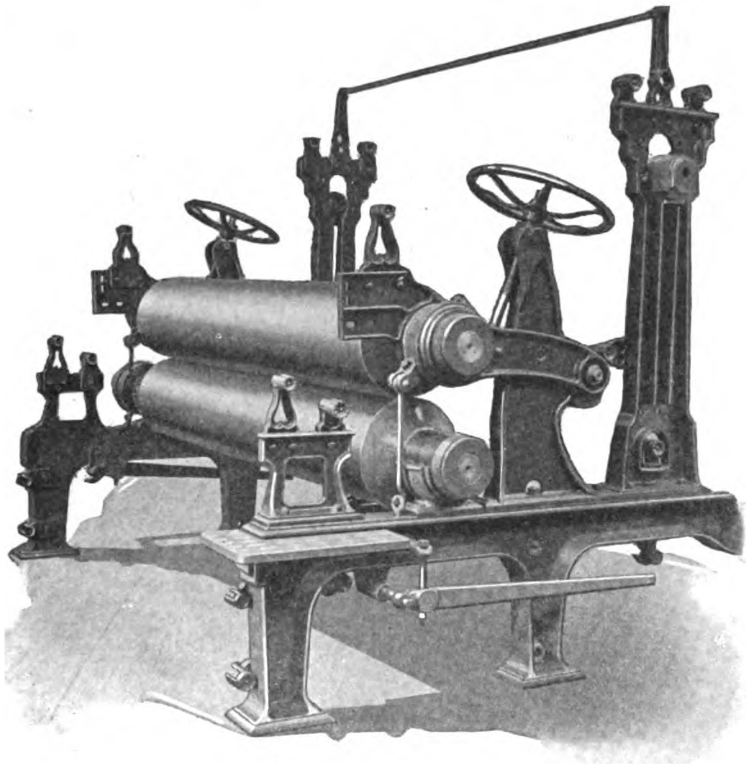
If the jacket should stretch in the center, the slack will generally remain in one position, a little behind where the upper and lower rolls meet, and unless the slack is excessive no harm will be done. If the slack becomes excessive, the machine must be shut down and the couch roll lifted, just as if a new jacket was to be put on, and then the jacket pulled forward and the ends re-sewed to take up the slack.

It should be noted that the center of the top couch roll is set back from 4 to 8 inches from the vertical line running through the center of the lower couch roll. This is so the wire, and consequently the paper forming on it, will be gently squeezed against the roll before being subjected to the heavy pressure where the two rolls meet. It the film of pulp in water were suddenly subjected to the full force of the pinch the paper would be "curdled" or "crushed" and the forming of the sheet interrupted. Moreover, this arrangement gives a straight fall-away for the water squeezed out by the rolls which would have to run around the circumference of the lower roll if their centers were set in a straight line.

Press Rolls.

The first press comes next to the couch rolls. The bottom rolls are made of iron covered with an inch of rubber, the surface being ground perfectly round and true and slightly crowned. On top of these rest wooden rolls from 24 to 30 inches in diameter. Between these rolls runs an endless woolen felt (sometimes known as a wet felt to distinguish it from dryer felts that will be dealt with later on) which runs over a system of supported rolls and a stretch roll to keep it taut. The web of paper is taken off the couch roll, and much of the water is taken out by squeezing through this massive wringer.

Press rolls are very essential indeed. The web of paper runs through each set of these rolls and the top roll is connected upon each journal with compound levers. On these levers are heavy weights and, as the rolls are naturally springy, there has to be sufficient crown put on them to offset the spring so that every

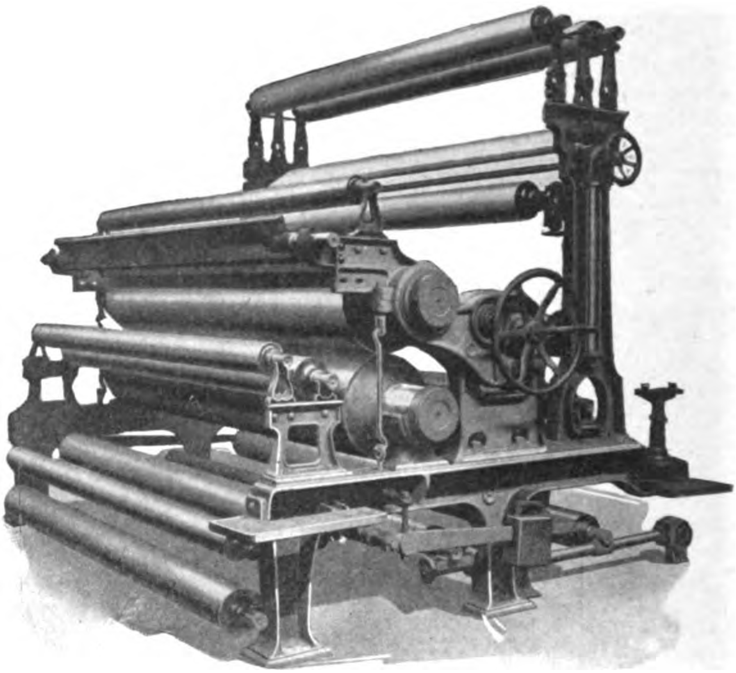


Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 123.—Press part of Fourdrinier machine showing swinging-arm type of press roll housing. In order to show the construction of the press part it is illustrated with the felt removed.

portion of the surface that comes in contact with the sheet will be perfect.

There are several reasons for the crowning of press rolls, the most important of which is the necessity of weighting the ends of the rolls with heavy weights. This in itself would cause the rolls to pinch on the ends, thereby pressing more water from the paper at this point than in the center of the rolls. To avoid this the bottom roll is ground with a crown or, in other words, it is of larger diameter in the middle with a gradual tapering toward the ends. Then again, supposing no weight were used on the ends of the press rolls, and the rolls were finished perfectly straight, resulting in an even amount of water being pressed from the sheet at all points. Now take the paper over the dryers and by drying soft you will find the edges of the paper dry and the middle part wet. This is caused by the dryer being hotter on the ends than in the middle, this condition being due to the deckles



Courtesy: The Pus., and Jones Co., Wilmington, Del.

Fig. 124.—Press part of Fourdrinier machine showing bell-crank type of housing. The equipment is illustrated with the felt removed so as to better show the construction and arrangement of the rolls and housing.

which do not entirely cover the face of the dryers, thereby leaving an uncovered space at each end on which the heat is unchecked. You, therefore, must go back and put a crown on the press rolls to overcome this difficulty. There are no definite standardized formulas which give the proper amount of crowning for the rolls. This is determined by experience only—by flexibility of the rolls—the width—the hardness of the rubber—the peculiarities of the machine as a whole. The metal rolls require less crown than rubber because they have less given to them. There are some machines which have peculiar traces such as uneven temperatures on the face of the dryers, formation of sheet, removal of water by vacuum system, which must be met and overcome by crowning the press rolls. As a general rule the first press should have about 10/1000 of an inch (in circumference) more crown than the second press. The only real way to ascertain the proper crown for the roll is by observing the sheet of paper when it is just a trifle on the damp side. If the middle of the sheet shows up damper than the edges, then the press rolls need more crowning, provided you are making an even level sheet on the wire. If the edges are damp and the middle dry then you have too much crown on the roll. When making such observations be sure that the presses are set evenly on both sides and have the levers all in same position.

The second press is the same as the first, and also the third. Paper should leave the third press about 35 per cent dry, and more than that if possible. Even then this leaves 65 per cent of the total tonnage of water necessary to evaporate in the sheet.

Suction boxes similar to those beneath the wire are placed under the felt, just in front of the pinch of the press rolls so the sheet gets the benefit of the suction just before it passes through the final squeezing of the press rolls. These suction boxes also prevent the paper from "blowing" which is the paper-makers' term for air getting between the felt and the paper and forming wet wrinkles when squeezed out by the press rolls. The suction boxes guard against this by removing the air. They also keep the felt clean, sucking out excess water.

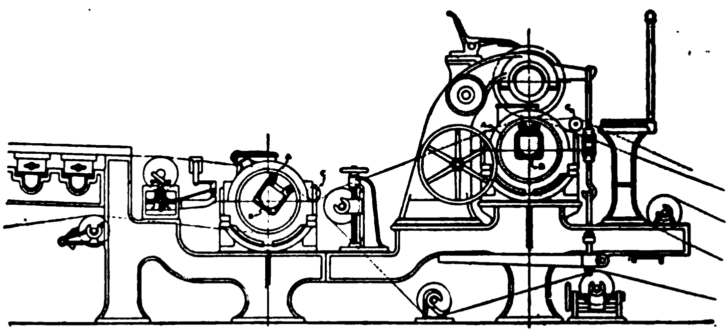
The top roll of the first press is sometimes offset from 3 to 4 inches for the same reason that the upper couch roll is (see page 308). It is also desirable to have the top wooden rolls a little longer than the bottom rolls to prevent the edges of the felt from curling. Each top wooden press roll is provided with a doctor-blade either of gutta percha or of maple wood, and even this is usually protected from direct contact with the roll by pieces of wool felt under the edge.

Suction Rolls.

Suction rolls are specially designed rolls to take the place of the couch roll or one of the press rolls, and which are intended to remove water from the paper by suction in the same manner as it is removed by the suction boxes, at the same time these rolls performing the usual functions of an ordinary couch or press roll. With the operation of wider and faster paper machines great interest has arisen in these rolls and many modern paper machines are equipped with them.

Since modern paper machines operate at very high speeds it is necessary that the water should be taken from the paper very rapidly and very efficiently, and paper machine designers have sought to improve on the older types of machine which depended for the removal of water on the drainage through the wire, the action of the suction boxes and the mechanical pressure of the couch and press rolls. Moreover, the removal of the water must be done carefully; there is a limit to the force that can be exerted by the couch and press rolls without breaking or crushing the newly formed web of paper.

In the ordinary couch roll the pressure is exerted on the line where the top roll comes in contact with the bottom roll, giving a very high pressure at any particular point in this area of contact. As the water is squeezed out of the paper at this point there is bound to be some disarrangement of the fibres of the paper. When this effect becomes excessive it is the cause of crush marks, felt marks, etc. The suction roll pressure is distributed



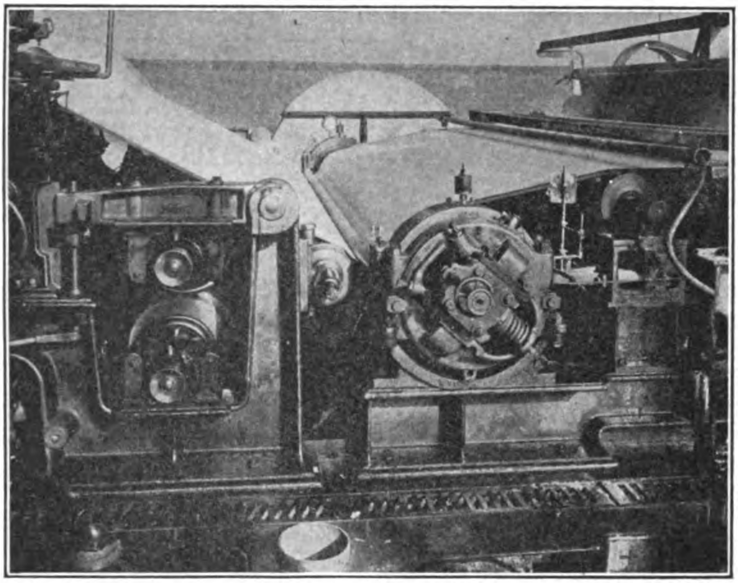
Courtesy: Sandusky Foundry & Machine Co., Sandusky, O.

Fig. 125.—Diagram showing construction and operation of suction couch and press rolls.

over a much greater area, that area being the whole surface of the roll.

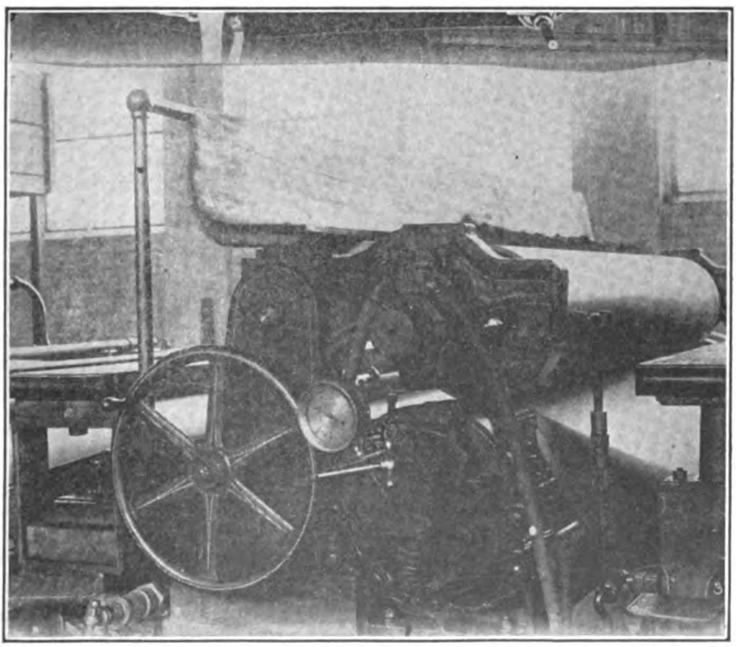
"The stationary suction chamber (B) is connected to a powerful rotary vacuum pump, usually located in the basement and driven from the constant speed line. The contact between the suction chamber and the inside surface of the revolving shell (A) is made with special hydraulic packing. A deckle arrangement is provided for adjusting the length of the suction area to accommodate any width of sheet made on the machine."

"The suction couch roll eliminates entirely the use of the old top couch roll with its felt jacket and guard board, both of which require constant attention and are responsible for many of the machine tender's troubles, such as crushing, wet streaks, wire marking, pick-ups, accidents to wires, etc. The suction couch roll does not displace all of the regular flat suction boxes on the wire. In many cases the number of flat suction boxes used may be reduced, or what is equivalent, the degree of vacuum carried on them lessened. The degree of vacuum that may be maintained at the suction couch roll in operation largely depends upon the weight and character of the paper made. Likewise the



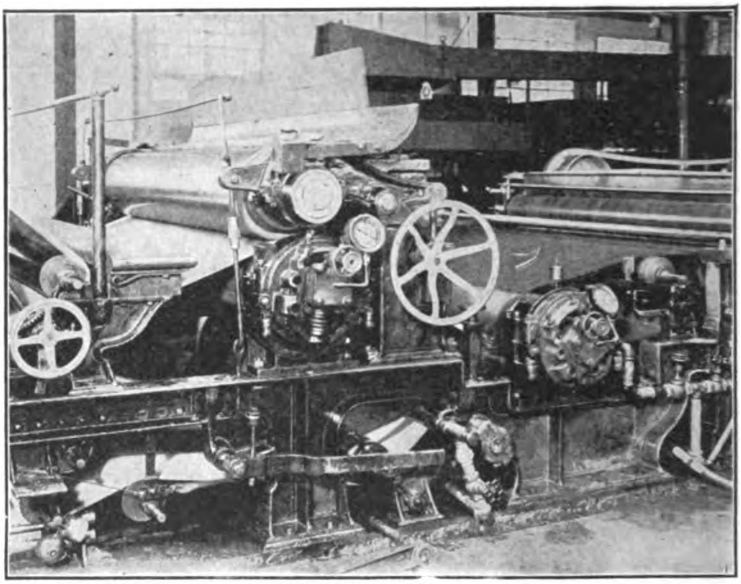
Courtesy: Sandusky Foundry & Machine Co., Sandusky, O.

Fig. 126.—Suction couch roll on Fourdrinier machine.



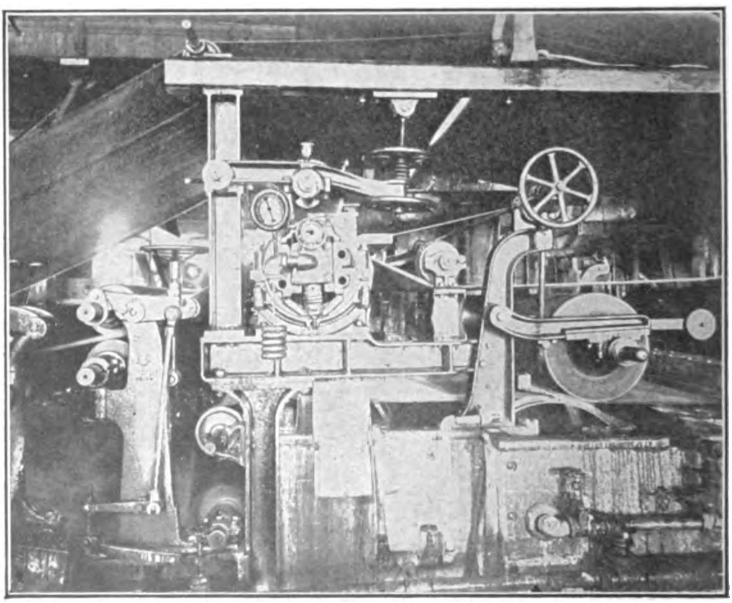
Courtesy: Sandusky Foundry & Machine Co., Sandusky, O.

Fig. 127.—Suction press roll on Fourdrinier machine.



Courtesy: Sandusky Foundry & Machine Co., Sandusky, O.

Fig. 128.—Suction, couch and press rolls on Fourdrinier machine.



Courtesy: Sandusky Foundry & Machine Co., Sandusky, O.

Fig. 129.—Suction Roll installed on cylinder machine making boards.

percentage of water that may be removed by the couch roll also varies, but to a larger extent this is proportional to the degree of hydration which the stock undergoes in its preparatory treatment. This accounts for the fact that on extremely slow stocks like grease-proof and glassine, the paper may be delivered from the suction couch roll as much as 25 per cent bone dry, whereas with quickly beaten stocks like news, the amount of water taken out may not quite equal or at least exceed that possible to take out with top and bottom couch rolls. On such papers, made from the free stocks, the suction couch roll must be supplemented with the suction press roll in order to effect increased dryness in the paper."

The use of suction rolls admits of widely varying weights of paper being made on the same machine. There seems to be no limit in the direction of heaviness to the papers which can be made on suction roll equipped machines, some very heavy boards being made in this way; but it cannot be used for very thin tissues and cigarette papers. It has been advanced by some paper makers that the suction couch roll would tend to remove filler from the paper, but this has never proved a serious difficulty in mills where the device is in constant use.

The suction press roll is quite similar to the suction couch roll, except that it is surmounted by the usual top press roll. The suction press roll is usually inserted in the first press. In addition to assisting in the removal of water from the sheet, it prevents the paper from sticking to the top press roll, a difficulty frequently encountered, because of the positive action of the suction of the bottom roll which holds the paper to it. Moreover, the air passing through the felt, on account of the suction, tends to keep the felt open and clean, lengthening its life.

It is the writer's opinion that the chief merit of suction rolls is that a greatly increased degree of suction can be obtained, without adding to the wear on the wire, as would be the case were this suction applied with flat suction boxes.

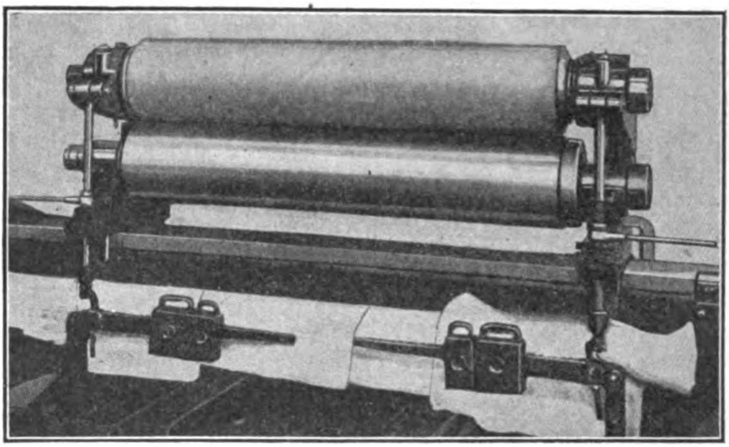
The first cost of suction rolls is a large item, but there seem to be so many advantages connected with their use, the speed of the machine can be increased with safety, breaks can be reduced, felts made to give longer service, etc., that they would seem to be an excellent investment.

Smoothing Presses.

Many modern paper machines are equipped with smoothing presses. This device is not strictly a press. Its function is not to press water out of the sheet, which is the purpose of the true presses. It is intended to smooth and flatten the sheet after it comes from the presses before it goes to the dryers, removing all wire and felt marks. Many such marks are easier removed at this stage of the formation of the sheet than later after the paper has dried.

The upper of the two smoothing rolls is covered with rubber, somewhat softer than ordinarily used on ordinary press rolls. The lower roll is provided with a gun-metal jacket which is ground very smooth. This roll has little or no crown; the upper roll is crowned somewhat more, but still very little.

The damp web of paper, usually reversed at the last press, so that the wire marks are underneath, is led over and around the upper rubber-covered roll, and passes between it and the gun metal roll underneath, whence it passes to the first dryer. The passing of the paper around the greater part of the upper roll tends to make the pull on the paper stronger in the middle than on the edges, thus avoiding tearing of the sheet.



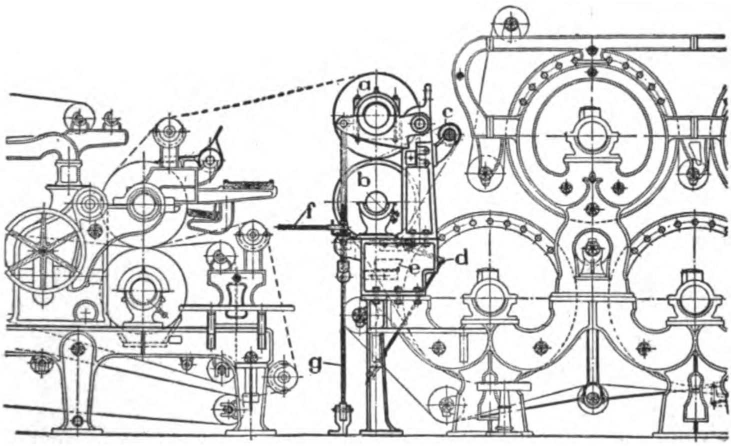
Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 130.—Smoothing press.

The success of the smoothing rolls is largely dependent on the care with which the upper roll is made. Exactly the right density or hardness is necessary if the perfect smoothing action is to be obtained. It is also very important that the smoothing action of the press should be uniform across the whole width of the sheet.

The smoothing press increases the strength of the paper due to the fact that it is smoothed before entering the dryers. It smooths the fibres in the sheet, thus allowing closer contact with the surface of the dryers, eliminating air-spaces between paper and dryer, and thereby enabling the paper to be dried better with the same amount of drying surface, or with a lower temperature in the dryers, which is beneficial to the paper. It yields a paper requiring less calendering and one which retains its finish better when glazed on the calenders only. Such a finish is not affected by the atmosphere. It obliterates all wire and felt marks at the moment when the sheet is most sensitive to mechanical finish.

Smoothing presses are chiefly useful in connection with the manufacture of good book and writing papers at moderate speeds. They are also useful in the manufacture of blottings and some specialities such as vegetable parchment.



Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 131.—Diagram showing method of installation of smoothing press.

Wet Felts.

The process of making paper-makers' felts, so far as the technical operations are concerned, is very much the same as that of making any woven woolen cloth, especially bed blankets. A paper-makers' felt is in reality a blanket and not a felt in the strict sense of the term, the latter being a sheet of wool fibre so felted or pressed together as to present a smooth surface but having no threads.

In making paper-makers' felt long, staple, strong wool is carded and spun into two kinds of yarns—the first being used for warp or threads lengthwise of the felt and the second for the filling or cross threads. The warp gives the strength and necessary pulling qualities lengthwise. The filling makes the surface of the felt and from these filling threads the nap is raised.

The seam of the felt is made by hand. A long fringe of warp is left on each end when the piece of cloth is woven. The felt being placed on a table with the two ends together, the joiner ties a knot in the ends of the two exactly opposite threads and draws one out; the other following is drawn in and takes its place. This operation being repeated first on one side and then on the other makes a perfect hand-woven seam.

The felting, fulling or thickening of the cloth then takes place and finally the raising of the nap. The coarseness of the yarns, as well as of the wool, varies with the kind of paper to be made.

The writer does not know who first discovered the use of woolen blankets as related to paper making, but for a great many years they have played an important part, not only in machine-made paper, but in hand-made paper as well.

The wool fibre among all textiles is the only one against which a wet sheet of paper may be pressed to remove the water and from which this water may again be removed by pressure. It is the only fibrous material which will pick up a sheet of wet paper from some other carrying medium and deliver it again to any desired point without injuring the sheet and with no particles of the paper stock adhering to it.

At first the two ends of a piece of felt were carefully sewed together to make the carrying belt for a paper machine; later the possibility of weaving the seam by hand and so joining the two ends to make a perfect endless belt, was realized, and on this as much as on the endless Fourdrinier wire, modern paper making depends.

Felts are of almost as many varieties as there are kinds of paper made; but, as a basis, it may be said that they are all made of strong fibered wools, varying in coarseness with the paper to be made. The main object to be gained is a felt of the greatest possible strength and resistance to friction, together with a texture so loose as to admit of maximum removal of water from the sheet of paper. Serving as a belt or carrying apron, it must be smooth and even in surface; must run straight and true; the edges must be firm and it must hold the desired width while running day after day under the varying conditions on the paper machine. It must be remembered that one of the chief characteristics of wool fibre is that it shrinks or felts together. This felting or fulling must be so supplied to the paper felt that it will not shrink more after being put on the machine.

Most felts which are used for finer papers have a nap to prevent the paper from being pressed against the threads and thus an impression in the paper being formed.

On the earlier types of machines, which were narrow and ran at slow speeds, there were only two presses. The first press of about 24 feet in length and a second press usually 12 feet in length. With the development of the Fourdrinier machine, extra width was added and speeds increased and it was found desirable to have both first and second press felts much longer, and finally, a third press, and in some cases a fourth, was added.

The invention of the Harper Fourdrinier machine also necessitated the use of very long felts, and as cylinder machines became adapted to the making of heavy boards and papers the felts were increased in length to take the paper from the additional cylinders.

While, as has been said, a woolen felt will carry the sheet of wet paper without the paper stock adhering to it, a certain amount of the stock. or of the filler run with the paper, is gradually taken up by the felt, necessitating washing either with a shower of water constantly pouring on the felt at a point where the felt may also be freed by being beaten with a driven cylinder with blades, or by shutting the machine down and removing the felt, or by washing on the machine by the method described later.

Another addition to the modern machine which has helped felts materially is the suction box. This helps to remove the water and to dry the paper, and without it the fast speed of the modern Fourdrinier machine would be impossible. There is much difference of opinion as to whether a suction box made of a plate with round perforations, or one with long slits with rounded edges, causes less wear on the felts through friction. The felts are finally worn out by friction and by the action of the water in which they are constantly run; the water must of necessity finally rot the woolen fibre. This is consequently a fixed condition so that the life of a felt depends very largely on the amount of friction to which it is subjected. This friction comes not only from the suction boxes but from the felt carrying rolls and from the presses through which the felt runs. The old-fashioned, iron bottom press rolls have been superseded by rolls covered with soft rubber. This one fact has caused the saving of an immense amount of money to paper manufacturers. The best practice today is to cover the bottom press roll with a coating of from ¾ to 1 inch of a comparatively soft rubber composition. As the roll wears and becomes uneven it should be turned down again; it is false economy to run rolls on which the rubber has worn down so thin and become so scored by wear that the friction on parts of the felt is very much increased.

The second cause of friction, which always materially shortens the life of felts, is the felt carrying rolls. Wooden rolls will not keep their shape in the extreme lengths of the modern machine and iron rolls, whether galvanized or not, soon become rusty and pitted so that even the small friction necessary to pull them creates a grinding effect on the surface of the felt which soon removes the fibre and injures the fabric. Many experiments have been made toward obtaining rustless felt rolls but the best modern practice is to have the rolls covered with brass.

In size, felts on the modern machine have gradually increased to lengths of forty, fifty and sixty feet. Here also, there is a great difference of opinion, but at the present time the majority of Fourdrinier machines are being built for first press felts varying in length from forty to sixty feet—the second and third press felts a little shorter in some cases than the first.

As has been said, the quality of felts used, varies with the paper to be made. Different paper makers (and in fact felt makers as well), have varying ideas as to the exact quality required for each particular kind of paper, but in general the following statement might be made.

For Fourdrinier machines the felts must vary in quality depending on whether the paper to be run is news, manila, book, writing, etc. All must have the quality of openness and free running and must be capable of running the longest possible time without washing, which is usually done by relieving the pressure on the press rolls and guiding the felt into the center until it forms a long rope which is pressed between the rolls as the machine runs slowly.

The felt on the second press is sometimes of the same quality as that on the first, but usually heavier, while third press felts are still heavier. The relative length of service of the first, second and third press felts on fast running machines seems to depend on the amount of work in drying the paper that each is made to do. In other words, the heavier the pressure on the felt and the heavier the suction, the shorter its life. Necessarily with the great increases of speed met with in modern Fourdrinier machine operation, the service required of felts has become much more severe. At the present time a great strain must be put on the felts lengthwise—in other words they must be run very tight—to keep them open, and admit of the high speed.

For tissue paper very fine felts with no nap are required and owing to the peculiar conditions on tissue machines, the thinness of the paper and the necessary thinness of the felt, as well as the fact that felts become filled with stock very quickly and require constant hard beating, the felts probably cause more trouble on these machines than any other.

Harper Fourdrinier machines require felts somewhat stronger, the same in general character as Fourdrinier machines running the same grades of paper.

Large cylinder machines running board on several cylinders, if the board is to be of high finish, require felts of great longitudinal strength to carry the strain of the cylinders and squeeze rolls and yet of sufficiently fine warp to give the required finish to the board.

Wet machines running pulp (for these also require carrying felts), should have very strong, coarse felts, thicker and heavier, with looser weave in the case of sulphite; closer and firmer, but still strong and open, in the case of ground wood.

These varying conditions, and this increasing severity of service, have presented a great problem to the felt manufacturer. He has constantly been obliged to change his felts to meet new and changing conditions and in many cases he has not been informed of contemplated changes until the felts he has been supplying have been blamed for not meeting conditions, for which they were not designed, and of which he had not been informed.

The life of a felt depends very largely on the treatment it receives at the hands of the machine tenders. To meet the conditions under which it is used, it must necessarily be a comparatively delicate woolen fabric, easily torn or injured, and yet it must do the work of an endless belt running constantly at a high rate of speed between heavy rolls, carrying a great weight of paper and water, and with constant liability to injury from unforeseen causes. There is no point in paper making where care and watchfulness count for more than in the treatment and use of felts. Felts in the stock room should be carefully watched and kept free from moths by the application of camphor, naphthaline or tarred paper; they should be kept free from all dirt and grease. The room should be dry and yet not hot.

Great care should be exercised in starting felts on the machine, since many felts are ruined by careless starting, whereas if a little precaution had been taken they could be made to give full and satisfactory service. The amount of service that can be obtained from a felt varies so greatly with different conditions that it is impossible to lay down any rule for this. Felts on two machines running side by side will sometimes differ 50 per cent or more in the amount of service given and the amount of paper made. It is possible for a felt to be injured in so many different ways that the felt itself should not be considered defective until every possible source of damage on or about the machine has been investigated and, in case the paper maker becomes convinced that the felt is defective in some way, it should never be sold or destroyed, but should be held until the manufacturer has been informed of the supposed defect. Felt manufacturers invariably make it a rule that felts claimed to be defective must be returned for their inspection and this rule is certainly a just one.

The treatment of worn out felts is always an important subject for consideration by the paper maker. In most paper making communities there is a demand for these old felts for use as blankets from people living in the vicinity. The felts should be carefully washed and cleaned, put in as attractive shape as possible and in a place where they can be easily inspected. Some of the poorest in which the fibre has become very rotten and threadbare can be disposed of only as waste material, but the heavy second and third press felts, and all felts that have been taken from the machine because they have been damaged, should be sold for blanketing at prices depending on the quality. This is an important source of saving to the paper maker and the careful handling of old felts may mean the reduction of cost by many hundreds of dollars in a large mill.

Proper Care of Felts.

Felts should be thoroughly inspected before being put on paper machines. The rolls, boxes, and journals should be thoroughly cleaned. The press rolls should be lifted high enough to give the felt plenty of clearance for passing under the roll. All felt roll journals should be exercised that the sharp ends of the journal do not cut the felt when passing through it. After all the rolls are in proper place and before letting down the press rolls, the felt should be straightened out as smoothly as possible, and in proper alignment with the machine. The top press roll may then be lowered onto the felt. The stretch rolls should be strained up only tight enough to take care of the slack in the felt. There should be a man on either side of the felt and in front of the press rolls to pull out any wrinkles that may pass between the rolls when first starting the felt.

Before applying any water, the felt should be run around and gradually strained up, but not too tight, as the application of the water causes it to full up, or shrink. This application must be very carefully done; one should never permit a solid stream from the hose, to be used, by holding it over one point as the felt runs around, causing a wet streak in the center, as this method usually results in spoiling the felt. In fact, such methods sometimes causes a felt to run in a straight wrinkle its whole length, caused by this portion of the felt fulling up, or shrinking in the streak where the water was applied. The only proper way to wet down a new felt previous to putting on the web of paper, is to apply the water through a shower pipe, preferably across the full length of a roll, so that the water may be evenly distributed as the felt runs around; the object being to give the felt an even amount of moisture its whole width so that when it passes between the press rolls, its very fiber will be made moist and it will thus shrink evenly.

Proper attention should be given to the seam in the felt, that it may run as nearly straight across the machine as is reasonably possible. It will be found that presses on account of the many rolls they contain, no matter how perfectly constructed, during a large number of revolutions will gradually lead the seam ahead or allow it to fall behind at one place or another. The only method of eliminating this trouble is to see that all the rolls are properly turned true in a lathe; this includes the press roll, as the crowning of the bottom press roll is sure to run the seam ahead in the center if such influence is not offset by the balance of the carrying rolls.

A seam that runs very crooked has the affect of pulling the warp in certain places to such an extent as to close up the meshes of the felt, thus allowing it to be filled up with the fine pulp in this particular streak, and finally, to mark the paper;

this produces what are known as "crush marks." The running of one side of the seam ahead of the other, presenting a diagonal appearance across the felt, can be corrected by the stretch roll. This should be attended to, as, if the felt is left with one side running several inches ahead of the other, it is very difficult to guide and liable to run into wrinkles and thus be injured.

The cause of one side of the seam travelling ahead of the other is that it does not have so far to travel around the circumference of the group of rolls in the press; hence the side of the seam in advance should be strained up so that the circumference will be increased.

Stretch roll arrangements are so constructed that the front side must be thrown out of gear in order to increase or diminish the circumference of one side. This makes it possible to operate only the back side of the stretch roll, so that if the front side of the felt seam is running ahead of the back side, the back side of the stretch roll should be slacked up thereby decreasing the circumference, allowing the back side of the felt seam to catch up to the front. If the seam runs in the reverse manner the process of adjusting should be reversed.

There is such a difference in the shrinkage of woolen felts that it is impossible to lay down any rules by which to be guided. It is usually the best practice to always use one kind of felt, of course, being sure that a felt is chosen that is best adapted to the grade of paper being made.

Some felts will shrink in length without appearing to become narrower while others will narrow up and stretch out in length.

Defects in the manufacture of felts are troublesome to paper makers. A felt often gives unsatisfactory service in spite of all the care and proper treatment that can be given. Many felts develop "bad spots"—that is, spots that will crush the paper, varying in size from a silver dollar to five or six inches in diameter. There appears to be a slack place in the weaving, leaving this particular place more closely woven, and causing the felt to "bag." Such places invariably crush.

The writer knows of no cure for this, and such a felt should be condemned, as it is the direct fault of the manufacturer.

Other felts develop into straight wrinkles in spite of the usual care in starting them when new. This is often, though not always, due to their manufacture; but it can be stated that if proper care is adhered to as above described and the felt wrinkles straight around, the blame can be placed with the manufacturer. Such felts should be carefully removed from the machine and put in safe keeping, subject to inspection or investigation by the felt manufacturer.

Many felts are ruined through carelessness of machine operators. It is not an uncommon occurence to see third hands or machine helpers when picking paper from the first press, throw it into the second press in large wads. This should never be done as it always results in injuring the felts especially if the weights are left on. The leaving on of the press lever weights when putting paper on the felts is careless negligence, and should not be permitted.

Felts should be supplied with automatic guides to keep them in the middle of the machine and in proper alignment. This is especially true of first, or wet felts. Second press felts can usually be guided by means of a hand guide.

Copper tacks commonly used around the paper machines should be used with discretion, as one of them will ruin a felt in short order.

Wooden rolls having worming or listing tacked on them, should be very carefully scrutinized when changing felts and tacks liable to work out removed or driven in.

Felts should never be run after becoming filled up; and under no consideration should the help be allowed to scratch the felt with wire brushes when it becomes filled up as this destroys the nap, rendering the felt unusable; whereas, if a felt in this condition is promptly washed, either on the machine or off, its life can be extended to a reasonable length.

The abuses mentioned have been practiced by unscrupulous machine help to aid them through their respective tours so that the work of washing or changing would fall to the workmen on the next tour. This is a narrow view of the matter, as such a method of procedure is detrimental to the production of the machine and to the company.

The application of strong acids or soda ash water to avoid washing felts thoroughly, should not be permitted. If the judgment of the machine help could be depended upon absolutely that they would never apply soda ash water strong enough to injure the fibers of the felt, the judicious use of a small amount might be permissible under certain conditions; but the ordinary procedure is to put from a pint to a quart of strong soda ash into a pail of water, boil this by means of a hose, and dump it upon the felt-grit, settlings and all. As there is sure to be a good quantity of these, soda ash if used, should be strained through a piece of fine cloth or a Fourdrinier wire to remove the gritty material after it is dissolved.

On the latest modern fast news machines it is not considered economy to spend much time in darning holes in felts, as in only unusual cases can this be done with any degree of saving. If, for instance, a felt should become torn when new, a careful and expert workman can often close the break with a fine cambric needle and soft silk thread so that it will run for sometime provided such breaks are not allowed to run until the edges become frayed out.

Soft woolen yarns, however, are used to a considerable extent on ground wood and sulphite wet machine felts as the imprint of the mending does not affect the quality of the product. The mending of a felt with woolen yarn should be done very similarly to the darning of a stocking—the threads should be properly crossed at the right intervals imitating the weave of the felt just as nearly as possible. The presence of knots and other hard particles of yarn should be avoided.

Each press in the paper machine should do its share of the work, the web of the paper never being allowed to pass one press without its proportional share of the water being taken out at this point, otherwise the second press levers must be loaded down to make up for what the first press did not accomplish. Presses should be kept in proper condition to allow the top press roll to rise and fall in proportion to any differences in the thickness of the material passing between it and the bottom roll. The levers should never be allowed to bind but should always remain flexible.

One side of a press should not be weighted to any extent heavier than the other. It sometimes happens that a little more pressure is necessary on one side to dry out the web evenly. In such cases it will usually be found that one or the other of the press rolls needs regrinding, or that the top roll is not in strict alignment with the bottom.

Save-alls under presses, and spouts leading from them to carry off water pressed from the sheet, should be kept free, so that such water will not run onto the felt. This would soon fill up the meshes with slime and cause the felt to crush. In rinsing up the machine around the presses care must be taken not to rinse grease and oil onto the edge of the felt.

If a felt becomes bare and napless from the fact of its having been in service for a considerable time on one side, it may be turned over, thus giving the benefit of the other side of the nap. Felt should never be put on a machine with the nap running the wrong way—it should be passed through the rolls so that the nap will be smothered down.

Felts speedily become worn out if they are not allowed to dry when the machine is shut down. This is one of the reasons for washing of felts on the machine. They cannot dry. The mechanical flaws of felts are very numerous and one of these is excessive tension. This tension, however, can be helped to a marked degree by proper choice of bearings and lubrication for the various sets of rolls.

At the present time there have been placed upon the market automatic felt washers which make it possible to wash the felts without the customary shut downs, and also give the felts an increased life. One of these machines is the Bennett Felt Cleanser. The washer consists of two rolls and steam pipes, the rolls controlled by means of a lever. The operation is of the simplest nature. Whenever the felts are to be washed steam is turned on and the steam pipe is pressed down against the felt. In a few seconds the felt is thoroughly cleaned of all dirty substances. This method is thorough and avoids wrinkles and creases so common to the present hand manipulation of felt washing. Moreover, the life of the felts are greatly increased and old felts (which under the old system seemed to have lost all their nap), when submitted to this washer take on a new life with the reappearance of nap that seemed to have been all worn off.

Dryers.

The purpose of the dryers is to remove by means of heat the 65 per cent or more of water still left in the paper after it has passed through the presses.

The dryer consists of a series of cast-iron cylinders usually erected so there is a double row of them, one on top of the other, and geared so they will all move at the same speed. Heat is supplied by steam piped into these cylinders; the water of condensation is removed by various devices.

The dryer cylinders are of cast iron, turned perfectly true on the surface and polished. The most ordinary size is 4 feet diameter. The castings must be perfect, as the presence of flaws, sand holes and other defects often found in large castings is dangerous, there often being a considerable pressure exerted on the dryers to provide the necessary degree of heat. The cylinders should be bored out smoothly so that the shell is of a uniform thickness throughout its circumference. Dryers not bored in this manner often contain considerably more metal on one side than on the other, which condition causes them to be out of balance and renders necessary the bolting on of a large piece of metal so as to offset the extra weight opposite. Moreover, varying thickness in the cylinder causes variation in the drying effect, owing to the great amount of heat necessary to bring the thicker metal up to the same temperature as the thinner.

Dryers should be turned on the outside and polished as bright and smooth as possible. The presence of tool marks or blemishes of any kind is fatal to the finish of the paper.

Arrangement of Dryers: The most usual arrangement of the dryers is that already alluded to, viz., in two rows, one above the other. With such an arrangement each tier usually has one long dryer felt. The majority of dryers in America are arranged in this way.

European machine builders have inclined more towards separating the dryers into two, three or more nests, each nest having an independent dryer felt. This permits of driving the different nests of dryers at slightly different speeds, which is sometimes an advantage for the following reasons: The dryers are all of equal diameter and connected together by a train of gears having equal numbers of teeth. Therefore, the speeds of the surfaces of the dryers must be equal. The paper, however, is shortening as it drys. If the paper were to slip to an equal degree on all the dryers this shortening would be of no consequence at all, but since the condition of the surfaces of the dryers is never quite the same for all of them, the paper as it shortens, slips a little more on one dryer than on another and is thus subjected to a certain amount of stretching. It is claimed that the loss of strength in certain fine papers due to this cause sometimes amounts to as much as 20 per cent.

Furthermore, each of the long felts comes in close contact with the wet paper coming from the presses and absorbs moisture, which shrinks it for a time. In shrinking the felt holds the paper alternately more and more tightly against the surface of the dryers, but as the wet paper and the partly wetted felts move on through the dryers they dry more and more, the paper tending to shrink and the felt tending to stretch out.

In making ordinary grades of paper these disadvantages in the American method of arranging dryers do not become of importance and machines making newsprint, a comparatively delicate kind of paper, run at very high speeds without breaks for days at a time.

However, the European practice of dividing the nest of dryers into several groups, capable of variations of speed has some advantages in making fine papers, because it really permits the paper to shorten as it drys. It does not lend itself so well to rapid production of large quantities of paper and almost the only case where the dryers are split into nests in America is where it is desired to insert a press for animal sizing between the two halves of the dryers.

Frequently the dryers are arranged in three tiers instead of two. This permits of some economy in space and also conserves heat to a certain extent.

Some installations of dryers have been made where the dryers are stacked up, one above the other, in two vertical stacks. This is very economical of space, but must be a very troublesome arrangement. The dryers have to be reached with iron ladders and the handling of broke and the making of adjustments and repairs on such a set of dryers must be a matter of great difficulty. However, for drying thick, heavy papers such dryers would have the advantage of conserving the heat units to a maximum extent as the heated air from the lower dryers would aid in the drying of the paper on the upper units.

Another similar device is the placing of the dryers in a gallery supported over the wire, couch and presses. This is solely to economize space. The best proof that there is little real necessity for all such innovations, and that the conventional arrangement of paper machine parts is best in the long run, is the fact that such peculiar installations are so rare. As a rule paper mills are built, in America at least, in localities where space is not at a great premium and where the usual form of paper machine is by long odds the best.

Heating of Dryers: The dryers must be piped in such a manner that the sheet of moist paper will not be scalded when it starts through the dryer. This is accomplished by having the first dryers next to the presses considerably cooler than those further along. In this way the temperature and the drying effect is raised gradually. There must be drying capacity enough to dry the paper at the required rate of speed without the exertion of undue force. If the sheet is seered or scalded at the beginning of the drying operation it traps moisture in the top of the sheet, thus requiring a great deal more steam to dry it, besides destroying some of the qualities desired in the paper.

There are different opinions as to the best methods for removing the condensation water from the dryers. It is very necessary that this water should be removed rapidly and regularly. Some operators favor siphons and some systems of dippers. It is objected to the syphons that they have a tendency to trap air in the dryers; the syphon pipe is supposed to be sealed in the water lying in the bottom of the dryer. A machine standing idle over Sunday becomes cold. Upon starting on Monday morning when the steam is admitted, the cold air is forced to the front, sometimes remaining in this condition for hours. This makes the front side of the dryer cooler than the back, causing an irregularity in the drying of the paper. Many schemes for extracting this air have been tried. Some operators put a small valve on the front end of each dryer to let out the air, just as air is let out of a steam radiator in a house heating system. It is also contended that syphons are wasteful of steam.

When systems of dippers are used, the dippers are necessarily bolted to the interior of the dryer cylinder and revolve with it. Water is dipped up at every revolution of the dryer and spills into the pipes and passes out. It is held by some that this method causes a waste of steam, since, as the dryers revolve, the dippers are at the top one-half of the time, and then being exposed to the direct pressure of the steam inside the dryers, it is supposed that the steam blows straight through and out of the drip pipes.

Machine builders place a trap on the inside of the dryer intended so that the drip pipe is never empty. Some of these traps are more efficient than others while the dripper is exposed to the pressure of the steam.

Whether syphons or dippers are used they should be kept in the best of condition. The pipes entering the neck of the dryer should never be permitted to rub against the dryer, forming holes, as in this way the efficiency of both parts of the apparatus is impaired. Under such conditions the steam is blown in and out of the dryer before it has done its work. The presence of holes in these pipes also prevents the removal of water. Dryers are often found half full of water when the pipes are in this condition.

Dryers cannot be maintained in proper efficiency without constant and intelligent supervision. If the dryers drain into a

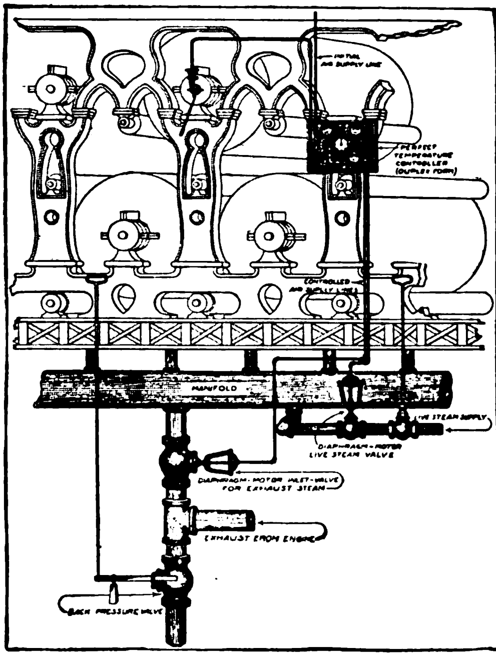


Fig. 132.—Witham system of automatic temperature control for dryers.

hot well and this hot well is not drained over Sunday and remains sealing the pipe from the dryers, the dryers will suck the water up as they cool and become full of cold water by Monday morning. This is typical of the large number of small points that have to be constantly remembered and cared for in connection with dryers.

The proper piping of the steam to the dryers cannot receive too careful attention. Piping dryers on a paper machine is a piece of work that varies markedly from ordinary piping for steam radiation, coils and other apparatus, to such an extent that an ordinary piper or piping contractor should never be permitted to introduce his own theories or ideas, but should be guided entirely by the judgment of some persons thoroughly experienced in the art of drying paper. Nearly all mills have different conditions which must be considered.

The writer has seen dryers piped up at the wet end from the exhaust of the steam engine attached to the machine, and the dry end piped up with a 1½ or 2-inch steam line direct from the boilers, carrying from 90 to 100 pounds pressure and only equipped with an ordinary valve, the degree to which this valve should be opened being left to the judgment of the ordinary machine help. It is obvious that such an arrangement as this can cause all kinds of trouble. In the first place, there is constant danger of blowing the dryers to pieces. In any case, the live steam lines will counteract the engine exhaust, causing back-pressure which slows down the engine and consequently the machine.

The paper is taken from the last press (either second or third), and carried around the dryers, under the bottom and over the top, and being threaded in this zig-zag manner the web of paper is held tight against the cylinders. When the web has passed the last dryer there is but from 5 to 10 per cent of moisture in it.

Automatic tighteners should be provided so that the sheet will at all times be hugged tightly against the hot surface of the dryers to prevent it from cockling, uneven shrinkage, and to insure even drying.

Dryer Felts.

Dryer felts are among the most difficult of paper machine accessories to manipulate. They are made of very hard and firm material—do not stretch like woolen felts, except by wetting and drying. If by any means they become wrinkled, such wrinkles are usually there to stay.

All rolls and dryers over which these felts must run should be absolutely level and in line. Rolls, whether of wood or iron, should be absolutely true.

Dryer felts should be equipped with an automatic tightener roll. They are subject to such a variety of conditions on account of the heat of the dryers, the moisture of the paper, the speed of the machine, etc., that it is very necessary that this take-up roll should be very sensitive, to respond to all the variations.

Carrying rolls not in proper alignment with the dryer felt are sure to cause the felt to travel from one side of the machine to the other, and in many cases to wrinkle. Corner rolls, especially, must be in perfect adjustment.

Dryer felts should be equipped with automatic guides which will respond readily to the slightest variations of the felts.

Old-time paper makers often believe in pulling wrinkles out of dryer felts which is bad practice, and after these felts become wrinkled straight around their entire length, they believe in steaming or wetting the wrinkle. They have many other notions equally as bad, but the only sure and true way to take care of these felts is to have the rolls properly lined-up and level and have them turned round and true.

The best results are obtained with reference to the widths of dryer felts, by having them overhang the dryers on either edge from 2 inches to 4 inches, as they then run much more steadily on the machine. These edges not coming in contact with the dryers on account of their overhanging, have a tendency to shrink a little more than the remaining part of the felt, and thus act as a resistance against any influence to move them from one side of the dryers to the other.

Replacing Dryer Felts: If the machine-tender will give a reasonable amount of his attention to the condition of the felt he will be forewarned as to its giving out, so that a new felt may be gotten in readiness to put on, as the new felt is led across the dryers by tying or stitching one end of it to an end of the old. If the dryer felt should break apart without being observed by the machine-tender, it would probably catch and wind around one of the dryers, or possibly run off from the machine entirely.

If the former should happen, it would be a hard matter to remove the felt from the dryer, as it could not be unwound, but would have to be cut off in pieces. Furthermore, the losing of a felt from the dryers often results in breaking or disabling the machine.

In putting a new felt on the machine, the dryers should be stopped and the old felt cut straight across that portion nearest the second press; the new felt can then be laid on the floor between the second press and the dryers if the bottom felt is to be replaced, or laid across the doctor of the second press of the top one. The new felt should be seamed to an end of the old, where it has been cut, to that portion which carries around the dryer. A man should be stationed on either side of the felt to help feed it along and keep it in alignment with the machine, being careful that it does not get tangled up; while two or three men should take the remaining end of the old felt and pull it along as fast as it comes off. The old felt can sometimes be so led off from the machine as to be able to put it on one of the reels and wind it up in a roll, a strong friction being applied so that the felt can be pulled off without the aid of men; but unless conditions are very favorable, it is best to run it off onto the floor into snug folds.

When starting to lead a new felt over the dryers it is also necessary to have a reliable man to operate the dryer friction so that the felt may be led very slowly and carefully over the dryers. When the felt has nearly reached its length, care must be taken not to run it too far, but to stop the dryers at the proper time so that both ends of the new felt are in proper place to seam. It must be borne in mind that if the felt is run 3 or 4 feet farther than it should be it is very awkward, and perhaps impossible to join the two ends of the felt without going over all the dryers and rolls and pulling back the felt by hand, to a convenient place where the seam can be made.

Felt Seams: There are several different methods of joining the end of these felts when putting them on the machine. The lap, or what is sometimes called the boot-leg, seam gives good results. This is made by bringing the two ends together and stitching a seam evenly across, through both plys, from 2 to 3 inches back from the ends. Slacking the stretch roll back as much as possible and removing a roll or two usually gives slack enough to do the seaming. Such a seam usually comes next to the paper; this answers very well for news, hanging, bag or Manila papers.

The seam above mentioned is likely to give better results if one ply is cut slightly shorter than the other—perhaps 1½ inches—so that the two ends will not come squarely together, thus reducing the abruptness of the two thicknesses. In cutting the felt, both ends should be drawn up as tightly as possible, after the stretch roll has been slacked back, and a roll removed, and tacked to a straight edge usually kept for this purpose, care being taken that both edges of the felt are in perfect line with each other. The ends may then be cut off, making necessary allowance for the lap in the seam, care being taken that each end is cut to follow a thread. The seam can then be made.

Fine book papers being more sensitive to clumsy or thick seams, it has been found best to use in this connection the seam made by butting the two ends of the felt together and putting in what is called a herring-bone stitch. This method does away with the objectionable thick seam above described.

In adjusting the stretch roll care must be taken not to run one end of the roll very far ahead of the other, as it must be remembered that a dryer felt is of a very unyielding nature —not at all like a woolen felt, which stretches out and has a flexibility which yields to the tension of the rolls. It must not be expected that the seam of the dryer felt will run absolutely at right angles with the machine. If one end of the seam is a little ahead of the other, but the felt runs smoothly over the dryers and rolls, it should be allowed to remain in that condition, there being no cause for worry on that account. It is time enough to change the stretch roll when the felt shows signs of wrinkling over the corner and loop rolls. These present the sharpest angles for the felt to pass over, and are the places which should receive attention when a felt shows signs of troubling.

Dryer felts should be strained up tight enough to prevent the paper from cockling, but never tight enough to leave the imprint of the weaving of the felt in the paper, or to cause the felt to wrinkle. A little careful observation will teach the machine-tender about where the tension of the felt should be. The use of an automatic tightener is supposed to regulate the tightness of the felt under various conditions.

The weight of the canvas from which these dryer felts are made should depend very largely upon the conditions to be met with on the various machines.

Guide Rolls: The guiding of the felt and the position of the guide roll should be calculated in a way that they may have the greatest control over the felt. If two carrying rolls be placed 12 ft. apart, it is always best to place the guide roll at least 8 ft. toward the roll, following the direction in which the felt is traveling. It sometimes happens that the guide rolls are placed 3 or 4 ft. nearer the roll in the reverse direction, giving a very short draw from the roll as the felt approaches the guide roll. The short distance between the roll and the guide roll, coupled with the unyielding nature of the felt, makes it impossible for the felt to respond quickly to the guide roll. Immediately after passing the guide roll, the felt has a long stretch to travel before passing another roll, the result being that it is very likely to drift back again, thereby losing a part of the distance which it has been brought by the guide roll. The reverse condition would operate more satisfactorily; that is—if the roll be placed as above described, so that the long distance between the back roll and the guide roll would yield more readily to the influence of the guide, and the short distance between the guide and the roll ahead of it would have a tendency to hold the full amount that has been gained by the guide roll. It may be said that this plan is applicable to any felt.

Briefly—the guide roll should be placed so that the felt may be easily turned to one side or the other, and the roll following should be near enough to hold all that the guide roll has accomplished.

Automatic guides should be of such a type, and so delicately adjusted, that the least pressure on the edge of the dryer felt will be sufficient to turn the guide roll without turning the edge of the felt. The guide roll should never be placed between two rolls very near together, or so high that the arc of contact of the felt on the roll shall prevent the guide roll from swinging easily, or shall bind it in any way. The felt should run over the top of the guide roll, inclining downward slightly on either side.

Water should never be allowed to drip on the top dryer felt. The steam and condensation should be extracted from the hood over the machine, if there is one, in such a manner as to prevent any dripping. This subject of ventilation is discussed in detail in Chapter XV. The chemicals, especially alum, contained in paper stock, rot a felt out very quickly if the drip be ever so slight; they also cause wet streaks in the paper, which are very objectionable, even if they are dried out before finally reaching the reel, as other portions of the paper must necessarily be over-dried in order to eliminate the moisture in these particular streaks.

Care must be exercised in rinsing up around the press nearest the dryers, that no water be spattered on the dryer felt, as this also has a tendency to rot the felt and thus shorten its service.

The careless use of spears for removing paper that has become wound around the dryers should not be permitted. There is a temptation for machine help to assume too great risk, the spear being frequently caught between the dryer and the felt, and taken around the dryer, which results in tearing holes and sometimes destroying the felt. If the dryers become clogged with paper, they should be stopped long enough to cut it straight across, and started very slowly so that the paper may be rolled up and removed without danger or injury.

The dryer felt running next to the press nearest the dryers, should always be protected by a good strong guard. The space between the dryer felt and this press is so limited that there is great danger of machine operators getting caught between the felt and the first dryer.

Pony Dryers.

Pony Dryers are drying cylinders, similar to those that dry the paper, but smaller (usually 24 to 30 inches in diameter), running in roller bearings and not connected with the ordinary dryer drive being revolved by the friction of the felt. They are so placed as to dry the felt as it passes back from the last dryer to the first so that it will be in condition to give maximum efficiency at the wet end of the dryer. These pony dryers are especially useful when pushing a machine to the limit of its capacity. It will be appreciated that if moisture were allowed to remain in the felt each time that it made a revolution this condition would gradually build up a moisture content in the felt that would result in it finally running very wet, even at the dry end.

Dryer Felt Rolls.

These rolls are made of iron or steel pipe from 6 to 12 inches in diameter, depending on the width of the machine. They are not turned down as this would reduce the thickness of the metal too much in certain portions of the pipe and slight irregularities in surface are unimportant since, owing to there being a number of these rolls, the irregularities will correct each other. These rolls are usually heavily galvanized.

Dryer Gears.

Dryer gears should be cut so as to be smooth running and avoid back-lash. A jerky condition on any of the dryers would put undue strain on the paper in places which might break it and in any case would be detrimental to the quality by straining the fibres apart.

They should be split gears to facilitate the changing of broken gears.

Machines have 25 or more four-foot dryers; it is customary to drive them with two pinions. These pinions have to start the dryers from a standstill and when the clutch is thrown in there is a terrific lifting tendency on the dryers immediately surrounding these pinions. This should be guarded against by having very strong holding-down caps over the journals on the back side. If the dryers lift they may break not only their own gears but many of those around them. Machines are frequently erected without these holding-down caps but we would advise that they be supplied and demanded in specifications for new machines.

Calenders.

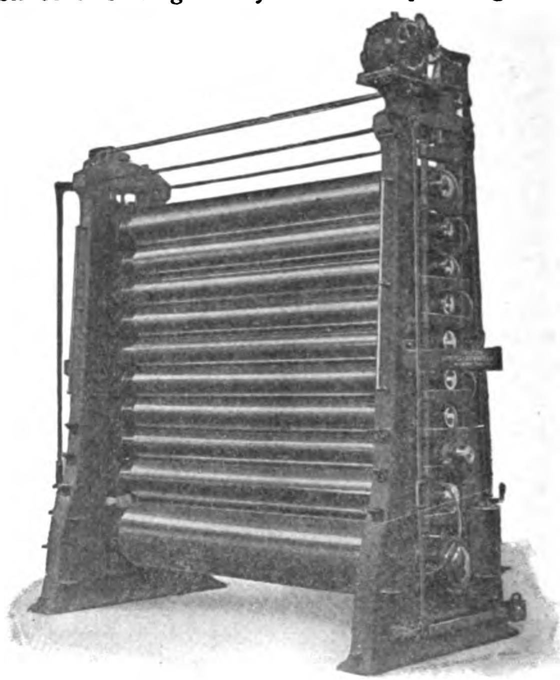
Calender rolls are cast and chilled and must be of fine grain and perfectly free from blemishes of any kind. They have to be most carefully ground and polished. They are mounted in housings, there being generally from seven to eleven in a stack, the whole stack being driven by the friction of the bottom roll. The size of the calender rolls depends on the width of the machine. The bottom roll is crowned and is usually from 24 to 25 inches in diameter on a 156-inch machine. On small machines the bottom roll may be only 18 inches in diameter. The roll next to the bottom is smaller than the bottom roll, but larger than any of the succeeding rolls. All of the remaining rolls are of uniform size except the top roll, which is somewhat smaller than the second roll but larger than any of the intermediate rolls.

The paper enters at the top of the calender stack being carried across from the dryers and under a spring roll which absorbs any tension due to uneven pull between the dryers and the calender stack.

The number of rolls in the calender stack which the paper is made to pass between is variable and depends on the finish desired to attain. Sometimes more than one calender stack has to be used to get the desired result. On some water-finished paper three stacks are used, one small and two large. The small stack is placed next to the dryers and is called the breaker stack.

The rolls must be kept in perfect alignment and, in order to preserve this alignment, an excellent foundation (concrete to rock or something equally massive), is required. Brass friction rings are provided to take care of the ordinary amount of endwise crowding normally present, but if this crowding becomes excessive the cause should be investigated. It will frequently be found that the cause is a worn journal box, or if the stack is equipped with compound weighted levers, these levers may be pressing unequally on one of the two sides.

In making water-finished paper very great pressure is applied by means of weights and levers and in order that the application of this weight may not cause pinching at the edges



Courtesy: Lobdell Car Wheel Co., Wilmington, Del.

Fig. 133.—Typical calender stack.

of the sheet, all the rolls as well as the bottom one must be slightly crowned according to the weight carried.

Calender Doctors: Calender stacks should be equipped with doctors, one doctor to each roll. These doctors are thin steel blades which are pressed against the rolls by springs. They are beveled so as not to scratch or score the roll or to cause any perceptible amount of friction. The function of the doctors is to keep the rolls free from little specks and scabs of paper, lint, dirt, etc., which would all tend to produce calender spots on the paper. Also they prevent the paper from running around the roll when it is put through the stack.

When a wet end goes through the calenders the rolls become covered with scabs. Sometimes the doctors will not remove these. To get the calenders clean the doctors should be released and the accumulation of lint, paper and dirt thoroughly cleaned out. A little kerosene is now sprinkled on the calender rolls. When the paper starts going through a little water or kerosene can be sprinkled on the paper. This will usually loosen all the scabs, but if not, the back tender or third hand can remove the obstinate ones with a calender scraper. The paper going through the calenders while this is being done should not be allowed to go on the reels but should go into the broke.

All calender stacks should be provided either with a hydraulic lifting equipment, or a threaded lift operated by a hand-wheel, with which to lift any number of rolls in order to remove wads of paper that may become caught between the rolls.

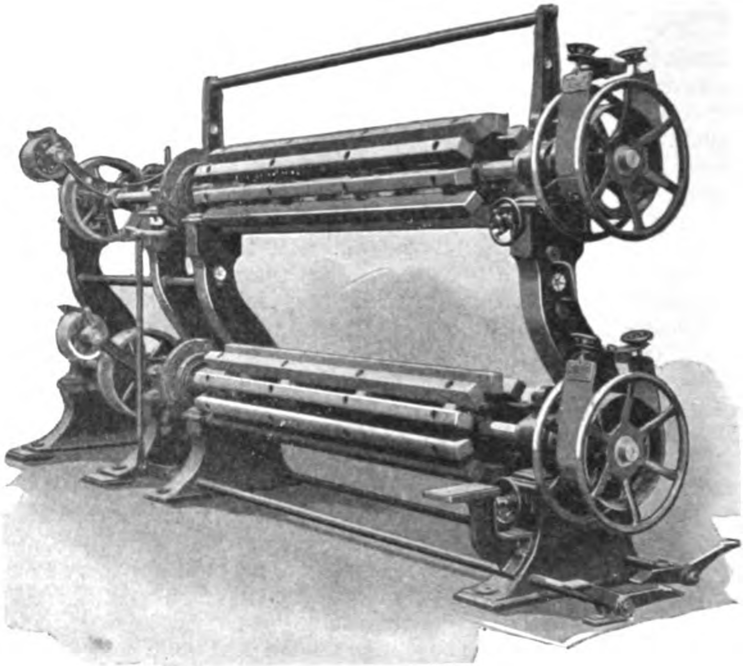
Air is blown against the calender rolls to keep them cool and to insure even expansion from what heat is inevitable. It will be realized that in such large, heavy masses of metal as calender rolls the expansion and contraction would be more or less uneven. This would tend to press the paper harder at some places than at others making it thinner and weaker there. When a roll shows soft spots a strong air blast should be directed against the calender rolls just at that point, as this part of the calender roll must have become overheated. Overheating frequently occurs at the ends of the rolls. Sometimes the paper comes from the dryers more perfectly dried at one place than another, thus carrying more heat, and this tends to heat the calender rolls unevenly.

Reels.

There are two different types of reels—stack reels and revolving reels. Stack reels are put one on top of the other in a vertical frame—usually two reels to a frame, sometimes three. The frames are so constructed as to permit the reels being taken out, after they are filled for the purpose of rewinding. After the reels are removed from the stack they are placed on a separate set of stands for rewinding into smaller rolls or for cutting off into sheets.

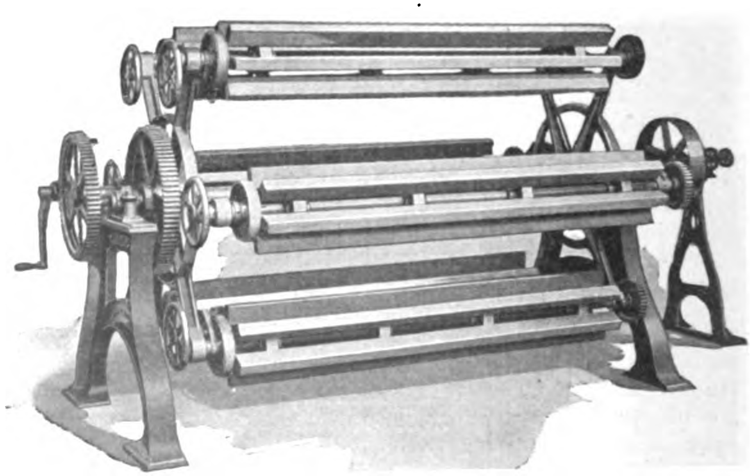
It is extremely dangerous, especially in case of high-speed news machines, to allow one reel to be winding up and another reel unwinding in the same stack, because if a man's hand or arm gets caught between the two reels he is sure to be drawn in and killed. This accident is unfortunately not uncommon in paper mills.

Revolving reels consist of a set of reels arranged in the form of a cylinder. It is really a reel of reels. The housing carrying the reels revolves so that by the time one reel is filled another is in position to take its place, and similarly by the time one reel is almost unwound another full reel is in position for



Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 134.—Two-drum vertical reel.

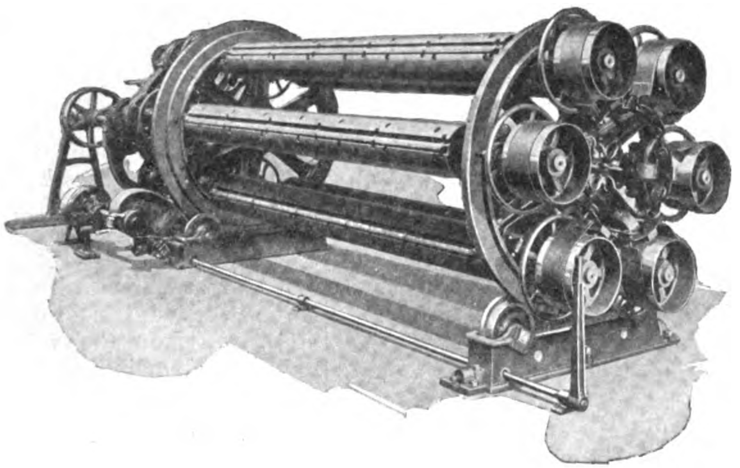


Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 135.—Four-drum semi-automatic revolving reel, of type used with moderate speed, medium width machines.

unwinding. These reels are specially adapted where the paper is taken from the reel to be cut into sheets.

The stack reels are driven with a clutch and a friction belt is provided so the speed of the reel can be controlled, both in winding when care must be exercised not to break the paper, and in unwinding when friction must frequently be ap-



Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 136.—Another type of semi-automatic revolving reel having six drums and being intended for high speed newsprint machines.

plied to keep the reel from going too fast and allowing the paper to become slack.

The revolving or cylinder reels are driven by a gear arranged so that the gear for each reel meshes into the driving gear when the reel reaches a certain point in its revolution. These reels are also provided with frictions for the same purposes as in the case of the stack reels.

Winders.

The winder is a machine for taking the paper from the reels and winding it in rolls of any desired size and at the same time cutting the paper into any desired width, which it does by means of knives that press on the paper as it is moving from the reel to the winder. The usual form of knife is a revolving one. These knives are known as slitters. Sometimes they are actuated by power and sometimes by the friction of the paper. There are a great many makes of these winders in use. This equipment will be described in detail in the chapter on the finishing room.

The Cylinder Machine.

The cylinder machine consists of one or more cylinders covered with wire, like the wire of the Fourdrinier machine, immersed in a vat of stock in which they rotate. For the sake of simplicity, we will first describe a single cylinder machine. As the cylinder revolves in the vat, naturally the stock tends to flow through the wire and the fibres being unable to pass are caught in a web on the wire. The water that passes through the wire is drained off from the end of the cylinder. The difference in level between the water in the cylinder and the stock in the vat provides a suction that keeps forming a film on the wire as the cylinder moves around. Facing the head of the cylinder is a plate of the same size and shape as the head, and around the combined edge of the cylinder head and this plate is a band tight enough to preserve the suction from the cylinder, but not too tight to interfere with the revolution of the cylinder. The amount of the suction and consequently the thick-

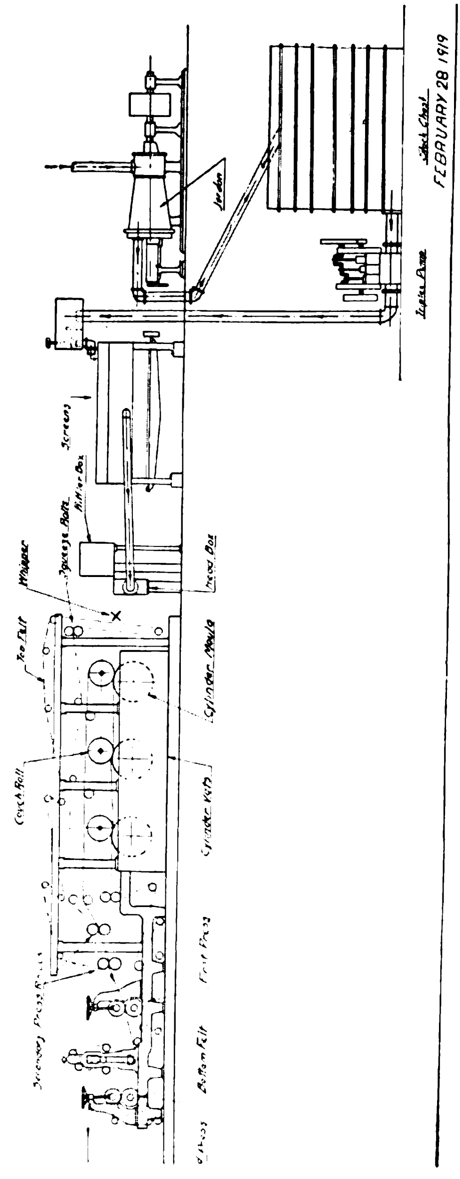


Fig. 137.—Diagram showing construction of cylinder machine.

ness of the layer of fibres formed on the cylinder is regulated by the height at which the water is allowed to stand in the cylinder. This is governed by a diaphragm controlling the opening by which the water drains away from the cylinder.

The long straight fibres are naturally drawn against the cylinder wire head on, like logs going down stream, and to prevent this action, which would not give as good a sheet as if the fibres felted and matted more on the screen, various devices are inserted in the vat to keep the stock in motion so that the fibres will be compelled to pass the surface of the screen with their length parallel to it to a greater or less extent, and consequently be pulled against it by the suction sideways.

At the top of the cylinder is a couch roll over which passes a felt moving in the same direction as the surface of the cylinder. This felt picks up the film of fibres and carries it along through one or two pairs of squeeze rolls to the presses and dryers which are arranged like those of the Fourdrinier machine.

For making heavy boards, which consist of layers of several different kinds of paper, after the felt has passed over the first cylinder it may pass over a second cylinder, revolving in a vat, receiving another layer of paper, and in the same manner a third and fourth—as many as eight sometimes being used.

Harper Fourdrinier Machine.

The Harper Fourdrinier machine closely resembles an ordinary Fourdrinier machine with the entire portion preceding the presses turned around end for end. In other words the wire is travelling away from the presses, instead of towards them. The paper formed on the wire is carried back from the couch rolls on a long felt (which is carried on rolls high over the wire), which supports the paper until it enters the presses and sometimes even until it enters the dryers.

The chief usefulness of this machine is due to the fact that the paper is constantly supported by a felt, or some other surface, there being no gaps to bridge, as between the couch rolls and presses in the ordinary Fourdrinier machine. This renders the Harper machine valuable for making very delicate papers such as tissues, cigarette paper, crêpe papers, etc. Since this kind of paper requires very little pressing, there is frequently only one set of press rolls on such a machine. The excessively long felt, often 100 feet in length, is one of the undesirable features of this machine. In the first place, it is very expensive and, secondly, it is very hard to keep free from injury. This fact, together with the upkeep of the Fourdrinier wire, makes the Harper a very expensive machine to maintain. Consequently its use is restricted to those kinds of paper that cannot well be made on any other machine, as outlined above.

Yankee Machine.

The essential difference between a Yankee machine and a Fourdrinier, Cylinder or Harper is the method used in finishing or surfacing a sheet of paper and the drying.

The Yankee machine has one very large dryer, sometimes considerably more than 10 feet in diam., while the ordinary machine dryers range from 3 feet to 5 feet in diam. The large dryer which is used on Yankee machines has a very highly polished surface, and against this surface a set of press rolls runs, the top press roll coming in contact with the surface of the dryer.

The press rolls are permanently fixed and the dryer is screwed back against the surface of the press roll by means of screw gears and hand wheels. This is so that when the paper passes between the rubber covered press rolls and dryer it can be pinched very hard.

There is also usually a dryer felt covering the big Yankee dryer the same as it covers ordinary dryers, care being taken to get all of the drying surface possible within the radius of the dryer.

The making up part of the machine is precisely the same as any other machine, namely straight Fourdrinier part, wet part of Cylinder machine or wet part of Harper Fourdrinier machine.

Sometimes there are small intermediate dryers and the big Yankee dryer is placed at some advantageous point in the section of dryers. The object of all of this is to give the sheet of paper a glossy finish on one side only.

The speed and production of the machine is limited to the capacity of the big dryer. For instance, if the machine was running a little faster then the big dryer would dry the paper alone, smaller dryers would be added either before or after the sheet passes the big dryer, usually before.

This leaves the right amount of moisture in the paper to iron nicely as it goes over the dryer. If the sheet of paper is too wet it does not give the desired surface or dryness and if it is too dry it takes away the excellent polish obtained. The idea is very similar to laundry work: ironing a shirt bosom, for instance. It has always to be sprinkled to a certain degree of moisture before flat irons are applied. This is the principle of the Yankee machine.

The Yankee machine is necessarily slow running and yields a low production and, as before stated, it is limited on account of operating the large dryer.

There can be the same number of presses and the same apparatus to form the sheet and get it ready for this dryer, as on any other machine. There are seldom any calenders on a Yankee machine, because when a sheet of paper goes over the big dryer it is supposed to be finished.

This machine gives an excellent shiny surface to the paper which cannot be obtained by ordinary calendering but it only gives the surface to one side of the sheet, the sheet of paper being hugged so tightly against this dryer by the dryer felt and moved so slowly, that by the time it goes over the dryer once it is ready to reel up nicely finished.

There are a great many uses for this paper, such as for the lining of duplex paper bags with the shiny side inward. It makes a very satisfactory appearance for a bag containing cereals of any kind, coffee, teas, confectionery, etc. Tissue paper is sometimes finished in this way, especially that used for wrapping confectionery goods. It is also used for paper for druggists' purposes. It may be used for blank leaves in technical books, novels, etc., where a nice finish is desired. Paper napkins and towels and all sorts of paper used for similar purposes may be made and finished on a Yankee machine.

The Yankee machine is adapted for thin and medium weight papers only, ranging from tissues to not thicker than 35 or 40 pound paper.

The reason for this is also on account of the limited production and slow running of such a machine, because all of the finish that it can possibly get is while the big dryer is making one revolution.

The reason for putting the big dryer at the dry end of the ordinary dryers is so that the ordinary dryers can be tempered so that the paper will come to the big dryer with just the right amount of moisture to give it the ironing effect. The whole machine must be run entirely in accord with the big dryer and its conditions, drying capacity, etc.

It is very essential that the surface of this dryer be kept absolutely clean. In many instances the dryer is supplied with some sort of a polishing apparatus like a revolving buffer or oscillating doctor, which is equipped with soft material that will not scratch the surface, as the finish of the paper depends entirely on the surface of this dryer. Any scratches or creases caused by ordinary doctors dragging on the surface will show up in the paper after running over this dryer.

A typical Yankee machine has no additional dryers, but these modifications can be applied in case of necessity to come nearer to the requirements for certain grades of paper.

Machine Drive.[1]

The general practice is to drive all the moving parts of the machine from a line shaft situated in the basement under the machine room. This shaft extends the length of the machine and is usually driven by a belt from a steam engine or electric

[1] The installation and drive of paper machines will be dealt with from the engineering standpoint in Chapter XV.

motor. Turbine-driven reduction gears have been tried in a few instances. Owing to the length of this shaft it is not advisable to have the engine or motor direct connected to it, and should this arrangement be installed for any reason it is necessary to introduce a flexible coupling between the engine and the shaft.

Steam engines are generally used in preference to motors since the exhaust steam is afterwards used in the dryers. Turbines might seem advantageous for this purpose, as they would deliver exhaust steam free from oil, whereas oil separators have to be installed between the engine and the dryers. However, where turbines have been used other facts have developed that militate

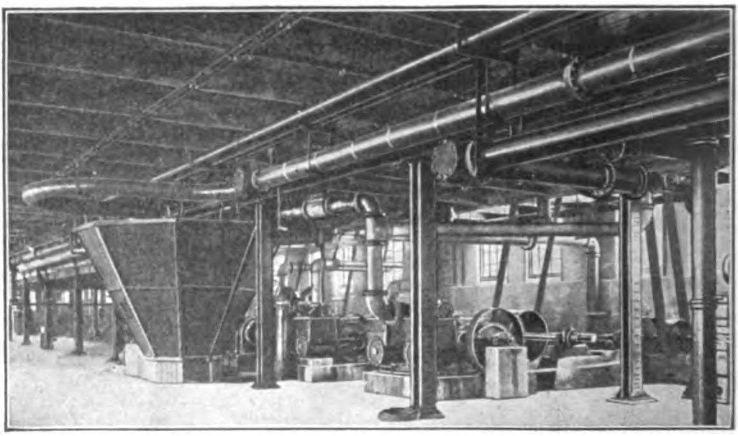
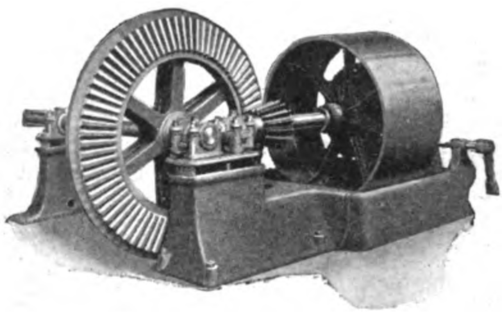


Fig. 138.—Basement of machine room showing machine drive, pumps and save-alls.

against their use. The turbine, on account of its high speed, is little adapted to the paper machine service, and complicated speed-reduction gears are necessary when turbines are used.

The line shaft is fitted with cone pulleys and, from these, belts pass up through scuppers to cone pulleys, mounted on stands specially designed for paper machine service, which drive the lower couch roll, lower press rolls, dryers and bottom calender roll. These stands provide for belt shifters and friction clutches, so that the belt can be advanced or retarded on the cones as needed and that particular part of the machine can be shut down independent of any other at any time.

In starting the machine the wire is first started, then the presses and finally the dryers, calenders and reels, the paper being led along from one part of the machine to the next by helpers. It is then necessary to adjust the tension of the paper between the various parts of the machine. If the paper sags too much between the couch roll and the first press it is obvious that the press is running too slow in relation to the wire, consequently we speed the press up a little and slow the wire down a little by means of the cone pulleys. If the paper apparently pulls in two between the couch roll and the first press, we would assume that the speed of the press was too high in relation to that of the wire and we would slow down the press a little and speed up the wire. In this way, without making any drastic



Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 139.—Typical cone drive with box bed plate suitable for large, high speed machines. For slower and smaller machines the same type of drive with flanged stands is frequently used.

alterations in speed anywhere, the working of tne entire machine can be tuned up, so there is no undue strain on the paper anywhere.

Starting the Paper Machine.

We will assume that the engine is running and that the constant and variable speed lines are both up to speed and ready to strike in the machine.

(1) The dryers must be started in advance of the other parts of the machine and steam must be admitted to the dryers so that they will be at the right temperature when the paper is put over. The dryer felt must be given a tension to see that it runs steady and safely. Steam must not be admitted to the dryers before they are started since, as water will probably be lying in the bottom of the cylinders, they would be heated unevenly and strained on account of the unequal expansion. It is also desirable to open the drip line valve to its full extent when the steam is admitted so that the excess water will be blown out quickly, after which the drip valve should be closed to a point where the water will be extracted without wasting steam. A three- or four-inch drip line valve should be open not more than three or four turns. After the dryers have been started

and water all exhausted the inlet valve should be set at a point adapted to the sheet of paper to be made.

(2) Each woolen felt, on the first, second and third presses, should be got into proper condition by starting it up carefully. If the presses have been left up prior to the starting of the machine, they should be carefully inspected to see that no lumps, foreign matter, tools, etc., are lying around, and then the presses should be let down, and the felt started. The shower pipes should then be opened, giving the felt a sprinkling. The presses should be run in this condition until the felts are thoroughly saturated. Then the water should be shut off and the presses run until the surplus water is all squeezed out and the felts running smooth. Then, the press weights are put on the levers. Be sure that the outlet of each save-all pan under each set of presses is clear, to prevent water from running down onto the felt. Treat each and every felt in this manner. Then shut them all down.

While this is being done, the dryers must not be forgotten and allowed to become overheated.

The preceding operations are usually attended to by the back-tender third hand and fourth hand. Simultaneously the machine tender is getting the Fourdrinier part and wire in readiness to start.

(3) First, the entire wire is given a thorough inspection, making sure that there is nothing lying around on the wire or near it that will injure it. The wire, deckle straps, apron couch roll, etc., are thoroughly washed with a hose. All showers are opened wide. The wire is started and run around for a few minutes to make sure that it is in perfect readiness for starting. All levers and weights on the couch rolls are inspected, to see that they are in proper place. When the machine tender is satisfied that his wire is in proper condition he stops it, and begins the "furnishing up" of the vats, screens, pump box, head box and save-alls.

(4) First, the fresh water supply is opened. All hands stand by while this operation is going on, keeping a sharp eye on anything that might need attention. The back-tender stands by the starting lever of the Fourdrinier wire. When the clear water furnish is at a sufficient height, the machine tender opens the stuff tap in the stuff box at the back side of the machine. The stuff mixes with the return water going through the pump and into the screens, head box and onto the apron. The machine tender watches the furnish, and when there are fibers enough in the water to make the sheet of paper he gives the signal to the back-tender to throw in the starting lever of the wire. The back-tender starts the wire and immediately takes up a hose and starts rinsing the jacket of the couch roll, as frequently the stuff runs up around against the guard-board. In case there is an old jacket, which has become threadbare, diffi-

culty in keeping the stuff from running up around the roll is encountered, and the only way to get it down is by washing with a heavy stream of water. Care must be taken to have the guard-board properly adjusted and free from grit and particles of stuff under the lip. The wiper must be put in place, and the shower on the jacket run as wide open as may be without running down the jacket. During this operation, extreme care and attention must be given to the save-all under the couchers, that the stuff may not pile up against the wire. Also to see that the wash-roll shower and doctor on the roll is doing its work. In fact, the wire rolls must be watched all the way along during this process of starting, to make sure that no lumps collect on any of the carrying rolls, or breast roll.

(5) The first felt is then started, being careful that no lumps of stock have fallen onto the felt; if so, they must be carefully rinsed off before the felt is started. The third hand operates the squirt gun, which delivers a needle stream of water on the wire, which cuts a narrow tail-end. This tail-end is lifted from the bottom couch by the back-tender and onto the first felt. This tail-end runs up onto the top press roll of the first felt. The back-tender steps along and pulls it down onto the second felt, and it is finally put up into the third press. The back-tender keeps a sharp eye on this operation, and at the proper time signals the third hand to slowly push in the squirt gun and gradually widen out the tail-end, until the entire sheet is passing through to the third press. By this time the back-tender has taken this narrow tail-end (or leader) across the dryers.

(6) The proper adjustment of the weights on the levers of all of the presses must be carefully taken care of. At the same time the proper temperature of the dryers cannot be forgotten, and the drying apparatus must be corrected according to conditions.

(7) Machines equipped with automatic temperature control may be set at the desired point for proper drying.

(8) During this process of starting up, the tension between the different sections must be carefully observed, as at this particular stage of the process the paper is extremely delicate and tender, and any unnecessary pulling strain between the sections will either cause the paper to break, or render it useless.

(9) The paper is thus taken across and put through the calenders at a point sufficient for the finish, and from the calenders to the reels. During this operation the machine tender stays up at the wet end and carefully scrutinizes everything connected with the Fourdrinier part making such corrections and adjustments as will ensure the safe running of the paper.

(10) If a dandy is used the dandy must be thoroughly rinsed and cleaned, and let down onto the wire before the paper has been carried through the presses. The suction boxes back

of the dandy must be regulated to give the proper moisture to the sheet as it passes under it. If left too wet the dandy is likely to leave crush marks in the sheet. If left too dry, it is likely to lick up the web in places; and even if it does not do this, it does no good to the sheet to let the dandy walk on it. It will be apparent that there can be no impression left in the paper by the weight of the dandy if the sheet is too dry.

Weaving Devices.

There is a strong tendency for the Fourdrinier Machine, no matter how efficiently the shake may be arranged, to cause the sheet to have a grainy appearance. In other words, the fibres all point in one direction leading to excessive strength in the machine direction, and inferior strength in the cross direction.

To overcome this feature many devices have been made to cross these fibres in order that the strength of the paper may be equalized. It is very essential in nearly all grades of papers, especially bag and market that this stage of equilibrium exist or otherwise such a sheet in bag use splits when it is attempted to carry objects of any appreciable size or weight. Such a sheet must be avoided as far as possible, regardless of the difficulty.

A recent patent covering the above work consists of a revolving cylinder, made of parallel steel rings, revolving at the same distance in the shallow depth of fibres and water, prior to reaching the suction boxes. As soon as this device has turned these fibres at an angle, or in other words crossed them, they come in contact with the suction box which in turn pulls these fibres down and holds them at that angle before they have an opportunity to straighten themselves out again.

This particular device has shown in many instances its vast importance. In using it, however, extreme precaution must be taken in that no stock or particles of dirt cling to the parallel bars, otherwise more particles will accumulate, fall off, and make spots in the paper.

Another method that has become recognized is that of a cross channel device placed under the slices prior to the stock going onto the wire. This apparatus consists of an aluminum box the width of the machine, about one foot in depth and six inches in height. The box is divided into two compartments, an upper and lower. Each compartment is further subdivided into small channels about two inches in width. The small channels of the lower compartments are all directed in one direction at an angle of approximately 45 degrees with the slices. The channels of the upper compartments are directed directly opposite to that of the lower section, thus forming two currents of stock.

With the use of this device the amount of water used determines the nature of the resulting sheet. If a large amount of water is being used at the slices the stock and water is forced out of the cross fibre device with great force and the stock tumbles around in all directions, even in a perpendicular direction to the wire. This boiling action results in a sheet of paper that is practically equal in strength in all directions which is no small feat when the original length of the fibres has been retained during the beating and refining operations.

If on the other hand but little water is being used at the slices, the two compartments, the lower and upper, practically form the two webs of paper containing fibres directly opposite to each other. This sheet has all the appearance of a duplex sheet.

Cause of Breaks on the Paper Machine.

Screens, Spouts and Pipes: All screens, spouts and pipes must be kept thoroughly cleaned to prevent the accumulation of slime. Slime spots are caused by the slime which has collected on spouts, pipes and screen vats breaking away and going through onto the wire, and making up with the web. If a slime spot gets by the couchers and presses to the reels, it makes dark spots, sometimes transparent, and more often leaves a hole in the paper the size of the slime spot.

Head Box: Dead corners in the head box cause lumps to accumulate and break away occasionally. The head box should be no larger than necessary and all square corners eliminated. Make these circular when possible by using fillets.

Apron: Wrinkles in the apron causes the stuff to roll and make lumps. Wrinkles should not be permitted. Holes in the apron cause stuff to roll into small hard lumps. Sometimes a patch can be temporarily used. A poorly folded apron causes stuff to work back under apron and deckle strap, causing bad edges or feather edges. The apron must always be folded with care and must be fastened to the angles in a way that will make square corners between the angles and the wire.

Breast Roll: Stuff carried back by the wire to the breast roll and under the apron will roll into little hard lumps and break the web. This can be eliminated by the use of a strong shower of water. The shower pipe must be so located as to force the streams of water up and between the apron and wire. This will prevent lumps from accumulating under the apron.

Tube Rolls: These must be in perfect alignment. A low tube roll allows the stuff to run under the deckle strap and make a poor edge which will break the web. Tube rolls that are sprung cause the rolls to wabble and run eccentric. This action makes bar marks, or thick and thin streaks across the web.

Tube rolls must not be allowed to stop and wear flat. Dragging over a dead tube roll wears the wire, and it also spoils the roll.

Tube rolls must always be handled very carefully. Tube rolls that are properly made are carefully balanced; if they are roughly handled, denting them or springing the journals the least bit, it throws the rolls out of balance and they will not run, but even if they do, they will not run true, but with an eccentric motion, the results of which have been already mentioned.

In changing a wire, workmen in their haste are apt to become careless and often inexperienced help may be called in from the Beater Room to assist, who not realizing the importance may do considerable damage.

For the changing of wires many mills, especially the larger concerns, have a well trained and well organized crew who do nothing else except repairs and changing wires, jackets and felts. This plan saves money and time, also accidents to the machinery.

Deckle Straps: Poor deckle straps with cracked edges, crooked places, worn edges and poor splices, uneven spots and projections should be avoided.

The deckle strap is nothing more or less than a dam against which the paper stuff forms, and a strap having any of the above mentioned defects will form an edge to the web of paper that will not safely run through the machine.

A cracked edge in a deckle strap will cause lumps and projections to form in the edge of the web and it will very likely break either on the couchers or presses.

Crooked places in the deckle strap are caused by hanging a spare strap up in a dry place and allowing it to stay in one position for so long that the rubber becomes slightly vulcanized and becomes set. A strap with this defect will not fit the wire closely and allows stuff to run under it making a bad edge on the web which often causes breaks.

Worn edges on the strap to the extent that they become rounded will also make a poor edge on the web.

Poor splices refers to the strap coming apart in the splice. With reference to this particular defect, it sometimes happens that the splice made in the strap is not stuck together so but what it will eventually come apart for a little distance at the beginning of the splice. The coming apart of the splice in the deckle strap is frequently avoided by being careful to put the deckle strap on so that the influence of the wire on the strap in pulling it around will pull *from* the splice instead of *against* it.

Uneven spots and projections on a deckle strap are caused by various things. Care should always be taken with deckle straps when putting on wires, whether the deckle straps have to be taken off entirely and laid away, or whether they are lifted with the deckle frame. If taken up with the deckle frame, it is necessary to tie the strap up in places where it sags so that it will not be in the way. In doing this they should never be tied with a small hard string, as this dents the strap and sometimes these dents will not come out for a long time. A piece of woolen felt 3 inches or 4 inches wide should be used. This is soft and pliable and will never dent the edge of the strap.

It should also be borne in mind that hanging straps over sharp projections like the edge of the deckle frame should be avoided. This will also nick straps on the edge and if left too long will cause indentures which may not come out for some time.

All of these little defects in the edge of the strap will cause like imperfections in the edge of the web of paper, which may lead to breaks.

A spare deckle strap should never be hung up in a dry place, even if hung over the proper circles, because the rubber in these straps will become slightly vulcanized and, where they go over the circles they will conform to that particular shape, which will not come out when the strap is put on to be run.

The old-fashioned way used to be to hang straps up on a prepared form of this sort with the idea that the strap would be turned around a few inches every day, but this method is so apt to be neglected that it is not wise to keep the strap in this way. The best way is to keep them in a box immersed in water, the box having sufficient room so that the strap will not have to be kinked or turned in short circles. If cared for this way the strap will always be fresh and good without becoming valcanized.

Suction Boxes: In making light sheets, sometimes the first box suction is closed. This box will fill with water and slop up through the sheet and cause breaks. It is better to lower the box down away from wire if not needed. Filings from a dead suction box dropping onto a wire are not desirable.

Couches: The tension or pull of the web from couches to first press must be carefully adjusted. If the web is pulled too hard, it will cause breaks on account of pulling fibres apart. If this condition does not cause breaks on felts, it may cause the sheet to snap off on the dryers and possibly not until the web reaches the calenders will it break. If pulled too slack at the couchers, it will cause wrinkling. Wet wrinkles will cut at the calenders. From one press to another the same thing applies.

Jackets dirty, worn, wrinkled, twisted, bagging or threadbare on edges will cause trouble. Doctor on top couch roll must be put down evenly on both sides. Must not run jacket too wet or too dry. If too wet it is likely to crush; too dry, filings from doctor likely to drop onto the sheet and break it.

Wires: Holes, cracks, ravelings, pitch spots, wrinkles, poor seams, slack edges and filled meshes, grease and slime spots, etc. These have been discussed in connection with care of the wire.

Dandy Roll: Running the sheet too wet under the dandy roll will cause crush marks. The dandy roll wallows or wades in water, which causes a crushed or cloudy appearance in the sheet. It depends on the cause of too much water running across the suction boxes and under the dandy, how it can be corrected. If the suction boxes are wide open and at the same time there is more water than is necessary to properly close the sheet, some of the supply of water may be shut off, at the same time lowering the slices.

If the stuff is short and slow, it may be difficult to stop the crushing. Very slow stuff necessitates carrying the slices very low and the use of as little furnish water as possible, and yet the sheet may run so wet across the suction boxes and in under the dandy roll as to make it impossible to run a dandy roll without crushing.

It is never intended to prepare stuff that is so slow as to cause troubles of this nature, but sometimes things slip in the beater room. An accident on the paper machine may hold up the dumping of a beater of stuff for hours after it is ready to dump into the stuff chests. In such cases the stuff is likely to slop and slush around in the beaters an unreasonable length of time, which always makes the stuff slippery and slow. Some mills may not be equipped with beaters that can be stopped when the stuff is ready to go to the chests. Sometimes the beaters may be furnished with slow stock without the beaterman being aware of this fact. If the beaters are furnished with this stock, and there is no way provided for the stopping of the beaters when the stuff reaches the correct stage, there is no way to run it on the machine with any degree of success at a speed consistent with the weight of the sheet. Cutting out white water and substituting clear fresh water may help some. Heating the water or stuff may also help in these extreme cases, but it is wasteful and not good workmanship and should be avoided.

If the sheet is run too dry the dandy merely walks on it and many times does what is termed by paper makers as "licking up." It picks up the sheet from the wire in places, sometimes to the extent of making holes and causing breaks, but many times these spots are only lifted slightly by the dandy and they drop back into place, causing a blemish in the sheet which resembles a blister. The dandy when run on a dry sheet has no smoothing or pressing effect and does more harm than good, therefore the amount of water in the sheet under the dandy roll must be correct, constant and uniform. This is especially important in making water marks. The sheet must be plastic and yielding enough to take a deep and clear impression of the water mark.

The Hand of a Paper Machine.

When standing at the winder and looking towards the screens if the drive is on the *right-hand* side the machine is a ***right-hand machine***.

Conversely, if when standing at the winder and looking towards the screens the drive is on the *left-hand* side, the machine is a *left-hand machine.*

Save-alls.

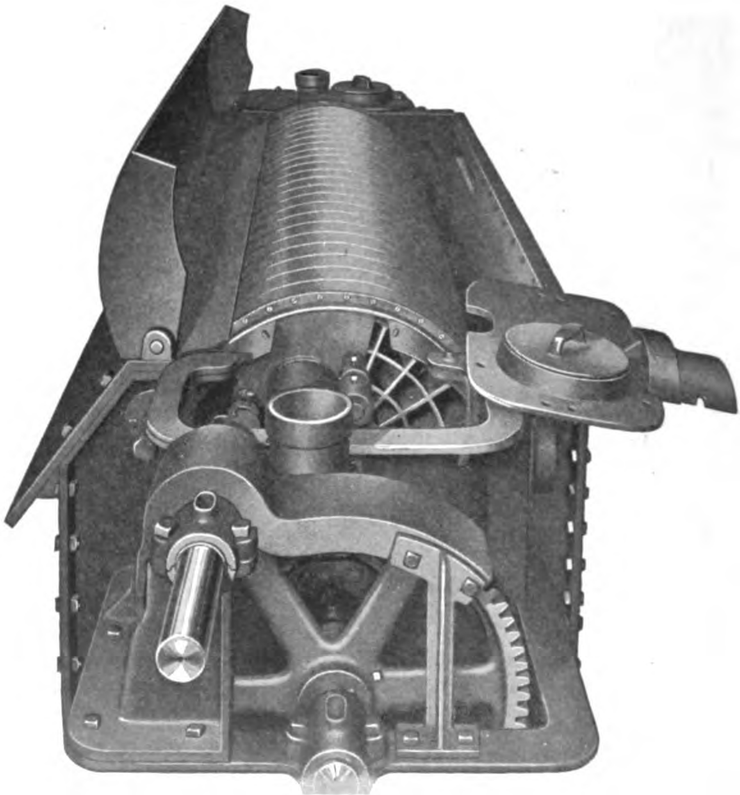
Save-alls for paper and pulp mills are precisely what the name implies. They are intended to save all of the fibres left in the white water, before it passes to the sewer and to waste.

There are many types of save-alls. The oldest type is very similar to a decker; a cylinder covered with fine wire is immersed in a vat of white water, suction is applied and the fibres in the water cleave to the surface of the cylinder and later in its revolution, a soft couch roll is brought in contact with the fibres adhering to the surface of the cylinder which are picked up by the couch and at a certain part of its revolution scraped from the couch by a wooden doctor blade, which is in gentle contact with surface of the couch. The fibres of pulp through this process form a thick mush which falls from the doctor into a convenient mill box truck. The pulp thus collected can be shoveled or forked into the beater.

The above type of save-all has only a natural suction, i. e., a suction due to the difference in the head of water inside and outside of the cylinder. If a cylinder of the above type is put into a vat of clear water, there will be no suction, as the clear water will seek a common level through the meshes of the wire, but if put in a vat containing fibres of pulp, the water will be prevented from reaching a common level, due to the fibres partly sealing the meshes of the wire (a revolving dam) which backs up the water several inches higher on the outside of the cylinder than the water on the inside of the cylinder, therefore the so-called suction, which is *not* an induced suction.

Another type of save-all is the induced suction or pneumatic type. A cylinder is placed in a vat of water containing fibres of pulp and by means of a suction pump connected to air tight chambers which communicate with the surface of the cylinder (at such times as the suction chambers are immersed in the water during its revolution) a suction is induced, which pulls the fibres onto the wire mesh. At a certain point in the revolution of the cylinder these suction chambers become pressure chambers, and by means of a blast of air the pulp is blown from the cylinder surface. This type of machine is also used for thickening pulp.

Unless the wire which covers the surface of the cylinder is of very fine mesh, very little of the very fine fibres or fillers such as clay, etc., is saved. Some manufacturers have thought it worth while to use save-alls of the settling tank type. These settling tanks must be of very large proportions to take care of all the white water from a pulp or paper mill. The capacity must be such that it permits of the water standing long enough to settle in the bottom of the tanks from which point the settled fibres and fillers are pumped. The white water is distributed by means of an annular trough, running around the entire circumference of the tank so that when it finally reaches the tank there is no velocity. This is to prevent agitation and allow the stuff to settle at the bottom, in the same way that a sample of it will settle in a bottle or glass jar.



Courtesy: Improved Paper Machinery Co., Nashua, N. H.

Fig. 140.—Pneumatic save-all showing manner in which the mould is divided into compartments for the alternate application of suction and pressure.

This method permits the savings being pumped back into the system without the extra labor required in the case of the first mentioned classes of save-all, where the savings are of such a consistency that they must be shoveled or forked into the beaters. The settling tank must be of ample capacity to effect a continuous operation, i.e., so that the white water may be running in at the top of the tanks, at the same time the settlings are being pumped from the bottom; these tanks do not function until they become full of white water, for then the incoming supply flows lazily and comes to rest on top of this body of water and begins to settle immediately.

Still another type of save-all extracts the fibres from the white water by means of centrifugal force. This method embraces many desirable advantages such as permitting of pumping the savings back to the system, instead of by manual labor, low first cost, ample capacity, low up-keep cost, self-cleaning and very low horse power for operating.

A cone 19 inches diameter at small end flaring to 10 feet at large end, 7 feet high, is stepped in a bearing with the small end

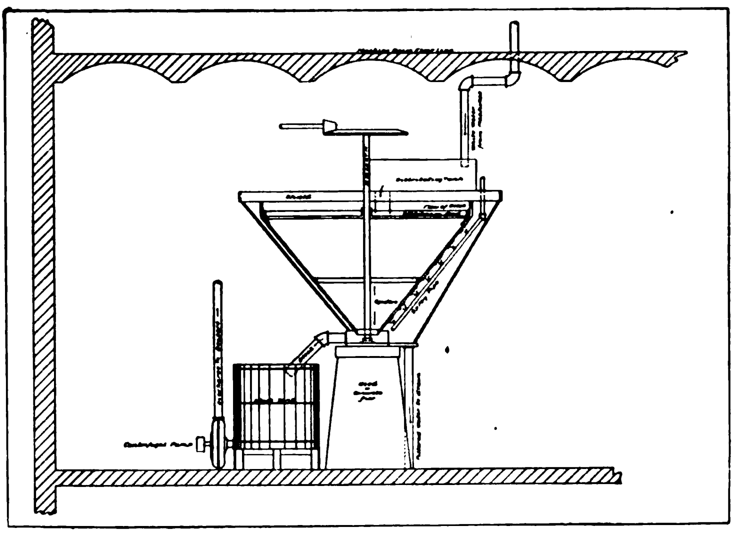


Fig. 141.—Witham-McEwen save-all as installed in paper mill.

of the cone downward (like a spinning top) and two spiders are keyed to a shaft, which passes through the center of the cone. The spider at the apex is 19 inches inside diameter. The spider at the center is 4 feet in diameter. The rims of both these spiders are on an angle or flare that coincides with the slope of the cone. The shaft passing through the center of the cone, protrudes through the small end and is stepped in a box (similar to stepping a water wheel). This same shaft protrudes at the upper end of the cone for applying a gear or pulley for driving or spinning the cone. Hardwood staves are bolted to the spiders at intervals; complying with the distance needed for fastening suitable screen plates. Screen plate sections with very large perforations are screwed to the inside of the staves. They are cut on an angle so that the border of each plate makes a butt joint coming together on each stave. Thus the entire inner surface is lined with foundation plates in a way that permits of a smooth surface being presented to the white water and fibre material.

On top of the foundation plates is fastened a very fine mesh wire, the fineness of the wire being determined by the class of saving it must perform. The finer the wire the finer the savings. The cone also has a vertical annular rim 6 inches to 12 inches high which prevents the water from slopping over into the compartment between the outside shell or housing, which encircles the cone, placed within this annular rim and clearing it two inches all around is a stationary solid head. On this head is also an annular rim. This head is adjusted to water level

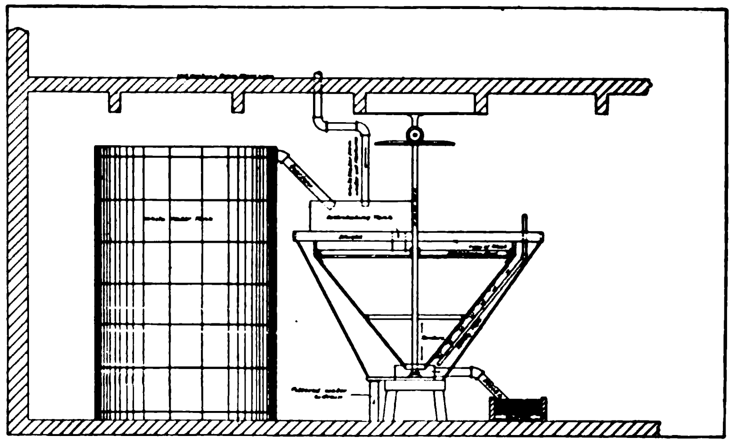


Fig. 142.—Witham-McEwen save-all as installed in sulphite pulp mill.

and the white water is spilled on this stationary head, which fills up and runs over the annular rim, which is about 4 inches high, causing the water to flow and distribute evenly all around the entire circle, falling against the sides of the revolving cone. The water is thrown through the wire mesh by centrifugal force, while the savings slip down the incline of the cone into a compartment directly under the small end, to which a centrifugal pump is connected; from this point the savings are pumped back into the system; surrounding the cone is a water tight shell usually made of tongue and grooved sealing, placed at a suitable distance from the cone. This shell or housing may be square, octagonal or round. It may or may not follow the lines and shape of the cone.

It will be seen that both the rejections and savings may be either pumped or run to waste as the case may require. In case this apparatus is used for water straining or filtering purposes, the clean water which is thrown through the meshes of the wire,

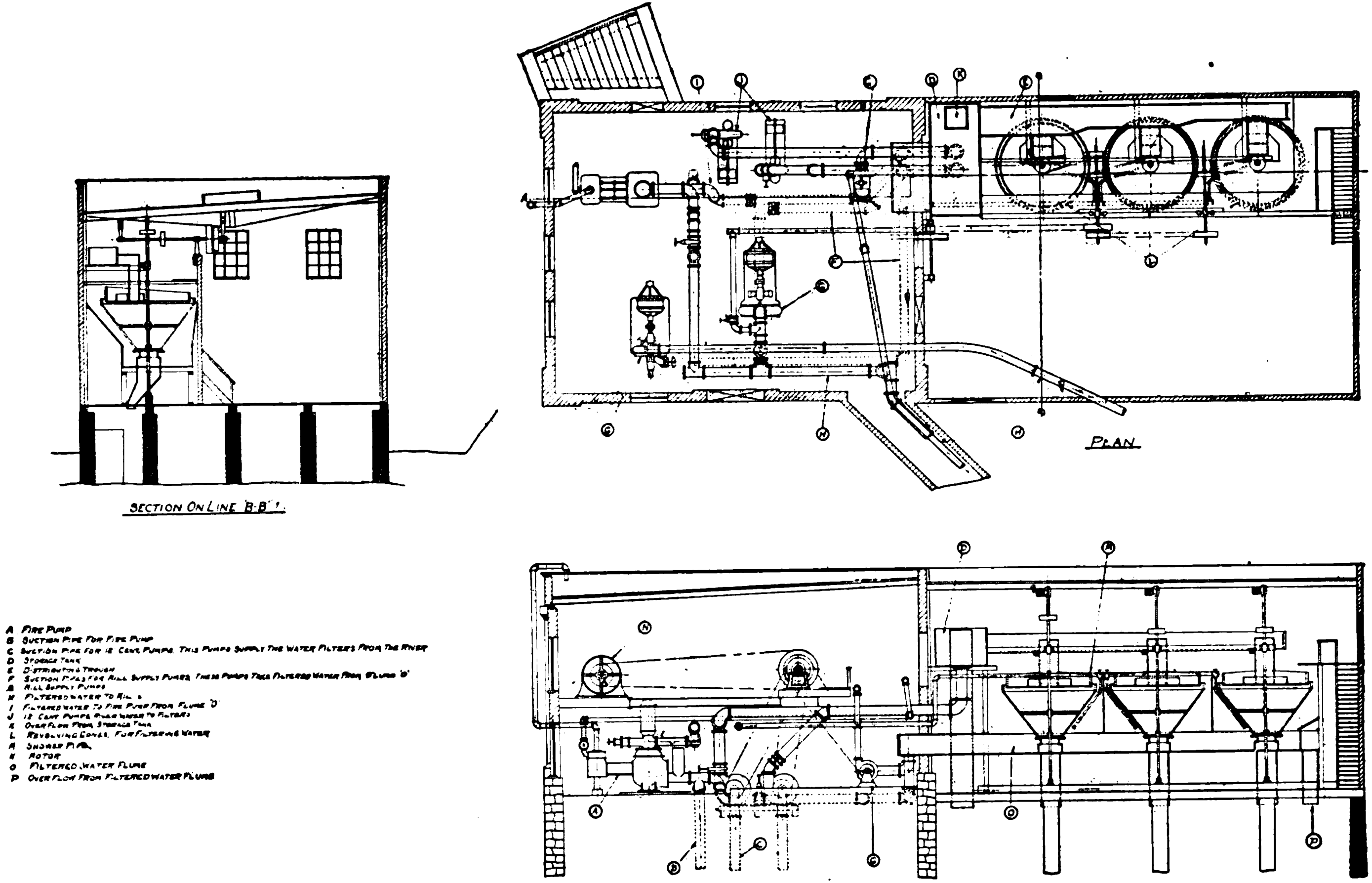


Fig. 143.—Diagram showing complete installation of Witham-McEwen save-alls as installed for water filtering at large pulp and paper mill.

may be pumped through the water system which serves the mill, while the savings which in this case will be dirt, slip down the incline of the cone and to waste. It will be seen that this save-all can be used for either saving pulp fibres or for filtering water, without making any change in its construction. The shape, speed and angle of the cone renders it self-cleaning. There is always enough water sliding down the incline of the cone to keep the filtering wire clean. A vertical shower pipe is placed adjacent to the cone and between the shell and the cone and following the slant of the cone, so that by opening a valve, the cone may be thoroughly showered, as it revolves, passing this fixed shower pipe. This is in case the meshes become filled up with sediment of any kind. In case of these save-alls being used as filters their capacity is nearly unlimited. One of these machines will filter two million gallons in 24 hours and will free water from all solid impurities, supplying absolutely clean water for paper machine showers and the like; in case they are used as a save-all the capacity is nearly as great.

The many desirable features of these machines and their adaptation to paper and pulp mill requirements should be attrative; 3 horse power is ample for one save-all; they need no supervision.

The only thing that wears is the inside fine mesh wire and this is only exposed to the slipping of the water and fibres down its surface.

Typical Specifications for Paper Machines.

CONTRACT SPECIFICATIONS

FOR

ONE (1) 166" FOURDRINIER NEWS PAPER MACHINE.

To Be Built By

(Name of Company)

(Address)

Contract No.

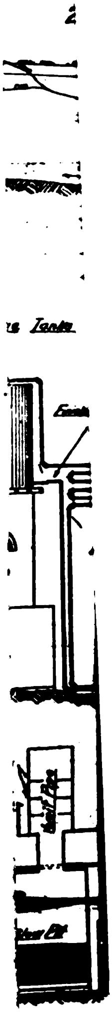
Date Estimate

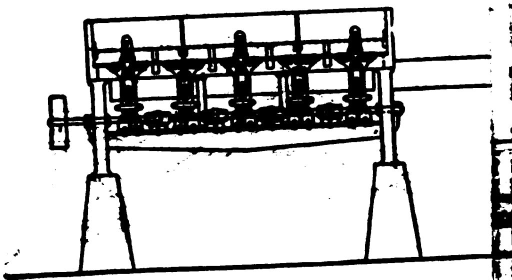
Hand.

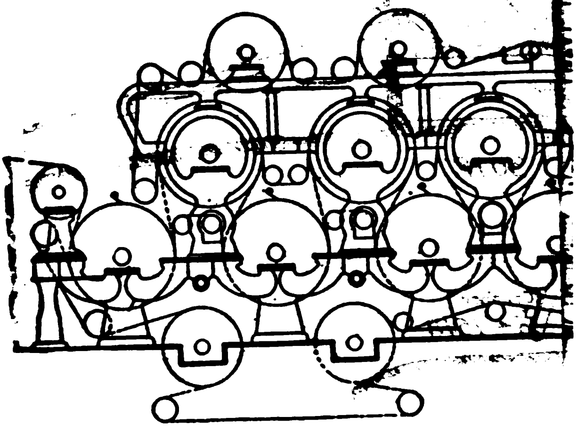
When standing at the winder and looking toward the Fourdrinier, the driving arrangement of the machine will be on the left hand side or right hand side, as decided by the Purchaser.

Widths.

Breast Roll will be	166 inches face
Table Rolls will be	166 inches face
Lower couch roll will be	166 inches face
Lower press rolls will be	164 inches face
Drying cylinders will be	162 inches face
Calender rolls will be	160 inches face
Reel drums will be	164 inches face
Slitter and winder will be	160 inches face







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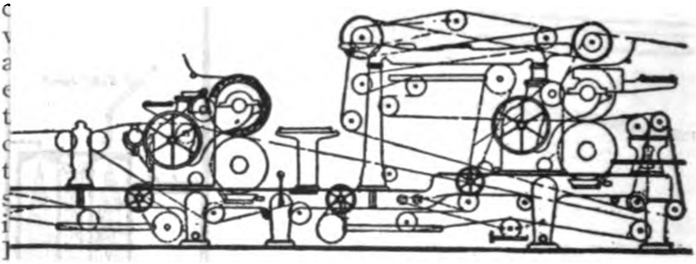
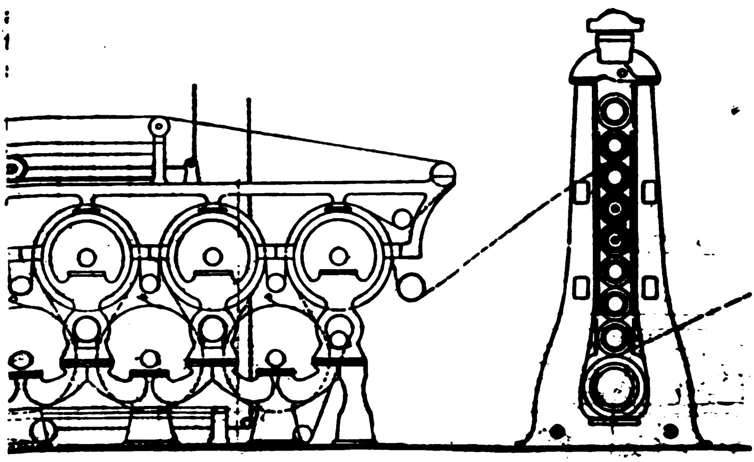




wo segments. The upper
·s the dryers and calender.

Flow Box and Apron.

The design of the flow box will embody the features of economy of space and the proper distribution of the pulp upon the apron. The flow box will be made of cypress wood, and will be put together in a substantial and workmanlike manner. Design to be approved by the Purchaser.

The apron is to be made of wood, carried on wooden folding brackets, attached to the flow box; to be compact in form, strong and stiff, and provided with adjustable and fixtures of brass.

Wire.

The arrangement of the fourdrinier part will be suitable for a wire 80 feet long, and 164 inches wide.

Breast Roll.

The breast roll will be 18 inches diameter, 166 inches face, body made of a shell of cast gun metal, bored on inside, secured to cast iron heads. The journals or gudgeons of the roll to be made of hammered steel and forced in the heads by hydraulic pressure. Heads to have brass covers and ends of gudgeons to be covered with ornamental brass sleeve outside of bearings. This design makes a roll of minimum weight, yet of maximum strength and stiffness. Journals carried in bronzed bearings having vertical adjustment.

Roll to be running balance for a speed of 700 feet per minute.

Table Rolls.

The table rolls located next to the breast roll and under the slices, will be 6 inches diameter, 166 inches face. Made of turned steel tubing encased with No. 14 S. W. G. brass tube, having cast iron heads with steel journals, 1½ inches diameter, 3¾ inches long.

All the other table rolls will be 5½ inches diameter, 162 inches face, made of brass tubing No. 10 S. W. G. having cast iron heads with steel journals, 1¼ inch diameter, 3¾ inches long.

All table rolls to be in running balance, as indicated by a Norton Balancing Machine, at a speed of 700 feet per minute.

Patented extruded brass table bars will support brass pintle yoke brackets to carry the brass bearings of enclosed type having grease reservoirs and lids, to carry the table rolls, and will be arranged to give vertical adjustment of the rolls. The bearings removable with the rolls when changing wire.

The table bars will also be fitted with brass screws and lock nuts, so arranged that the screws will come against the ends of the journals of the table rolls, thus taking the end thrust, and eliminating the friction that would otherwise occur from contact of the shoulders of the rolls against the ends of the bearings, thereby preventing undue wear on the wire and the rolls, that otherwise would be caused by excessive endwise movement of the rolls.

Automatic Guide Roll.

The automatic guide roll will be 10¾ diameter, made of turned steel pipe encased with No. 14 S. W. G. brass tube, having cast iron heads with steel journals carried in M. & W. No. 5 patented automatic wire guide with patented lever palm attached to work in contact with one side of wire.

The roll to be in running balance as indicated by a Norton Balancing Machine, at a speed of 700 feet per minute.

Return Wire Rolls.

Stretch roll 10¾ inches diameter, all other return wire rolls 9⅝ and 8⅝ inches diameter. These rolls to be made of turned steel pipe encased with No. 14 S. W. G. brass tube, having cast iron heads with steel journals, 2 7/16"x13", 2 3/16"x13" and 1 15/16"x13", carried in bronze-lined, collar oiling bearings, carried in supports in such a way that the bearings are removed with the roll, in placing new wire on the Fourdrinier.

The rolls will be in running balance as indicated by a Norton Balancing Machine, at a speed of 700 feet per minute.

Wire roll nearest breast roll arranged to be easily removable.

The vertical stretcher will be so geared that both sides may be operated simultaneously or the back side independently, by a hand wheel on front side of machine. The bearings for the stretch roll designed to permit the weight of the roll to act as the stretching pressure.

Ductors.

Wooden ductors arranged on the outside return wire rolls.

Couch Rolls.

Upper couch roll 26 inches diameter, 170 inches face.

Lower couch roll 26 inches diameter, 166 inches face.

The upper roll will have a casing ½ inch thick, of special quality gun metal bronze, forced by hydraulic pressure over a hollow cast iron body, having cast iron heads and hammered steel journals; the body having been turned in balance, and made as light as is consistent with proper strength and stiffness. The journals forced by hydraulic pressure in the heads and the heads bolted into the ends of the bodies. Journals 7 inches diameter, 11 inches long. Ornamental brass caps to cover ends of gudgeons outside of bearings. Upper roll to be drilled to suit purchaser.

The lower roll will have a casing ½ inch thick; of special quality gun metal bronze, forced by hydraulic pressure over a hollow cast iron body having cast steel heads and journals, the body having been turned in balance. The combined heads and journals forced by hydraulic pressure in the ends of the body. Journals 9 inches diameter, 14 inches long. Ornamental brass caps to cover end of journal, outside of bearings on tending side, and half lug clutch fitted to journal outside of bearing on driving side for driving purposes.

Rolls to have center collar oiling and center thrust rings.

Couch Housings and Pedestals.

The journals of the upper roll will be carried in bronze-lined pedestals attached to ball crank swinging arms in a way to admit of variation for different amounts of couch. The pedestals will be connected to a system of levers and weights, so as to properly distribute the weight over the entire surface of the journals, thus giving additional pressure to the weight of the roll on the paper, if so desired.

Improved couch housings to carry the bell crank swinging arms. The Housings arranged with geared brass screws operated by handwheels for lifting each end of the upper couch roll to give clearance between rolls for convenience in putting jacket on upper roll and putting on new wire.

The Journals of the lower roll will be carried in bronze-lined pedestals on blocking pieces, resting directly on the side frames of the machine, arranged so that the wire can be put on without lifting the lower roll more than ½ inch, and without removing pedestals. Blocking pieces removable.

The pedestals for both the upper and lower rolls will be water-cooling and collar-oiling.

Guard-Board.

Very heavy and well braced and held in position by cast iron brackets on the couch arms. Guard-board arranged with a series of adjustable spring fittings to give flexibility and adjustability to the guard-board blade.

Dandy Roll.

One wove dandy roll 13 inches diameter, 166 inches face, No. 50 wire face, made as light as possible; journals large in diameter and made hollow to suit an internal brass shower pipe. Dandy roll to have central bearing for shower.

Wooden wiper bar and trolley for removing dandy roll.

Adjustable brass bearings so designed as to enable the machine tender to raise or lower both ends of the roll at the same time, when standing on either side of the machine.

Suction Boxes.

Eight (8) extruded metal suction boxes with expanding heads. Hard maple covers, 1¾ inches thick. A system of pipes for priming both ends of each box to the same water level, so that the machine tender need observe the tending side of machine only. Outlet pipes 3½ inches diameter. Side flanges to strengthen the box against the pull of the wire, will be so arranged that they will also form a channel way to catch and conduct beyond the outside edges of the wire, the water and pulp that may be scraped off the underside of the wire by the edges of the suction box covers.

The suction pipes will be connected to the boxes by an improved device, by means of which the pipes are attached to, or released from the boxes by making one turn of one screw. Suction pipes attached to manifold pipe. Attachments to the stationary rails will be furnished, and also suitable bars to facilitate the placing and removal of the boxes.

The dandy roll will be placed so that two suction boxes will be between it and the breast roll and six suction boxes between it and the couch rolls.

Boxes to be arranged with wheels to facilitate removing.

Deckle Arrangement.

A pair of flanged brass deckle pulleys, 28 inches diameter, suitable for deckle straps 2¼ inches wide, 2¼ inches deep. One brass slice, 10 inches deep with center and end adjustment to insure even thickness of the sheet of paper. Slices to be placed over breast roll. Two patented brass wash troughs provided with proper shower pipes and sliders for washing the deckle straps, and also drain pipes to carry off the water.

The brass side frames carrying the above equipment will be supported by heavy brass tubes with special end journals, resting in babbitted brass bearings in such a way that the deckle frames and equipment can be lifted from their bearings when putting the wire on the machine. To change the deckle width of the paper, a system of brass screws, rods, bevel gears and cranks will operate the deckle arrangement on both sides of the machine independently, while the machine is running.

To carry the return ends of the deckle, there will be a pair of brass wheels 28 inches diameter, 8 inches face, mounted on a tubular brass shaft carried in adjustable brass bearings, that will permit of the easy removal of the shaft and wheels. Bearings to have ample take-up. To secure the brass wheels to the shaft there will be a quick clamp device that can be operated by hand, for the easy adjustment of deckles to suit different widths of paper.

Intermediate deckle support, gallows frame type, will be placed between the wash trough and the return deckle wheels, to prevent excessive sag of the deckle straps.

Shake and Stationary Rails.

The shake and stationary rails will be of steel, brass cased; the shake rails 9 inches wide, 2 inches deep, and the stationary rails 8 inches wide, 2 inches deep.

The shake rails will carry the deckle frames and table rolls, and stationary rails the return deckle wheels, dandy roll and suction boxes.

Save-all Boxes.

Located under the table rolls which are nearest to the breast roll and made in one section of sheet brass, of strong design, having sides of the triangular girder type. Carried by hollow cast iron stand at each side of the machine. The stand on the tending side will be provided with an iron roller for the easy removal of the cross save-all.

This save-all will discharge the water which falls into it, through openings in the ends of the box, front and back, and through the hollow stands into the concrete pit under the Fourdrinier part.

Suitable porter bars for handling this save-all will be furnished.

Water Pipes and Showers.

A complete system of galvanized iron water pipes, comprising two 6 inch pipe sections, provided with an 8 inch inlet tee and with branch connections to the shower pipes, fill pail, suction boxes, hose and water jet.

The branches will be provided with straightway shut-off valves, and with brass fitted unions, located beyond the shut-off valves.

There will be four brass shower pipes 2½ inches diameter, for the returning wire, one brass nozzle spray shower 2 inches diameter over the flow box, one nozzle spray shower 2 inches diameter at the slices, one brass shower in the dandy roll, one brass shower stream 2 inches diameter at the guard board, and one special brass shower 2 inches diameter, 7 ft. long, with hose connection and trolley for each press felt. Located between the last suction box and the guide roll, there will be a water jet for cutting the paper on the wire.

Shake.

The patented shaking frame with spring supports, forming cantilever side frames with the shake rails. Spiral spring arrangements to take side thrust of Fourdrinier due to shake, thus relieving the shake head and shaking frame from undue strain and wear.

The feet of the frames of the fourdrinier will be so elevated by cast iron tapered blocks, that the top of the breast roll will be 18 inches above the top of the guide roll, thus giving this amount of drop or pitch to the wire.

Where the shake and stationary rails meet they will be supported by substantial steady frames, connected across the machine by a heavy cast iron tie frame, thus preventing the shake motion being carried into the stationary part of the Fourdrinier.

Shake head of improved design for shaking the Fourdrinier frame, with heavy fly wheel and adjusting crank pin for varying the shake, and with a registering dial to accurately determine and record the amount of shake. Sleeve with pulley, 24 inches diameter, 6 inches face, with friction clutch attached for starting and stopping the shake. Sprocket wheel and drive to same, furnished by Purchaser.

Fan Pump.

One (1) 8" fan or centrifugal pump, for the white water from the Fourdrinier part. Pump casing or shell to be halved in such manner as to permit the fan to be exposed without disturbing the pipes or shaft. Casing also to be provided with a hand-hole and cover.

The pump case housings and the two cast iron ring-oiling shaft bearings to be mounted on a heavy cast iron base plate, thus making the pump self contained.

The piping to and from the fan pump is not included in these specifications.

Press Rolls.

First press, upper roll, 26 inches diameter, 168 inches face, wood.

First press, lower roll, 26 inches diameter, 164 inches face, rubber covered.

Second press, upper roll, 26 inches diameter, 168 inches face, wood.

Second press, lower roll, 26 inches diameter, 164 inches face, rubber covered.

Third press, upper roll, 24 inches diameter, 165 inches face, gun metal cased.

Third press, lower roll, 26 inches diameter, 164 inches face, rubber covered.

The upper wooden rolls will be made of sweet gum wood, having heads and journals cast in one, and held by a large diameter center rod through the entire length of the roll. Journals 7 inches diameter, 11 inches long.

The upper gun metal cased roll will have casing ½ inch thick, of special quality gun metal bronze, forced by hydraulic pressure over a hollow cast iron body having cast steel heads and journals; the body having been turned in balance and made as light as is consistent with proper strength and stiffness. The combined heads and journals forced by hydraulic pressure in the ends of the bodies. Journals 7 inches diameter, 11 inches long. The extension of the journal of the upper rolls outside of bearing, on the tending side, will be covered by ornamental brass caps, and on the driving side by cast iron sprocket caps.

The lower rubber covered rolls will have rubber covering ¾" thick over a hollow cast iron body, having cast steel heads and journals; the body having been turned in balance. The combined heads and journals forced by hydraulic pressure in the ends of the bodies. Journals 9 inches diameter, 14 inches long. The extension of the journal outside of bearing on the tending side will be covered by an ornamental brass cap, and on the driving side a half lug clutch will be fitted. The rubber covering will be of such density and hardness as will equal that of certain samples of rubber chosen by the Purchasers from samples submitted by the Builders, or otherwise, the Purchasers will accept the density of hardness of rubber covering selected by the Builders in accordance with their experience in building machines of this class.

Rolls to have center collar oiling and center thrust rings.

Press Housings and Pedestals.

The journals of the upper roll will be carried in bronze-lined bell crank swinging arms, connected to a system of levers and weights so as to properly distribute the weight over the entire surface of the journals, thus giving aditional pressure on the weight of the roll on the paper if desired.

Puseyjones patented housings carrying the bell crank swinging arms will be arranged with geared brass screws operated by handwheels for lifting each end of the upper press roll, to give clearance between upper and lower rolls for convenience in putting on press felt.

Housings for first and second presses suitable for 28 inch upper roll, to take care of large diameter wooden roll.

The journals of the lower press roll will be carried in bronze-lined pedestals on blocking pieces, resting directly on the side frames of the machine. The bearings for both the upper and lower rolls will be water cooling and collar oiling. The blocking pieces removable for changing felts.

Ductors.

One vibrating ductor for each upper press roll with steel frames. Wooden ductor blades for the wooden upper rolls and hard rubber ductor blades for the gun metal upper press roll. Vibrating arrangement complete including worm wheel and worm, and sprocket gear drive from extension of upper roll journal on driving side.

One crumb catcher for each press.

Save-alls.

A trussed wooden save-all of proper form and dimensions will be arranged under each lower press roll, carried on cast iron brackets on inside of press frames.

Footboards.

A wooden footboard with the necessary steps with special treads and supporting frames, will be arranged at each pair of press rolls.

Press Frames.

Complete extending under the entire press part and join these under the couchers. These main frames, of our latest design, will support the upper press roll housings, lower press roll pedestals, footboard supports, small stands, save-all brackets and felt roll brackets.

Water log arrangement in press frames to take press save-all water.

Three sets of holes will be arranged in the frames for holding the first and second press housings. By using one set of holes, the center of the upper press rolls can be run directly over the center of the lower press rolls, or by using the other set of holes, the center of the upper press rolls can be couched 2 and 4 inches toward the Fourdrinier part. In the case of the third press, two sets of holes will allow the upper roll to be directly over the lower roll, or to be couched 2 inches toward the dryers.

General Arrangement of Felts.

The first and second press felts will pass in a forward direction through their respective presses, and the third press felt will pass in the reverse direction through its press. Arrangement to suit press felts exactly 85 feet long.

Felt Rolls.

All the necessary press felt rolls will be 9⅝ and 8⅝ inches diameters, made of turned steel pipe, encased with No. 14 S. W. G. brass tube, having cast iron heads with steel journals 2 3/16 in. by 13 in. and 1 5/16 in. by 12 in., carried in bronze-lined bracket bearings, the journals extending beyond the bearings to form handholds to facilitate in placing new felts on the presses. The larger diameter felt rolls will be used in the places where the strain of the felt is greatest, and the smaller diameter rolls will be used in the places where the strain of the felts is lightest.

One of these felt rolls for each press felt will be "wormed" on the face with brass strips, which strips will be secured and pinned to the body of the roll.

Felt Stretchers.

One horizontal press felt stretcher for each felt so fitted with brass gears and screws that, if desired, both screws can be operated simultaneously, or the screw on the driving side independently, by a hand wheel on the tending side of the machine.

Automatic Guide.

One automatic guide for each felt, with hand adjustment on the tending side.

Suction Boxes.

One open type suction box, for the first felt, and one open type suction box for the second felt, made of 8 inch diameter galvanized iron pipe, with extruded brass edges where same come in contact with the felt. Suction boxes arranged on the lead of the felts before entering the nip of the presses.

Shower Pipes.

One special brass shower pipe for each press felt, as before mentioned.

Paper Rolls.

The three paper rolls at the third press will be 7½ inches diameter, made of brass tubing No. 10 S. W. G. having cast iron heads and steel journals carried in ball bearing brackets. These three rolls will each be fitted with a fly wheel pulley to be driven by a belt from a corresponding pulley on the end of one of the felt rolls.

Rolls to be in running balance, as indicated by a Norton Balancing Machine, at a speed of 700 feet per minute.

Small Stands.

All necessary small stands and frames for the general arrangement of the press part.

Dryers.

Thirty-two (32) cast iron paper dryers, each 60 inches diameter, 162 inches face.

The inside of the shell of each dryer to be bored and the outside face to be turned and polished. The tending side head of each dryer to have a manhole fitted with specially designed manhole cover. Journals 10 inches diameter, 13 inches long. The extension of the journal outside of bearing on the tending side will be covered by an ornamental brass cap and on the driving side keyseated to receive driving spur gears. Dryers to be balanced.

One cast iron overhung paper dryer, 24 inches diameter, 162 inches face.

This dryer which is overhung toward the press part and receives the paper therefrom will have the outside face turned and polished. Journals 7 inches diameter, 12 inches long. The extension of the journal outside of bearing on the tending side will be covered by an ornamental brass cap, and on the driving side keyseated to receive driving spur gear. Dryer to be balanced.

Two (2) cast iron felt dryers, 48 inches diameter, 162 inches face.

The inside of the shell of each dryer to be bored and the outside face to be turned and polished. The tending side head of each dryer to have a manhole fitted with specially designed manhole cover. Journals 9½ inches diameter, 12 inches long. The extension of the journal outside of bearing on the tending side will be covered by an ornamental brass cap, and on the driving side keyseated suitable for driving gear, if it is found desirable to add same later. Dryers to be balanced.

One of these dryers will be placed on the return of the first upper felt, and the other placed on the return of the first lower felt to help dry these felts. They will be arranged so that the side of the felt which comes next to the paper will be next to the surface of the dryer.

Dryers to have center collar-oiling and center collar thrust.

Dryer Dippers.

Arranged in each dryer at the driving side will be an internal duoliptical dipper to remove the water of condensation from the dryer.

Air Valves.

Hand operated brass air valves to be placed on the end of the journals of each dryer on the tending side of machine, capable of being operated while machine is running.

Steam Joints.

To the extension of each dryer journal on the driving side will be fitted a patented combined steam joint and safety valve, arranged to admit steam to the dryer, and connected by pipe to the dipper to remove water of condensation therefrom.

Cooling Dryers.

The last upper and last lower dryer will be arranged with a shower pipe to uniformly cool the surface of the dryer. Funnels arranged with pipe connections will catch the overflow from ends of journals, both front and back. The standard equipment of dippers, steam joints, piping, etc., will be furnished for these two dryers, so that they may be installed later if found necessary.

Vertical and Horizontal Piping.

The vertical steam inlet pipes 3 inches diameter and the vertical water outlet pipes 3½ inches diameter, will connect at the upper ends of the steam joints above mentioned, and to the horizontal steam and water pipes by improved clamps. The horizontal steam pipe will be 8 inches diameter, and the horizontal water pipe 4 inches diameter and each will extend the full length of the dry part.

The steam pipe to be divided into two sections, each section having at the middle an 8 inch by 8 inch by 10 inch special distribution tee. A 10 inch by 10 inch by 12 inch distribution tee will also be furnished which will connect to the 8 inch by 8 inch by 10 inch distribution tees with 8 inch piping.

The water pipes will be divided into four sections by blank flanges, each section having a tee connection at the middle, to which tees the Purchasers will connect from steam traps.

Each vertical steam pipe will be fitted with a brass mounted union placed just above the machine room floor.

Dryer Pedestals.

Cast iron dryer pedestals fitted with phosphor-bronze shells so designed that the shells may be renewed without removing the pedestals from the machine Pedestals arranged for collar oiling and to have cap covers.

Dryer Frames.

Cast iron dryer side frames will be arranged to carry the pedestals of the sixteen dryers in the upper tier. Hand rails across the open spaces between the upper frames on tending side.

The pedestals of the sixteen dryers in the lower tier resting directly on sill plates 10 inches high, which will also carry the upper dryer frames.

Frames for carrying the upper felt equipment and the upper felt dryers will be furnished complete.

To carry the lower felt equipment on the return, in the basement, there will be furnished the necessary channel beams to be attached to the steel columns furnished by the Purchasers, to support the machine foundations.

Dryer Gears and Pinions.

The cast iron driving spur gears for all the paper dryers will have machine cut teeth 2 inches pitch, and hubs of the clamp design. All the spur gears will be 5 inches face, with the exception of the four spur gears meshing with the driving pinions, which are to be 7 inches face. The two driving pinions will have machine cut teeth 2 inches pitch, 7 inches face.

Gear guards placed where necessary.

Doctors.

Five doctors with rock maple blades and spring tension arrangement to be placed on the last four lower dryers and the last upper dryer.

Footboards.

An iron footboard, supported by cast iron columns, will extend the whole length of the nest of dryers on the driving side, and will have two flights of cast iron steps and the necessary iron hand railing. Also a cast iron footboard supported by cast iron brackets at the press end of the dryers on the tending side of machine.

General Arrangement for Felts.

Will be for two upper and two lower felts.

Felt Rolls.

All the necessary dryer felt rolls will be 10⅝ and 9½ inches diameter, made of turned steel pipe having cast iron heads with steel journals, 2 7/18 in. and 2 3/18 in. diameters, carried in bronze-lined collar oiling bracket bearings. The large diameter felt rolls will be used in the places where the strain of the felts is greatest, and the smaller diameter felt rolls be used in the places where the strain of the felt is lightest.

Guides.

One automatic guide, one hand adjuster and one hand guide for each felt.

Automatic Tighteners.

One anti-friction automatic tightener, having horizontal guides and weight tension arrangement complete.

Paper Spring Roll.

Located at the end of the nest of dryers to lead the sheet of paper to the calenders, will be a spring roll 10¾ inches diameter, made of turned steel pipe, having cast iron heads, with steel journals, 2 7/16 inches diameter, carried in bronze-lined, self-oiling bearing, mounted in brackets by circles of springs to allow for uneven tension of the draw of paper.

Roll to be in running balance as indicated by a Norton Balancing Machine, at a speed of 700 teet per minute.

Calenders.

One stack of chilled iron calender rolls, comprising ten rolls, as follows:

One 18 inch top roll,
Seven 13 inch intermediate rolls,
One 12 inch next bottom roll,
One 28 inch bottom roll,

all 160 inches face, with heavy 5,000 lb. box pattern housing. Housings wide enough to permit the intermediate rolls to be taken out endwise.

All journal boxes to be babbitted and cored for water-cooling and those for the bottom roll made self-oiling. All necessary levers and weights for applying pressure to the journals of the top roll.

Lift rods on outside of housings. The strongbacks rod to rod under the roll boxes will be of steel, and will be carried by adjustable nuts on the lifting rods, which will be operated by Farrell Hydraulic Lift and hand pump.

Brass chafing rings for intermediate rolls.

Complete equipment of "Warren" Doctors and Feeds.

The doctor for the bottom roll will be placed against the side of the roll nearest the dryers so that in starting up, the first run of the paper may be directed through an opening in the floor.

Reel.

One (1) 164 inch Uniform Speed Reel, arranged with two winding drums.

The driving drum is 42 inches diameter, the shell and heads being made of cast iron and similar in design to a dryer shell. The tending side journal to be fitted with an ornamental brass cap and driving side journal with half lug clutch.

The driving drum is carried in bronze-lined pedestals which rest on heavy cast iron frames. An extension arm on each of these frames carry a doctor having wooden blade and suitable equipment of bearings, levers and weights.

Two winding drums each 8½ inches diameter made of extra heavy steel pipe, turned on the face. Each end of pipe to be fitted with a cast iron head into which the steel journal is forced. Each journal is square on the end, to suit a crank, for turning drums by hand when on the unwinder. The tending side journal of each drum is fitted with a cast iron spur pinion, having machine cut teeth, which is used in connection with friction arrangement on the unwinder.

The winding drums are carried in swinging arms having brass-lined bearings with caps; the bearings being adjustable to insure even contact on driving drums. Each set of swinging arms is keyed to a cross shaft, this shaft being supported in rigid bearing on tending side and adjustable bearing on driving side. For raising the roll of paper from the riving drum a quadrant mounted on cross shaft at tending side engaged with a compound train of gears, the bearing being operated by a hand wheel.

The hand wheel is equipped with a clutch device for holding roll in a given position. The balance weight arrangement may entirely or partially relieve the back pressure of the gears when winding paper on the drums. Suitable spreader bar to be furnished.

The maximum diameter roll of paper that can be wound on this reel is 42 inch.

Unwinder.

One unwinder of the geared type to receive the drums filled with paper taken from the reel.

The unwinder to consist of one pair of stands with bronze-lined bearings. The bearing on tending side is equipped with screw and handwheel for lengthwise adjustment. The tending side stand is mounted on a base and is equipped with screw and ratchet wrench for crosswise adjustment.

The spur pinion on reel drum meshes into a spur gear having machine cut teeth, which is keyed to a pin, the other end of pin being fitted with friction pulleys. The pin revolves in a brass bushing which is fitted into hub on tending side stand. The friction pulley is fitted with strap, screw and handwheels for applying pressure.

The bearing cap on tending side bearing is made with cover to protect the gears.

With the geared design of unwinder it allows the changing of drums without disturbing the friction arrangement, and it also allows a large friction pulley to be used, this arrangement reducing the liability of heating the friction straps.

One reel drum duplicate of ones on reel to be furnished for use with the unwinder.

Slitter and Winder (Combined).

One (1) 160 inch slitting machine, combined with a 160 inch two-drum uniform speed winder, of designated standard make. Cast iron drums 16 inches diameter. Upper slitter bar 4⅞ inches diameter. Lower slitter shaft 7⅜" diameter. Lower slitter shaft to have a center adjustable bearing. Six upper slitters; six lower slitters, double edged, 12 inches diameter. The winding shaft will have quick opening boxes and will be arranged with threads and nuts to suit 3 inch gas pipe cores. Intake shafts connected to drums with flanged couplings.

Drums to be balanced at a surface speed of 1500 feet per minute.

Driving Arrangement.

Of the parallel rope type, beginning with a large sheave wheel with grooves suitable for 1½ inch diameter cotton ropes, a short heavy shaft, two ring-oiling, babbitted, rigid pillow blocks, and two wedge-adjusting cast iron stands.

Power is to be supplied to this shaft and sheave by the Purchasers, who are expected to couple direct to the shaft, a sufficiently powerful variable speed electric motor or engine, 375 revolutions of which will produce a speed of 700 feet of paper on the machine, as a maximum. From this large sheave, multiple ropes (English System) will deliver the power to the various parts of the machine having a variable speed, and to the reel counter.

It is understood also that the Purchasers will furnish an independent variable speed electric motor for driving the countershaft in the basement, of the slitter and winder, as before mentioned, and also they will furnish an independent electric motor for driving the constant speed shaft and equipment.

For each of the seven driven parts of the machine, a sheave wheel, about 5 feet 0 inches diameter will be furnished which will be mounted on a shaft carried by at least two and in nearly all cases three ring oiling babbitted rigid bearings and wedge adjusting stands, in the basements. To this shaft a cone pulley, about 54 inches diameter and about 30 inches face will be keyed and will drive upward through the floor of the machine room, to a corresponding cone pulley on a short parallel shaft. This short shaft will be connected to a second short shaft by means of a patented cut-off friction clutch (24 inch triple disc on the couchers and calenders, and 24 inch double disc on the three presses and two dryer nests). To the latter short shaft will be keyed the pinion of a pair of cast steel and cast iron spur gears having machine cut, helical, herringbone teeth. The proportion of the gears will be about 1 to 4. The large spur gear will be keyed to the intake shaft of each part of the machine. The two short shafts and the intake shaft will each be carried in two ring-oiling, babbitted, rigid pillow blocks, mounted on a heavy box bedplate. This box bedplate will have attached an extension which will come up to within 1 or 2 inches of the intake shaft of the inboard and so that a block of wood can be inserted for this end of the shaft to rest on when lug clutch is thrown out and the roll removed.

The position of the belt on the cones is to be controlled by a suitable belt shifter. The friction clutch cut off coupling is to be operated from front or tending side of machine.

The drive of the reel will be through cones and pulleys from the sheave jack shaft of the calender drive in the basement, and will start and stop with the ropes.

All gears to have proper guards where they turn in.

Foundation Plates and Bolts.

A complete set of cast iron foundation plates, 12 inches, 14 inches, 17 inches and 18 inches wide from standard patterns, extending from flow box to winder inclusive. At the dry part, the plates will have ¾ inches wide, 1 inch high, upturned flanges on both sides.

All joint bolts to be furnished by the Builders, but all foundation bolts and washers are not included in these specifications.

In addition to these foundation bolts and washers, just mentioned, the foundation bolts and washers for holding the drive stands and bedplates are not included in these specifications. The holding down tap bolts for fastening the feet of the machine frames to the foundation plates will be furnished by the Builders.

Drawings.

There will be furnished without charge, by the Builders, the necessary drawings for erection, including a drawing showing a plan view of the foundation walls on which the machine may rest and the basement shafting and stands.

Speed.

Machine designed for a maximum speed of 700 feet of paper per minute.

In General.

The object of these specifications is to set forth and describe as clearly and definitely as possible all parts of the machine and its equipment that are to be furnished by the Builders, and it is their intention that in workmanship, materials and finish, this machine will be fully equal to others of its class that they have built.

Exceptions.

The Fourdrinier wire, apron, deckle straps, jackets, felts, bolts, etc., comprising the clothing for this machine; also the steam, water and stuff piping to and from the machine, not otherwise specified, are not included in these specifications. However, a full set of cotton drive ropes are included.

Delivery.

The machine to be painted the Builders' standard color, and to be boxed and crated suitable for railroad shipment, as per contract.

Erection.

The Builders further agree to furnish the services of a skillful Erecting Engineer whose duty it shall be to superintend and further assist in the erection of the before-mentioned machine upon arrival of same at destination. The board and lodging of the said Erecting Engineer shall devolve upon the Purchasers, but his wages and traveling expenses shall be paid by the Builders. In this connection, however, it is further understood that should the said erection be delayed beyond the term of say seven weeks, of fifty-four hours each, then the Purchaser shall pay such additional services of the said Erector.

If desired by the Purchasers, the Builders will also furnish the services of an Assistant Mechanic whose board and lodging, traveling expenses and wages will be paid by the Purchasers.

The Purchasers are to furnish all necessary laboring help and millwright help; also use of crane and other handling apparatus, to expedite the erection.

SPECIFICATIONS

FOR A

156" FOURDRINIER PAPER MACHINE FOR MAKING MANILA WRAPPING PAPER, ETC.

MADE BY

(Name of Builder and Address)

FOR THE

(Name of Purchaser and Address)

(Address and Date.)

General Conditions.

The Design, material and labor embodied in this contract, unless otherwise specified, is to be the best of the several kinds, and is intended to cover the general detail and construction of one Paper Machine, as hereinafter specified and described, subject to the approval of ....Company, hereafter referred to as the Purchaser.

The ....Company (the Builder) shall allow inspection of the work at any time by the Purchaser, or his Agent.

In cases where a possible doubt exists as to the interpretation of these specifications, the Builder shall consult with the Purchaser before taking steps towards the performance of the work.

Extras.

These specifications are intended to embody a complete machine in all its parts, as called for by the contract; but any changes or additions, or extra parts, that may be called for, shall not be charged as "Extras" unless the same shall have been called to the attention of the Purchaser and done in pursuance of a written order from the Purchaser or his Agent.

Nothing that is necessary for a complete installation of the work herein called for shall be construed as "Extra."

Guarantee.

The Builder herewith guarantees that the material and workmanship shall be the best, and agree to replace and make good to the Purchaser, at any time within one year from the date of first operation of the machinery, any portion that may have proved to be defective, under ordinary wear, during that time.

Any breakage or damage to the machine, caused by the negligence or incompetence of the employees of the Purchaser, shall not be included in the above clause.

Hand.

When standing at the Breast Roll and looking toward the Reel, the driving arrangement will be on the Right Hand side.

Size and Wire.

The machine will be made for Wire 156" wide and seventy feet (70') long.

Widths.

Breast Roll	158" face
Table Rolls	158" face
Guide and Stretch Rolls	158" face
Dandy Roll	158" face
Top Couch Roll	160" face
Bottom Couch Roll	158" face
Top Press Rolls	155" face
Bottom Press Rolls	154" face
Dryers	154" face
Calenders	152" face
Reels	156" face

Screens and Flow Box.

No Screens to be furnished by Builder. Overflox Box made from latest designs for economy of space, and the proper distribution of pulp upon the apron, with adjustable Overflow Pocket in end of box, and 6" galvanized iron pipe connecting same with Fan Pump Box, so as to prevent the flooding of the Wire.

Composition Slide Gate and Washout Valves.

Pumps.

Eight inch (8") improved Iron Turbine Fan Pump, made so that top half of the pump case may be removed without interfering with the shaft or motor. To have thrust and ring oiling bearings. Fan Pump Box.

No other Pumps to be furnished.

Wire Guide.

Nash Patent Wire Guide.

Breast Roll.

Of Gun Metal ½" thick, 18" diameter, 138" face; made with shaft running entirely through the roll, with cast iron spiders pressed on the shaft by hydraulic pressure, and keyed. The Gun Metal shell to be accurately bored and pressed on the spiders under 5000 lbs. pressure to the square inch.

Journals 4"x8". Gun metal adjustable swivel boxes. Wood Doctor for Breast Roll. Composition heads for ends of roll.

Brass Rolls.

A sufficient number of brass Table Rolls 5½" and 5" diameter, No. 10 gauge, 138" face, to fill the space between the Breast Roll and the first Suction Box; journals 15/16" diameter, 3¾" long, of steel, with adjustable Gun Metal bearings, with end thrust attachment. The 5½" rolls to fill the space between the Breast Roll and the Slices.

All Needful 5"x158", No. 10 gauge; and 10"x158" brass Wire Rolls, No. 6 gauge, with journals 2" diameter x 8" long. Gun Metal shells in boxes for the 10" rolls.

The Wire Stretch Roll and the Guide Roll to be of brass, No. 6 gauge, 10" diameter and 158" face, and to have journals projecting beyond the boxes to serve as handles for facilitating the handling of the rolls.

Wooden Doctors to be placed on two of the lower rolls which carry the returning Wire.

All rolls to be made of seamless drawn brass tubing, accurately balanced and ground true in, our improved grinder.

Deckle Arrangement.

Deckle Rods and Shafts 5½" diameter, made of iron pipe covered with brass tubing.

One extra Deckle Shaft 2½" diameter, with two flanged pulleys to support straps. Improved brass Shield to support center of Deckle Straps, with Drain Spounts for taking off the water.

Twenty-two inch composition Deckle Pulleys; hubs 1¾" bore, 4½" long. Brass Deckle Drums 20" diameter x 12" face, to be located near the Dandy Roll and between the third and fourth Suction Boxes, to carry the Deckles at that point; the drums to revolve with a brass cased Shaft resting in adjustable brass stands.

Brass Slices made extra wide; one-half of Slice to have hole—the other half to have slot. Improved Deckle Poppets made extra heavy. Deckle Pulleys made for 2"x2¼" Deckle Straps. The Deckle Frames to be operated from the front side of the machine.

Suction Boxes.

Five cast composition Suction Boxes with wide ribs, or flanges, on same to prevent their springing or becoming set, and made with handles on each end so that they may be readily removed from the machine. Boxes to be hung to the Fourdrinier rails with bolts, and supported with wood girts covered with brass plates. Also adjusting screws for same.

Suction Boxes to be stationary. Each box to have straightway valve connecting with 4" Suction Pipe, and to be operated from front side of machine. Perforated 1¾" Rock Maple Plates. Deckle Straps to cross three of the Boxes. A system of brass piping for priming both ends of the boxes to the same water level, so that the machine tender need observe the tending side of the machine only.

Dandy.

One 10"x158" plain Dandy, covered with No..... mesh of wire, and to be equipped with an internal shower pipe. Composition combination stick stands, having vertical adjustment. Brass Shower Pipe and Wiper Bar. The Dandy to be located between the third and fourth Suction Boxes. Trolley Arrangement for removing the Dandy from the machine.

Water Pipes.

Eight inch (8") Water Main of heavy galvanized iron pipe; large brass supply pipes to Breast Roll; Foam Pipe; Save-all Fans; Stretch Roll, Suction Boxes, Pail Fill; and Coucher Shower, with improved connections and straightway valves. The unions to be located above the valves.

The Shower Pipes at Wire Stretch Roll and Hand Guide Wire Roll to have Pistons. The Shower Pipe over the Breast Roll to revolve.

Brass Water Jet for cutting the sheet.

Shake Rails.

The Shake and Permanent Rails to be of steel, covered with cast brass, 8" wide x 2¼" thick. The Shake Arm to come close to the floor so as not to interfere with the putting in or taking out of the Breast Roll, and to be driven by our improved Cone Driving Arrangement, and Friction Clutch.

Posts Under Shake Rails.

2¾" diameter, of brass.

Save-all Pans.

Five inches deep, made in sections with spouts for each, so the different sections may be removed between the posts. Girts for the above pans to be made of channel iron 6" wide, trussed and covered with Copper.

Couchers.

Both rolls to be covered with Gun Metal; top roll 24" diameter x 160" face; bottom roll 28" diameter x 158" face. Journals of top roll to be 6" diameter x 10" long; journals of bottom roll to be 7" x 12".

Both the rolls to be made with a shaft running entirely through the roll, with cast iron spiders forced onto same by hydraulic pressure and keyed. The Gun Metal shell to be accurately bored and pressed on the spiders under 5000 lbs. pressure to the square inch.

Bottom roll to have composition water ring heads; no composition heads for the top roll. The Coucher Stands and Frames to be of our latest design for facilitating the putting on of the Wires and Jackets. The Boxes for the top roll to be on the under side of swing arms; the boxes for the bottom roll to be water jacketed. Both rolls to have gun metal lined boxes. Coucher Board to be trussed with an 8" bowed truss. Large brass Shower Pipe. Foot Board between the Couchers and first press with brass Hand Rail. Compound Levers of Iron, Weights, etc.

Our improved Screw Jack Lifting Arrangement for lifting the Top Roll, greatly facilitating the putting on of the Wires and Jackets.

First Press.

Bottom Roll to be covered with Rubber, 5/8" thick, 24" diameter, 154" face. Top Roll made of Gun Metal, 24" diameter, 155" face; journals of both rolls 9" diameter x 12" long.

Felt Arrangement for 48 foot felt. Brass Shower Pipes, etc.

Cast composition Suction Box for Felt, with perforated Rock Maple cover 1" thick. Felt Stretcher with screws of Gun Metal 1 11/13" diameter, and brass cased. The Stretch Roll to be operated by large Hand Wheel and Sprocket Chain, and to be equipped with eccentric motion for operating either end of the roll separately.

Gun Metal lined water jacketed boxes, and our improved Screw Jack Lifting Arrangement, for lifting one or both rolls. Swing automatic Felt Guide; one Hand Guide. Improved Scoop Doctor with brass blade. Compound Levers, Weights, etc.

Second and Third Presses.

Same as the First Press. The Gun Metal shells to be 5/8" thick and forced onto the iron body by hydraulic pressure.

No Suction Box for second or third Press Felts. No Swing automatic Felt Guides. Otherwise the same as the First Press.

Dryers.

Forty cast iron Dryers, 48" diameter, 154" face, arranged twenty at the bottom and twenty on top. Journals 8" diameter, 13" long.

One Receiving Dryer about 24" diameter, 154" face; journals 5"x9". Eight Felt Dryers—two for each Felt—33" diameter x 154" face; journals 5½"x9½" long.

All the Dryers to be fitted with .... Steam Joints and Improved Scoops.

All Dryer Boxes fitted with Phosphor Bronze linings, with our improved Grease Caps.

The Dryers to be arranged for two bottom Felts and two top Felts. Each Felt to have one Hand Guide, one Automatic Guide; one Automatic Tension Roll, and one Horizontal Felt Stretcher.

Dryers to have the Yoke Drive.

Walk with steps and Hand Rail at the back side. Improved Gear Guard. Stretcher Screws 1 11/16" diameter, brass cased. The Stretch Rolls to be operated by large Hand Wheels and Sprocket Chains, and to be equipped with eccentrics motion for operating either end of the rolls separately. Ring oiling boxes for all Felt and Paper Rolls at Dryers.

The Dryer Gears to be CUT GEARS, with SPLIT HUBS. First bottom and last top Dryer to be fitted with Improved Doctors, and steel blades. All dryers to be accurately turned, balanced and highly polished on the face.

Calenders.

Three stacks of chilled iron Calender Rolls, each to consist of nine rolls—one 28", one 16", six 14" and one 16" all 152" face.

Housings of our latest design for removing the rolls endwise. Journals to be extra long. Composition Friction Rings at shoulders of journals. All rolls to be accurately bored and Water Jacketed to prevent the journals from heating. Dillon Calender Feed, without air pipes or Blowers.

Hydraulic Lifting Device for lifting the Calender Rolls.

Compound levers, Weights, etc.

Reels.

One set of our latest and most improved Two Upright Reels, 18" diameter, 156" face. Reels made with both the endwise and lateral adjustment, and driven by independent belts, with tighteners.

Friction Wheels, Straps, etc., complete. 22" Hand Wheels.

Slitting and Winding Machine.

To be of any standard make designated by purchaser.

Felt and Paper Rolls.

All Felt Rolls about the Presses of steel, 8½" diameter, made in the latest and most permanent manner, turned and covered with Brass Jackets, with improved journals. The two Paper Rolls in front of the third Press to be of brass; lower roll 7" diameter; upper roll 7" diameter and made light.

The Paper Roll over third Press to be of brass, 8" diameter and driven by power.

All Felt Rolls about Dryers of steel, 8½" diameter, turned true and smooth on the face.

All Felt and Paper Roll Stands about Presses to be Gun Metal lined. All Felt Roll Stands to be of the most improved adjustable type, with six springs. Gun Metal lined Boxes.

Two 2½" brass rolls, one to go in front and one back of the first Press, to be used as Blow Rolls.

Frames.

Of our heaviest, latest and most improved designs.

Shafting.

Constant and variable lines, and countershafts, 5 7/16", 4 7/16" and 3 15/16" diameter. All the Shafting to be milled and polished and fitted with Flanged Couplings.

All Collars for Shafting to be of cast iron, of the safety type, with two set screws quartering and countersunk.

Steam Pipes.

All necessary about machine, made of wrought iron. Ten inch steam main and six inch exhaust main. 2" and 1" uprights.

Pulleys.

All large and wide on the face, balanced and keyed to Shafting. The Cone Pulleys to be keyed to Shafting and to be operated by patent CUT OFF COUPLINGS.

All the pulleys on both the constant and variable lines to be SPLIT PULLEYS.

The Couchers, Dryers, and Calenders to have 27", and the Presses 24" Cut Off Couplings. Set Screws over all keyes.

Driving Arrangement.

Machine to be driven by any required system of drive, detaile specifications concerning which are to be furnished by the purchaser. The Constant and Variable lines to be driven by engines, or motors, furnished by the Purchaser.

The Builder is to furnish one driving pulley for the Constant Speed Line, and one driving pulley for the Variable Speed Line.

The Main Line to be located in the basement, with adjustable ring oiling boxes for same.

All the Shafting Boxes, Dryer Boxes, Coucher and Press Roll Boxes to be dowelled after the machine is erected, so as to obviate any possibility of their being moved.

Foundation Plates.

Of iron, with gutters cast on the side, with spouts connecting same with the space between the machine foundations. Anchor bolts and washers for holding the foundation plates. The floor at the foundation plates, at the back side of the machine, to be level with the top of the plates.

Exceptions to a Complete Machine.

Felts, Belts, Wires, Deckle Straps, Jackets and Aprons.

Speed of Machine.

The machine to be guaranteed strong and sufficiently rigid to run successfully at a speed of 550 feet per minute.

To Be Complete.

Ready to ship from our works, by........................, 19....., contingent upon strikes, fires, accidents and other causes beyond our control.

Erection.

The Builder is to furnish the time of one competent man to superintend the erection of the machine in the mill of the Purchaser.

The Purchaser of the machine is to pay his traveling expenses and board and to supply all necessary millwright and laboring help.

General Conditions.

All feet of stands to be planed, and all other parts where required. All moving parts to be accurately balanced. The machine is to be suitably painted. The machine shall be built along lines that will give every possible provision for the safety of the machine tenders.

Drawings.

There will be furnished without charge by the Builder a drawing showing a plan view of the machine and its driving arrangement, as hereinbefore specified, and also a drawing showing a plan view of the foundation on which the machine may rest.

Price of Machine.

Terms of Delivery.

F. O. B. (Location of mfrs. plant).

Terms of Payment.

Signed...

....

Signed...

....

XIV. The Finishing Room.

The work of the finishing room divides itself into two general classifications, which are themselves much further subdivided. The two classifications are (1) making rolls of paper (2) making bundles of paper.

Whether bundles or rolls are to be made depends entirely on the purpose for which the paper is to be used.

The extent of the operations of the finishing room will vary all the way from the very simple state of affairs in a newsprint mill where the rolls are shipped practically as they come from the machine, to that in a mill making a wide line of book or writing papers, or specialities of some kind, in which case the finishing room may well be one of the most extensive and important parts of the whole plant.

Roll Finishing.

Rolls of Paper: The first classification is the simplest. In most cases the paper, as it is rewound from the jumbo roll formed on the reels in the machine room, passes through a rewinder. This machine usually consists of a rewinder and slitter combined so that, by means of various cutting devices, the operators are able to obtain whatever sized rolls their orders may call for.

This rewinding and cutting operation requires the severest attention. A dull knife will often result in spoiling many rolls of paper. The knives must be placed at exactly the right points for cutting the paper; otherwise oversized or undersized rolls will result. Actually the slitting process and the rewinding process are not distinct and separate operations, but must be considered one in relation to the other.

The rolls must be wound absolutely straight to insure a uniform advancement of the web of paper from the jumbo roll. The sheet of paper must be held rigidly, and must have been properly calendered to insure presenting a good uniform surface from the jumbo roll to the finished rolls, otherwise causing rolls to be formed that have hard and soft spots. A roll of this sort would not be particularly objectionable if it were to be used as a counter roll, but if it were going to be further cut up or used in a bag machine or any other automatic machine for making paper products, serious difficulties would follow. For instance, the roll could not be properly fed to the machine. The slackness of one side would cause wrinkles, followed by breaks. This would mean an immediate rejection of such a roll of paper.

There are hundreds of little things at this particular stage of paper making—the finishing room—that can completely offset the value of a good sheet of paper. Paper that has had all the attention and care that paper possibly could have, before being sent to the finishing room, may be completely ruined. Consequently extreme precaution must be exercised.

The machinery should be of the best and most improved makes and care should be exercised to keep it in the best order. The knives of the slitters must be kept properly sharpened and not allowed to sheer, otherwise feathery edges will result, or an overlapping will take place between the consecutive rolls. This works a hardship on the operators who are taking away the paper from the rewinder, and often results in the spoiling of a roll due to the inability of the help to separate it from another roll. Spreaders of various types are used to prevent this, the most usual type of spreaders being a steel strip pressing on the paper which is bowed out at the point where the spreading is required.

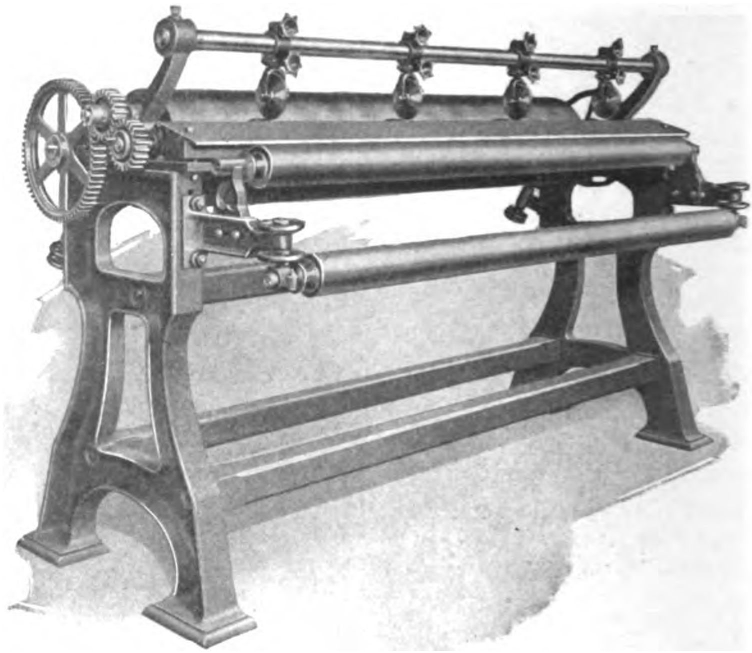
Rewinding.

There are various methods of performing this operation of cutting and rewinding. One of these is the *surface rewind method*. By this method all the rolls are formed side by side on a single shaft by surface contact with a pair of revolving support rolls, on which the rolls of paper rest. No power is applied directly to the rewind shaft. This method, when the equipment is properly designed, and when accompanied by the proper method of slitting, is decidedly superior to the old center rewind method. The *center rewind method* is not practical when narrow rolls are required, as they will not stand alone after they have been built up to any considerable diameter. Further trouble with this method is due to variation in the thickness of the paper across the width of the sheet, causing the rolls to build up largest where the web is thickest, thereby pulling the paper faster on the thicker portions, thus causing the web to feed unevenly and preventing first class work.

As has already been stated it is generally conceded that the surface rewind method is the better one, and the next point to be considered is what is the best method of slitting so that the two operations, quite distinct from each other, will work in perfect unison with each other.

Slitting.

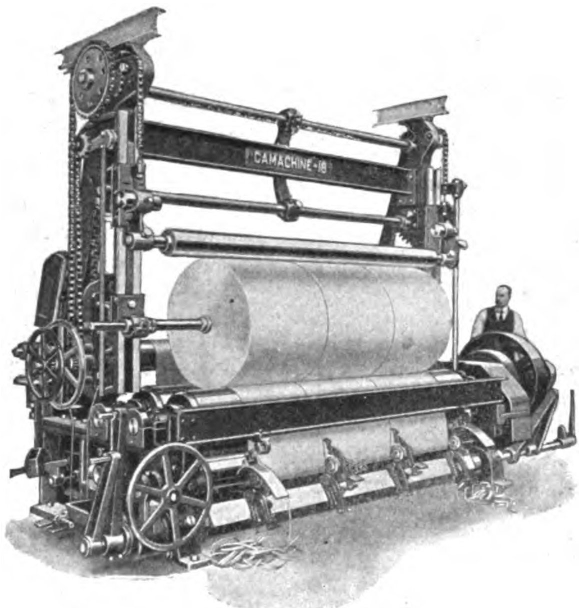
The rotary shear, or rotary slitter, method is one that in the past has been widely used and was, at one time, considered to be the last word on the subject of slitting. To work properly the rotary shears must have a keen edge, and yet this edge is bound to become dulled slightly, even after only moderate use, thereby causing a ragged or frayed edge on the strips, which then become interlaced or meshed together in the rewinding process. As before stated, when this interlacing takes place it is often impossible to separate the rolls from each other. The slitter shaft should be heavy enough not to vibrate or chatter and should be well braced and the knives should be large enough in diameter that they do not have to rotate excessively fast.



Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 144.—Winder and rotary slitter.

On account of serious difficulties in maintaining production and high class finishing with the rotary slitters, some of which have been touched on above, the *score cutter* has come to be much used in modern finishing rooms. This device consists of a single cutting disc with a "V" edge, so mounted as to revolve under spring pressure against the surface of a glass-hard steel cylinder. This surface is very smooth and highly polished. The steel cutter wheel is mounted on ball-bearing centers, revolves practically without friction and has an actual cleaving action through the paper at the point of contact with the cylinder against which it is pressed. This appliance invariably yields a clean cut, even, perfect sheet or roll of paper. The edge of the paper is not stretched, owing to the cleanness of the cut. Further, there is not the same difficulty in keeping these steel cutter wheels sharp as there is with the rotary slitters, since they do not have a regular knife edge but rather a very hard permanent edge, something like a cold chisel. The variety of materials that can be handled with such equipment is very great—all the way from the most delicate tissues to coarse boards, also fabrics, textiles, etc. Great difficulty was experienced with rotary slitters



Courtesy: Cameron Machine Co., Brooklyn, N. Y.

Fig. 145.—Score cutter type of winder and slitter.

at very high speeds, but the score cutter apparently knows no limit as to speed.

No matter what principle has been embodied in reducing the jumbo roll to the sizes specified in the orders, whether to 9-inch rolls or 40-inch rolls or what not, one can hardly place too much emphasis on the necessity of taking every precaution to prevent bad edges, slitter breaks, slack edges and to insure exact and proper width of roll.

Another precaution that must be taken is the prompt insertion of plugs in the rolls, so that when these are later piled up in transportation or storage they will not be pressed inward and flattened and loose their symmetrical cylindrical shape.

After the rolls have been cut to the proper size, plugs inserted, etc., they are ready for the final stages of finishing. This consists in putting on the wrapper, which may be done either by hand or mechanically. In large, modern finishing plants mechanical methods are usual on account of the high cost and uncertainty of labor. The roll is wrapped with either one, two or three plies of good durable paper. A strong sheet of 60-pound Kraft is suitable for this purpose. This is to insure against rough usage and tumbling during transportation.

The width of the wrapper is, of course, determined by the width of the roll; sufficient allowance being made to have the ends of the wrapper almost meet when folded over on the ends of the roll. An inside header should be placed under this folded portion to prevent any paste reaching the outer edges of the roll. The outside header is then pasted over the ends of the roll, serving not only as a means of securing the end, but adding to the neatness of the roll when properly applied. The work is now completed with the exception of stenciling and labeling. Care should be taken that this work is done neatly and not in haphazard fashion, otherwise when a number of rolls are stored in a jobber's warehouse the appearance of good workmanship is lost. With a material like paper, appearance, even in minor details, counts for a great deal.

Bundle Finishing.

Returning to the other phase of finishing—*bundle finishing*—it is well to note at the outset that, although this operation is not so difficult as roll finishing, it is more tedious and requires more operators.

Large jumbo rolls averaging 29 inches in diameter are brought from the machine room and placed on an unwinder, from which they are fed to the cutters, where they are cut into the desired widths and also cut off transversely at regular intervals, thus making rectangular sheets of regular and exact size. The sheets are gathered up, counted and placed in piles. In some mills this is still done by hand, but the majority of finishing rooms now use machines called "lay boys" for this purpose.

The smaller sizes of sheets are shipped flat. These are wrapped and tied, the nature of the wrapper varying with the size of the bundle. The bundles are, as far as possible, arranged at a weight of 100 pounds. The wrapper in such a case should be of three sheets of paper of 60-pound basis. This operation naturally varies with the nature of the paper and the degree of caution taken by the maker. Also there is a difference according to whether the paper is for domestic or export trade. Bundles for export trade are sometimes enclosed in heavy cases of wood or fibre board.

Frequently orders are taken calling for large size sheets which cannot conveniently be shipped flat. These are folded. The folding is done in two ways, depending on the customer's preference. One way is simply to fold the sheet, permitting the pressure of the bundle to crease it rather sharply. The other method of folding is the interlapping method in which the sheets are interlapped by the ream so as to prevent creasing when compressed by the weight of the bundle. Of the latter method there are again two subdivisions, the loose and the hard, depending on the customer's preference.

Efficient handling of cut paper is necessary in order to maintain production and orders should be so arranged that there will not be too much waste as a result of the trim.

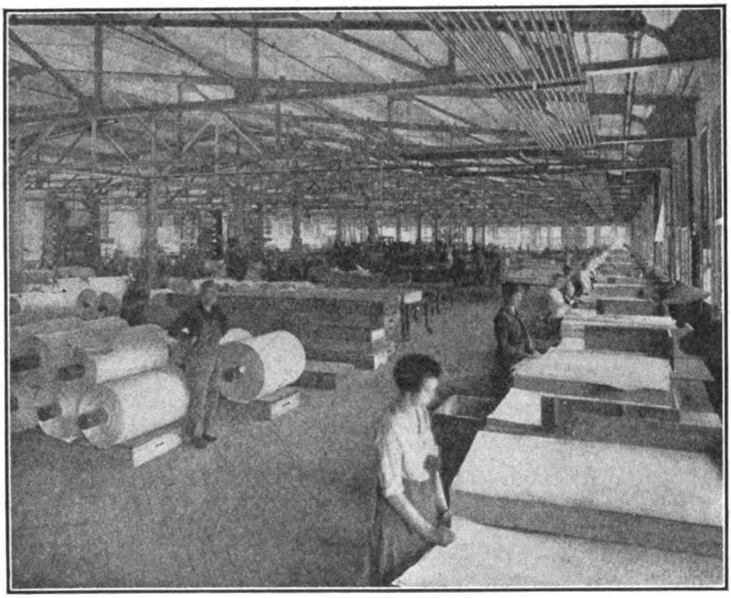


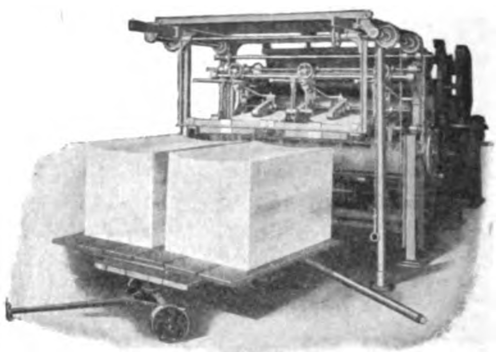
Fig. 146.—Typical finishing room equipped for sorting, counting and bundling fine paper by hand.

Sheet Cutters and Cutter Tables or Lay Boys: There are many various types of sheet cutters. It is necessary to select a make best suited to the needs of the particular kind of paper to be cut.

The function of sheet cutters is to cut paper from jumbo rolls into sheets of specified lengths and widths. Some of these cutters are equipped with two fly knives making it possible to cut two different lengths of sheet at one operation.

The widths of the sheets are determined by the slitters. The paper is first slit into desired widths before passing to the fly knives. Slitters are mounted on revolving shafts located on the cutter frame, but back of the revolving or fly knives, so that when the sheets pass through the slitters they are already cut to the desired widths. In cutting some grades of paper such as market paper, the cutters may be furnished with either 8 or 12 jumbo rolls and the paper is counted as it is cut. With 8 rolls 3 cuts make one quire; with 12 rolls 2 cuts one quire, a quire being 24 sheets.

In cutting fine papers it makes no difference as to the number of rolls cut at the same time, as this grade of paper cannot be counted as cut on account of the very careful sorting required; in the case of market papers, etc., the paper can usually be counted and sorted satisfactorily in one operation. The above applies only to the ordinary cutting table and cutter girls for laying, sorting, counting and jogging into reams or quires.



Courtesy: Moore & White Co., Philadelphia, Pa.

Fig. 147.—Lay-boy as used in connection with cutter in finishing room.

The lay boy is an automatic machine which is attached to the front side of the cutter, which receives the sheets as they are delivered from the fly knives and places them on the jogging table automatically. The capacity of these lay boys is far greater than the hand operation, especially on fine papers as the paper is heavy and lies flat without curling.

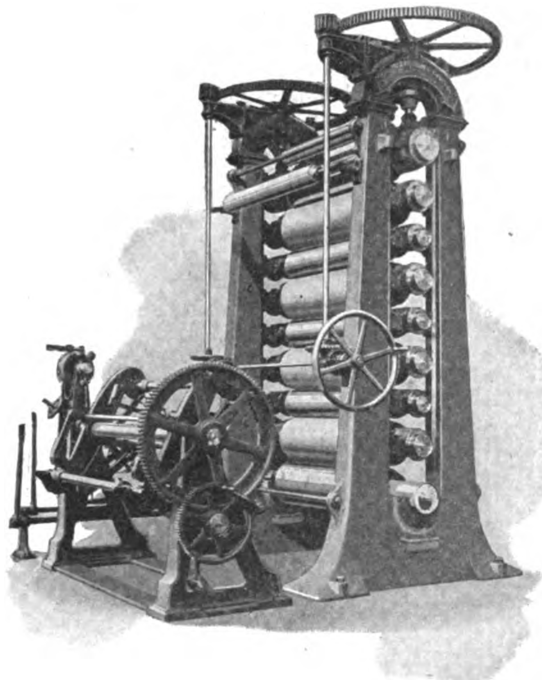
Super-Calendering.

Super-Calenders: The Super-Calenders are machines used for giving a smooth surface or glazing to papers requiring more finish than can be given on the calenders at the end of the paper machine.

A stack of these super-calenders usually contains either nine or eleven rolls. One roll is of chilled polished steel and the next roll of cotton or paper. These rolls are placed alternately in the stack beginning at the bottom with a steel roll—first steel and then cotton or paper. The reason that these stacks of calenders contain an odd number of rolls, such as 7, 9 or 11 rolls, is so that the paper may go over the top of the first roll and pass down through each nip of the calenders, and come through the last or bottom nip on the working side of the stack.

The cotton or paper rolls are made by pressing discs of the material onto an iron or steel core by dydraulic pressure and then they are turned, ground and polished on the surface.

These paper or cotton rolls thus prepared and finished make a beautiful surface when placed alternately in the stack. The steel rolls having a hard polished surface and the cotton or paper

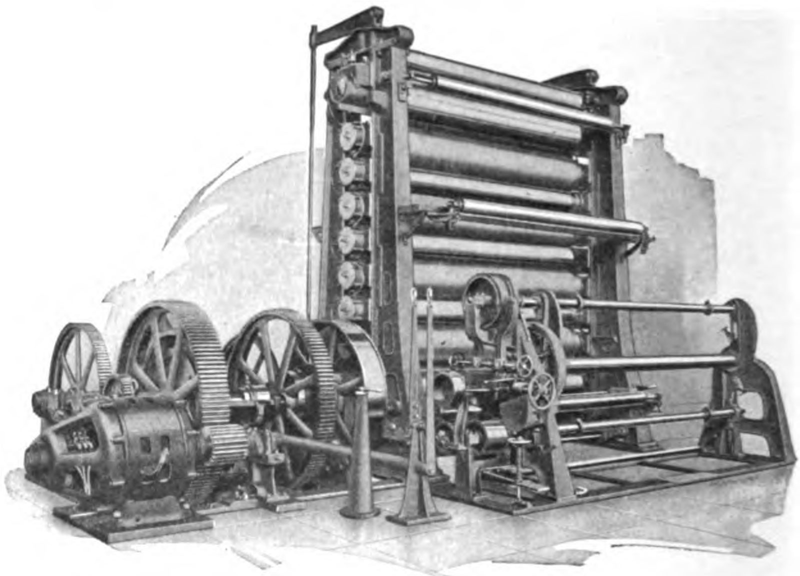


Courtesy: The Pusey and Jones Co., Wilmington, Del.

Fig. 148.—Super-calender.

rolls also being polished, but of a more yielding nature, have an effect on the surface of the sheet of paper resembling the ironing of a shirt bosom. To add to this ironing effect the stack of calenders must be run for a time without the sheet on them and until they became quite hot, due to friction. This finishing effect is also augmented by applying steam showers to the surface of the paper just as it enters the top of the stack in the first nip. In some cases, steam showers are applied to both sides of the sheet, but the most common procedure is to apply to one side at a time and turning the sheet over every time, it is run through the stack. This is done to insure an even finish on both sides of the paper and also to prevent the sheet from curling; all papers treated in this manner are called super-calendered. These super-calenders are run at a speed of approximately 1,000 feet per minute.

An immense variety of finishing room machinery has been developed, all of which it would be impossible to describe in such a work as this. However, all of these machines follow the main types we have described and vary only in the introduction of special devices intended to increase production, improve quality and facilitate and lighten the work of the operators.



Courtesy: Holyoke Machine Co., Holyoke, Mass.

Fig. 148a.—Motor driven super-calender stack.

Storage and Shipment.

The efficiency of a modern finishing room depends largely on the equipment installed for handling the rolls and bundles of paper. Of recent years much has been done in this connection by introducing traveling cranes and overhead conveying systems for bringing the jumbo rolls into the finishing room from the machine room and for storing the finished rolls and bundles. Tiering machines have also proved exceedingly useful. These are small trucks with an elevator device. The roll of paper is rolled onto the truck when the platform is at ground level, then the platform is elevated and the roll pushed off into its place in the warehouse or car. These devices will handle considerable weights, lift to any reasonable height and can be operated with facility by one man.

The less the paper is handled by manual labor the better, because while a roll of paper is not exactly fragile, it is comparatively easy to damage. If a corner of a roll of paper is damaged the roll must be unwrapped and stripped until the entire damaged portion is removed.

It is always preferable to store roll paper standing on end because this preserves the cylindrical shape of the roll. Also in the majority of cases it utilizes the storage space to the best advantage. Even a short period in storage or transportation lying on its side will subject a roll to enough pressure that it will not remain perfectly cylindrical. This gives rise to a great deal of trouble on modern printing presses as the paper unrolls in an irregular manner, and even the most imperceptible alterations in tension give much trouble on these delicate high speed machines.

Special trucks have been devised for handling paper, the nose of which is flat and thin, consisting of a single piece of steel. This is easily inserted under the edge of the roll, as it stands on end on the floor, and when the roll is tipped back it reclines in a cylindrical steel plate depression, in which position it cannot possibly be injured.

Care should be taken not to leave rolls standing where they will be in the way of trucks, etc. Much good paper is needlessly damaged by attempting to utilize passages in warehouse, etc., for storage.

Cars in which paper is to be shipped should be carefully examined for nails, bolts, etc. The floor of the car should be covered with strong paper before any rolls are loaded. It is a good plan to nail a strip of clean wood around the car about four feet from the floor. If the car is only partly loaded the rolls should be specially well braced with strong timbers and care should be taken that the ends of these timbers do not come in direct contact with any of the rolls. Although under present circumstances cars are frequently loaded double-deck it is better as a general rule only to have one tier. It is a good rule to assume that whatever the rated capacity of the car may be, if the entire floor is tightly packed with rolls of paper, it is carrying a sufficient load. However, at present, two tiers are frequently necessary, and that being the case, even more care should be exercised with the top tier than the bottom one, as it will be more affected by the motion of the train. Before closing the car heavy timbers should be placed across the doors.

XV. General Design of Pulp and Paper Plants.

It is not possible to give in a single chapter, or even a single book, such information as would enable a previously inexperienced person to undertake the complete design of a plant for making any kind of pulp or paper.

If that were possible, there would be small need for the services of engineers who have made the design of plants for this purpose a life study. The final efficiency (or inefficiency) of a big pulp and paper mill will depend on how a multitude of minor problems have been settled, and the highest qualities of engineering experience and good judgment alone suffice to meet these requirements.

Anyone contemplating investing money in a plant for manufacturing any kind of pulp or paper should retain the services of a competent engineer, preferably one known to have had previous experience in such matters, and then his decisions should be abided by.

However, there are a considerable number of items that anyone taking an active part in the manufacture of pulp and paper should know about, that do not exactly fit into any of the other chapters of this book, and so are being considered under the present heading.

Such are problems of location, water supply, railroad facilities, fire protection, illumination, ventilation, piping, power transmission, etc. Each of these subjects might well be the subject of a separate treatise. Excellent works have been written on many of them. Consequently, they will only be discussed briefly in the present connection, with special reference to the actual manufacture of pulp and paper.

Location.

Three chief factors influence the location of a pulp and paper plant: supply of raw material, power and disposal of finished product. If a plant could be located at a point favorable both to the obtaining of raw material and the market for the finished paper it would be ideal. This is now rarely possible. The modern tendency is to locate the plant where the raw material is. Immense pulp and paper mills are being operated in the most remote parts of Canada, far from any market for their products. In common with all other manufacturing processes, if anything has to be shipped a long distance, it is better to ship a comparatively small bulk of material which has been enhanced in value by manufacture than a larger bulk of material yet to be enhanced in value. The latter proposition involves paying freight on a lot of substance that is subsequently got rid of in manufacture.

Many paper mills, especially those making the finer grades of paper and specialties, are located far from any source of raw material. This is largely due to circumstances connected with power and labor. Years ago groups of mills grew up at certain points because at that time they were advantageously situated with regard to power and raw material. The communities that have grown up around these mills are largely populated with men familiar with the industry. It is easier to get the highest class of labor in such a location. Moreover, the power is still there and consequently the mills remain there.

Other factors that influence the location problem are nearness to supplies of equipment and chemicals, climate, water, taxation, personal preferences of important officials, sentimental considerations, etc.

The above remarks deal merely with the general location, i. e., why mills are numerous in some parts of the country and scarce in others. We will now consider the details regarding a suitable pulp or paper mill site.

If we consider first a development consisting of a sulphite mill, ground wood mill and paper mill, where the wood is received by rail, it is obvious that such an industry should preferably be situated on the banks of some large body of water. When we come to discuss water supply later in this chapter we will deal with the reasons for this, but assuming that several million gallons of water are required per day, the advantages of such a location are immediately apparent. Failing this, artesian wells must be sunk at great expense. Some of the paper mills in the Kalamazoo district have had to do this, owing to the gradually increasing inadequacy of the water supply, which was originally quite sufficient.

Now, the banks of rivers are very various in formation, and putting the plant near the river will sometimes increase the engineering work necessary to provide suitable foundations and room for buildings. It is ideal when a level location can be secured right beside a good sized river or lake. However, in many cases, on account of the desire to utilize water power, pulp and paper mills are located at points where the site has literally to be carved out of the banks of the river.

The most natural arrangement of the parts of such a plant is to have the sawmill, wood room, digester house, sulphite mill, beater room, machine room and finishing room follow right one after the other in the order named, material thus progressing through the plant in a straight line. Frequently, however, to secure economy of space and to surmount natural obstacles, some parts of the plant have to be in basements below others. The less of this that is done, the simpler will be the conveyor and elevator systems required, the less will be the power used up in elevating materials and the arrangement of the piping for steam. water, stock, etc., will be just that much easier. Provided the conditions (viz., coal storage, ash handling, etc., will permit) it is always preferable to place the boiler house centrally, or so that steam lines supplying paper mill and sulphite mill will be reduced to a minimum.

Room must be provided for storage of wood. This subject has already been discussed at some length in the chapter on the wood room. Due precaution should be exercised that the area chosen for wood storage is not liable to be flooded and is not a fire menace to the plant or to other adjoining properties.

Railroad Facilities.

In laying out the plant regard should be given to the location of sidings, which should be of adequate capacity. Also, if there are several railroads touching the point, the sidings should be arranged so as to have the most convenient connections with all of them. Sometimes the plant is located on a slope with one railroad on the high level back of the plant and another along the water-front. In such a case it is very convenient to arrange to receive raw materials over the road on the high level and to ship finished products out on the low level. Frequently it will pay the mill well to own a locomotive for switching purposes, thus being more or less independent of the service rendered by the railway company. Apart from steam locomotives, small gasoline locomotives are used for this purpose, which are specially useful as all fire risk is removed. Excellent electric locomotives are also obtainable, operating either from a trolley, a third rail or with storage batteries. Car-hauls, which are hoists arranged for pulling cars short distances around a plant, will be found very useful when a locomotive is not at the disposal of the plant. If a crane is at hand for loading or unloading coal or wood it can be used as a car shifter. In laying out sidings ordinary good judgment must be exercised so that cars which are being loaded or unloaded will not be in the way of other operations.

Piping.

For water supply and fire protection, cast-iron pipe is usually used. This variety of pipe lasts very well when buried in the ground, and is generally satisfactory when used in 12-foot lengths, with caulked joints of the bell and spigot type. Wrought iron or steel pipe can be, and often is, used for this service, but its use is not desirable as it cannot be depended on as can cast-iron pipe. Not only will it seldom last so long, but it may corrode and give out unexpectedly soon. This is a drawback inseparable from the nature of the material. Galvanizing has some preservative effect, but not much in actual practice. Wrought iron, however, is much superior to steel pipe.

Cast-iron pipe can also be used for many other purposes around the pulp and paper mill. This material can now be obtained in almost any diameter from 2 inches up, and in any length required. Flange joints can be had, as well as bell and spigot joints, and all kinds of fittings. Such small cast-iron pipe is excellent for handling bleach liquor.[1] Cast-iron pipe is also used for handling stock from the blow-pit to the screens in the sulphite mill, etc.

For ordinary connections for water and stock in the beater room and machine room where Kraft and ground wood (neutral or alkaline) stock predominates, wrought iron pipe is satisfactory. If sulphite predominates galvanized, flanged cast-iron pipe is preferable because most satisfactory in the long run, although first cost is higher. Wrought iron pipe has higher tensile strength than cast-iron pipe of the same size and is less liable to be damaged by strain, blows, etc.

In the acid plant, and for acid lines in the digester house, hard lead pipe or lead-lined iron pipe is used. Hard lead is lead which contains a small percentage of antimony. It resists almost all acids. Unless made with special skill, lead lined pipe will give trouble through the lead lining separating from the pipe. There is at least one line of lead-lined pipe on the market which has been developed to such a point that no trouble of this kind is experienced. All kinds of fittings and valves can also be secured in this material.

Bronze piping is used for some of the smaller connections where acid containing liquids are being handled. It has not the resistance to acid of the lead, but it is easier handled in small sizes and has greater mechanical strength.

All pipe lines carrying steam or hot liquids should be well insulated with magnesia or some other good insulating material. The manufacturers of these materials have compiled tables (which can be obtained from any of them) which will enable exactly the right thickness of insulation to be estimated.

Steam piping should be wrought iron or steel. Manufacturers of this material make three grades: "Standard," "Extra Heavy," and "Double Extra." For pressures up to 160 pounds all pipe over 14 inches should be ⅜-inch O. D. pipe. All other pipe should be standard full weight, except high-pressure feed and blowoff lines, which should be extra heavy. For pressures from 160 to 200 pounds, and with superheated steam, all high pressure feed and blow-off lines, high pressure steam lines with threaded flanges, etc., should be extra heavy. Pipe 14 inches and over should be ⅜-inch O. D. pipe. Full weight pipe should be used for all steam lines other than those mentioned above on

[1] See "How We Solved Bleach Pipe Problem," W. H. Scott. Paper Industry, Nov., 1919, pg. 623.

which pressures between 150 and 200 pounds are maintained. Flanges should be cast iron, threaded, except for superheated steam, when solid rolled steel flanges should be used. Welded flanges are used on many lines with satisfactory results.

Steam piping is best carried out by a reliable piping contractor, whose experience will tell him just what weight and variety of pipe, flange, fitting and methods of support to use in any given case. Moreover, such people have devised many special joints and fittings. However, the above brief notes may be considered good practice as far as they go.

In designing systems of steam piping, when the proper size and weight of pipe has been determined, the next item to consider is the removal of the water of condensation that is always present, but which can be much reduced by efficient heat insulation. The effect of water moving through a pipe at a high velocity is much the same as that of a solid body when it comes in contact with elbows, valves, etc. Even if there is no actual destruction of pipe or fittings from this hammer effect, there will be a constant hammering and abnormal vibration which will in time loosen the joints and cause leaks.

The system should be so arranged that there are no places where water will be pocketed and carried along by the steam in slugs. This is particularly important with lines leading to coils used for heating tanks, digesters, etc., and engines. The cold liquid surrounding the coil may condense the steam so perfectly as to cause the formation of a vacuum. The water will then be shot through the pipe at a very high velocity, causing tremendous hammering and vibration. This effect, on a smaller scale, is probably familiar to all of our readers who have steam heating systems in their homes.

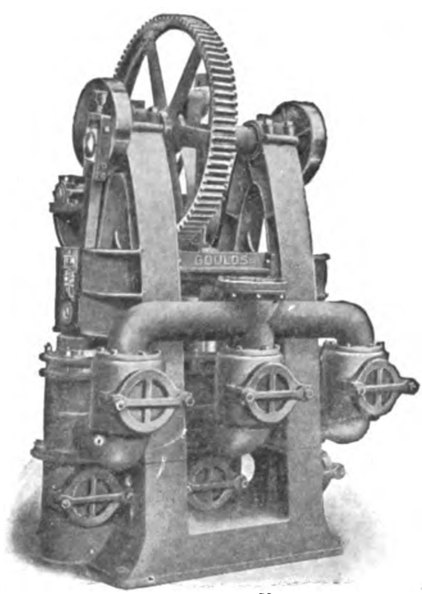
To avoid condensation, all pipe should pitch in the direction of the flow of the steam, and if this is impossible, a trap or drain should be installed. All main headers and manifolds should end in a drain pocket connected to the drainage system. Branch lines should be taken from the top of headers, when possible, never from the bottom. Separators should be placed in the line leading to each engine or evaporator or other steam consuming unit, as near the unit as possible, and all such separators should be connected to the drainage system. Care should be exercised that valves and other fittings do not form water pockets. Globe valves should always be set with the stem horizontal; gate valves may be set with the spindle vertical or at an angle. All meters, etc., should be provided with by-passes.

Piping should always be arranged so that there are no unusual strains due to expansion and contraction. In supporting the piping certain points may be fastened firm, or anchored, and the expansion and contraction between these fixed points taken care of with expansion joints, bends and sliding supports. Systems have been devised where all the supports are of the sliding variety. All supports should be from the building and not from equipment.

It is frequently a good plan to have a distinctive color of paint for all the different lines carrying water, steam, acid, stock, bleach, vacuum, etc. Thus any part of any line can be immediately distinguished wherever it is met with in the mill. The same system of colors can be adhered to in the drafting room. No piece of steam heated equipment should ever be set up without some provision for taking care of excess pressure, such as a good safety valve.

Pumps.

A complete description of all the various types of pumps used in pulp and paper plants would require a book in itself. Moreover, excellent works now exist on the theory and practice of



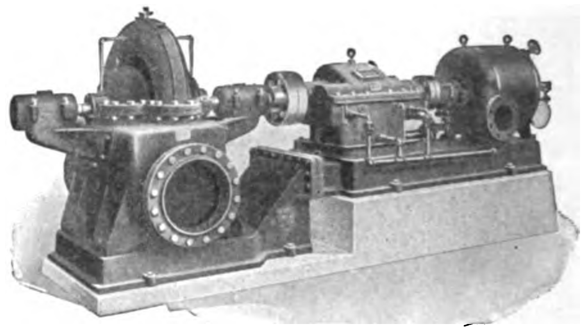
Courtesy: Goulds Mfg. Co., Seneca Falls, N. Y.

Fig. 149.—Typical triplex plunger stuff pump.

both plunger and centrifugal pumping equipment, as well as on the general subject of hydraulics and hydrodynamics.[1] Consequently, we will only touch on the matter very briefly here. The pumping equipment required in the boiler house is dealt with in the special chapter on that subject.

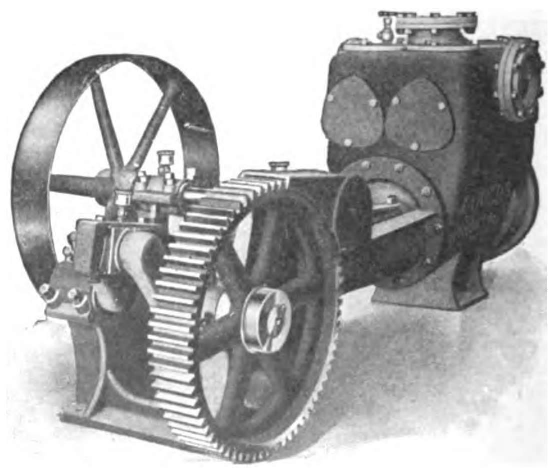
[1] Among other works we might suggest: W. M. Barr—"Pumping Machinery." Edward Butler—"Modern Pumping and Hydraulic Machinery." R. L. Daugherty—"Centrifugal Pumps." C. G. DeLaval—"Centrifugal Pumping Machinery." A. M. Greene—"Pumping Machinery." E. W. Sargeant—"Centrifugal Pumps." G. E. Russell—"Textbook on Hydraulics." All obtainable from the publishers of this book.

Pumps are to the paper mill what the heart is to the human system. Hence it is very poor policy to install a cheap pump. In fact, there is hardly any place in the design of a mill where it is more necessary to be liberal and to play safe. The failure of some comparatively insignificant pump may close down a whole system for hours, or even days.



Courtesy: Goulds Mfg. Co., Seneca Falls, N. Y.

Fig. 150.—Typical centrifugal pump direct connected to geared steam turbine.



Courtesy: Goulds Mfg. Co., Seneca Falls, N. Y.

Fig. 151.—Horizontal vacuum pump suitable for use with paper machines.

Also, it is well to remember that a pump may be a very fine piece of machinery and still be totally unsuited for pulp and paper mill work. Some of the pump manufacturers have sales engineers who have given special attention to the problems of paper mill work. In any case the buyer should examine all claims advanced by the pump manufacturer, who (while meaning well) may perhaps not fully understand the nature of the service that will be expected from the pump. It is well to stick to makers who have made somewhat of a specialty of pulp and paper mill work, even if others offer slightly more attractive prices or deliveries.

Some of the points to look out for in a pump are: Strength, simplicity, nature of material (*i.e.*, if it will resist the chemical action of the fluid to be pumped), mechanical efficiency (*i.e.*, economy of power), durability and ease with which repairs can be made.

Belting.

Belting is the most ordinary means of transmitting power in pulp and paper mills. In order to be of maximum efficiency the belting will need to fill definite requirements of pliability, strength, durability, freedom of stretch and a surface that will reduce slipping to a minimum.

Belting is made from a number of materials such as leather, rubber (or more correctly, canvas impregnated with rubber), canvas, camel hair, etc. The selection of the right variety of belting for a given set of conditions is a matter of much importance. Leather belting is more durable than any other, and is the most generally useful, but there are some places where it cannot be used. Tests recently carried out by E. D. Wilson[1] at the Mellon Institute, Pittsburgh, support the following conclusions: (1) Leather belting possesses a greater power transmitting capacity than any other belting material. (2) This advantage persists at all speeds up to 5,000 feet per minute. (3) The relative capacities of the various belts remain the same no matter what kind of pulley is used. (4) Leather belting possesses a higher overload capacity than other belting. (5) Leather belting is the only type of belting that improves with age, all other kinds being best when new. (6) Leather belting does not need to be as wide as other belting to produce the same effect. These conclusions are based on tests of the most exacting and scientific nature, and may be accepted as correct.

Rubber belting is chiefly used in very wet or steamy places. Around screens, and any place else where frequent "washing up" has to be done, rubber belting is generally desirable. Rubber belting is quickly destroyed by oil or grease. Paper mills ordinarily being considered wet, sloppy places, rubber belt is very generally used for all purposes, but in many instances it would be better to use leather belting and remove the cause of the wetness or slop. In general it is always better to remove destructive conditions, if possible, than to allow them to persist and get a belt that will stand them. For instance, if a rubber belt seems desirable and cannot be used on account of oil

[1] Paper Industry, Sept., 1919, pg. 443.

dripping on it, it is the most logical thing to protect the belt against the oil, not to seek for a belt that will stand up against oil. Many times when the wrong kind of belting is in use it is because when the belt had to be replaced none of the right kind was on hand, but the wrong kind was. Errors of this kind when once made are often persisted in. It is good economy to have a good stock of all kinds of belting used in the mill.

Camel hair belting is excellent where a belt is required that will resist acid and alkali. It does this better than any other kind of belting. It also resists high temperatures that would destroy leather, canvas or rubber belting.

The following practical hints regarding the use of belting may be found useful:

1st. It is better to select a wide thin belt and a pulley with a wide face, rather than a narrow thick belt of the same strength. The belt can then be run looser without slipping as it has more contact surface. For example—A 12 in. 4-ply belt of the same strength as a 6 in. 2-ply would be much better to use, since it has twice as much surface of contact with a pulley and does not have to be run so tight to prevent it from slipping. A thin 4-ply belt is also much less liable to buckle when going around a small pulley whereas a thick 8-ply is stretched on the outside and buckled on the inside, thereby considerably shortening its life.

2nd. It is better to have a belt run loose than tight. If a belt has to be drawn "fiddle string" to make it transmit power properly without slipping or if a sticky dressing has to be applied to prevent it from slipping when run only moderately tight it is a positive indication that the belt is too narrow and a wider one substituted even if broader faced pulleys have to be put on. In certain cases where it is necessary to shift a belt as elevators and cone pulleys, the edges of the belt are subjected to much wear. In such cases a thick, hard belt will last longer than a broad thin one. Sometimes a very firm, hard, stiff belt is better to use than a soft, pliable one; judgment in such cases is necessary to decide what to use.

With belting of the proper size and pulleys of the proper width of face to transmit the power required of them the belt ought to run moderately slack without slipping. The use of "dressing" should be resorted to only as a temporary remedy for a slipping belt and should not be indulged in as a general practice.

Rosin should never be put on a belt to prevent slipping as it is very injurious and its action is only temporary. For this reason a small supply of dressing should always be kept on hand to use in case of emergency to prevent the necessity of having the rosin. The surface of belts and faces of pulleys should be kept clean and smooth. All accumulations or lumps on pulleys should be removed and the surface of belts be kept smooth not by "scraping" unless absolutely necessary but by wiping or washing.

A running belt can be very nicely wiped by holding on it a rag wet with gasolene.

A leather belt running under the proper conditions seldom requires any treatment. If it is running in a very dry place and seems inclined to get hard, an occasional application of castor oil both inside and outside will keep it soft and pliable. Wool fat or degras is also excellent for this purpose, but such treatment should not be repeated too frequently so as to make the leather too soft and greasy as it then becomes "stretchy" and loses to some extent its firmness and strength. All that should be done is to use an occasional dose of castor oil or wool fat just sufficient to keep the leather from getting harder than it was when new and to keep the surface "velvety" when it appears to be getting a trifle too hard and glassy.

Rubber belting is more sensitive to the use of dressing than leather and it requires considerable care and attention to keep a rubber belt in good condition.

The natural rubber with which a rubber belt is covered is the best contact surface that can be had so long as it is kept in good condition. When the white powder with which a new rubber belt is coated is rubbed off, exposing the soft velvety surface of the rubber, this presents almost an ideal contact surface of a pulley. All that is necessary, therefore, is to keep this rubber surface in its natural condition for as long a time as possible.

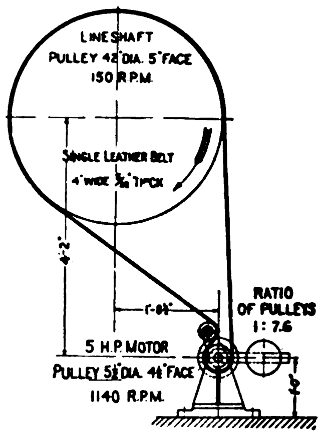
When the inside surface of a rubber belt appears to be somewhat too hard or glassy it is best to clean it with a rag and gasolene, then apply a very small amount of linseed oil. The best way is to moisten a rag with the oil. By passing the rag lightly across the belt while it is running, only a film of oil gets onto the belt.

The rag should not be soaked to such an extent that too much would get on the belt at one time. The object is only to get a trace of oil on the surface of the belt, so as to take off the "glassy" surface and have the rubber surface velvety or in its natural condition. If too much is applied the belt will slip until the oil soaks into the pores, and by soaking in too much oil the life of the rubber coating is injured and it becomes more or less rotten. The object is, therefore, to take off only the "glase" and form only a film of soft rubber in its place.

It should not penetrate the rubber and soften it as castor oil or wool fat does to a leather belt.

Stretched cotton belts stuffed with grease require only tó be kept clean and free from accumulations of dirt the same as any belt, and to be kept in a soft greasy condition, by the application of oil. As before stated, they are the best variety of belt to use in places where oil gets on them. This would soon ruin a leather or rubber belt, but is beneficial to this kind of a belt.

The ideal belt drive is horizontal. However, such a drive is exceptional, and the best has to be made of other conditions. In driving beaters and other such equipment it is advisable to have the belt wrap around the driven pulley as far as possible. With a horizontal drive, this is partially accomplished by allowing the upper strand of the belt to run slack. This arrangement is not desirable in driving beaters, as space and economy of belting do not permit of such drives. The same effect can be secured, and improved on, by an idler pulley, as shown in the illustration. The best known of these devices is the "Lenix"



From: "The Paper Industry," Chicago, Ill.

Fig. 152.—Diagram showing belt drive for beater or other similar equipment, illustrating use of idler pulley.

which was invented by a French artillery officer and is now used in connection with all kinds of machinery. An article describing this device in great detail will be found in "Paper Industry" for January, 1920, pg. 853, by V. Sahmel.

In driving beaters the Lenix device is frequently used in the following manner: The lineshaft is arranged vertically below the shaft of the beater pulleys. The Lenix device is operated by means of a hoisting rig from the beater floor in such a way that when it is desired to stop the beater the resilient idler pulley, or Lenix, is thrown back. When it is desired to start up the beater, the Lenix is thrown forward so as to engage the full width of the belt with the driving pulley. This accomplishes the same effect as the ordinary tight and loose pulley arrangement, but is much better for the belt. With the tight and loose pulley arrangement the full starting load is carried by one edge of the belt and the other edge tends to become bruised by the belt shifting fork.

Unless a great deal of money is to be wasted belting must be figured very carefully. Speeds of driving and driven pulleys should be taken with a speed counter and over a long period of time. The old formulas, such as the one that "the horsepower to be transmitted, multiplied by 800 and divided by speed of the belt in feet per minute would give the width of the belt in inches," are not to be trusted in these days of high priced belting. They are all figured so as to give a generous factor of safety and will frequently result in much wider belts being selected than there is any need for.

Rope Drives.

Rope drive is quite extensively used in pulp and paper mills, especially for machine drive. For general purposes this method of drive is much commoner in England than in America. However, recently several large paper machines have been equipped with rope drive in this country and it is also used for driving beaters, electric generators, etc.

There are two systems of rope drive, the Continuous and the Multiple. The continuous system has been most used in America and the multiple in England and on the continent of Europe. In the continuous system a single rope is passed as many times around both driving and driven pulleys as there are grooves to be filled, and is then carried across the whole width by means of tension pulleys. This system is very useful where drives have to be carried around corners or angles. In the multiple system there are as many rope belts as there are grooves on the pulley. This system has the advantage that if one strand breaks the rest will carry on the work until a suitable opportunity arrives to remedy the defect.

Users of rope drive claim that it is much more efficient than belt drive. Belts depend entirely on friction for their grip on the pulley. Moreover, a film of air is always caught between the belt and the pulley, which tends to cause slipping. The rope runs in a groove so cut that the rope takes a firm hold on the groove, but does not fill it entirely, the air passing freely out through the open space under the rope. Finally, the best cotton rope is cheaper than an equivalent amount of leather belting. Cotton rope is preferable for rope drives, although manila has been used.

In driving paper machines by rope drive a large grooved fly wheel is placed in the basement under the dryer part of the machine. From this wheel ropes lead up and down the basement, conveying power to short counter-shafts situated in the basement under the several roll shafts of the paper machine. Upon these counter-shafts below and roll shafts above are the cones, between which power is transmitted by a loose belt with a tightener pulley. The advantages claimed for this method of drive are the doing away with bevel gearing and the long main line shaft, avoiding the loss of power usually occasioned by the numerous bearings of this shaft.

Ventilation.

When we consider that paper leaves the paper machine containing approximately 5 per cent moisture, whereas the stock from which the paper is made is nearly 100 per cent water, and when we recollect further that 55 or 60 per cent of the water is removed as vapor in the dryer part of the machine, we are in a position to attribute some importance to ventilation in the paper mill.

Moreover, at the wet end of the machine there is a certain amount of moisture from the stock flowing over the wire, the various showers, etc. Also, the air of the beater room and other parts of the mill is moist. If a pond is used in the wood room it gives off vapor, especially in winter when the temperature of the water is raised to remove ice from the wood. Finally, in the digester house there are sulphur fumes and moisture, and in the bleaching room there is chlorine.

There are two main effects to be considered in discussing the ventilation (or lack of it) of a paper mill. One is the effect on the product and the other the effect on the workmen.

Moisture, if not carried off, will condense on roofs, girders, piping, etc., and drip back on the paper or into the stock. This can be avoided entirely by a proper system of fans and heaters for blowing hot air along the upper part of the machine room. The amount of moisture that air will hold increases with the temperature and a comparatively slight increase in temperature will prevent all condensation.

In one of the best systems for accomplishing this fresh air from outside is drawn into a compartment filled with steam coils which raise the temperature of the air to about 71° F. By means of a blower and a system of flues this air is distributed all along the roof of the machine room. The slope of the roof, the design of the hood placed over the dryers and many other factors (for instance, if one end of the machine room is more exposed to cold winds than the other) affect this problem, and a careful study should be made of conditions and the combined heating and ventilating system designed to meet them. This is far from an unimportant matter since several tons of moisture are given off daily in a mill of any size.

Many well-meant attempts at ventilation are almost useless, because the details of the design have not had the attention of anyone competent to deal with such problems. Frequently the fans for removing moist air will be of much greater capacity than the system for supplying fresh, warm, dry air. This will result in cold air being drawn into the building in winter through window frames, doors, cracks, etc. In other cases an unnecessarily large volume of warm, dry air is furnished in the effort to do the thing thoroughly which is simply wasting electricity and steam to no good purpose. Hoods over dryers are sometimes not properly placed so that every unusual draft through the room causes steam to be carried out into the room. Mills roofs are frequently designed so that moisture pockets form which are full of stagnant, humid air, not reached at all by the currents created by the fans. This is an argument against very steep roofs. If a steep roof is necessary on account of the snowfall, a ceiling or false roof should be provided, nearly flat, so as to prevent pockets of moist air. However, it is better to avoid such ceilings, as the space between is hard to ventilate and usually affords an opportunity for rot and decay to attack the whole roof.

The lack of a good ventilating system in the machine room will result in much paper being damaged and the loss from this source in a year or so would pay for suitable ventilating equipment.

Some mills use steam pipes arranged in rows along the roof but this system is inferior to blowing hot air into the building since the moisture tends to collect and condense on the walls and elsewhere and it will gradually rot the window frames and other wood work and corrode the machinery.

A good ventilating system is a great help in keeping the product uniform, regardless of what the weather conditions may be. There are firms designing what is known as "air conditioning equipment," which is simply scientifically designed ventilating equipment, which will guarantee exactly the same conditions of humidity and temperature the year round regardless of what the external weather conditions may be.

Modern mills frequently deliver heated air between the drying cylinders of the machine to carry off moisture as it is evaporated. The volume of this air must necessarily be very large—from 25,000 to 100,000 cubic feet of air per minute. The air must be hot enough to carry off the moisture at maximum efficiency, but not hot enough to reduce the strength of the paper being made. About 140° to 150° F. is right. The air is usually distributed through 6-inch pipes placed between the dryers, one pipe for each roll. The pipes are slotted to discharge the air, the slots running the length of the pipe and being about 6 inches long by ¼ to ½ inch wide.

The above remarks are all related to the influence of ventilation on the product. There is also the effect on the help to consider. Workmen today are not satisfied to work in a humid, steamy, uncomfortable and unhealthy atmosphere because they know that such conditions are preventable and unnecessary. Moreover, even if they will remain on the job in such a mill, they cannot do as good work as if the working conditions were more agreeable.

Adequate provision for ventilation is especially necessary, for obvious reasons, in rooms where waste paper and rags are being sorted, dusted, cut and otherwise prepared for use. In old-fashioned establishments this work was frequently carried out in dark, unventilated, evil smelling holes, unfit for any person to work in. The rag sorting rooms of the modern paper mills using rags are clean and sanitary enough to eat a meal in. Not only has this change made the work much better from a sanitary and humane point of view, but it results in increased efficiency on the part of the workers.

Portions of the mill where bleach is being handled should be provided with good ventilating systems and the fans and air passages should be protected against the action of chlorine vapors, which rapidly corrode metal work. There are a number of paints and lacquers which are more or less resistant to chlorine, but for fans the most satisfactory material is rubber covered iron. The metal work of the fan is covered with a rubber coating by the same process whereby rolls are given their rubber coverings. Lead coating or galvanizing will not stand up against chlorine and its compounds. Some form of gas mask or respirator ought to be at hand for use in case of a break down of the ventilating system and for making repairs. In fact, such equipment will come in useful in many parts of the paper mill—in the digester house, blow pits, acid plants, around sulphur burners, in case of fire in any part of the mill, etc. Gas masks of high efficiency originally designed for military purposes are now offered for sale by several firms. These are much better than ordinary respirators which withhold dust and similar material but not chemical vapors or smoke.

Another place where proper ventilation is very needful is in the grinder room of ground wood mills. It is almost as necessary to have hoods over the grinders, or some other adequate means of ventilation, as in a machine room, and grinder room roofs will frequently be found in a very bad state of repair through ignoring this fact.

The following hints on the design of a ventilating system are offered by R. J. Blair[1] of the Forest Products Laboratories of Canada, McGill University, Montreal.

In the design of a ventilating system the first thing to receive attention is the amount of moisture which will leave the dryers. For a machine room this figure may be determined by finding the difference between the moisture of the sheet as it goes onto and leaves the dryers along with the output of the mill for any stated interval. It is also necessary to know the amount of moisture in the air as taken into the mill. Knowing the temperature of the air as it enters and leaves the room, one

[1] The Paper Industry, February, 1920, pg. 1005.

can find with the help of Psychrometric Tables what amount of moisture may possibly be carried by any volume of air. A safe margin should be held so that one does not figure upon the air leaving the mill saturated with moisture. An idea of the amounts of moisture which may be held by air at various temperatures and various degrees of saturation is given in the following table, where the data given has been selected or estimated from the complete tables contained in "Psychrometric Tables" by C. F. Marvin, of the Weather Bureau, U. S. Department of Agriculture, Government Printing Office, Washington, 1915.

AMOUNTS OF MOISTURE HELD BY AIR AT DIFFERENT RELATIVE HUMIDITIES

Grains of water in suspension per cubic feet of air.

Temperature F.°	PERCENTAGE OF SATURATION 10%	40%	70%	95%	100%
—20	0.017	0.066	0.116	0.157	0.166
—20	0.028	0.114	0.200	0.270	0.285
0	0.048	0.192	0.337	0.457	0.481
10	0.078	0.310	0.543	0.736	0.776
20	0.124	0.494	0.864	1.173	1.235
30	0.194	0.774	1.354	1.836	1.935
40	0.285	1.140	1.994	2.703	2.849
50	0.408	1.630	2.853	3.870	4.076
60	0.574	2.298	4.022	5.459	5.745
70	0.798	3.192	5.586	7.578	7.980
80	1.093	4.374	7.654	10.378	10.934
90	1.479	5.916	10.353	14.045	14.790
100	1.977	7.906	13.836	18.765	19.766
110	2.611	10.445	18.278	24.806	26.112

As soon as one has determined how much moisture will be carried by any definite amount of moving air, and knowing the amount of moisture in it at the start, he can find what volume of air should pass through the system at any given time. The simplest way of finding if the ventilating system is sufficient may be noted by the presence or absence of condensation in any part of the mill after the system has been running for some time with all doors and windows closed. The presence of any condensation would show one of two things: either that more air should be moving through the ventilating pipes, or else that the air should be heated to a higher temperature. Any of these systems should be built so that the capacity may easily be changed to correspond with varying degrees of weather so that much more dry, warm air may be sent into the mill on a very cold or a very moist day than on a day when the weather is moderate.

A system designed in this way should be satisfactoryg as regards condensation on the ceiling of the room, but it would not be sufficient to prevent condensation in concealed places between roof planks and the roofing paper. In all probability it would not be economical to attempt such a result with ventilation alone, but by following a scheme of roof construction especially designed to take care of these difficulties, the dangerous condition may be avoided. Such construction consists in some proper use of insulating material in connection with the roof.

Problem. How much air should be used to ventilate a machine room in a paper mill where seventy-two tons of water are evaporated by the dryers in twenty-four hours? The weather is —20°, the relative humidity is 75%, and the air used in ventilation leaves the mill at 110°.

Solution. Moisture sent into the room by the dryers: 72 tons per 24 hrs. = 3 tons per hr.; *i. e.*, 100 lbs. per minute = 700,000 grains per minute.

The fresh air at 70% relative humidity and at —20° taken in for heating and ventilating the mill contains 0.116 grains of water per cubic foot (see tables); suppose this air leaves the mill at a relative humidity of 95% when heated to 110°. It is then carrying 24.806 grains of water per cubic foot. In passing through the mill it has taken up 24.806 — 0.116 = 24.690 grains of moisture per cubic foot. Then it will require $\frac{700{,}000}{24.69} = 28{,}351$ cubic feet of air per minute to ventilate this machine room.

The question of the distribution of steam to the heating and ventilation system is further dealt with in the chapter on the power plant.

Lighting.

Of recent years mill lighting has advanced to such an extent that there now is a new class of technical men known as illuminating engineers. The need for good light in a paper mill is almost too obvious to mention, but the most economical method of securing good lighting is far from simple. Moreover, frequently the wish to provide good lighting is not coupled with the knowledge of how to do it and illuminating units are placed in unsuitable places where they are detrimental rather than useful. *Powerful illumination is not necessarily good illumination.* Good lighting implies exactly the right amount of light of the right quality at the right place.

H. T. Spaulding, in a paper read before the American Pulp and Paper Mill Superintendents' Association, July, 1919, Green Bay, Wis., gives the following list of effects of good lighting:

"1. Reduction of accidents.
2. Greater accuracy in workmanship.
3. Decreased spoilage of product.
4. Increased production for the same labor cost.
5. Less eye strain.
6. Better working and living conditions.

7. Greater contentment of workmen.
8. Better order, cleanliness and neatness in the plant.
9. Easier supervision of the men.

"In this list it will be noted that items 5, 6, 7, 8 and 9 have a bearing on accident prevention. R. E. Simpson of the Travelers Insurance Company in a paper presented before the Illuminating Engineers' Society, October, 1918, states: 'A survey of 91,000 accidents from the records of the Travelers Insurance Company for the year 1910 showed that 23.8 per cent were due to improper or inadequate illumination.' The same authority explains that it is hardly possible that this percentage prevails at the present time, due to progress in illumination, but he goes on to say: 'There is some foundation, however, for assuming that 18 per cent of our industrial accidents are due to defects in the lighting installation.'"

As a result of the investigation of lighting by insurance companies, engineers and others, several states have adopted lighting regulations and the state of Wisconsin maintains an Industrial Lighting Commission to see that factory lighting in that state is in conformity with modern ideas.

The insurance companies, the manufacturers of lighting equipment and various government agencies will all be found willing to help those who wish to have the best lighting at the lowest cost.

There are many points that seem of minor importance at first sight, which, if remedied, will do much to improve the lighting system. Lights are frequently hung too high or too low to properly illuminate the work without glare. In many cases some system of indirect, or semi-indirect lighting will avoid shadows, which are especially annoying around complicated machines. In some cases the glare from a brightly polished portion of a piece of machinery is a constant source of annoyance. This can often be remedied by painting the portion offending, or if this is not possible, by changing the position of the light. Steady reflection of light from a moderately polished surface, such as the surface of a sheet of highly finished paper, is very exhausting to the eyes in time. This can be improved by having a more diffiused source of light. Where color is of importance lamps should be chosen which modify the natural quality of the electric light so as to make it more nearly resemble daylight. These lamps are readily obtainable today and not only permit of close matching of colors, but also are more restful and agreeable to the eyes.

Where matching of colors has to be carried out with great exactness, special color matching outfits can be obtained which exactly simulate daylight. Around paper machines and other equipment, portable lights, protected with wire screens, should be available for making adjustments and repairs in parts of the equipment not reached by the ordinary illumination.

In addition to satisfactory artificial light, every effort should be exerted to admit as much sunlight as possible. A maximum amount of steel sash and glass in the walls with overhead skylights of large extent is typical of modern factory construction and makes for increased efficiency.

The liberal use of a good white paint especially made for factory use so as to stand moisture, chemical fumes, etc., will do wonders in increasing the effectiveness of either day light or artificial illumination.

Water Supply.

In consequence of the very large volumes of water required in pulp and paper manufacture an adequate supply of water of a suitable degree of purity is a matter of prime importance.

The quantity of water used will vary greatly with the kind of paper being made. In a mill making fine papers from rags, where the stock is washed for a long time with a great deal of water, volumes of water will be required that are enormous in comparison with the output of the mill. In mills making news-print, wrappings, etc., the washing is not so elaborate, but the greater volume of material handled makes the volume of water very large. According to Griffin and Little[1] the volume of water used in making a ton of paper is probably never less than 50,000 gallons and is sometimes as much as 200,000 gallons.

One mill making 80 tons of bag and wrapping paper per day, with which is considered a sulphite mill making 125 tons of unbleached sulphite pulp, uses approximately 15,000,000 gallons of water per day for all purposes.

The writer knows of one mill making no pulp, but only paper from rags, purchased pulp and other materials, where the water consumption is approximately 4,500,000 gallons per day. As the mill only turns out about 25 tons finished product per day this is a large consumption of water, accounted for by much washing of rags, bleached stocks, etc.

If there is any impurity in the water it will get into the paper since the fibres in the forming web of paper on the wire form a regular filter that will catch and retain any sediment or coloring matter.

There are two kinds of coloration in water. Coloration due to sediment, which can usually be removed by settling or by coagulation with alum or sulphate of iron in settling tanks or ponds, and dissolved color, usually resulting from decaying vegetable matter, such as peat bogs, which is very hard to get rid of.

Hard water is water containing mineral salts in solution which are chiefly lime salts, of these the carbonate being the most common. Rain water is perfectly soft, but as it falls through the atmosphere it dissolves carbon dioxide and this

[1] The Chemistry of Paper Making, pg. 330.

enables it to dissolve lime and other minerals out of the soil and rocks over which, or through which, it runs. Thus, almost all water taken from streams, lakes, wells, etc., requires to be softened before using.

In pulp and paper mills objection is made to hard water on two general grounds. First, it should not be used in the boilers. Second, it is unsuitable for use in the actual manufacture of pulp and paper.

Considering the second point first, if hard water is used in the beaters, an excessive amount of alum will have to be added, in order to get rid of the hardness, because no size will be precipitated by the alum until all hardness is removed from the water. Not only does this use up alum, but it also imparts an element of uncertainty to the whole sizing operation, since the hardness of the natural water will vary from day to day and the beaterman will never know exactly how much alum should be added. Frequently beatermen will attribute this trouble to variations in the chemical strength of the alum, but usually the water is actually at fault.

Hard water is undesirable for washing any kind of pulp, either after manufacture, or after bleaching. In fact, it is much better if the mill has a uniform supply of soft water so that no hard water need be used at all at any stage of the process. Since a water softening system ought to be installed anyhow for the use of the boiler house, it is a comparatively easy matter to make it at the same time of sufficient capacity to serve the whole mill.

Treatment of Boiler Feed Water: It is not possible within the scope of this work to enter into detail on the treatment of boiler feed water, a subject which would require a complete treatise in itself. It is necessary, however, to touch on the great importance of this matter as a problem in practical pulp and paper mill operation. Preparation of water for boiler feed purposes falls naturally into two main classifications. One is the removal of sediment and mechanically suspended material of all kinds. The other is the softening of the water, or the removal of dissolved salts of lime, magnesium, etc., which tend to incrust or corrode the boilers.

Hardness in boiler feed water is the direct cause of scale, leaky flues, muddy burning and many of the other troubles incident to large scale steam production. It shortens the life and reduces the efficiency of the boiler; increases the repair expense and frequently causes inopportune and costly delays and shutdowns. Most harmful of all, the scale, acting as a thick and effective insulation of the flues, causes an enormous increase in the consumption of fuel. The fuel wastage due to the use of hard water may be anywhere from 10 per cent to 30 per cent.

The cost of boiler cleaning, boiler repairs, boiler compounds, etc., all due to the use of hard water is also a big item in the operation of a large plant. Boiler compounds should be viewed with suspicion. They are only temporary make-shifts at best. A steam boiler is not designed as a vessel in which to carry out chemical reactions, and the constant adding of materials to the water in the boiler cannot help but corrode and weaken the boiler itself. The aim should be to supply as nearly as possible pure water to the boiler, the purification having been effected in a purification and softening plant outside the boiler system.

If the reader will turn to the advertising pages of any technical periodical, especially those dealing with power plant engineering, or with the pulp and paper industry, he will note the advertisements of numerous companies offering systems for purifying and softening water. The fact that all of these concerns have systems installed at one plant or another, the owners of which find satisfactory for their purpose, seems to indicate that there must be more than one method of purifying and softening water that is satisfactory. It is not within the scope of this book to describe all these systems, but all concerns exploiting such equipment are ready at all times to supply excellent literature covering not only their particular system, but water purification and softening in general. Which system to install must be decided largely on a basis of cost and prestige of the manufacturer, unless the reader is enough of a chemist and water purification engineer to decide on the relative merits of the different systems from the data supplied by the manufacturers.

However, these systems mostly fall into three classes. These are (1) The Lime Process (2) The Soda Process (3) The Lime and Soda Process.

Lime Process: The carbonates of lime and magnesia, to which the hardness of the water is due, are precipitated with slaked lime in solution (lime water) in some suitable form of apparatus, either with or without heat.

Soda Process: Soda ash (sodium carbonate) and caustic soda (sodium hydroxide) are added either alone or together to the water to be softened. Caustic soda is more efficient in this process than soda ash. This treatment is used with water containing *sulphates* of lime and magnesia. Barium hydrate is sometimes used instead of caustic soda or soda ash, or in certain proportions with them.

Lime and Soda Process: When both sulphates and carbonates of lime and magnesia are contained in the water to be softened, this process is used. The soda is added first, enough being used to consume all the sulphates present, and then lime added.

Simple boiling will soften water if it is merely afflicted with "temporary hardness," i. e., contains *carbonates* of lime and magnesia. If the water possesses "permanent hardness," i. e., contains *sulphates* of lime and magnesia, mere boiling is of no avail.

Zeolite Process: There is one other excellent method of softening water—the zeolite system, which is the property of the Permutit Company. This system avails itself of the properties of an interesting material known as a zeolite, which automatically removes calcium salts from the water, yielding perfectly soft water from any ordinary source. In time the zeolite becomes exhausted, but can easily be renewed by a simple treatment. This system is in successful use in many industrial plants. It is a rather expensive system for use simply on boiler-feed water, but is ideal where *perfectly* soft water is needed as in textile manufacturing and certain branches of paper manufacture.

There are some other troubles with water, which are important from the power plant point of view, besides hardness.

Acidity: This may be due to industrial waste dumped into streams by chemical plants, tanneries, textile plants, smelters, other pulp mills, etc. In sulphite mills there is always a possibility, if check valves do not work properly, or in the event of indirect heating equipment for digesters becoming leaky, of acid getting into boiler feed water. This causes acid corrosion which creates more havoc even than scale. If there is any possibility of acid getting into the boiler feed water, very frequent tests should be made with litmus, or an electric device may be rigged up which will ring a gong as soon as there is enough acid content in the boiler feed water for a current of fixed intensity to pass through the water, the conductivity of which is increased by the acid. Such devices are much used in Sweden and Finland where indirect cook is much used in the digester house.

Foam: Microscopic organisms, sewage, industrial wastes, etc., are the chief substances present in water which cause this trouble. Filtration, sometimes preceeded by the addition of a coagulating agent such as alum or sulphate of iron, is the usual cure for this evil.

Priming: This is the giving off of steam in spurts and belches, caused by excessive amounts of salts in solution in the boiler feed water. Too much soda, added to get rid of scale-forming impurities, is a frequent cause of this evil. Frequent blowing down of the boiler is the usual remedy for this evil. If this has to be resorted to at too frequent intervals it is advisable to look about for some new source of water supply.

Any and all of the systems of water softening may be preceded by a system for clarifying or removing suspended matter and sediment. This usually consists of filter beds or tanks, the use of a coagulating substance, such as alum or ferrous sulphate (sulphate of iron) being now quite general. Alum, in addition to removing sediment, will frequently remove dissolved colorations.

None of the above systems should be confused with water treatment for sanitary purposes. Water may be perfectly crystal clear, and also perfectly soft by chemical test, and, therefore, entirely suitable for boiler feed or for making paper, and yet contain large numbers of bacteria of the most virulent nature. To purify water in the sanitary sense, as is done by towns and cities, extensive filtration, accompanied by treatment with chlorine or bleaching powder, is needful.

So far we have said much about the quality of water and nothing about the quantity. The water supply of a pulp and paper mill should be adequate to take care, not only of the normal needs, but also of requirements in case of fire. There should be a storage tank of adequate capacity mounted on a tower sufficiently high to give a satisfactory nozzle pressure at the top of the highest building or wood pile in the plant. The water supply should be connected with the supply of the town, city or village (assuming that the plant is situated near one) or of some other nearby large manufacturing plant, so that assistance can be rendered in case of fire or explosion putting the power plant out of commission. Conversely, this enables the pulp and paper mill to be of mutual service in case of emergencies.

Assuming that a pulp and paper industry consists of a ground wood mill, a sulphite mill and a paper mill; should each of these have its own main water supply, or should there be a single pumping installation? This will depend entirely on local conditions, the distance separating the various parts of the plant, etc. This is typical of the engineering questions concerning paper mills about which no general directions can be given.

Neither can anything definite be stated with regard to the kind of pump to be used for general water supply. Both centrifugal and plunger pumps are used, multi-stage turbine pumps being very generally satisfactory.

XVI. The Power Plant.

It is not the author's intention to deal with the subject of steam engineering in a general way in this chapter. Rather is it intended to point out certain particular points about the subject which must be given special attention in the pulp and paper plant.

Steam engineering is a subject on which many excellent books have been written. Any man working in a pulp and paper mill who hopes ever to rise very far in the industry must have at least an elementary knowledge of the general principles of steam engineering, and we earnestly recommend that all readers of this book (unless already expert power plant engineers) secure some good general works on this subject and study them carefully. We would specially recommend the following books, which are accessible to anyone and are written in a simple and direct manner:

"Steam: Its Generation and Use," Babcock & Wilcox Co., New York.

"Finding and Stopping Waste in Modern Boiler Rooms," Harrison Safety Boiler Works, Philadelphia.

"How to Build Up Furnace Efficiency," Jos. W. Hays, Rogers Park, Chicago.

"Efficiency in the Use of Oil Fuel," J. M. Wadsworth, issued by U. S. Bureau of Mines and obtainable from the Government Printing Office, Washington.

Kent's "Pocket Book for Mechanical Engineers" will be found to contain all the various tables necessary in making power plant calculations and will be found a great help, not only in the power plant, but throughout the mill.

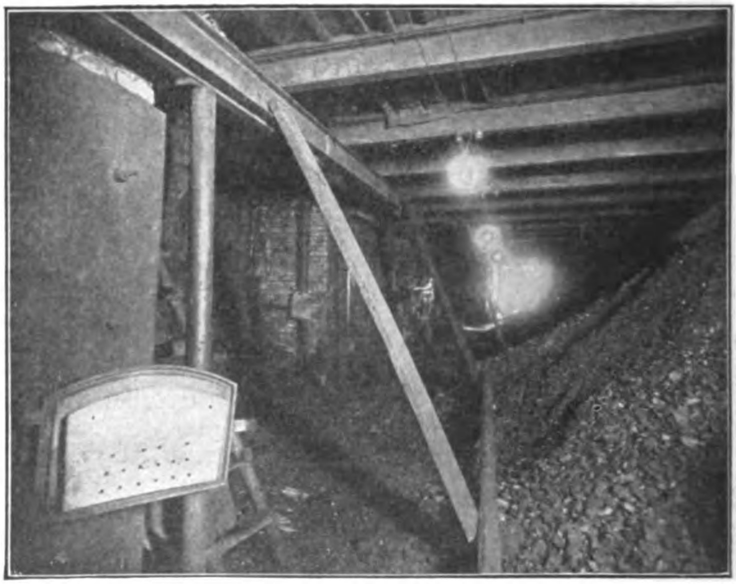
It is a good plan to keep a collection of the catalogs and bulletins issued by the different concerns making stokers, boilers, etc. These often contain valuable information and most of these concerns are genuinely interested in promoting boiler room efficiency as well as in selling their equipment.

The progressive pulp and paper mill superintendent should subscribe to such papers as "Power" and "Combustion" and should read them carefully, the advertisements as well as the reading matter. Only in this way can one profit by the latest developments in power plant engineering.

Pulp and paper plants—sulphite, soda, kraft and paper mills—run constantly, night and day, 24 hours per day and six days per week. This makes necessary the very best equipment and the very best firemen and engineers possible in the power plant. In order for a plant to run constantly in 144-hour stretches without breakdowns demands that everything should always be in the best order.

However, after an experience covering a little more than 35 years in the pulp and paper industry, the writer has come to the conclusion that no department is so frequently neglected as the power plant.

In some mills the boiler house is still called a "fire hole" and around the town one will hear firemen discussing it. Each



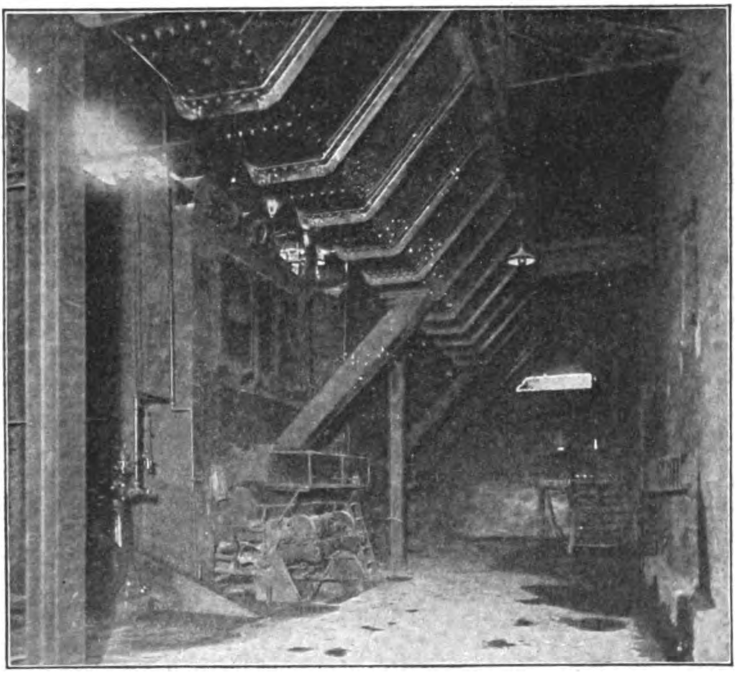
Courtesy: American Engineering Co., Philadelphia, Pa.

Fig. 153.—Boiler room of pulp and paper mill before introduction of automatic stokers.

fireman will be bragging about how hard he has had to work and how much coal he has had to shovel in a desperate effort to keep steam anywhere near the proper working point.

Such conditions were more common in the days when automatic stokers were not so common as they are now. Then boilers were mostly flat or hand fired. Of course, this method, if well conducted, can be made to yield the highest possible economy, but owing to the high cost of labor and (for that matter) the scarcity of it at any price, people have encouraged and urged the use of automatic appliances, which have been developed to a high point, and any saving that would exist with hand firing is more than offset by the high cost of such firing.

It has been customary in most mills to make necessary repairs to the boiler plant on Sundays, the only time when they well could be made. The writer has frequently been forced to believe that executives, although interested in plant economy, do not have the necessary technical or practical knowledge to analyze the boiler room conditions personally, so that the burden



Courtesy: American Engineering Co., Philadelphia, Pa.

Fig. 154.—Boiler room of same plant as shown in Fig. 153 after introduction of automatic stokers.

falls on the operating engineer, and in many such instances either the owners need a new engineer or else the engineer needs a new boss. There are many plants where the superintendent is constantly being nagged because of the high cost of production where the blame can all be traced to the boiler plant.

Those responsible for a modern pulp and paper mill should not hesitate to provide all approved boiler plant accessories. The plant should be equipped with indicating and recording instruments and these instruments should be made use of. Water should be metered. Flue gases must be tested. All these things must be done regularly and systematically to know whether the plant is being operated on an economical basis or not.

A steam plant serving a paper, sulphite, kraft or soda mill does not differ essentially from any other up-to-date steam plant, except that in the case of the chemical pulp mills the steam plant is frequently called on for sudden and unusual steam pressures on account of the intermittent operation of the digesters. Whenever the digesters are filled and ready to steam the inlet valve is opened. These valves are not usually less than 4 inches in diameter, so it will be seen that this is a rather sudden and drastic call on the boiler plant, and if the boiler plant is not able to meet these requirements to the full a great deal of trouble will be caused.

In modern pulp and paper plants sulphite, soda or kraft (any or all of these) is made in the same plant where paper is made. Also there may be rag pulp made and bleaching carried on. All these processes comprise a single plant in many cases and, naturally, one boiler plant serves them all.

Paper manufacturing is a steady operation and does not call for extreme overloads of power; the speed must be uniform and the steam pressure constant in order to make uniform and standard weights of paper, so that if the paper mill steam supply is taken from the same boiler plant as the sulphite mill, for instance. any uneven pressure or unusual load caused by the operation of the digesters is reflected in the paper mill by causing the steam engines which run paper machines to slow down or speed up as the case may be and there is hardly any limit to the harm such a contingency can create.

There is no real thorough-going cure for this except to have the paper mill supply from a separate set of boilers and a separate steam line, and in some cases, this is being done. The next best solution is to have good co-operation between digester operators and the firemen in the boiler house. There should be a system of signals, or a telephone, so that at least an hour before the digester valve is expected to be opened the firemen may be warned to be ready for the excessive pull on their plant. In this way such times can be passed without any unusual condition.

When slack coal could be placed in the stoker hoppers for about a dollar per ton, there certainly was not much incentive to work out and maintain more efficient methods of combustion, and as a matter of fact in many cases the expense involved in obtaining better results was not justified by the saving produced.

But that condition does not obtain now. The present price of fuel will justify the expenditure of money for better furnaces and the various instruments that are necessary to obtain and maintain proper combustion. That the consumer is wide awake to the necessity of economy in the use of fuel is evidenced by the unprecedented demand for boiler and furnace instruments.

It is here that a warning should be sounded. The writer has seen many cases where a plant has been equipped with expensive indicating and recording instruments and then left alone with the idea that somehow the instruments would automatically secure the desired results. The object here is to call attention to the wrong use made of, and the wrong impressions that may be gained from the carbon dioxide (CO_2) recorder.[1]

Although this instrument still leaves something to be desired in its construction and operation, it is highly enough developed to be of very great value in obtaining proper combustion, but, in the majority of cases, the instrument is installed and the fireman is told to maintain a certain percentage of CO_2 in the escaping gases. He soon learns that if he has a deep fuel bed and a small amount of air a high CO_2 reading will result, but what he does not know is that such a condition is also a good one for the production of CO and that a high percentage of CO_2 in the flue gases very often means a high percentage of CO.

Thus the record from the CO_2 recorder may show that very good results have been obtained, whereas just the opposite may be true and large quantities of fuel in the form of incompletely consumed carbon have passed out with the products of combustion. There are conditions that will produce CO other than the one just mentioned. It should be kept in mind that the kindling temperature of CO is rather high, about 1200 deg. F., so that if there is not a thorough mixing of air and fuel before coming in contact with the comparatively cool heating surfaces incomplete combustion will result.

It is vitally important that the results from the CO_2 recorder be checked frequently by making a complete gas analysis with the Orsat apparatus. This checking with the Orsat serves two purposes; first, it shows whether or not the recorder needs adjustment, and second, if there is any CO present.

There is a tendency to surround the Orsat apparatus with a great deal of mystery and to create the impression that its use is limited to technically trained men. This attitude is particularly unfortunate, for there is not an engineer worthy of the name that cannot master the use of the Orsat apparatus in two hours or less. Such a man has been setting valves and determining the horse power of reciprocating steam engines by means of the steam engine indicator for years, and there is no doubt that the Orsat is easier to use and the results more easily analyzed. A knowledge of chemistry is not necessary. The chemicals or solutions can be secured from any dealer in chemical reagents.

The Use of the Orsat.

The burette a is graduated in cubic centimeters up to 100, and is surrounded by a water jacket to prevent any change in temperature from affecting the volume of the gas during analysis.

For accurate work it is advisable to use four pipettes, b, c, d, e, the first containing a solution of caustic potash for absorb-

[1] For descriptions of the various types of CO_2 records, see "Finding and Stopping Waste in Modern Boiler Rooms," Vol. II, pages 151 to 156. Harrison Safety Boiler Works.

ing carbon dioxide, the second an alkaline solution of pyrogallol for absorbing oxygen, and the remaining two an acid solution of cuprous chloride for absorbing carbon monoxide. Each pipette contains a number of glass tubes, to which some of the solution clings, thus facilitating absorption. In pipettes d and e these tubes contain copper wire to strengthen the cuprous chloride solution as its absorbent power becomes weakened. The rear half of each pipette is fitted with a rubber bag, one of which

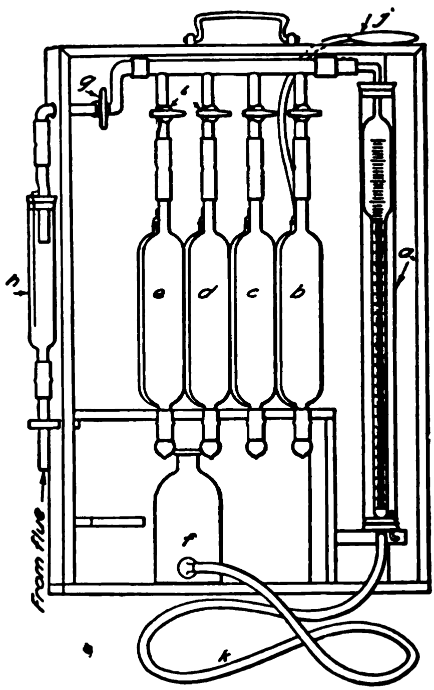


Fig. 155.—Diagram of Orsat apparatus for testing flue gases. (a) Burette; (b) caustic potash pipette; (c) alkaline pyrogallol pipette; (d, e) cuprous chloride pipettes; (f) levelling bottle; (g) 3-way cook; (h) U-tube; (i) cock; (j) rubber bag; (k) tube.

is shown at j, to protect the solution from the action of the air. The solution in each pipette should be drawn up to the mark on the capillary tube.

The gas is drawn into the burette through the U tube h, which is filled with spun glass, or similar material, to clean the gas. To discharge any air or gas in the apparatus, the cock g is opened to the air and the bottle f is raised until the water in the burette reaches the 100-cubic centimeter mark. The cock g is then turned so as to close the air opening and allow gas to be drawn through h, the bottle f being lowered for this purpose. The gas is drawn into the burette to a point below the zero mark, the cock g then being opened to the air and the excess gas expelled until the level of the water in f and in a are at the zero mark. This procedure is necessary in order to obtain the zero reading at atmospheric pressure.

The apparatus as well as all connections leading thereto should be carefully tested for leakage. Simple tests can be made. For example, if after the cock g is closed the bottle f is placed on top of the frame for a short time and again brought to the zero mark, the level of the water in a is above zero mark, a leak is indicated.

Before taking a final sample for analysis, the burette a should be filled with gas and emptied once or twice, to make sure that all the apparatus is filled with new gas. The cock g is then closed, the cock i opened, and the gas driven over into b by raising f. The gas is drawn back into a by lowering f and when the solution in b has reached the mark in the capillary tube, the cock i is closed and a reading is taken on the burette, the level of the water in the bottle f being brought to the same level as the water in a. The operation is repeated until a constant reading is obtained, the decrease in volume, in cubic centimeters, being the percentage of CO_2, in the flue gases.

The gas is then driven over into the pipette c and the apparatus manipulated in a similar manner. The difference between the resulting reading and the carbon dioxide reading gives the percentage of oxygen in the flue gases.

The next operation is to drive the gas into the pipette d, the gas being given a final wash in e, and then passed into the pipette c to absorb any hydrochlorid acid fumes that may have been given off by the cuprous chloride solution, if old; such fumes would increase the volume of the gases and make the reading on the burette less than the true amount.

The sum of the percentages by volume of CO_2, O, and CO is subtracted from 100 and for practical purposes this difference is taken as the percentage by volume of N.

The gas must be passed through the burettes in the order named, as the pyrogallol solution will absorb carbon dioxide and the cuprous chloride solution will absorb oxygen.

As the gases in the flue are under less than atmospheric pressure, they will not of themselves flow through the pipe connecting the flue to the apparatus. The gas may be drawn into the pipe in the way already described, but this is tedious. A rubber bulb aspirator connected to the air outlet of the cock g will quickly draw a new supply of gas into the pipe. Another form of aspirator draws the gas from the flue in a constant stream, thus insuring a fresh supply for each sample.

The analysis made by the Orsat apparatus is volumetric; if the analysis by weight is required, it can be found from the volumetric analysis as follows:

Multiply the percentages by volume by the molecular weight of each gas, and divide the products by the sum of all the products; the quotients will be the percentages by weight. For most work the use of the oven values of the molecular weights insures sufficient accuracy.

The even values of the molecular weights of the gases that appear in an analysis by an Orsat are:

Carbon dioxide (CO_2)	44
Carbon monoxide (CO)	28
Oxygen (O_2)	32
Nitrogen (N_2)	28

The following table indicates the method of converting a volumetric flue-gas analysis into an analysis by weight.

Conversion of a flue-gas analysis by volume to one by weight:

CONVERSION OF A FLUE-GAS ANALYSIS BY VOLUME TO ONE BY WEIGHT

Gas	Analysis by volume (per cent)	Molecular Weight	Volume times molecular weight	Analysis by weight (per cent)
Carbon dioxide (CO_2)	12.2	12 + (2 x 16)	536.8	$\frac{536.8}{3022.8} = 17.7$
Carbon monoxide (CO)	.4	12 + 16	11.2	$\frac{11.2}{3022.8} = .4$
Oxygen (O_2)	6.9	2 x 16	220.8	$\frac{220.8}{3022.8} = 7.3$
Nitrogen (N_2)	80.5	2 x 14	2254.0	$\frac{2254.0}{3022.8} = 74.6$
Total	100.0	....	3022.8	100.0

From the flue-gas analysis the weight of air actually used for combustion can be computed from this formula provided the percentage by weight of C in the fuel is known:

$$\text{Weight of air} = 3.036 \left(\frac{N}{CO_2 + CO}\right) \times C$$

Where N, CO_2 and CO are percentages by volume in the flue gas and C is the percentage by weight of carbon in the fuel.

The quantity of heat (B. t. u.) lost in the flue gases per pound of fuel is $L = 0.24\ W(T - t)$.

Where W = weight in pounds of flue gases per pound of dry fuel.

T = temperature of flue gases, °F.

t = temperature of atmosphere, °F.

0.24 = specific heat of flue gases.

The weight W of the flue gases per pound of dry fuel is computed from the analysis by the formula:

$$C\left(\frac{11\,CO_2 + 8\,O + 7\,(CO + N)}{3\,(CO_2 + CO)}\right)$$

where CO_2, O, CO, and N are the percentages by volume, by analyses of the flue gas. C is the percentage by weight of the carbon in the dry fuel.

The quantity heat (B. t. u.) lost per pound of fuel burned through incomplete combustion of carbon and the presence of CO in the flue gas is in B. t. u. obtained by using the formula:

$$L = 10{,}150 \times \left(\frac{CO}{CO + CO_2}\right) C$$

where CO and CO_2 are the percentages of the gases by volume in the flue gases and C is the percentage of C by weight in the fuel.

Design of Steam Plants for Pulp and Paper Mills.

In considering the design of a steam plant as applied to the paper industry, consideration should be given to the following main headings.

Logical fuel to burn.
Various kinds of boilers.
Various types of stokers or grates.
Kinds and types of auxiliary equipment for the boiler house.
Fans and engines for producing draft.
Soot blowers.
Boiler feed regulators.
Balanced draft.
Gauges and gauge boards.
Distribution of steam throughout the plant.
Types of steam units used for driving the paper machines.
Heating system for the mill.
Reclamation of heat units.

Logical Fuel to Burn.

While it is conceded that the use of anthracite and bituminous coal predominates in most industries in this country—and the paper industry is no exception—the exact type of fuel used must be determined by the general location of the plant, freight rates, freight facilities, flexibility of coal deliveries, nearness to mines and large coaling stations, nearness to supplies of oil or other fuel, tank steamer facilities, etc.

In addition to coal natural gas is used as fuel in the paper industry in some instances (chiefly in the Virginias) and crude oil is used in mills on the Pacific Coast and in some Maine mills.

Coal: A pulp and paper mill engineer should secure government and other publications describing the coal from different seams. If not competent to judge himself, he should avail himself of the services of a combustion engineer in selecting his coal and drawing up specifications for it. All coal should be bought on specification based on sampling, testing and chemical analysis. The Keystone Consolidated Publishing Company of Pittsburgh get out a Coal Catalog which contains all the necessary information and should be in the hands of every large user of coal. The U. S. Bureau of Mines will also supply literature on this subject.

Until quite recently the different grades of anthracite were burned in the paper industry with induced draft, i. e., either with natural draft produced by chimneys or by fans. Then followed a combination of induced and forced draft. Hand fired installations used approximately ½ inch to 1¼ inch of draft in the pit. Hand firing, with various types of grates, and with an air space of approximately 9 to 11 per cent, was fairly satisfactory and in many cases really economical, at least at pre-war prices for anthracite coal. However, it had its limitations, and a steaming capacity of from 20 to 30 per cent and many times as much power, could be obtained from bituminous, with more modern firing equipment.

The large percentage of ash, and the consequent increase in coal required to equal bituminous steaming, makes the labor cost of the hand fired operations approximately twice as high as with an automatic stoking installation.

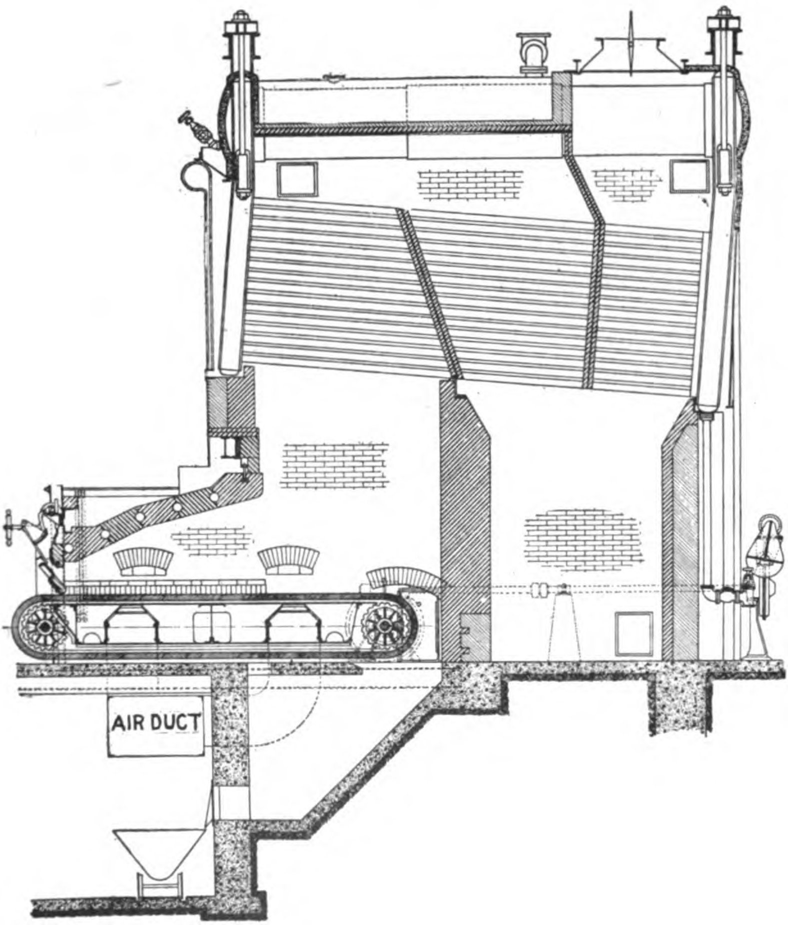
However, offhand we would state that it does not pay to seriously consider the installation of stokers in any pulp or paper mill unit that does not exceed 1,000 or 1,500 H. P.

Oil: According to government statistics 165,000,000 barrels of fuel oil were used in 1917 in the United States. Oil has the advantage of simplifying firing, high evaporation, high capacity per square foot of grate surface or radiating surface, lessened labor cost, cleanliness, flexibility, i. e., ability to change quickly to maximum or minimum supply of steam. On the other hand, we believe that the impingement of the flames on the tubes necessitates a lot of tube renewals. In some localities fuel oil is the logical fuel, but with the increase in the price of fuel oil since the war, its disadvantages have been given more consideration, and it is not in so much favor as in pre-war times. Full information about every detail of the use of fuel oil in power plants is given in the copiously illustrated booklet entitled "Efficiency in the Use of Oil Fuel," published by the U. S. Bureau of Mines. The author of this booklet is J. M. Wadsworth and it can be obtained by sending 15 cents to the Superintendent of Documents, Government Printing Office, Washington. Anyone thinking of using oil fuel will find everything they need to know in this handbook.

Natural Gas: Of this fuel we cannot speak from personal experience, never having operated plants with this fuel. We understand, however, that its advantages are high steaming capacity, flexibility, reduction in labor cost, cleanliness, compactness, and (in certain localities) cheapness.

Stokers.

There are a number of excellent stokers on the market and we would not have any reader infer that the particular ones

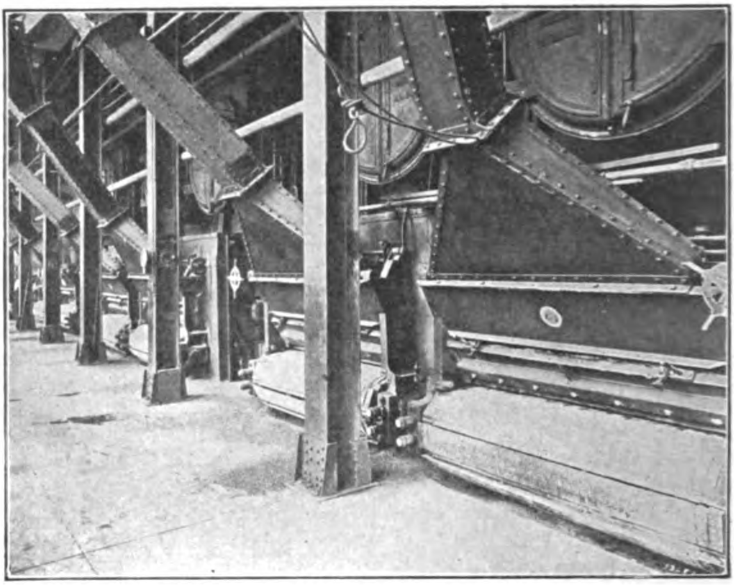


Courtesy: Combustion Engineering Corpn., New York.

Fig. 156.—Typical installation of Coxe stoker under horizontal water tube (Edgemoor) boiler.

we have happened to illustrate here are, in our opinion, the only ones to use in pulp and paper mills.

The main thing is, apart from mechanical efficiency in the stoker itself, that the stoker installation should have a high reserve capacity (several per cent over-rating frequently being required) because sometimes, owing to two or more digesters being blown in at about the same time, wash-ups on the paper machine, etc., sudden very large demands for steam are made. This possibility of sudden, irregular, excessive demands for steam is the principal unique factor in power plant design for the pulp and paper industry.



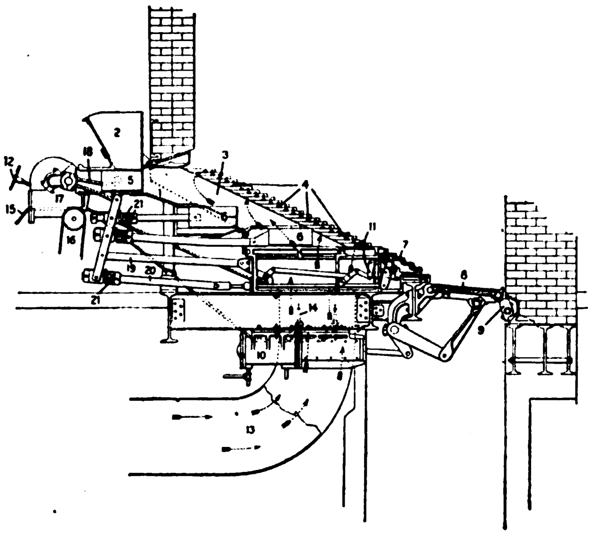
Courtesy: Combustion Engineering Corpn., New York.

Fig. 157.—Installation of six Coxe stokers under 250 H.P. boilers.

The stokers which we have illustrated we consider excellent examples of efficient modern stokers that have proved their value in hundreds of installations. However, we have selected them to illustrate simply because the illustrations were available. In addition to the Taylor and the Coxe, there are the Babcock & Wilcox, Westinghouse, Jones Underfeed, Harrington, Green, Files, LaClede-Christy, and many other good makes.

To sum up: no matter what the type of stoker, have plenty of draft. In the case of forced-draft installations have a good, generous force draft fan, preferably two units of sufficient size to furnish the required draft in the pit (zero to at least 6 inches) without the fan engine speed exceeding 50 to 150 r. p. m. The fan engine to be enclosed, preferably horizontal with forced feed lubrication for both engine and cylinder oil.

A good stoker should be scientifically planned to utilize the peculiarities of bituminous or semi-bituminous coal, or of mixtures of such coal with limited amounts of anthracite steam sizes. It is not merely a device for feeding coal; rather, it is a complete system of combustion, comprising means for feeding the coal in quantities as needed, supplying air in proportionate amounts, causing the air and distilled gases to mix and burn without smoke, burning the solid fuel (coke), discharging the ashes.



Courtesy: American Engineering Co., Philadelphia, Pa.

Fig. 158.—Taylor stoker with power dump.

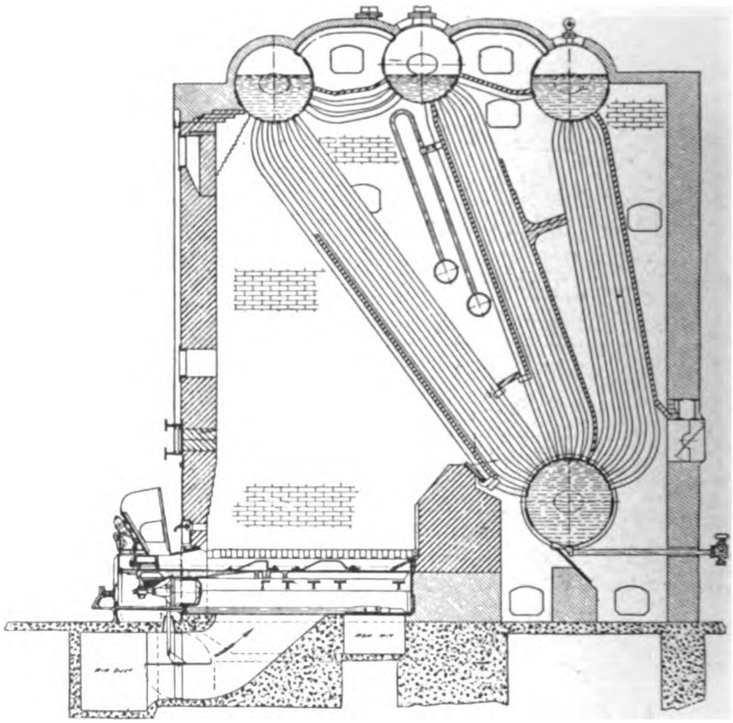
1. Retort.
2. Hopper.
3. Tuyere Box.
4. Tuyeres.
5. Feeding Ram.
6. Distributing Rams.
7. Extension Grate.
8. Dump Plate.
9. Pawls, supporting Dump Plate.
10. Steam Cylinder of Power Dump.
11. Damper controlling draft to extension grate.
12. Hand Wheel controlling damper No. 11.
13. Air Duct fan draft.
14. Dampers in air duct.
15. Handle controlling dampers No. 14.
16. Sprocket Chain Driving Worm gear No. 17.
17. Worm and Gear driving stoker.
18. Connecting Rod.
19. Link forming fulcrum for lever by which motion is imparted to rams, 6, 6, and extension grate.
20. Link by which extension grate is reciprocated to prevent clinkers from adhering.
21. Spacing Washers by which lengths of stroke of rams 6, 6, and link 20 are determined.

All these processes are carried out with a high degree of precision by mechanical means, and with minimum dependence on the human element.

Specifically, the following results should be accomplished:

(1) Coal-burning capacity, and therefore steaming capacity should be enormously increased. Continuous operation at from 200 to 300 per cent of rating is often secured, according to the boiler design and the coal used. Operation at even higher rates

is possible. Note: A "boiler horsepower" is equivalent to 34.5 pounds of water per hour evaporated into steam at 212° Fahr. and atmospheric pressure. In an actual boiler the water starts at less than that temperature, is evaporated into steam at a higher temperature and pressure, and is probably superheated also. Hence, the weight of water per horsepower actually evaporated is



Courtesy: Combustion Engineering Corpn., New York.

Fig. 159.—Installation of Combustion Engineering Corporation's type E stoker under upright water tube (Stirling) boiler.

less than 34.5 pounds, to allow for the heat added before and after evaporation.

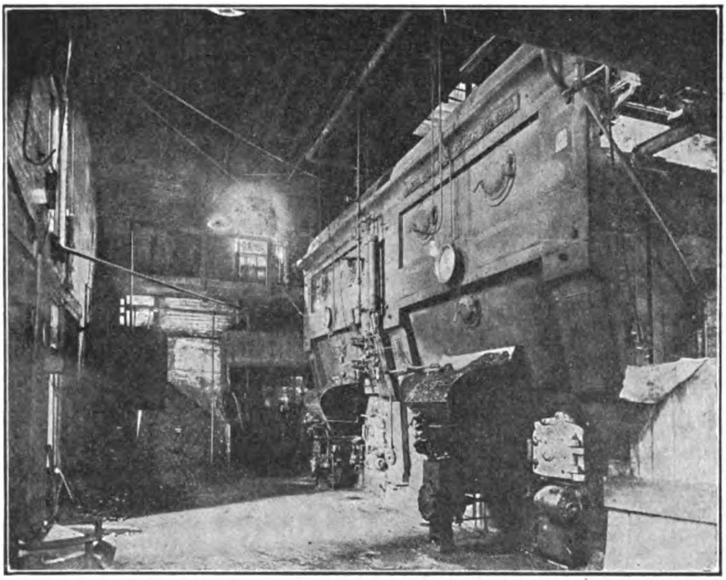
Water-tube boilers are generally rated at one boiler horsepower for every ten square feet of heating surface. "Operation at normal rating" means that for every square foot of heating surface the boiler is evaporating 3.45 pounds of water per hour "from and at" 212° Fahr., or its equivalent for the actual conditions.

"Operation at 200 per cent of rating" means that the boiler is evaporating double the rated quantity of water per hour. It does not imply higher steam pressure.

A hand-fired boiler will deliver only its normal rating or a little more, and its efficiency falls very rapidly as the output is forced.

(2) A saving in fuel is effected of from 10 to 20 per cent for equal steam output, as compared with hand firing at normal rating, assuming that the same degree of intelligence is exercised as would be the case with high-class hand firing.

(3) Response to varying loads should be almost immediate. With good stokers it is unnecessary to incur the stand-by



Courtesy: Combustion Engineering Corpn., New York.

Fig. 160.—Two type E stokers installed in boiler room of a paper mill. Nominal rating of boilers 219 H.P. each.

losses of many banked boilers held in readiness for a sudden demand.

(4) Smoke is greatly reduced or wholly eliminated.

(5) By proper adjustment of feed and draft, varying grades of fuel are successfully burned.

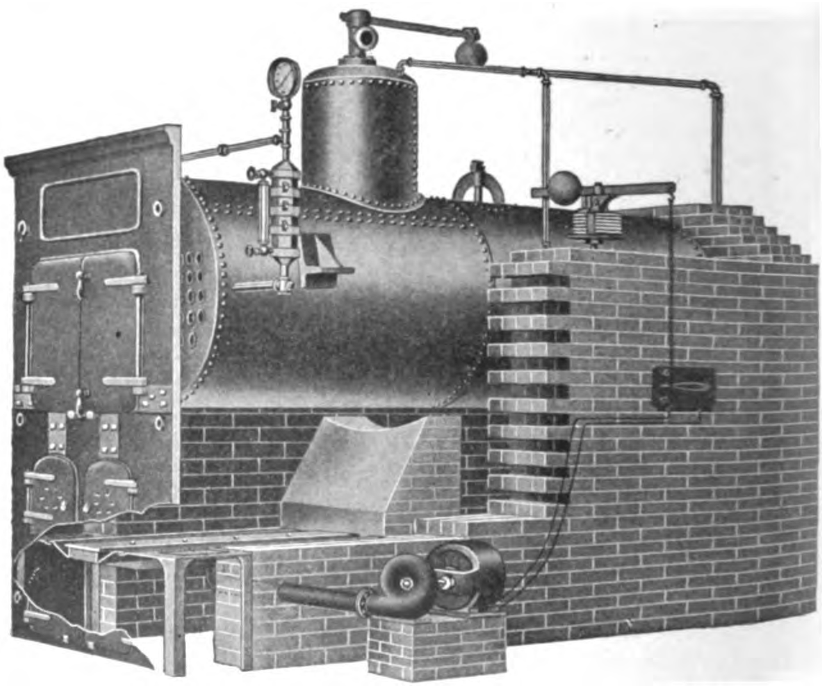
(6) Repair expenses should be nominal.

(7) Labor expense is minimized. With fuel of average quality, one operator can look after 12 to 15 modern stokers of ordinary size, representing 10,000 rated boiler horse-power. (The above exclusive of ordinary boiler-house labor such as laborers, ash-handers, chartmen, foremen, etc.)

Stoker Engines: These should be of a modern enclosed type and should be approximately 1/3 to 1/2 larger than ordinarily recommended by the makers themselves.

Smith Force Draft Equipment.

In addition to stokers, we have found very useful the Smith Force Draft Equipment. The installation of this appliance adds much to the flexibility of the plant, enabling it to burn various

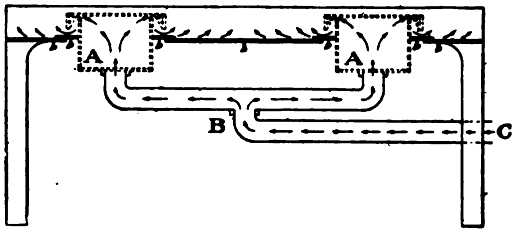


Courtesy: Mechanicville Specialty Supply Mfg. Co., Mechanicville, N. Y.

Fig. 161.—J.R.S. low and high grade coal burner in position under boiler.

grades of coal, down to and including anthracite screenings dust, also buckwheat, coke breeze, etc.

It consists of filler plates covering the entire fire box area, all free air being sealed from entering through the ash pit. The plates are so arranged that draft delivered under pressure upward into the fire box is returned downward in a lateral flow that distributes the oxygen through the fuel so perfectly and steadily that all heat units ordinarily passing off in the form of gas and smoke are entirely consumed. It tends to correct faulty chimney drafts and variations in chamber size. It can be placed in any type of furnace and used in connection with either mechanical or hand stoking. The draft is applied automatically and can be quickly set to handle minimum requirements or peak loads. It is claimed by the makers that this device



Courtesy: Mechanicville Specialty Supply Mfg. Co., Mechanicville, N. Y.

Fig. 162.—Front elevation of J.R.S. burner showing circulation of air under pressure.

will show material savings in cost of operation, and our own experience all tends to confirm this, especially in case of low grade fuel.

Boilers.

The type of boiler to be used depends largely on the size of the plant. Arguments can be found for both Return Tubular and Water Tube boilers. Water Tube boilers have undoubted advantages, but where the size of the plant is small (mills up to and including 40 tons) Return Tubular might well be considered. For larger plants install ordinarily good Water Tube boilers, having in either case one boiler in excess of normal requirements to take care of increased loads due to variations in weight, steam requirements in winter months, repairs, etc.

Babcock & Wilcox in "Steam: Its Generation and Use," which they supply free to boilers users, outline the advantages of Water Tube boilers in general. Those we consider most important are, quick steaming, greater safety and easy access for repairs. For details as to all the best makes of both types of boiler consult "Condensed Catalogues of Mechanical Equipment," published by the American Society of Mechanical Engineers and "Sweet's Engineering Catalogue." These are both well-known publications, free to people seriously interested, and give pictures and descriptions of all the best makes of boilers and boiler room equipment.

In a mill having four 13-ton digesters, and manufacturing approximately 125 tons sulphite and 80 tons paper, boilers were installed as per the table on following page.

In sulphite mills suitable provision should be made for burning refuse. For such work combination forced and induced draft is preferable. For a furnace of approximately 8 ft. x 7 ft. size, grates of Herringbone type are very satisfactory, embodying quick dumping features, making it possible to burn down the

TABLE OF STOKER AND BOILER CAPACITY IN STEAM PLANTS OF FOUR TYPICAL MILLS

Mill	Capacity (Tons)	No. of Machines	No. of Digesters	No. of Boilers	How Fired	Fuel Used	Percentage of Rating Operated	H. P. per Ton Product	Grate Area per Ton Product (sq. ft.)
Paper...	50	2							
Sulphite	50		2 (13-ton)	4	Under-feed Stoker	Bit. Coal	137	14.2	2.7
Paper...	80	2							
Sulphite	125		4 (13-ton)	8	Overfeed Stoker	Bit. Coal	120	11.7	1.6
Paper...	40	1 (large)		4	Hand	20% Bit. 80% Anth.	100	18	4
Paper...	45	2 (small)		6	Hand	20% Bit. 80% Anth.	100	25	7.3

refuse quick, before the brick-work would become cooled down. In such a case approximately 1.1 square feet of grate surface and 45 cubic feet furnace capacity should be provided for each ton of sulphite made.

This is in case the wood is prepared with a barking drum. The power capable of being generated from refuse from a barking drum, in which 125 cords of green wood is being barked, is equal to approximately 200 H. P. per hour for 20 hours.

TABLE OF APPROXIMATE CUBICAL CAPACITY OF BOILER ROOM, COAL BUNKER SPACE, ETC., REQUIRED PER TON OF PAPER IN MANUFACTURE OF GRADES RUNNING FROM 100% SULPHITE TO 100% KRAFT SHEET—WEIGHT FROM 30 TO 50 LB. BASIS.

Cu. Ft. Boiler Room	Cu. Ft. Bunker Space	Sq. Ft. Floor Space	Sq. Ft. Heating Area	Sq. Ft. Economizer Surface
2588	240	96	296	148

NOTE: These figures can be safely used for manufacturing of most papers from sulphite.

In considering the available power from refuse made in preparing wood with disc barkers, it is safe to assume that 62 boiler H. P. can be obtained from every cord of wood prepared.

Ordinarily a 13-ton digester will require a minimum of 300 H. P. at the time of steaming, a maximum at the time of starting (about 2½ hours after steaming) of 700 and an average of 550 H. P. per hour for the period covering a 9-hour cook.

As before mentioned, the personnel of the plant has a large bearing on the boiler capacity necessary to operate a pulp mill, especially a sulphite mill. For example, in a mill operating two 13-ton digesters, cooking 50 tons of high-grade unbleached stock, there will be from 4¼ to 5 cooks per 24 hours. It will be obvious that the efficiency of the operation, viz.: the reclamation of the acid, the making of the acid, and the general efficient operation of the plant will be dependent on the proper timing of the cooking operation. If the digesters are bunched in such a 50-ton sulphite mill, it is possible to pull on the boiler house to the extent of 1,200 horsepower. On the other hand with proper spacing of the cooking operation, the maximum horsepower might well be in the neighborhood of 850 H. P.

Anyone with any practical experience in making pulp will recognize that it is impossible at all times to space the digesters perfectly, because, owing to the various contingencies, such as steam and water conditions, blow pit conditions, screening, etc., it will often be necessary to bunch the digesters. It is for this reason that in designing boiler installations for sulphite mills, generous provision must be made for taking care of just such unavoidable contingencies.

TABLE GIVING SIZE AND TYPE OF BOILERS IN TWO TYPICAL MILLS AND ONE WITH TWO 13-TON DIGESTERS AND ONE WITH FOUR 13-TON DIGESTERS

No. Digesters	No. Boilers	Nominal Capacity	Type	How Fired	Per cent of Rating Operated
2	2	1740	Water Tube	Stoker	137%
4	4	1200	" "	"	120%

Auxiliary Equipment for Boiler Use.

We consider this one of the most important items in the proper design of a power plant for a pulp and paper mill. The most important point to be considered under this heading is boiler feed apparatus with which to supply raw water for boiler purposes. We have found that beyond a possibility of a doubt, it pays well to have at least three independent means by which to supply the water to the heaters and the boiler feed pumps.

Provision should be made so that the water can be by-passed

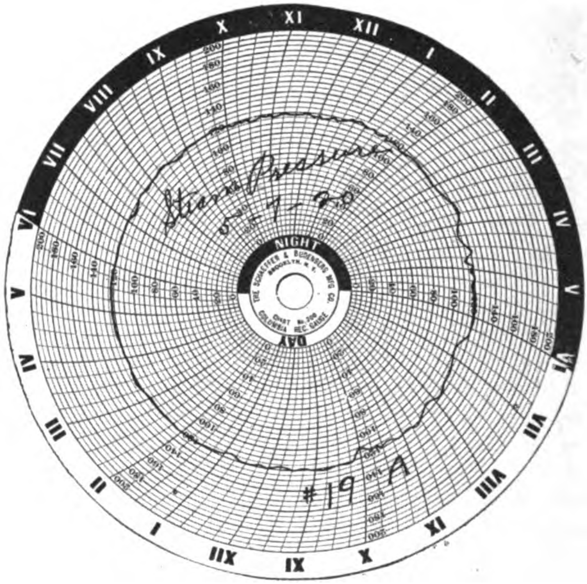


Fig. 163.—Typical pressure chart for power plant of mill making sulphite and paper.

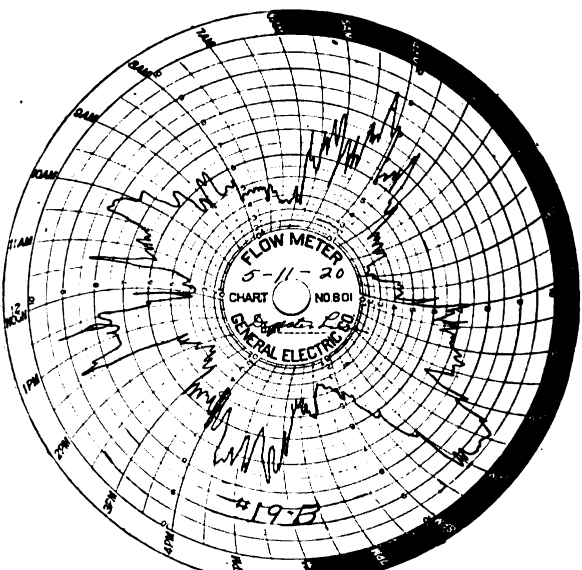


Fig. 164.—Typical flow meter chart for power plant of mill making sulphite and paper.

from the heater direct to the suction of the pumps. For instance, one might provide an emergency connection direct from the underwriter pump, whether it be duplex or turbine type. Moreover, there should be two different sources of supply, one electrically driven and one steam driven for water for the heaters proper. The water should in all cases be filtered and if necessary softened so as to be free from ingredients tending to form scale. This subject has already been dealt with in Chapter XV, under the heading "Water Supply."

With specific reference to the various methods for feeding boilers, there is first the old stand-by, the individual large inspirator or injector. For pulp and paper mill work of any size this equipment is practically obsolete, although there are instances where its utilization for emergencies has proved to be a good investment. More to be recommended are the usual single and duplex plunger pumps and direct connected turbo units. The writer has found a unit embodying a turbine direct connected to a four-stage centrifugal pump entirely satisfactory for this service. However, numerous manufacturers, both of turbines and pumps, are capable of supplying excellent equipment for this purpose.

We will not attempt in this chapter to deal in detail with figures on the proper amount of power which should be utilized for auxiliary boiler room equipment under various conditions. Such information can be found in the various standard text books on steam engineering. In considering pulp and paper mills, it is almost immaterial what type of auxiliary units are used provided that the capacity is sufficient and that proper provision is made for the utilization of the excess exhaust.

To return to the question of boiler feed pumps, there is one important fact on which we can hardly lay too much emphasis. While the turbine pumps are very desirable, under no consideration should any pulp and paper plant be operated without one good, big, generous, modern, duplex or triplex pump of substantial design in the boiler room.

We would consider the following an ideal installation for a 50-ton sulphite mill and 50-ton paper mill: (1) One motor driven triplex pump, size 8 x 10, 200 g.p.m. capacity. (2) One steam driven duplex outside-pack plunger pump, 200 g. p. m. capacity. (3) One direct connected turbine driven centrifugal pump of 200 g. p. m. capacity. (Note: This type preferable when accurate Venturi meter readings are required.) The valves in the plunger pump should be of good quality composition backed by some stiff metal.

Ideal specification for the turbine driven pump: 4-inch Horizontal two-stage split case, centrifugal pump, equipped with bronze impellors, bronze covered steel shaft, and having an extended base and flexible coupling direct to 40 H. P. steam turbine. Pump to have a capacity of 300 g.p.m. against a pressure of 175 lbs. Efficiency 55 per cent. Steam turbine to be of single stage, horizontal type.

All units when possible should be properly regulated on the basis of steam pressure and the pressure on the boiler feed line.

When figuring capacities for boiler feed pumps, particularly of duplex type, first see to it that at least sufficient head is provided for hot water purposes, to maintain a pressure of at least 9 pounds (this pressure contingent on the temperature of the water being pumped) on the suction proper, figuring normal rating of the boilers. In fact if the actual boiler horsepower readings are available, take actual and add one-half to the theoretical, and you will then have what we have found from experience to be a good boiler pump installation.

Under no consideration would we consider a piston speed much to exceed 40 ft. per min. In the event of other units which might be well considered as auxiliary equipment such as the various draft generating apparatus, be this induced or forced, we have found that the manufacturers' suggestions as to sizes best be multiplied by approximately 50 per cent. This is based on actual experience in operation. The average engineer figuring on this work does not anticipate some of the dangerous contingencies that arise.

We will cite one example—bunching of digesters; perhaps the steaming of two or three beaters simultaneously, the starting of two machines in unison. With the above, while pulling the normal rating of say 100 horsepower, the mill will sometimes pull as high as from 1,200 to 1,500 horsepower, particularly during the starting up of the machines or in the event of their pulling a full 1½ inch to 2½ inch steam supply, when the paper is running wet, etc., etc.

Soot Blowers.

The author is decidedly of the opinion that soot blowers are a good investment and add materially to the efficiency of modern boilers. However, a soot blower, to be a profitable investment, should be used in an intelligent manner. The blowing should be done several times a day because when soot and ash first collect on the tubes it is easier to remove, whereas, if it is allowed to remain, the heat will fuse it into a hard substance which can only be removed by scraping. There are a number of excellent soot blowers on the market, any of which will soon pay for themselves by the savings effected.

Boiler Feed Regulator.

These are sometimes called feed water regulators. Many engineers do not favor the installation of these regulators. It is our experience, however, that they are a good investment. They tend to decrease the variation of pressure when the load on the boilers is heavy, as well as presenting certain other advantages.

Although these devices differ in construction, they are all designed to accomplish the same results and the following description of the work accomplished by the Copes regulator could well apply to any of the reliable makes of feed water regulator.

The regulator feeds continuously as long as there is a load on the boiler. On heavy loads it automatically drops the water level so as to increase the steaming capacity. On light loads it automatically raises the water level, and saves the furnace heat which would otherwise be wasted. On steady loads, it maintains a constant water level.

The governor maintains a fixed excess in the feed line above boiler pressure. As the pressure varies, the feed pressure varies correspondingly. The same governor, with a charge in connections, will give a fixed constant pressure.

Balanced Draft.

Balanced Draft is obtained by the automatic regulation of both the supply of air to the furnace and the escape of the gases from the furnace in such manner as to maintain at all times a constant predetermined draft in the furnace for all rates of combustion.

Its principle is to supply all the air needed for perfect combustion but no more, and at the same time maintain as little suction in the furnace as possible and still have sufficient draft to take away the gases from the furnace chamber as rapidly as they are formed.

These requirements are independent functions. They must be controlled separately and independently if the best results are to be obtained.

Balanced Draft control of the air supply meets the first requirements perfectly. By its use, any required amount of air can be forced through fuel beds of any thickness or density, thus maintaining whatever rate of combustion may be desired.

Balanced Draft control of the flue damper meets the second requirement as the flue damper is kept constantly in its correct position by automatic opening and closing, thus keeping the removal of the waste gases under perfect control.

Pressure in the combustion chamber tends to rise when either the air pressure increases or the flue damper closes, or when the two act simultaneously. It falls when the air pressure decreases or the flue damper opens, or both act simultaneously. If both are controlled automatically, it is apparent that any desired pressure can be obtained in the furnace chamber under all conditions.

Atmospheric pressure or slightly less than atmospheric is found to be the most economical in a great majority of furnaces. At this pressure, whether in hand-fired plants or where stokers are installed there is no inrush of air above the fuel bed from open fire doors, through cracks or pores of boiler settings, through observation doors, or through other openings of whatever kind. The amount of air passing through the fuel bed is also restricted to the amount required for perfect combustion. The excess air admitted to the furnace, therefore, is reduced to the minimum.

Since air is not drawn in above the fire, when Balanced Draft is installed, the hot gases are not diluted. The initial temperature is greater for this reason, and the percentage of CO_2 in the flue gases is higher.

Heat absorption by the boiler is proportional to the difference between the temperature of its heating surface and that of the gases. The temperature of the furnace gases above that of the boiler heating surface is maximum when Balanced Draft is installed. Therefore, the absorption of heat by the boiler is maximum under these conditions.

With the quantity of air passing through the fire reduced to the minimum necessary for perfect combustion, the resulting volume of gases above the fire is also the minimum and the velocity of their passage through and out of the boiler setting is correspondingly reduced. These intensely hot gases, therefore, have ample time to transmit their heat to the boiler.

The inevitable result is increased evaporation per pound of coal and per square foot of heating surface. Furthermore, because the gases in the furnace chamber are held back, they diffuse and penetrate to the most remote parts of the heating space, coming into contact with every square inch of heating surface.

By the use of Balanced Draft on boilers formerly operating on natural draft, 250 per cent increase in capacity is frequently obtained without the slightest decrease in efficiency. This feature is of particular value when peak loads have gone beyond the capacity of the power plant. In a plant where several boilers have ordinarily been in use, it is possible to take one out of continuous service for reserve.

The results are brought about by the obvious possibility of increasing boiler capacity economically by increasing the rate of combustion. Greater economy in normal operation is also secured by burning a reduced amount of coal to develop the same power. How so radical an improvement can be effected is apparent from the fact that Balanced Draft combustion produces intensely hot gases and improves the transmission of heat from gas to boiler by increasing (1) the area of contact and (2) the period of their application diffusion of the gases over the heating surfaces.

With the volume of chimney gases reduced by the elimination of excess air, the stack is required to remove only the gases of combustion. Being also relieved of the burden of pulling air through the fuel bed, its effective capacity is increased to such an extent that additional boilers may be attached to a chimney which formerly was overloaded. The troublesome back pressure on the last of a line of boilers operated on ordinary forced draft and connected to an overload stack, is relieved by Balanced Draft.

Whenever furnace doors in hand-fired boilers are opened, large volumes of cold air rush in. This occurs also in stoker-fired boilers through openings for inspection of the fires and for the removal of clinker and ash. The cold air, striking the highly heated tubes of the boiler and the interior of the setting, chills them suddenly and causes rapid contraction. When the opening is closed, the quick rise in temperature causes equally rapid expansion. There can be but one result from such violent alternation of contraction and expansion—leaky tubes, cracked boiler setting and linings.

Balanced Draft eliminates the objectional conditions just described, with the result that the life of a boiler and its setting is greatly prolonged and repairs radically reduced. The decreased maintenance cost is not only the advantage as avoiding the inconvenience of having boilers out of service for repairs is a very important consideration.

Practical economy naturally demands that one fireman in a plant attend to as many boilers as possible. With the fireman's mind relieved of all care of the draft, he is able to give undivided attention to his other duties and so extend the range of his service. This is particularly desirable in stoker-fired plants.

Then, too, Balanced Draft is an assurance that the highest furnace efficiency will be maintained day in and day out, under all conditions of load and weather, even by an unskilled fireman, at the same time effecting very gratifying savings in fuel cost.

Since it is not always possible to hire and keep intelligent and conscientious firemen this is a very important consideration.

A very large saving by the use of Balanced Draft is very generally effected by changing from a high grade, expensive fuel, to a low grade, cheaper one. Frequently a local coal can be substituted for one brought from distant mines at high freight rates, and burned with equally good or better results. Surprisingly good results can sometimes be obtained by mixing anthracite and bituminous coal.

As the principle of Balanced Draft relates to perfect combustion irrespective of method of fuel supply, it applies to all hand-fired furnaces, to those mechanical stokers which are already or which can be fitted with pressure air supply, and to furnaces using hard or soft coal, oil or blast furnace gas. The method of application is similar in all cases, requiring only slight modification to suit individual cases.

Gauges.

There is no appliance which, in our opinion, will pay as good returns upon the investment, as a modern segregated control and gauge board. Such a board should contain, (1) master gauge,

(2) gauges for recording feed water temperature, (3) indicating and recording flue temperature pyrometers for each boiler, (4) recording draft gauge, (5) individual steam meters for each boiler, (6) U gauges and balanced draft gauges for each unit, (7) instrument for recording time and length of time at which the flues were blown, (8) instrument for recording time and length of time at which boilers were blown, (9) instrument for

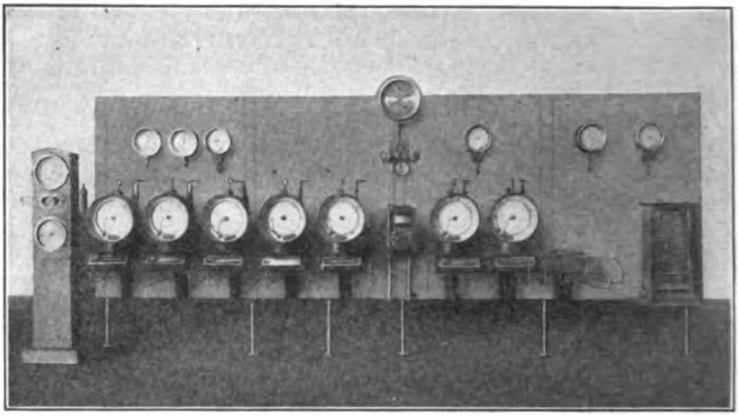


Fig. 165.—Gauge Board recently installed in large plant manufacturing sulphite pulp and paper. In the center of the board, projecting above the top, is the master steam gauge. Immediately beneath this is a G. S. Witham, Jr., draft fan engine regulator. To the left of the master gauge are respectively, in the order named, the flue gas temperature recorder, draft pressure recording gauge, and feed water temperature recording gauge. To the right of the master gauge are instruments for recording the temperature of feed water into and out of the economizer. In the center of the board beneath the Witham regulator, is the indicating pyrometer and immediately to to the left and right of this are steam flow meters (one of these yet to be installed). Under the row of steam flow meters is a row of balanced draft gauges. At the extreme right hand lower corner of the board is the CO_2 recorder. To the left of the board, standing on the floor is the Venturi meter.

recording time and length of time at which safety valves were blown, (10) Venturi meter for indicating volume of water furnished to boilers (various types of flow meter can be substituted for this), (11) CO_2 recorder of any good make.

The Venturi meter reading together with the steam output reading and a number of pounds of coal burned makes it possible to calculate very accurately the general efficiency of the boiler installation.

Steam Pressures.

It is not our intention to enter into detail regarding steam pressures. We will simply state that it is pretty generally con-

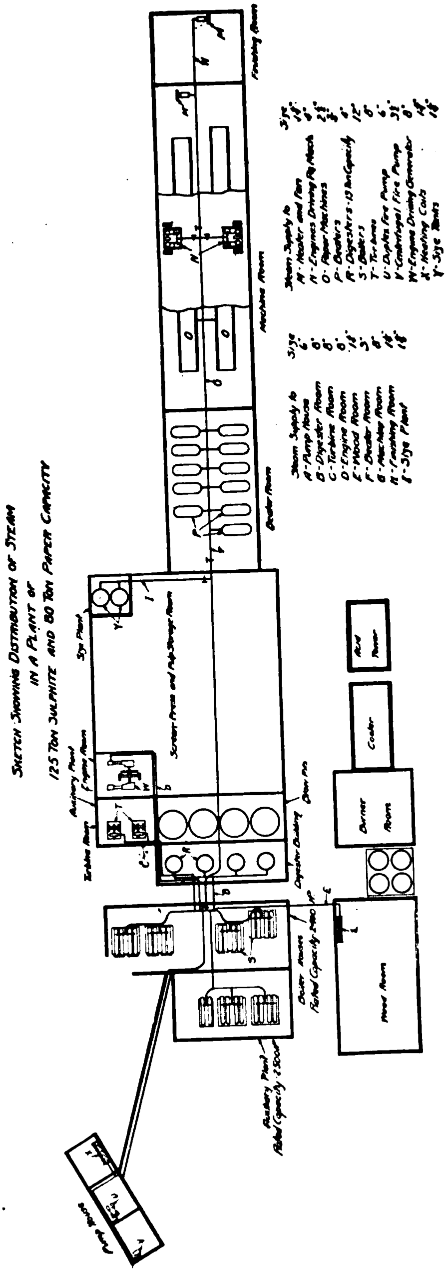

Sketch Showing Distribution of Steam
in a Plant of
125 Ton Sulphite and 80 Ton Paper Capacity
Finishing Room
Machine Room
Beater Room
Screen Press and Pulp Storage Room
Size Plant
Engine Room
Auxiliary Plant
Turbine Room
Drain Pit
Digester Building
Boiler House
Rated Capacity 2480 HP
Auxiliary Plant
Rated Capacity 2300 HP
Wood Room
Burner Room
Cooler
Acid Tower
Pump House
Steam Supply to
A - Pump House
B - Digester Room
C - Turbine Room
D - Engine Room
E - Wood Room
F - Beater Room
G - Machine Room
H - Finishing Room
I - Size Plant
Steam Supply to
M - Heater and Fan
N - Engines Driving Pap. Mach.
O - Paper Machines
P - Beaters
R - Digesters - 13 Ton Capacity
S - Boilers
T - Turbines
U - Duplex Fire Pump
V - Centrifugal Fire Pump
W - Engine Driving Generator
X - Heating Coils
Y - Size Tanks

Fig. 166.

ceded that 150 to 175 pounds pressure is pretty good practice in pulp and paper mill work. Whether or not you are operating a steam turbine and generating your own power has a bearing on the seam pressure and degree of superheat. Some arguments have been advanced in favor of the utilization of superheated steam for cooking pulp and for paper making. The author's experience about cooking with superheated steam is limited, and in general, we are not in favor of so doing. Neither do we favor the utilizing of superheated steam for operating paper mill engines and for drying paper. We have found it very unsatisfactory. Saturated steam, after passing through the engines, gives up its heat much more readily, increases the drying capacity of the machine and gives a more uniform sheet of paper. Moreover, our experience tends to show that the use of saturated steam gives a little stronger sheet of paper.

Distribution of Steam Through the Plant.

Considerations as to different kinds of pipe, types of flanges, gaskets, drip systems, etc., are ordinarily taken care of by the designing engineer. We will not attempt to enter into details on

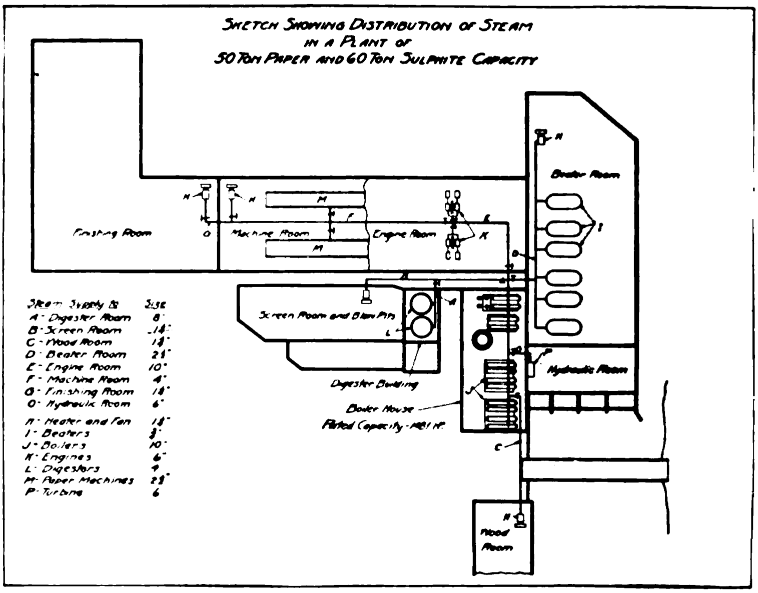


Fig. 167.

this subject in this book. A great deal of data relative to such installations, the proper sizes, velocities, etc., can be obtained from standard text books and engineers' hand books.

After operating several different kinds and types of plants, however, we are frank to admit that there are two respective types of steam mains which we favor. The first is the Holly Drip System which calls for good generous receiver separators at the engine proper. The second system which we favor is a modern drip system embodying drip connections opposite each boiler connection. In other words, a substantial drip connection on the bottom of all tees in the boiler house proper, this running to a receiver and the utilization of one trap, this connecting to the hot well. Further, a generous size of drip connection on all

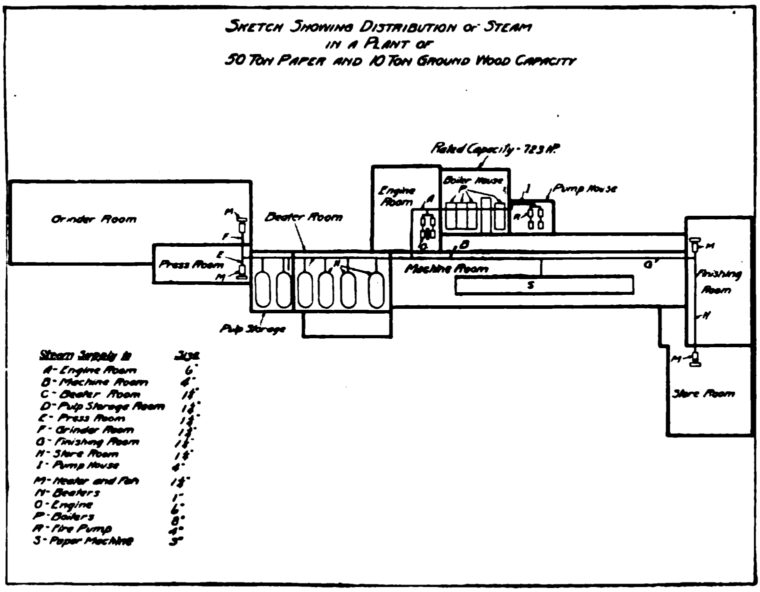


Fig. 168.

mains throughout the plant, same being piped to the receiver, and the employment of a drip from which the trap discharges to the hot well.

Closed Loop Trap Systems: The point emphasized by the enclosed trap system people is substantially that latent heat is lost when condensation is returned to an open heater. On careful examination, however, of heat reclaiming systems, such as we will show later, it will be appreciated that it is much better to segregate the waste heat units, convert these into hot water and in turn use this hot water as a substitute for live steam. In this event the alleged loss will be materially reduced primarily because the feed water temperature of the hot water in question will be kept below the flash point and not lost to the atmosphere.

The following is a description of one of the best known closed loop boiler feeding systems. This is the Farnsworth system which calls for a special type of boiler feeder and a special type of condensation pump, both designed by the Farnsworth Company and both, in the writer's opinion, highly efficient.

Figure 170 shows the Farnsworth system applied to a paper machine having a basement underneath it. This system is explained as follows:

The paper machine is divided into two sections, one of these sections to have 75 per cent of the dryers and the other section

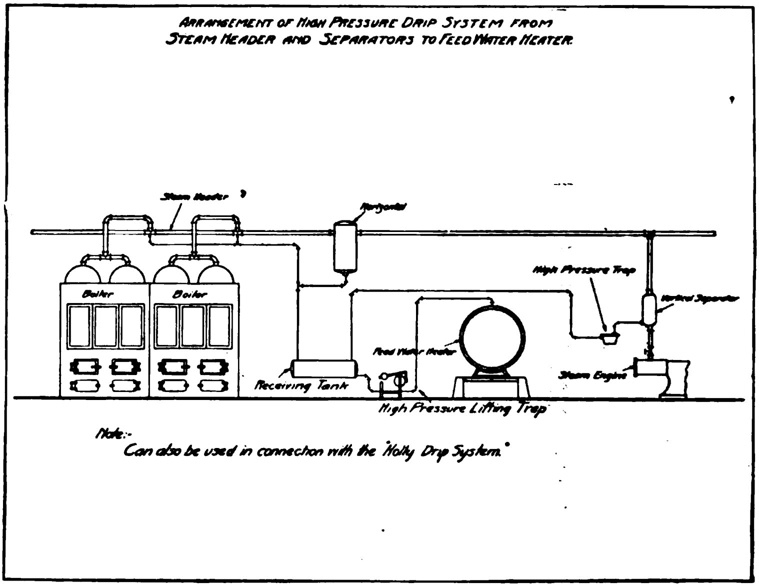
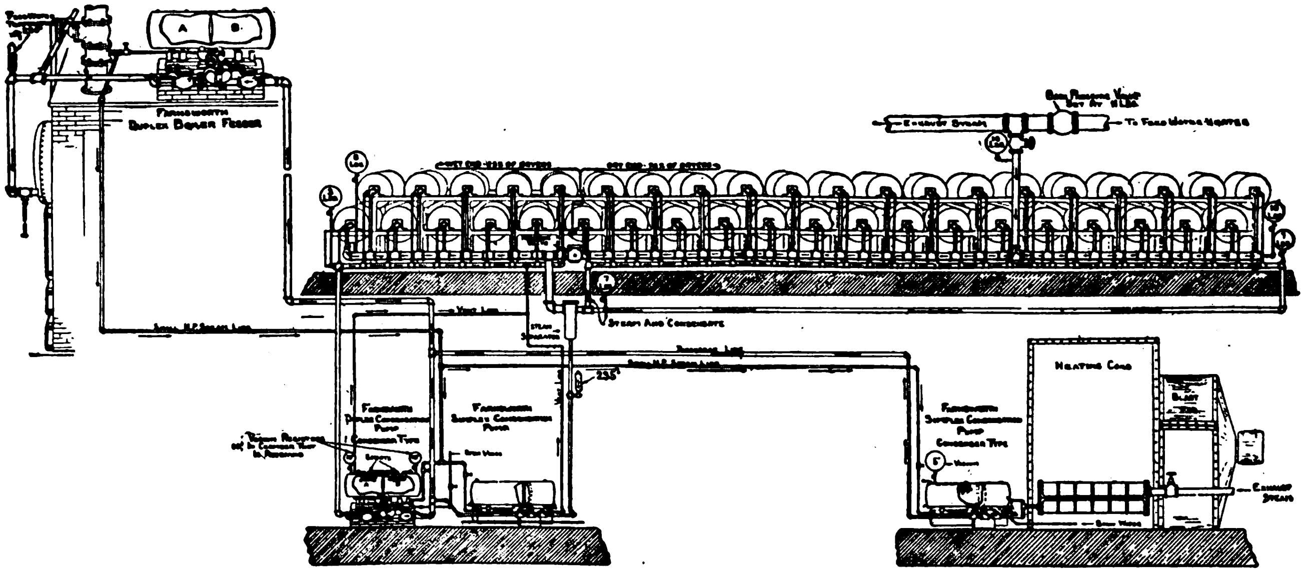


Fig. 169.

the remaining 25 per cent. The steam and return headers between the two sections are cut, and a steam separator is placed on the end of the return header for the dry end section which separates the condensation from the steam which has blown out into this portion of the return header. This steam is passed over to supply the steam header for the remaining dryers on the wet end. On the end of the return header for the wet end dryers is placed a duplex condensation pump, condenser vacuum type. This machine has cold water sprays in the top of the tank. The spray water condenses the vapors in the return line producing a forced steam circulation.

In other words exhaust steam enters the dry end of the paper machine and passes through the dryers on the dry end at a high



Courtesy: Farnsworth Co., Conshohocken, Pa.

Fig. 170.—Farnsworth system applied to a paper machine having a basement underneath it.

velocity due to the condensing of the steam in the wet end section assisted by the vacuum produced by the condensing sprays in the duplex condensation pump on the end of the return line for the wet end section. This also produces a high velocity of steam through the wet end section with the result that water and air is eliminated from both sections and a constant, even, known temperature at all times is produced.

The dryers on the dry end are hottest with a gradual decrease in temperature as the wet end is approached.

If for any reason insufficient steam should pass through the steam separator to maintain the required pressure in the wet end section steam is by-passed through a reducing valve and the proper amount is supplied.

Summing up, therefore, the steam supply line for the paper machine is connected at or near the beginning of the dry end. Steam is allowed to blow through all the dryers in the dry end section and out into the return line carrying with it all the water and air in these dryers. These dryers are, therefore, nothing more than the steam supply line for the dryers on the wet end.

The condensation is then separated from the steam that has blown through, and this steam is passed over to supply the dryers on the wet end section. The condensation that collects in the separator is drained into a simplex condensation pump. The air which enters the receiving chamber of each machine escapes through the vent.

In the closed loop boiler feeding system the condensation which is collected in the simplex condensation pump and in the duplex condensation pump, condenser vacuum type, is pumped automatically during the operation of the machine to the receiving chamber of the duplex boiler feeder located from 3 to 10 feet above the high water line of the boilers.

The duplex boiler feeder has two chambers—one of which is always receiving while the other is delivering the condensation with all its latent heat directly into the boilers giving a high feed water temperature and saving anywhere from 10 to 30 per cent of the coal. The duplex boiler feeder and the condensation pumps require only one-tenth to one-fourth the amount of steam used by the common pump because in these machines steam is applied directly in the surface of the water instead of behind a piston.

The condensation from all high pressure traps is discharged directly into the line leading to the receiving chamber of the duplex boiler feeder. The condensation from all low pressure heating systems, fan coils, etc., is drained into simplex or duplex condensation pumps and is forced up to the receiving chamber of the duplex boiler feeder by the application of live steam on the surface of the condensate in the tank while it is in the receiving position.

The Closed Loop Boiler Feeding system is a very efficient method for handling condensation because the pressure is never relieved from the surface which would lower the temperature to correspond with the decreased pressure.

Figure 171 shows the systems applied to a board mill using live steam in the dry end containing one-third of the total number of dryers; the remainder of the dryers are supplied with exhaust steam. In this case the machines which drain the paper machine are set in pits, there being no basement underneath the paper machine.

Under these conditions the live steam division of the paper machine and the exhaust steam division are each divided as in the case of Figure 170. That is to say, each division is subdivided into two sections, one section to have 75 per cent of the dryers, and the remaining section 25 per cent.

With this arrangement live steam blows through the first section on the dry end and out into the return line at a high velocity. It passes through a steam separator and over into the second section of the dry end where it is condensed, and this condensing effect, assisted by the simplex condensation pump, condenser vacuum type, on the end of the return line produces a forced steam circulation system through both sections.

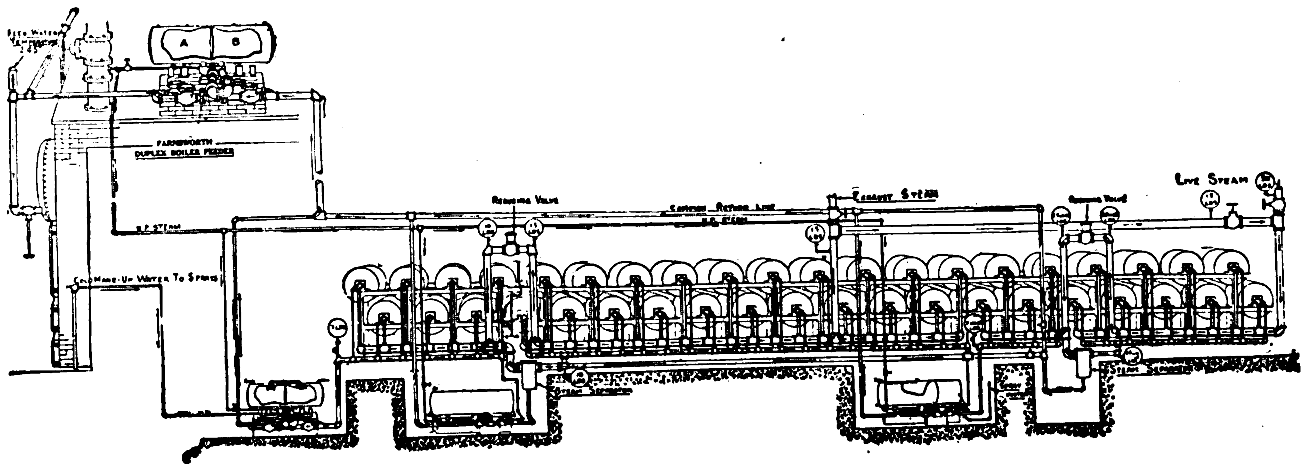
The exhaust steam division of this paper machine is handled exactly as described for Figure 170.

The dryers on the dry end are hottest with a gradual decrease in temperature as the wet end is approached. The hot dryers on the dry end set the paper as it leaves the machine. The condensation which is drained into the separator on the live steam dryers is forced to the receiving chamber of the duplex boiler feeder by the pressure carried on the dryers.

The other three machines pump the condensate to the receiving chamber of the duplex boiler feeder, and, as previously stated, all the condensation with its valuable heat units is delivered directly into the boilers.

One of the main points we want to warn against in laying out steam mains for a plant is to have any kind of installation that will make it out of the question to make repairs in each division without shutting off the complete main. The shutting off of a complete main will frequently do more harm, even if only done once a year, than operating the plant under constant heavy steam pressure for several years. Reliable shut-off valves should be provided for each department, making it possible to repair various units without allowing the mains to become cooled.

In addition to the above, we have found that more damage has been done to steam mains, and more leaks have been caused, by improper dripping than from any one other cause. It is a very easy item to so pitch the pipe, and to so provide separators, that all wet steam is taken care of when the plant is operating week days. But the important item—the neglect of which has (as we have often seen) spoiled otherwise excellent plants—is to



Courtesy: Farnsworth Co., Conshohocken, Pa.

Fig. 171.—Farnsworth system applied to a board mill.

make provision for the elimination of water pockets and to provide at least some current through the steam mains on Sundays.

We have seen steam plants leaking in hundreds of places owing to the fact that the plant is shut down dead on Sunday, the management depending on the mains tightening up on Monday. It can readily be seen that, after the pipes have been filled with water, which causes a tremendous strain, and after the joints

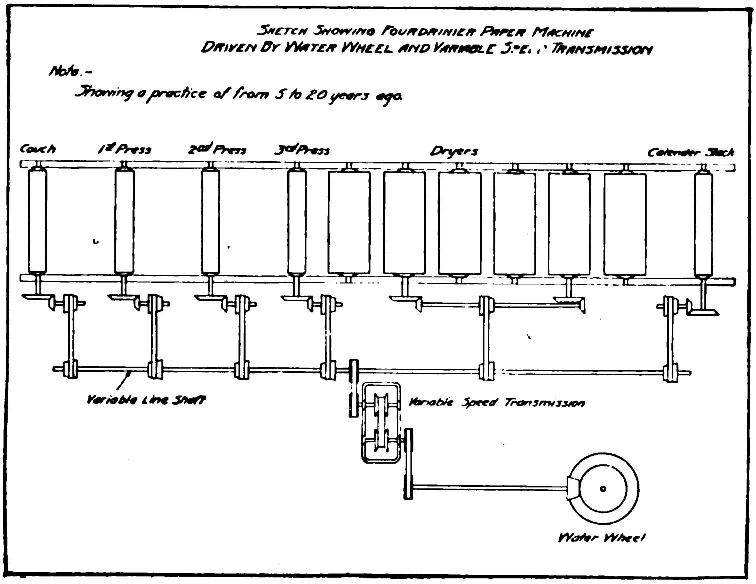


Fig. 172.

have been leaking for a few Sundays, the leaks inevitably become chronic, causing high repair cost and coal losses.

Pipe Covering.

Few items in power plant design are more important than good pipe covering. We will not dwell on this subject here because excellent information can be obtained free from the Magnesia Association of America, Philadelphia, who have gone to great expense to work out specifications covering all the uses of the products sold by the companies belonging to the association. Every operating engineer should have this literature, which will be sent free to any person interested. It will enable the calculation of just the right thickness of covering for any pipe line.

In general we might state, however, that any pulp and paper mill superintendent who has not given serious, careful and scientific consideration to proper pipe covering is simply throwing away money in an inexcusable manner.

Types of Units for Driving Paper Machines.

There are various types of units used for driving paper machines and these are used in several different combinations and connected in different ways to the steam system. It is easier to make this clear by drawings than by verbal explanation, and we have prepared a number of drawings which, we hope, will be clear without detailed explanation.

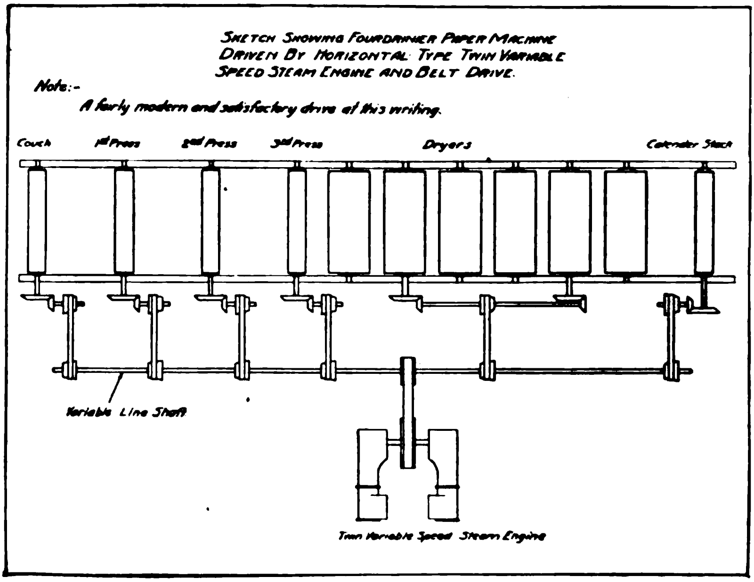


Fig. 173.

In general, there are the following systems:—Direct drive from water wheels (Fig. 172); Slow speed Corliss engines, belted direct to the line shaft (Figs. 173 and 174); High speed turbine units, driving through belts (Fig. 175); High speed turbines with speed reduction gears.

There have been recent important developments along the lines of electric drive. The earliest electrical systems consisted of constant speed motors with mechanical speed changing devices, similar to those used when the machines were steam driven. A later development consisted of adjustable speed motors.

All of the above systems employed the usual mechanical features of paper machine drive (Marshall system) consisting of main line shaft, bevel gears, cone pulleys with vertical belt drives, friction clutches, etc. This has already been touched on in the chapter on the machine room.

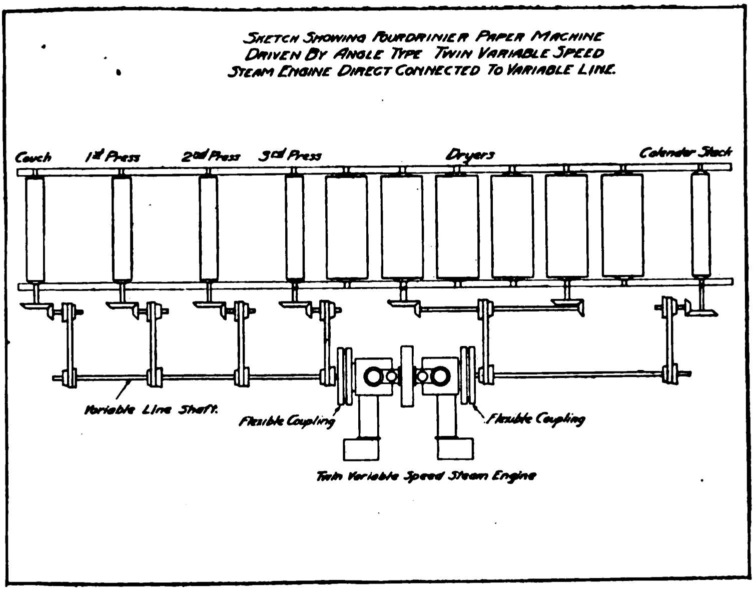


Fig. 174.

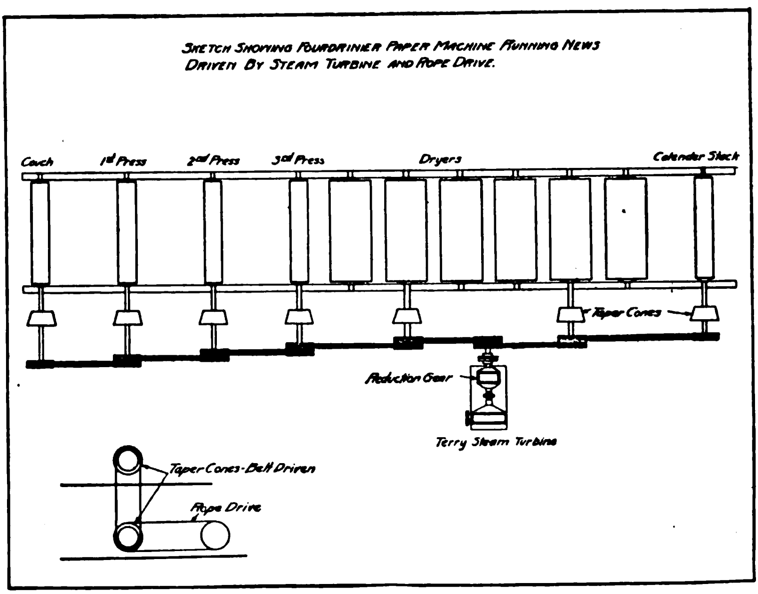


Fig. 175.

The most recent development consists of individual motors for each section of the paper machine, these motors being regulated by electrical devices. It is claimed for this system that the special automatic regulator used will maintain each of the motors in its proper relation to every other motor and to the machine as a whole. At the present time this system is just making its début in the paper industry and it seems to be succeeding. Such equipment, if perfected, will permit of higher speeds and will enable paper machines to be installed in much less space (for instance, the basement can be dispensed with) and will have many other advantages.

A still more recent development is a system employing direct connected individual steam turbines for each section of the machine, these turbines being controlled and regulated by an automatic device.

TABLE OF FRICTION AND FULL LOAD READINGS TAKEN FOR VARIABLE SPEED SHAFTS DRIVING A 156-INCH FOURDRINIER PAPER MACHINE, 60-INCH CYLINDER MACHINE AND 126-INCH FOURDRINIER.

Friction Load of 156 inches Fourdrinier Paper Machine	319 H. P.
Full Load of 156 inches Fourdrinier Paper Machine when running 30 lb. Manila Paper—Formula 60% Sulphite, 40% Ground Wood	391.92 H. P.
Power required to drive Variable Speed Shaft on 156-inch Fourdrinier Paper Machine—All machines down	132.78 H. P.
H. P. per inch width of 156-inch Fourdrinier Paper Machine when running 30 lb. sheet 60–40 formula	2.5 H. P.
H. P. per inch trim of 156-inch Fourdrinier Machine trimming 146¼ inches	2.7 H. P.
H. P. per inch of paper on 156-inch Fourdrinier Machine with deckle set at 152 inches	2.6 H. P.
H. P. required to drive 126-inch Fourdrinier Paper Machine 112-inch deckle when running on Envelope 24 x 36 inches—63½-lb. basis	237.8 H. P.
H. P. per inch width of above machines	1.85 H. P.
H. P. per inch width of paper on above machines	2.12 H. P.
H. P. required to drive 96-inch Cylinder Machine running with 84-inch deckle on 144-lb. Bristol Board	110.7 H. P.
H. P. per inches width of machine on above machines	1.32 H. P.
H. P. per inch of Paper on above machines	1.23 H. P.

All these developments are taking place because of the constantly increasing dissatisfaction with the usual line shafts, gears, friction cones, etc., which, for years, have been a troublesome feature of the back drive of paper machines. When high speeds are encountered, as in modern newsprint and bag paper machines, great trouble is experienced, not met with in the old days at lower speeds.

Consequently, there is no doubt that the new drives have come to stay. They take a long step towards the complete elimination of excessive friction, vibration, lubrication, etc.

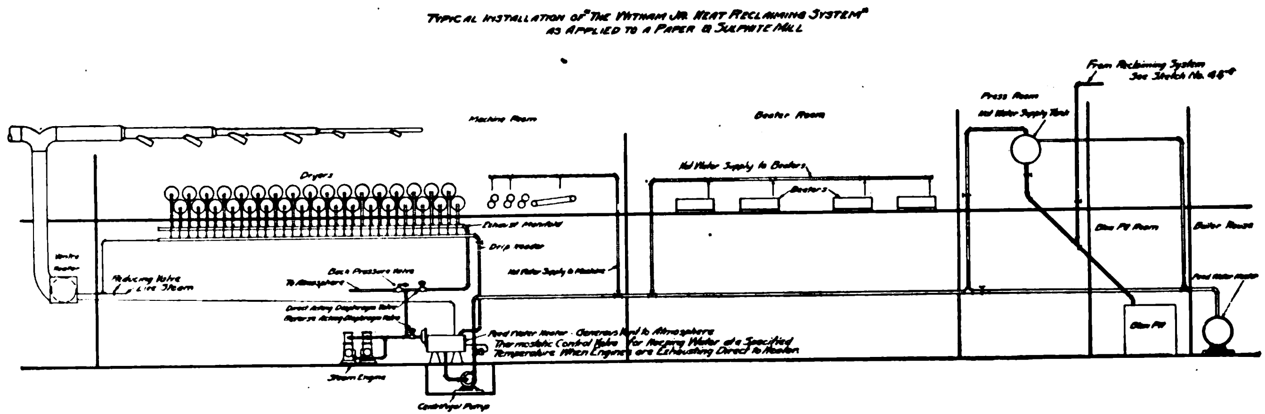

Typical Installation of "The Vitham Jr. Heat Reclaiming System"
as Applied to a Paper & Sulphite Mill
Machine Room
Beater Room
Press Room
Hot Water Supply Tank
From Reclaiming System
See Sketch No. 46
Blow Pit Room
Boiler House
Feed Water Heater
Blow Pit
Dryers
Exhaust Manifold
Drip Header
Hot Water Supply to Machine
Hot Water Supply to Beaters
Beaters
Back Pressure Valve
To Atmosphere
Reducing Valve
Live Steam
Steam Engine
Centrifugal Pump
Thermostatic Control Valve for Keeping Water at a Specified
Temperature When Engines are Exhausting Direct to Heater

Fig. 177.

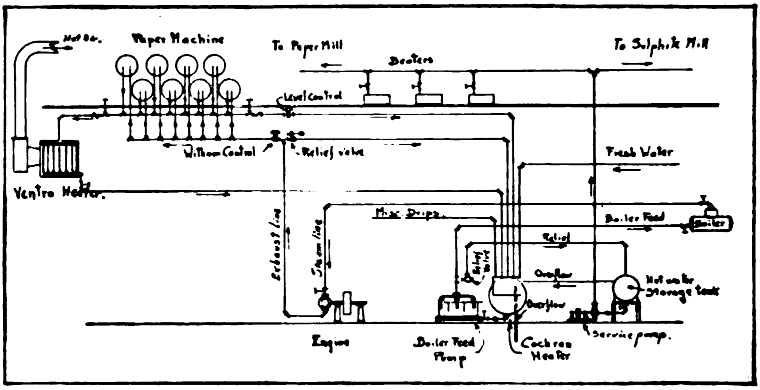


Fig. 176.—Diagram showing application of Witham, Jr., heat reclaiming system.

Distribution of Steam to the Paper Machines.

This is one of the subjects in pulp and paper engineering on which almost no two men agree. We find many engineers of acknowledged ability absolutely at variance with one another on this subject. We have prepared some drawings illustrating systems which we have found practical and which we hope will be of service as suggestions.

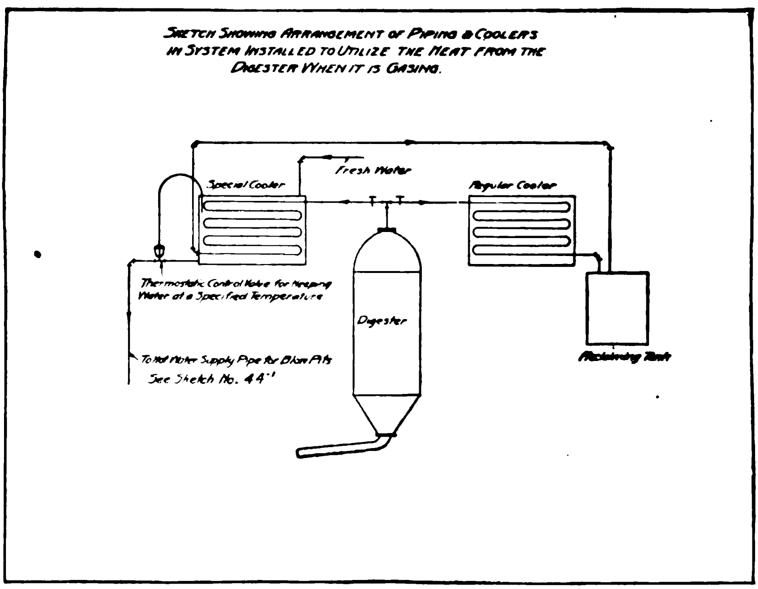


Fig. 178.

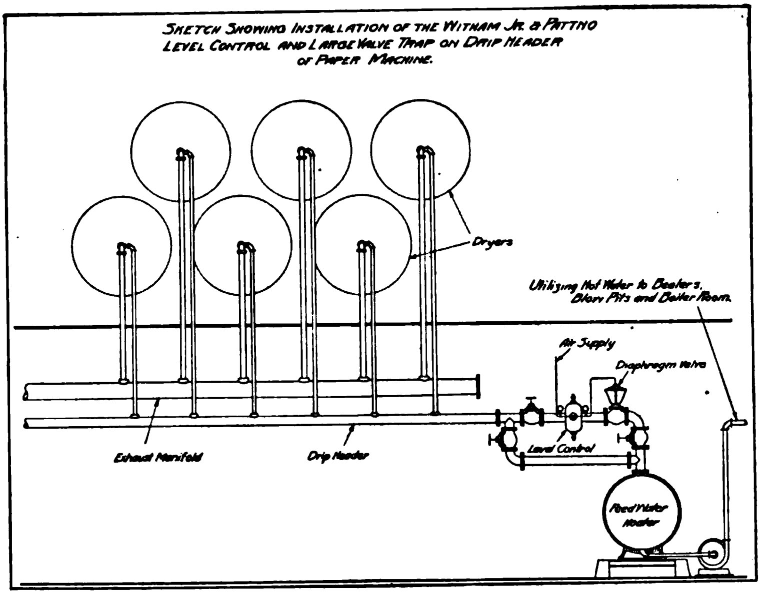


Fig. 179.

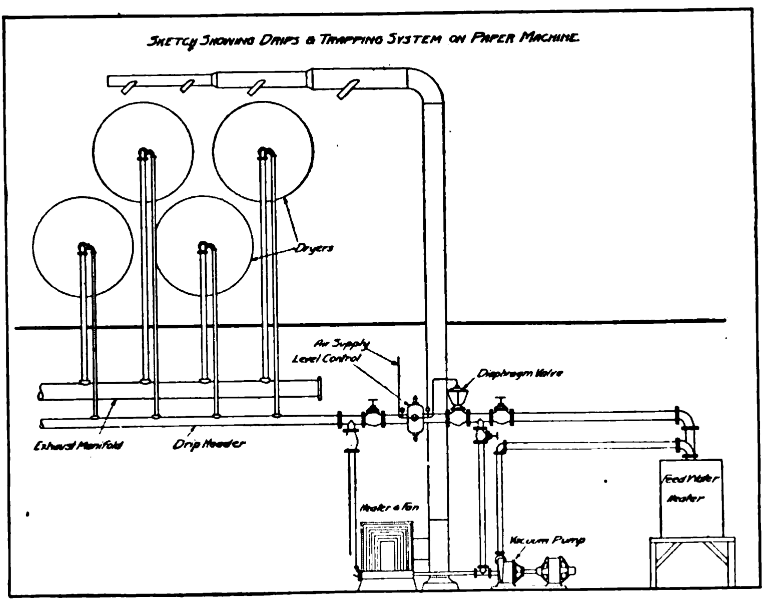


Fig. 180.

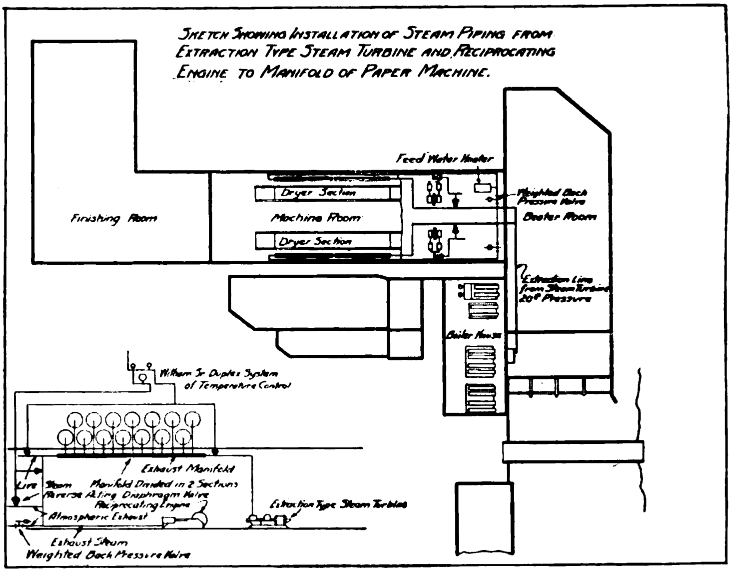


Fig. 181.

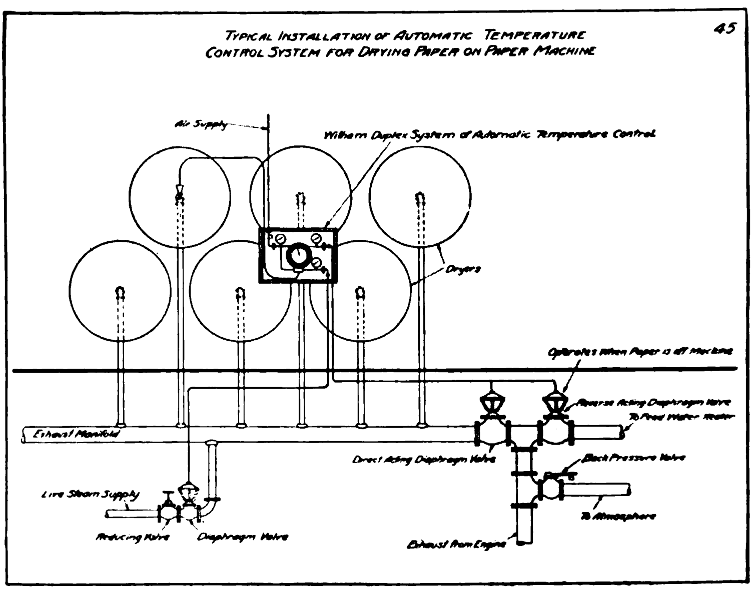


Fig. 182.—There are several types of controllers for regulating the drying of the paper. This subject has already been discussed in the chapter on the machine room. The above is a type of installation which the writer has found to be satisfactory.

Heating System for Paper Mills.

The nature of the heating system must vary in each and every mill. There are two main methods in use today—the direct radiation system and the hot blast system. In plants of any size a combination of the two is usually best. This is especially true of the finishing room where generally a large force of both male and female (nowadays largely female) help is required. Usually, however, the wood room, digester house, blow pits, screen room, beater room and machine room can be satisfactorily heated by the hot blast system.

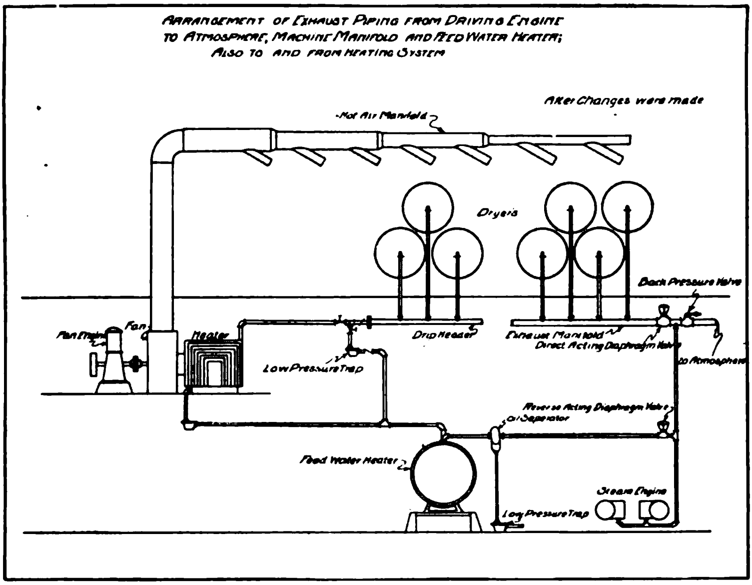


Fig. 183.

We show two illustrations of systems we have found useful. Those interested in making a detailed study on this subject, we would refer to the very complete manuals published by the B. F. Sturtevant Co., of Hyde Park, Boston, Mass., and the Harrison Safety Boiler Works of Philadelphia, Pa. We understand that these books are sent free to interested parties, and they are very complete—especially the "Exhaust Steam Heating Encyclopedia" of the last mentioned concern.

Reclamation of Heat Units.

This subject is so inextricably bound up with the foregoing topics—proper heating of pulp and paper mills, distribution of steam to the paper machine, etc., that little remains to be said, except to point out some of the writer's opinions as to the advantages. The numerous illustrations present the details of the various systems much better than could any number of pages of text.

One of the most recent developments in this regard is the reclamation of heat units from the digesters, as shown in Figure 178.

As an argument in favor of careful working out of the heat reclaiming system, we will cite the case of a plant formerly su-

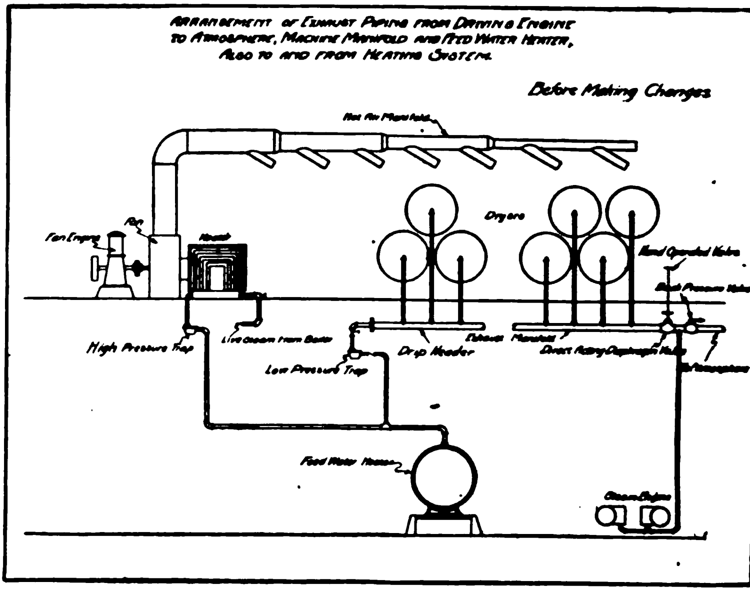


Fig. 184.

pervised by the writer which operated for twelve years under substantially the following conditions:—

The plant produced 50 tons of paper, the grades being bonds, Manilas and envelope papers. There were two beater machines —one 90-inch cylinder machine and one 126-inch Fourdrinier machine. The power plant included 5 return tubular boilers and the coal consumption averaged about 80 tons per day. Live steam was utilized for every beater, the size of the steam lines to the beaters being 1¼ inches. There were six 1800-lb. beaters. The bleaching equipment was capable of handling 20 tons of stock and the live steam lines for the bleaching equipment ranged in size up to and including 2 inches. Size was made at the plant, the water being heated by steam. Color mixing was done in the beater room, the color barrels being agitated with steam. In addition to the above barrels all waters were heated

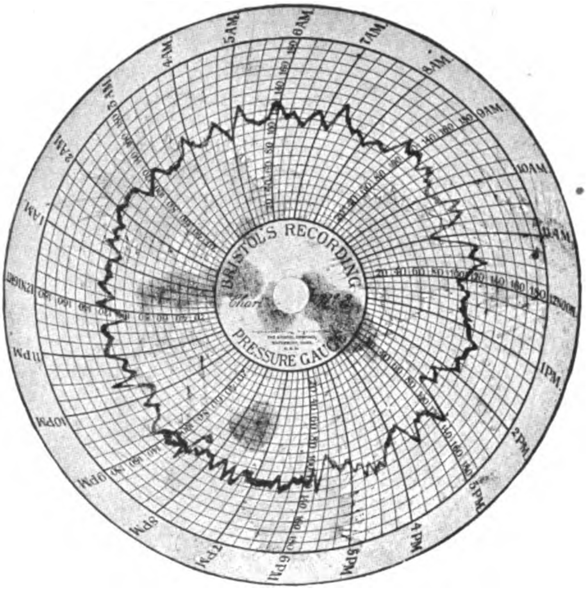


Fig. 185.—Typical boiler room pressure chart before installing modern equipment and methods.

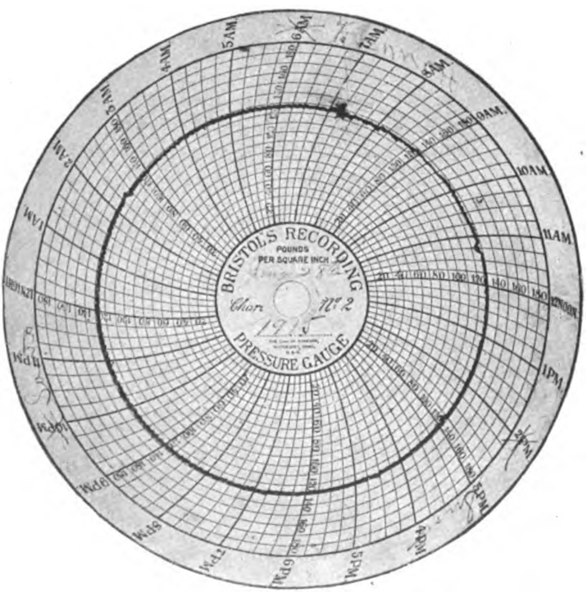


Fig. 186.—Typical boiler room pressure chart after installing modern equipment and methods. (Note regularity of steam pressure line.)

TABLE OF POWER REQUIRED PER TON OF FINISHED PRODUCT IN MILL OF 125 TON SULPHITE AND 100 TON OF PAPER CAPACITY

Dept.	Unit	Power Required	Power Required per Cord of Wood	Type
Wood Room	Jack Ladder	40 H. P.	.32 H. P.	Endless chain angle type
" "	Saw Feed Carriage	25 "	.2 "	Standard saw carriage
" "	Circular Saw	50 "	.5 "	60″ Circular Saw
" "	Conveyor	15 "	.15 "	Endless Chain V Trough
			Per ton of Gr. Wd.	
Gr. Wood Mll	Barker	15 H. P.	6 H. P.	Disc 60″ Barker
" "	Grinder	350 "	150 "	3 Pocket Grinder
" "	Screen	40 "	4.9 "	Cent. Screen
" "	Wet Press	8 "	1 "	Stand. Felt Type
			Per ton of Sulphite	
Barking Drum Plant	Barking Drum	75 H. P.	.37 H. P.	American suspended Type
Barking Drum Plant	Conveyor	30 "	.15 "	Endless chain "V" Type trough
Wood Room	Barker	15 "	.12 "	60″ Disc Barker
" "	Chipper	150 "	.75 "	4 Knife Disc Chippers 84″
" "	Crusher	30 "	.15 "	
" "	Chip Elevator	15 "	.12 "	Drag Flight Type
" "	Refiner	15 "	.12 "	Rotary Type
" "	Chip Elevator	15 "	.12 "	Belt Type
Acid Pump	Acid Pumps	30 "	.24 "	2″ Cent.
Digester Room	Acid Pumps	40 "	.32 "	8″ Cent.
Blow Pit Room	Stock Pump to Riffler	75 "	.6 "	10″ Cent.
Screen Room	Knotter Screen	5 "	.04 "	Perforated Cyl. Type
" "	Stock Pump from Riffler to Screen	135 "	1.12 "	10″ Cent.
" "	Stock Screen	40 "	.32 "	Cent.
" "	Tailing Stock Screen	40 "	.32 "	Cent.
" "	Wet Press	8 "	.06 "	Stand. Felt Type
" "	Screen Chest Agitators	8 "	.06 "	Paddle Type
" "	Screen Stock Pump	15 "	.12 "	6″ Cent.
" "	Screen Grinder	75 "	.6 "	Emerson Plug Jordan
" "	Screen Press	8 "	.06 "	Stand. Felt Type
Kraft Shred. Plant	Shredder and Pulper	250 "	2.5 "	
Kraft Shred. Plant	Agitator in Chest	30 "	.3 "	Revolv. Paddle Type
Kraft Shred. Plant	Stock Pump	40 "	.4 "	8″ Cent.
Paper Mill			Per Ton of Paper	
Beater Room	Deckers	8 "	.08 "	Revolv. Cyl. Type
" "	Agitator in deckered stock chest	10 "	.1 "	Revolv. Paddle Type
" "	Stock Pump to Beaters	20 "	.2 "	Cent.
" "	Beater 1500 lb.	50 "	.5 "	Roll and Tub 1500 lb.
" "	Agitator in Jordan Chest	10 "	.1 "	Horizontal Type Agit.
" "	Stock Pump to Jordan	15 "	.15 "	12 x 12 Trip. Plunger
" "	Jordan	225 "	2.25 "	Wagg Majestic Jordan
Machine Room	Agitator in Mach. Chest	10 "	.1 "	Horizontal Type Agit.
" "	Stock Pump to Stuff Box	15 "	.15 "	12 x 12 Trip.
" "	Stuff Pump	30 "	.3 "	Cent.
" "	Diaphragm Screen	7 "	.07 "	Flat Diap. Screen
" "	Constant speed low	85 "	.85 "	A. C. Model
" "	Fourdrinier Paper Mach.	450 "	4.5 "	4 Cyl. Angle Typevar.spd.
" "	Reels and Winders	50 "	.5 "	Upright Reels
" "	Elevators	15 "	.15 "	Hydraulic

NOTE—The plant containing the equipment as shown on this Table was of 125 tons sulphite capacity and from 80 to 85 tons of paper. This paper varied from 100% sulphite to 100% Kraft sheets.

Total Power Required in Mill Manufacturing 100 per cent sulphite wrapping paper was 3150 H. P. or 63 H. P. per ton of paper and prepared with soap by means of live steam for the washing of felts.

In the above plant in 1913 under the conditions described, the coal consumption per ton of paper ranged from 1100 to 1150 pounds. After the installation of a few modern accessories and the re-arrangement of the piping with the introduction of an efficient reclamation system, the coal consumption at this plant was brought down to approximately 600 pounds of coal per ton of paper.

This meant a reduction of approximately 40% in the coal consumption in the boiler room. It also allowed of a reduction in labor of one man one each shift, or three men from the total power plant crew.

In connection with this improvement it is interesting to know the difference in the two steam pressure charts shown in figures 185 and 186.

Estimate of Power Required in Pulp and Paper Mills

It is manifestly impossible to furnish any estimate of the power required for the manufacture of pulp and paper that will cover all different cases, or any particular case, by direct application.

The length of conveyors alone, which will call for a considerable variation in power, will never be the same in any two plants. The boiler horsepower required for the digesters will depend on the manner in which the cook is conducted at any particular mill. Many other factors will vary. However, the figures given here are based on practical experience and care has been taken to mention what is not included in any of the estimates.

It is assumed that the wood is received at the mill in 4-foot or 2-foot lengths and that the preparation begins with the removal of the bark.

It is assumed that log hauls and other conveyors are of average length, not exceeding 500 feet in any case, and of modern construction.

It is also assumed that the entire plant runs 24 hours per day, except Sundays, with the exception of the wood room, which is assumed to run 9 hours per day.

Grinders are to be driven by electric motors or hydraulic turbines through direct connection. All other equipment, except paper machines, is assumed to be motor driven, either direct connected or otherwise. Paper machines are assumed to be driven by their own separate engines, turbines or electric motors.

It is not necessary to add anything to the figures given, as they have all been calculated very liberally so as to be always on the safe side. Allowance is made in all cases for normal stoppages, but it is assumed that all equipment, motors, shafting, etc., is maintained in normally perfect condition by competent mechanics.

Thus, the estimate will furnish a skeleton to which individuals can add, subtract or otherwise adapt, so as to suit the particular conditions with which they are confronted.

EQUIPMENT FOR A 100-TON GROUND WOOD MILL

Number of Units		Horsepower Required *Min.*	*Max.*	*Average*	
1	Log Haul	8	20	15	
1	Gang Saw (1-60" saw slashing 4' wood)	8	40	20	
1	Conveyor to barking drums*	5	7	6	
1	Barking drum installation	50	75	60	
	or				
10	5 ft. barkers (one always held in reserve)	70	120	100	
	or				
1	*Centrifugal pump for pond if wood is floated to barking drums instead of being handled on conveyor.	12	12	12	
1	Splitter	1	4	2	
1	Conveyor to grinder room	6	9	8	
	Total for Wood Room			45	(24 hr. av.)
	Using barking drums (operation 9 hours only)	78	155	121	(9 hr. av.)
16	assumed to be connected in lines of 4 each. (54) x (27) inch 3-pocket grinders, capacity 6.67 tons per 24 hours. One grinder assumed as idle.	6000	6800	6500*	
4	Pumps for supplying pressure to grinders (if driven directly by turbines)	70	70	70	
1	Centrifugal pump for white water	50	50	50	
1	Centrifugal pump for stuff	30	30	30	
1	Silver screen	5	5	5	
8	Centrifugal screens	120	120	120	
	or				
6	Twelve plate screens, coarse	12	12	12	
25	Twelve plate screens, fine	50	50	50	
1	Pump for general water supply (capacity 3,000,000 gallons per 24 hours)	80	80	80	
	Fan pump to deliver stuff to wet machines, or deckers	70	70	70	
	Total grinders and screens	6507	7287	6987	
	Total for Wood Room and Grinder Room	6507	7442	7032	I
	IF PULP IS TO BE LAPPED FOR STORAGE OR SHIPMENT				
15	Wet machines, 72-inch face	140	180	160	II

*For news grade of g. w. pulp. For fine grades, as 8000 h. p. may be used for 100 tons of pulp.

IF PULP IS TO BE PREPARED FOR IMMEDIATE MANUFACTURE INTO PAPER

Number of Units		Horsepower Required *Min.*	*Max.*	*Average*
12	Deckers or pulp thickeners..........	36	36	36
1	Centrifugal pump to beaters.........	25	75	40
1	Agitator in deckered stock chest......	15	15	15 III
	Total........................	76	126	91
	Total *power required to make 100 tons lapped pulp per day (I + II)..............	6647	7622	7192
	Total *power required to make 100 tons deckered stock per day (I + III)...........	6583	7568	7123

EQUIPMENT FOR 100-TON SULPHITE MILL
(9-hour operation)

1	Log haul.........................	8	20	16
1	Gang saw (1–60″ saw cutting 4″ wood)	8	40	30
1	Conveyor to barking drums*........	5	9	7
1	Barking drum installation (2) drums..	100	150	120
1	Barking machine (5 ft.) for handling wood imperfectly prepared in drums	7	12	10
	or			
20	5 ft. barkers (1 always in reserve)....	140	240	200
1	*Centrifugal pump for pond if wood is floated to barking drums or barkers instead of being handled on conveyor.	12	12	12
1	Splitter..........................	1	4	2
1	Conveyor to chippers*.............	8	12	10
1	Centrifugal pump if wood is floated to chippers......................	12	12	12
3	7 ft. chippers (1 running only part of the time)......................	120	275	200
2	Crushers.........................	50	80	60
3	Shaker screens for chips............	12	24	15
1	Conveyor to shaker screens..........	3	3	3
1	Conveyor to chip bins..............	20	30	25
	Total for Wood Preparing Plant.................	342	659	498 (9 hr. av.)
	Operating 9 hours only.........................			186 (24 hr. av.)
	Acid Plant, Digester House, Etc.			
1	Pump for general water supply (capacity 7,000,000 gallons per 24 hours. (Newspulp)....................	100	100	100
1	Elevator for limestone.............	10	10	2
1	Pump for tower system............	15	15	15
5	Digesters 49 ft. high x 15 ft. diameter, holding approximately 26 cords chips and yielding 12 tons pulp (air dry) per cook.			
1	Centrifugal pump for pumping stock from blow pit tanks to knotters....	25	25	25

*Exclusive of power required for heating buildings in winter, providing ventilation for grinder room, regrinding slivers from silver screen, transportation of lapped pulp by conveyors or trucks to storage or cars, illumination, etc. Neither is any allowance made for hydraulic pressing of pulp taken from wet machines.

Number of Units		Horsepower required *Min.*	*Max.*	*Average*
4	Knotters	6	6	6
1	Centrifugal pump for pumping stcok from riffler to head box of screens	40	40	40

It is assumed that the stock is sluiced from the blow-pits to storage tanks below and is pumped from them to a mixing box from which it flows to the knotters, hence to the riffler, from the lower end of which it is pumped to the head box of the screens.

10	Centrifugal screens, including secondary screens	175	175	175
1	Screenings, jordan or other grinder	75	75	75
1	Centrifugal pump from screens to wet machines or deckers (not required if mill is arranged so stock can gravitate from screens) which would ordinarily be the case	30	30	30
Total for	Wood Preapring Plant and Digester House, etc	466	1135	654 IV
IF PULP IS TO BE LAPPED FOR STORAGE OR SHIPMENT				
7	Wet machines, 72 inches face	84	84	84
IF PULP IS TO BE PREPARED FOR IMMEDIATE MANUFACTURE INTO PAPER				
12	Deckers, 72 inches face	30	30	30
1	Centrifugal pump to beaters	20	70	25
2	Agitators in deckered stock chests	30	30	30
	Total	80	130	85 VI
Total* power required to make 100 tons lapped sulphite per day (IV + V) =		550	1219	738
Total* power required to make 100 tons deckered stock per day (IV + VI) =		546	1265	739

EQUIPMENT REQUIRED FOR MAKING 100 TONS NEWSPAPER PER 24 HOURS

4	Beaters (25 ft. x 11 ft.) usual Hollander type	120	150	140
4	Stuff chests with agitators	30	45	40
2	Pumps for pumping stock from chests to jordans	40	40	40
2	Jordans	240	300	280
1	Dissolver for clay	5	5	5
2	Agitators for clay water	10	10	10
2	Paper machines, total power required for all parts of drive as well as for stuff pumps, suction pumps, calenders, reels, slitters, blowing system, etc., but not boiler horsepower for dryers	850	1000	950
1	Pump for general water supply, capacity 3,000,000 gallons per 24 hours	60	60	60
	Boiler horsepower required for dryer	800 to 900 B.H.P.		

*Exclusive of power required for heating and lighting buildings, ventilating digester house, transporting lapped pulp by conveyors or trucks to storage or cars, hydraulic pressing of lapped pulp, operation of save-alls, etc.

The power required to drive paper machines [1] varies greatly with their width, speed and other conditions obtaining at individual mills. In general news machines from 140 to 170 inches in width require from 400 to 500 h.p. for the entire machine from screens to winder, both constant and variable speed shafts, when running at about 600 feet of paper per minute.

Book machines, ranging in width from 110 to 140 inches wide require from 150 to 250 h.p. Machines for fine writings, from 80 inches to 110 inches wide, require from 50 to 125 h.p.

The speed of modern news machines generally at least is 600 feet per minute,[2] and more recently built machines are frequently run much faster; book machines run from 150 to 250 and writing machines from 60 to 175.

Use of Estimates of Power Required

With a little ingenuity, requiring no great amount of mathematical ability, the above estimates can be made the basis for a great many calculations. For instance, the total power required to make a particular grade of paper in given quantity per day can easily be figured out. Suppose the paper is a news containing 20 per cent sulphite and 80 per cent ground wood. Obviously, the power required for the sulphite for 100 tons of such paper will be 20 per cent of the paper shown in the tabulation for a production of 100 tons of sulphite per day. Similarly, the power required for the ground wood will be 80 per cent of that required to make 100 tons of ground wood per day. Adding these together, and to the sum adding the power required to make 100 tons of paper per day, will give the total mechanical horsepower required. To this can be added the boiler horsepower required for the digesters and the dryers on the paper machine. This will give the total horsepower required and the necessary installation of boilers and prime movers can be figured from this from data supplied by manufacturers of such equipment, after a suitable figure has been added to take care of heating in winter, lighting, machine shop, blacksmith shop, carpenter shop, coal and ash conveyors, etc.

The figures given for the manufacture of paper will hold true for most usual kinds of paper, such as news print, ordinary book, magazine, writing, wrapping, bag, hanging and other such papers. For fine writings, specialties, etc., the power consumption will, of course, be greater per ton of production.

With some adaptation the estimates made for a sulphite mill will apply to a sulphate, kraft, or soda mill. From the blow pits on the figures will be about the same. The boiler horsepower for the digesters will be different and no general figures could be given for the recovery systems as these vary tremendously in the number of pumps, agitators, etc., they employ.

[1] See also table, page 448.
[2] Excepting in the case of machines of considerable age.

XVII. Testing of Paper and Paper Materials.

Inasmuch as this is not a work on analytical chemistry, or even on such portions of analytical chemistry as pertain to the paper industry, it is not our intention to give detailed instructions for analyzing the various materials which are used in a pulp and paper mill.

The Technical Association of the Pulp and Paper Industry appoints committees from time to time to investigate standard methods of testing, and such methods as are approved are discussed in detail from the practical point of view in "Paper" and other journals. The Canadian Association has also done some excellent work along these lines, which is also reported in detail in the various journals.

Griffin and Little, in "The Chemistry of Paper Making," give a great deal of useful information on this subject as well as an excellent general outline of chemistry as it relates to the pulp and paper mill.

The testing work of a modern pulp and paper mill can be roughly classified as follows:

(1) *Chemical testing or analysis,* covering all raw materials such as sulphur, lime, soda ash, sulphate of soda, bleach, alum, size, etc. Also coal, water, lubricating oils, building materials, paints and miscellaneous materials used in the construction and operation of a large modern industrial plant.

(2) *Paper Testing,* that is a series of standard tests made on the product being produced by the mill at regular intervals so that an accurate record can be kept of the quality of the product and the efficiency of the plant, and so if anything is going wrong it can be detected and remedied before much harm is done. The nature of these tests will be described more in detail later on.

(3) *Microscopic Testing.* Frequently examination of paper or of pulp with a microscope is necessary to detect the presence of particular materials. Certain solutions are used in connection with the microscope to give characteristic colorations with different fibers.

Chemical Control of the Mill.

Chemical control enables a manufacturer to know and realize the value of his product so that he can guarantee every pound of it. Such a guarantee is a liability, for it must be lived up to at all times, in spite of variations in raw material, labor difficulties, weather conditions and other variable factors.

Chemical control is one of the chief items in the list of factors which enable a manufacturer to convert this guarantee, which he is compelled to give, into an asset instead of a liability. Moreover, continued watchfulness for defects helps to build up the good will of the concern and to establish a firm reputation as a reliable producer.

Paper making is a peculiar industry in that it is in part mechanical and in part chemical. The chemical and mechanical aspects of the problem are so interwoven that it is hard to say where one begins and the other ends. There are some paper makers who have risen from the ranks to be superintendents who almost ignore the chemical aspect of the industry, leaving whatever attention is paid to the chemical operations of the plant to the part of a chemist, who may or may not be competent to discharge such important duties. On the other hand, there are men trained as chemical engineers in charge of large paper industries who pay little attention to the enormous and important problems in mechanical engineering constantly arising. Either of these attitudes is wrong.

Chemical control does not mean having a laboratory with some glassware and balances and a man (usually a young chemist just out of a technical school) confined to the laboratory, testing and analyzing such samples as are sent to him from time to time. It means having a man experienced in the art of making pulp and paper, and at the same time with a broad chemical education, so that he can investigate all mill problems and work out new ideas, and such a man must have sufficient prestige and authority to be able to carry out such improvements as may suggest themselves to him after they have been submitted to careful analysis and discussed with his associates. Such men are not easy to find and the mill is to be regarded as fortunate which possesses such a man.

With increased introduction of chemical control in pulp and paper mills there has come about a more efficient utilization of fuel and of many of the raw materials consumed, such as clay, sulphur, limestone, soda ash, bleach, dyestuffs, etc.

Some of the problems the mill chemist will have to wrestle with are investigations into water conditions from time to time, making size emulsions, determining proper proportions of alum, the proper furnish of raw stock, the proper colors, etc.

In the sulphite mill the need of a chemist or chemical engineer is perhaps more obvious than in the paper mill since the process is more distinctly chemical. Chemical control steps in at the very first stage of the process—regulation of the burner gases in order to prevent formation of SO_3 and consequent formation of the undesirable calcium sulphate or gypsum in the digesters, etc. Following this is the proper preparation of the raw acid and cooking acid and the whole subject of reclaiming, the maintenance of high free and low combined. There is an opportunity here for the chemist to apply as much theoretical chemistry as he knows. The problems are very complex and it is generally realized that many improvements are yet to be made which must wait for adequate scientific consideration of the general laws governing the various reactions.

One of the most important opportunities for chemical control is in the cooking operation itself. Moisture in the wood must be ascertained in order that the cook may know the nature of the raw material he is handling.

Chemical control does not necessarily imply having a large force of trained chemists. There are many chemical tests which any intelligent workman can be taught to make at regular intervals. The workman may not understand the underlying causes of the reactions, but that does not prevent him from following directions, and entering up the burette readings on a form. Frequently the chemist can greatly simplify such tests by adjusting his standard solutions so that burette readings will give percentages directly without any calculation. For instance, acid makers can be taught to make the necessary iodine and caustic titrations to estimate total and free SO_2. If the standard solutions supplied to them by the laboratory are made up exactly 1/16 N., then a 2 cc. sample of acid will give a burette reading which will give the percentage of SO_2 directly when the decimal point is moved one place to the left. This method assumes the specific gravity of the acid to be 1, which is, of course, incorrect, but the error introduced in this way is not enough to vitiate the result for practical purposes.

Similarly, men can be taught to make simple chemical estimations instead of using a hydrometer in making up bleach. The use of the hydrometer in this connection is very inaccurate, on the other hand many mills have no chemist, and in many mills which do, the trouble of taking samples and sending them to the laboratory is considered not worth while.

Practically all the chemical tests connected with the operation of boiler feed water treatment systems can be handled by workmen once they are shown the routine of the operation.

The writer suspects that one reason so many mills seem obstinately backward in introducing chemical control is because so many chemists shroud their operations in so much mystery that they antagonize the non-chemical men about them. In reality, the majority of chemical tests are absurdly simple compared with many of the other duties of intelligent workmen, and there is no reason why, wherever a chemical test is absolutely necessary, it cannot be carried out if the chemist will supply a simple method for doing it. Of course, the chemist should not load the help down with so much work of this kind that they will have no time for their more ordinary duties. We have seen mills, in more than one industry, where foremen and others were kept so busy filling out forms and making reports of a complicated nature to send back to the office or laboratory to satisfy some alleged "efficiency expert" that they became mere clerks to the great detriment of the operations over which they were supposed to exercise control.

Paper Testing.

Paper may be examined from three different points of view, physical quality, mechanical quality and composition.

The various tests classified under physical testing are: weight, thickness, bulk, strength, stretch, sizing, etc.

The chief mechanical test is for strength and this is subdivided into tests for tear, punch, bursting, etc.

Under composition falls the determination of the materials used in making the paper and their proportions.

In addition to the above tests, special tests may be used on special grades of paper, viz., absorbency and permeability for blotting papers, resistance to blood in butchers' papers, etc.

In most cases no one of the above tests will give an accurate working knowledge of the paper. Moreover, frequently some one test may show the paper to be of excellent quality, but when this paper is put to use it is found to be worthless; consequently the nature of the test used on the paper must be in accordance with the treatment the paper will encounter in actual use. For example, for testing strength there are several machines in general use which give the punch test, bursting test, tear test, etc. It is often quite desirable to have a sheet of paper comparatively low in punch test but high in tear, for example, a bag paper. A punch test applied to such a paper, or to any paper for that matter, shows the hardness and rigidity of the sheet. However, this is not what should determine the value of a bag sheet. A thin sheet of celluloid would test very high on such a machine and would have no value at all for bag manufacture, and this is only an extreme case of the conditions prevailing with some papers. Consequently, the sheet to be tested must be dealt with in such a manner that its tearing resistance will be shown and the extent to which the fibres will peel when they are torn apart. A wrapping or bag paper that peels when torn will be much better than one that does not. A punch test will not show this peeling quality at all. In fact, if two sheets of bag or wrapping paper were made, one stiff and hard with little crossing of the fibres, the fibres beaten short and the sheet well colored and sized, and the other sheet made soft and flexible, with the fibres brushed out long and interwoven on the wire, the punch test would show the first sheet to be the better of the two, as it would give a higher test. In reality the second, from the point of view of service, would be far the better sheet and a tear test would indicate this, as would also a peeling of the fibres.

The above remarks will illustrate the necessity not only of making tests, but also of making the right kind of tests.

The following are descriptions of some of the commoner paper testing machines with some remarks as to the purposes for which they are useful.

The Mullen Testing Device: The construction and operation of the Mullen Paper Tester is almost too well known to require description. By means of a hand wheel the pressure is

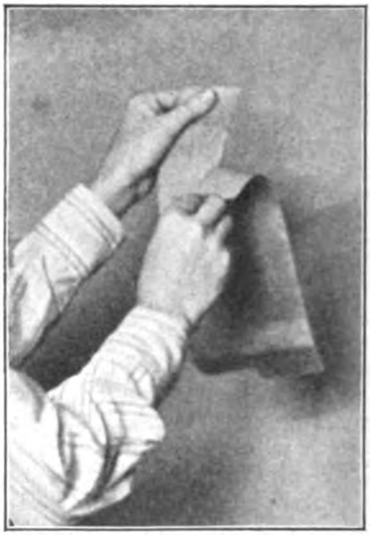


Fig. 187.—Photograph showing manner in which fibres peel when a sheet of wrapping paper is torn naturally by the hands.

increased on a column of glycerine which drives a small rubber ball through the sheet of paper which is tightly held between two flat surfaces. The pressure is read on a dial graduated so as to give the breaking strength in pounds per square inch.

The operation of this machine is very simple and tests can be made very quickly. Consequently, it has been very widely adopted throughout the paper industry and for some grades the Mullen Test is really a very fair criterion of the strength (or the particular variety of strength required). However, as previously explained, for many kinds of paper the Mullen Test is of very little value and is frequently positively misleading.

The Schopper Tester: This machine measures the strength required to tear paper and other materials. It is very accurate and registers the tearing strength throughout the whole period that the paper is being torn. However, this machine is very intricate and expensive and is not adapted to making quick tests and consequently is not suitable for the ordinary commercial and manufacturing purposes of the paper industry.

The Witham Tear Testing Machine: This machine imitates the tear given to a sheet of paper by the human fingers but in such a manner that the weight necessary to effect this tearing is registered accurately automatically down to small fractions of a gram. The construction and method of operation of this machine can readily be seen from the illustration.

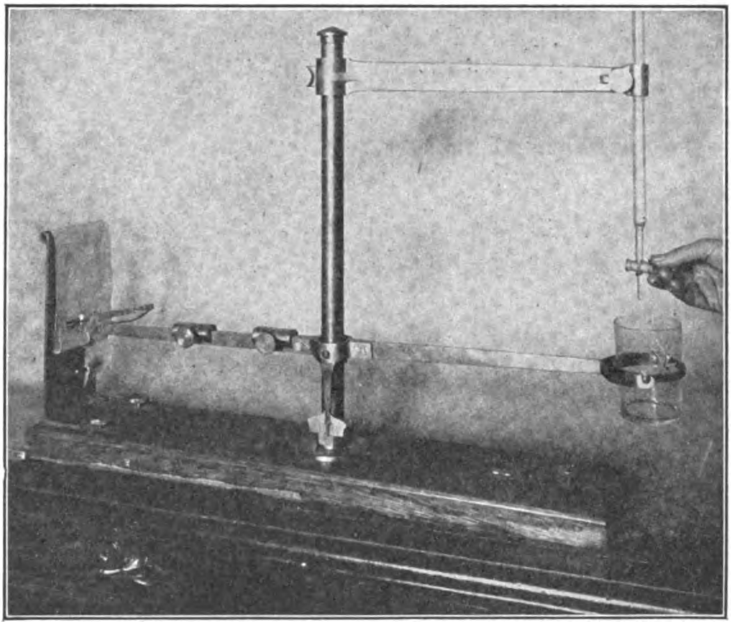


Fig. 188.—Original form of the Witham tear testing machine.

The paper is torn to a certain distance whereupon a round hole is punched in the sheet—insuring an absolutely fair start or co-efficient for the tear. This is important because a sheet of paper partially torn will allow the tear to continue with much less stress than would be required to start the tear in the first place. When the paper is fixed in the device the liquid is turned on and the weight on the balance gradually increases by the dropping of the liquids. When the paper tears the operator turns off the liquid and reads the burette.

The Widney Testing Machine.[1] This is a very useful machine for determining the stiffness, resilience and point of yield in any

[1] See: "The Widney Tester," C. D. Allen, "The Paper Industry," June, 1919, page 208.

pliable material. The tearing resistance of paper can be definitely determined in ordinary units. This machine is especially applicable to heavy papers, boards, etc., where stiffness is one of the most important properties.[1]

The Webb Tester. This is a testing machine of the puncture type, which gives more satisfactory results than the Mullen Tester and which can be used for certain products such as fibre board, for which it is not possible to adapt the Mullen machine. In addition to the puncture test, the Webb machine may be used for tensile tests, elongation tests and compression tests. While its use was developed in connection with the testing of fibre boards and corrugated fibre containers, its usefulness is not confined to this class of materials. It can be used for testing any kind of paper, cardboard, building boards, fabrics, etc.

System of Making and Recording Tests.

The following is a description of the tests and the method of recording them which the writer has found suitable, after many years of experimentation, for controlling the quality of the product of a large paper mill.

The Technical Bureau.

One of the chief points to take care of in maintaining a Bureau of Tests, is such an organization that the mill men as a whole do not take it as a spying system upon their activities. In other words if the personnel and the activities of the Bureau of Tests can be so woven into the manufacturing end of the game so as to serve for reproducing facts which in turn may be posted on the Bulletin Board for the employee, a tremendous amount of good will come from this organization.

We have stated that it has been our experience that a happy medium may be arrived at, by which a tremendous amount of time is not wasted and money spent on elaborate analyses of materials which usually the seller is capable of furnishing without the mill necessarily maintaining an elaborate analytical department for this purpose. As we have said before the ultilization of the Bureau of Tests for checking the paper as it is being made, thereby preventing the manufacture of poor paper and incidentally checking various points of manufacture, as relating to the cost during the operation, to our minds constitutes its chief function.

This system calls for two departments—a Bureau of Chemistry and a Bureau of Physical Tests. These departments work more or less in conjunction with each other but yet each have their definite duties. The Bureau of Chemistry finds its work principally in the scientific valuation of purchased raw materials

[2] See complete illustrated article by J. D. Malcolmson in "Jl. of Ind. & Eng. Chem.," Vol. II, No. 2, page 133, February, 1919.

SULPHITE - MILLS
EFFICIENCY of CHIPPER OPERATIONS

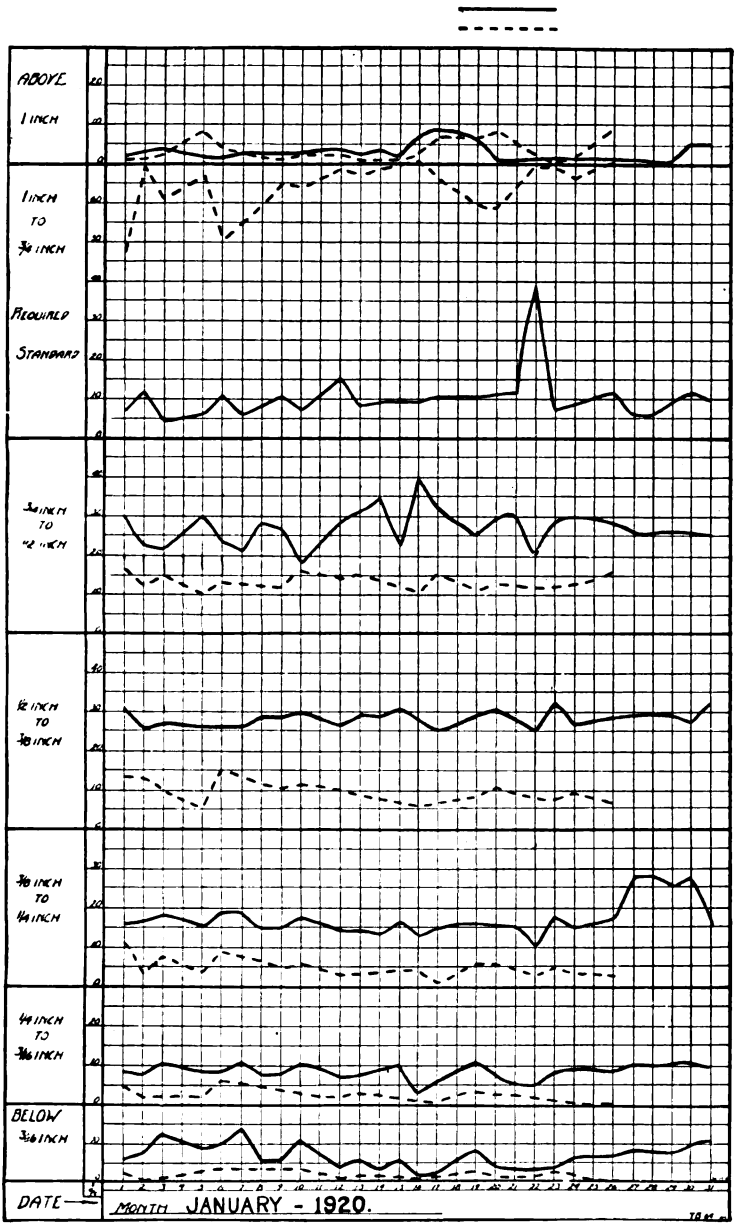


Fig. 189.

going into the manufacture of pulp and paper and also is engaged in testing the efficiency of these various purchased raw materials as utilized by machinery and workmen in the plants—such as coal, sulphur, limestone, rosin, alum, etc. In conjunction with the above all stages at which the quality of the pulp is apt to be destroyed, are constantly inspected and checked. The quality of the wood is carefully watched—its moisture content and soundness. By means of laboratory screens, the efficiency of the sizes of chips made in the chippers is carefully regulated in order to aid the digester cook further on in the process, to secure more uniform cooking conditions. A large blue print (Figure 189) is posted on the Bulletin Board for the benefit of the workmen, illustrating various percentages of different size chips from day to day. It is quite essential in the modern sulphite mill of today to have installed a system for checking the various operations of the sulphite process, such as burner gas temperature, SO_2 content, condition of the acid in the towers and finishing tanks, temperature of cook, blow, etc. The following charts are typical of the manner in which these facts are recorded:

Figure 190—Acid Room Report; Figure 191—Screen Room Report; Figure 192—Press Room Report; Figure 193—Stock in Water Report.

These all go to show the extreme care necessary in checking up this one operation not only from the standpoint of maintaining quality but also of keeping down rising costs of manufacture by the elimination of needless waste of materials. These charts are self-explanatory and by their means the executive is enabled to trace the history of any cook blown beginning with the wood pile up to the time it reaches the wet presses, at which stage further inspection takes another course.

In the beater room, as an aid and check upon amounts furnished to the beaters, the beatermen are supplied with data, as in Figure 194. Another such chart indicates the amount of rosin to add for the different basis weights of paper being run.

One of the next steps is a careful checking of each roll of finished paper as it is finished on the machine. As the finished reel is cut up into rolls, each roll is stamped with the name of the mill, the machine tender's name, date, grade, weight and also reel number, thus enabling operators who finally pass upon the quality of the paper to reject any rolls that appear to be below standard. At the end of each machine we have a paper inspector responsible to the Bureau of Chemistry, who takes from the finished reel three samples 12 inches wide and in length each sample taking in the full width of the reel.

He then takes one sample, folds it and carefully weighs it in grams on an analytical balance sensitive to .01 of a gram. The sample is then placed in an electric oven and allowed to remain for about two minutes depending upon the weight of the paper. The dry sample is then weighed and the percentage of

ACID ROOM REPORT

Date 4-2-20

	First Tour Lbs.		Second Tour Lbs.		Third Tour Lbs.		Total	
Sulphur Burned	30	00	42	00	50	00	122	00
Limestone								

Digesters Cooked 48.8

Sulphur per Ton 239 #

FIRST TOUR

BURNER GAS % SO_2		7am	8am	9am	10am	11am	12M	1pm	2pm
Inlet New Cooler		17.4%		18.4%		17.4%		16.4%	
Inlet Old Cooler									
Outlet New Cooler		27°		28°		26°		27°	
Outlet Old Cooler									
Storage Tank No. 1	Total	4.78				4.33			
" " "	Free	3.59				3.30			
" " "	Combined	1.19				1.03			
" " "	Beaume	5.8				5.4			
" " "	Temp.	22°				24°			
Storage Tank No. 2	Total			4.71				4.51	
" " "	Free			3.52				3.49	
" " "	Combined			1.19				1.02	
" " "	Beaume			5.8				5.7	
" " "	Temp.			22°				22°	
Reclaiming Tank No. 3	Total	5.25		5.17		4.86		5.17	
" " "	Free	4.04		4.00		3.72		3.94	
" " "	Combined	1.21		1.17		1.14		1.23	
" " "	Beaume	6.2		6.0		6.1		6.9	
" " "	Temp.	22°		22°		22°		21°	
Finishing Tower No. 1	Total	4.21		4.11		4.06		4.00	
" " "	Free	2.12		2.79		2.72		2.69	
" " "	Combined	139		1.32		1.34		1.31	
" " "	Beaume	5.9		5.1		5.1		5.0	
" " "	Temp.	17°		17°		16°		17°	

SECOND TOUR

BURNER GAS % SO_2		3pm	4pm	5pm	6pm	7pm	8pm	9pm	10pm
Inlet New Cooler		16.2%		18%		18.8%		20%	
Inlet Old Cooler									
Outlet New Cooler		29°		28°		29°		31°	
Outlet Old Cooler									
Storage Tank No. 1	Total	464				486			
" " "	Free	356				369			
" " "	Combined	108				118			
" " "	Beaume	57				61			
" " "	Temp.	22°				20°			
Storage Tank No. 2	Total			471				478	
" " "	Free			356				359	
" " "	Combined			115				119	
" " "	Beaume			5.9				60	
" " "	Temp.			19°				19°	
Reclaiming Tank No. 3	Total	509		471		501		486	
" " "	Free	384		352		375		352	
" " "	Combined	126		119		126		134	
" " "	Beaume	6.3		6.0		6.7		6.1	
" " "	Temp.	20°		20°		19°		18°	
Finishing Tower No. 1	Total	381		386		445		406	
" " "	Free	250		259		298		276	
" " "	Combined	131		127		147		130	
" " "	Beaume	47		4.8		5.7		4.7	
" " "	Temp.	17°		14°		13°		14°	

THIRD TOUR

BURNER GAS % SO_2		11pm	MM	1am	2am	3am	4am	5am	6am
Inlet New Cooler		20.0%		19.0%		18.0%		17.6%	
Inlet Old Cooler									
Outlet New Cooler		31°		32°		32°		32°	
Outlet Old Cooler									
Storage Tank No. 1	Total	458				493			
" " "	Free	346				378			
" " "	Combined	112				115			
" " "	Beaume	5.7				6.0			
" " "	Temp.	18°				18°			
Storage Tank No. 2	Total			474				471	
" " "	Free			365				356	
" " "	Combined			109				115	
" " "	Beaume			5.7				5.6	
" " "	Temp.			18°				20°	
Reclaiming Tank No. 3	Total	480		493		505		474	
" " "	Free	357		365		368		346	
" " "	Combined	123		128		137		128	
" " "	Beaume	5.9		6.1		6.0		6.7	
" " "	Temp.	17°		17°		16°		15°	
Finishing Tower No. 1	Total	501		486		406		411	
" " "	Free	330		272		269		272	
" " "	Combined	171		134		137		139	
" " "	Beaume	6.4		6.1		5.0		6.1	
" " "	Temp.	13°		13°		13°		10°	

	Digester No.	Weekly No.	Cook No.	Temp.	Time Taken	
Finished Acid 442-327-1.15	2	19	4328	23°C.	9^15 AM	Acid pumped 15' 8"
" " 458-340-112	1	20	5322	22°C.	3^00 PM	" " 15' 4"
" " 451-340-111	2	21	4329	18°C.	11^45 PM	" " 15' 6"
" " 482-368-114	1	22	5323	20°C.	4^05 AM	" " 15' 4"
" "						

SHUT DOWN	Down At	Started At	Lost Time
Belts			
Line Shafts			
Pumps			
Coolers			
Water			
Power			
Mis.			
Gen. Remarks			

	First Tour Gal.	Second Tour Gal.	Third Tour Gal.
Acid in Storage Tanks			
Acid Use			
Acid Made			
Total Acid Made			

1st Tour Acid Maker Wilbur Juesker
" " " Tester Lon McCarthy
2nd Tour Acid Maker Alex Collison
" " " Tester Harold Cook
3d Tour Acid Maker Archie McInnis
" " " Tester Lee Murphy

Total H_2SO_4 in chips 35.70%
Excess H_2SO_4 in chips per digester 4.0 Tons
City water 7°C - River water 3°C - Difference 4°C.
Time used 9 Hs.

Signed: H. Jacobson
Approved: P. D. Garrigan Supt.

Fig. 190.

SCREEN ROOM AND BLOW PIT REPORT

Date Feby. 25, 1920.

Tour	No. of Blow	No. of Pit	Time of Blow	By	Time Finished	By	Started to Sluice	By	Finished Sluicing	By	Req. time for Washing	Req. time for Sluicing	Shut Downs	Down At	Started At	Loss of Time	Total Lost Time
	52 54	I	10^{45} PM	C G	11^{00} PM	A F	3^{15} AM	P L	8^{00} AM	G B	4½ hr	4¾ hr					
	42 62	II	3^{30} AM	C G	3^{45} AM	P L	8^{30} AM	G B	1^{00} PM	G B	4¼ hr	5 hr	Pits				
1st	52 54	I	9^{20} AM	F G	9^{30} AM	G B	1^{30} PM	G B			4 hr		Pumps				
Total Men Working 2													Screens				
													Belts				
													Wash				
													Water Wheels				
													Stock				
													Power				
					Lost time washing stock 1^{00} PM to 1^{30} PM—½ hr.												
	52 55	I	9^{30} AM	F G	9^{39} AM	G B	1^{30} PM	G B	7^{00} PM	A F	4 hr	5½ hr	Pits				
2nd	42 63	II	3^{10} PM	R G	3^{25} PM	A F	7^{30} PM	A F			4½ hr		Pumps				
Total Men Working 2	52 56	I	7^{45} PM	R G	8 PM	A F							Screens				
													Belts				
													Water				
													Water Wheels				
													Washing Stock	7^{00} PM	7^{30} PM	½ hr	
													Power				
	42 63	II	3^{10} PM	R G	3^{25} PM	A F	7^{30} PM	A F	1^{15} AM	P L	4½ hr	5¾ hr	Pits				
3d	52 56	I	7^{45} PM	R G	8^{00} PM	A F	1^{15} AM	P L			5½ hr		Pumps				
Total Men Working	42 64	II	3^{50} AM	C G	4^{05} AM	P L							Screens				
													Belts				
													Water	11^{00} PM	11^{05} PM	1/12 hr	
													Water Wheels				
													Stock				
													Power				

Remarks: 4 Digesters run

Checked by A. W. Peppler

Supt. R. D. Garrigan

Fig. 191.

PRESS ROOM REPORT

Date Feby 25/1920

	PRODUCTION	TRUCKS	TONS	SHUT DOWN AT	CAUSE	STARTED AT	LOSS TIME		SHUT DOWNS	DOWN AT	STARTED AT	LOSS TIME
FIRST SHIFT	No. 1 Press		22,365	1^{00} PM	Blowout wire	1^{15} PM	1/4 hr		Friction			
FOREMAN									Whipper Belts			
	No. 2 Press		21,125	1^{15} PM	Blowout wire	1^{30} PM	1/4 hr		Drive Belts			
E. J. Gardner									Moulds			
	No. 3 Press		565	7^{00} AM	No stock	1^{45} PM	6 3/4 hr		Felts			
				2^{00} PM	" "	3^{00} PM	1 hr		Felt Rolls			
	No. 4 Press			1^{45} PM	" "	2^{00} PM	1/4 hr		Motor			
				1^{45} PM	" "	2^{00} PM	1/4 hr		Motor Belts			
Total Men	No. 5 Screenings		8,815					No	Stock	1^{00} PM	1^{30} PM	1/2 hr
Working 7									Water			
	Total		52,870						Power			
									Remarks			
SECOND SHIFT	No. 1 Press		18,540						Friction			
FOREMAN									Whipper Belts			
	No. 2 Press		17,160						Drive Belts			
2. Litzner									Moulds			
	No. 3 Press			3^{00} PM	No stock	11^{00} PM	8 hr		Felts			
									Felt Rolls			
	No. 4 Press								Motor			
									Motor Belts			
Total Men	No. 5 Screenings		11,390						Stock			
Working 6									Water			
	Total		47,090						Power			
									Remarks			
THIRD SHIFT	No. 1 Press		14,135						Friction			
FOREMAN									Whipper Belts			
	No. 2 Press		14,530						Drive Belts			
F. Bonen									Moulds			
	No. 3 Press								Felts			
									Felt Rolls			
	No. 4 Press			11^{00} PM	No stock	7^{00} AM	8 hr		Motor			
									Motor Belts			
Total Men	No. 5 Screenings		19,430						Stock			
Working 6								No	Water	11^{00} PM	11^{45} PM	3/4 hr
	Total		48,095						Power			
									Remarks			

Grand Total Production: Over presses — 26,499; deckers — 26,043

Total Running Time: Total tons — 52,542

Checked by A. W. Peppler

Supt. R. D. Garrigan

Fig. 192.

BUREAU OF TEST—Per cent of Stock in White Water Date________

PRESS ROOM	FIRST TOUR: PER CENT OF STOCK	FIRST TOUR: Condition of Wires, Decker, Etc. GOOD	FAIR	BAD	TIME TAKEN	SECOND TOUR: PER CENT OF STOCK	SECOND TOUR: Condition of Wires, Decker, Etc. GOOD	FAIR	BAD	TIME TAKEN	THIRD TOUR: PER CENT OF STOCK	THIRD TOUR: Condition of Wires, Decker, Etc. GOOD	FAIR	BAD	TIME TAKEN
No. 1 Press	.0011 %					%					%				
No. 2 Press	.0017 %					%					%				
No. 3 Press not running	%					%					%				
No. 4 Decker not running	%					%					%				
No. 5 Screenings Press	.0037 %					%					%				
#5 Decker not running															
No. 1 Decker	%					%					%				
No. 1 Save All	.0015 %					%					%				
No. 2 Save All	%					%					%				
MACHINE ROOM															
No. 1 Save All	%					%					%				
No. 2 Save All	%					%					%				
Sewer Drain from Wet Press Room	.0026 %					%					%				
Sluice " " "	.0026														
Blow Pit Drain	.0000 %					%					%				
No. 1 Decker Stock	.0023 %					%					%				
No. 2 Decker Stock	%					%					%				
No. 3 Decker Stock	%					%					%				

Remarks #3 Press, #4 Decker, & #5 Decker not running. Fixing white water pump.

Percent of Acid in Decker water
Grove No. Percent
5.284 .00172

Tested by Elmer E. Johnson
Approved Dean J. Still

Fig. 193.

BEATER CHART

1500 LB. BEATER
SULPHITE–GROUND WOOD FURNISH

% SULPHITE	WET WEIGHT SULPHITE	DRY WEIGHT SULPHITE	% GROUND WOOD	WET WEIGHT GR. WD.	DRY WEIGHT GR. WD.	TOTAL WET WEIGHT	TOTAL DRY WEIGHT
100	4397	1671	0	0	0	4397	1671
96	4229	1607	4	226	68	4455	1675
92	4068	1546	8	446	134	4514	1680
90	3989	1516	10	563	169	4552	1685
86	3824	1453	14	790	237	4614	1690
82	3658	1390	18	1016	305	4674	1695
80	3579	1360	20	1133	340	4712	1700
77	3451	1312	23	1306	392	4757	1704
75	3368	1280	25	1426	428	4794	1708
72	3242	1232	28	1600	480	4842	1712
70	3158	1200	30	1716	515	4874	1715
68	3076	1169	32	1836	551	4912	1720
64	2905	1104	36	2070	621	4975	1725
62	2821	1072	38	2193	658	5014	1730
60	2739	1041	40	2313	694	5052	1735
57	2608	991	43	2493	748	5101	1739
55	2523	959	45	2613	784	5136	1743
53	2434	925	47	2736	821	5170	1746
50	2303	875	50	2916	875	5219	1750
47	2168	824	53	3100	930	5268	1754
45	2084	792	55	3223	967	5307	1759
42	1947	740	58	3413	1024	5360	1764
40	1860	707	60	3536	1061	5396	1768
37	1726	656	63	3720	1116	5446	1772
34	1600	604	66	3906	1172	5506	1776
30	1405	534	70	4153	1246	5551	1780
27	1268	482	73	4340	1302	5608	1784
24	1129	429	76	4533	1360	5662	1789
22	1037	394	78	4663	1399	5700	1793
20	945	359	80	4783	1435	5728	1796
18	852	324	82	4920	1476	5772	1800
16	810	308	84	4983	1495	5793	1803
14	663	252	86	5180	1554	5843	1806
12	571	217	88	5310	1593	5881	1810
10	476	181	90	5440	1632	5916	1813
8	382	145	92	5570	1671	5952	1816
6	287	109	94	5700	1710	5987	1819
4	189	72	96	5833	1750	6022	1822
2	94	36	98	5963	1789	6057	1825
0	0	0	100	6096	1829	6096	1829

R.P.S.

% MOISTURE IN GR. WD. 70% AIR DRY PULP 30%
% MOISTURE IN SULPHITE 62% AIR DRY PULP 38%

TB1516

Fig. 194.

moisture computed. The results of this test are recorded on the other two samples and plotted on the Paper Inspection Chart, from which the machine tender can obtain the results of the test.

PAPER INSPECTION

Division—————————— *Date*——————

Sample No.—————— *Mach. No.*—————— *Tour*———

Time—————————— *Grade*——————————

	Standard	*Actual*
Basis Weight, 24 x 36............	______	______
Mullen Test....................	______	______
Points Mullen per Pound..........	______	______
Moisture, %....................	______	______
Speed, Ft. per Min...............	______	______
Prod. per Hour, Lbs..............	______	______
Sets per Hour....................	______	______
Sizing Quantities................	______	______
Girt...........................	______	______
Color..........................	______	______
Folding........................	______	______

Machine Tender——————————————————

Back Tender——————————————————

Remarks——————————————————

——————————————————————

——————————————————————

Inspector——————————

Fig. 195.

The inspector then takes another sample, weighs it to .01 gram and multiplies the weight obtained by .528 thereby converting the weight to pounds per ream. This he notes on the form stamped on each sample shown in Figure 195. The sample after being weighed is taken and tested with the Mullen Tester, an average of six readings being taken and reported on the sheet.

Following this is the Sizing Test, which consists of floating a piece of the paper about 3 inches square on the surface of a 5 per cent solution of potassium ferrocyanide and when the solution appears to come through the fibers a small brush dipped in a 5 per cent solution of ferric chloride is brushed across the surface of the paper. As soon as penetration has taken place a deep coloration (Prussian Blue) forms. The time taken for the operation is noted in seconds and plotted as such. There are other methods of making sizing tests, but the writer has found the above satisfactory for most grades of paper. Along with these other operations the inspector notes the speed of the machine for the hour and the number of sets run off and from the above data computes the production for the hour. The formula used is as follows:

$$\frac{\text{Ream Weight} \times \text{Speed (in feet per Minute)} \times \text{Deckle (in inches)} \times \text{Number of Minutes}}{34560}$$

Any shut-downs are noted and remarks made on same.

This completes the actual operations of the paper inspector. He places the two sets of samples that have all the data placed upon them in a tightly covered galvanized iron can, and at the end of each tour one complete set is forwarded to the Bureau of Chemistry and one to the Department of Physical Tests.

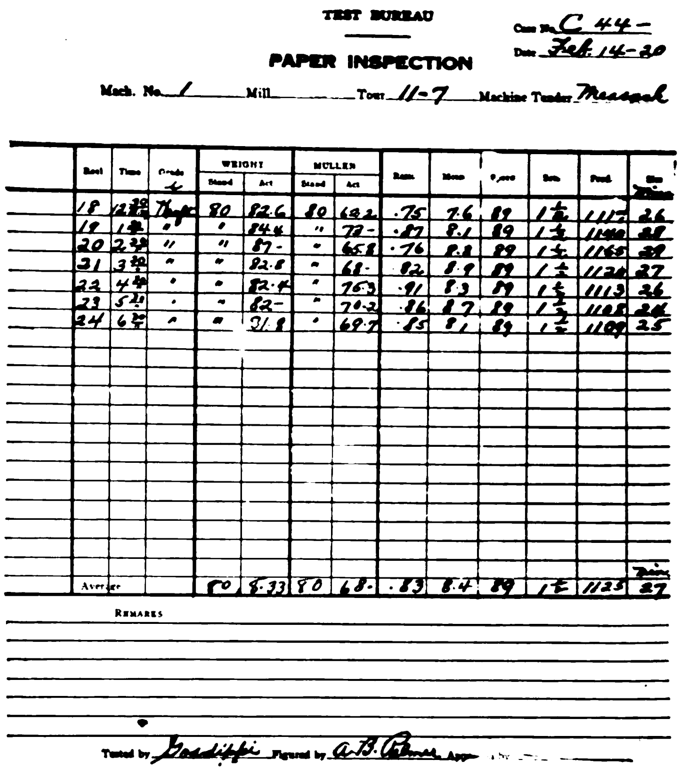
Upon receipt of the samples by the Bureau of Chemistry, they are immediately weighed and placed in a large steam heated oven at a temperature of 220°F. The samples are allowed to remain there for twelve hours, by which time they have reached a constant weight. The figures obtained by the Test Bureau and those obtained by the Paper Inspector are examined and any discrepancies are quickly followed up.

The Bureau of Chemistry next compiles the data obtained from each sheet upon a Machine Tender's Paper Inspection Report shown in Figure 196. The object of this report is to serve as a summary of the work of a machine tender covering (in a general way) the external qualities of the paper produced by him, the amount produced, and any shut-downs that may have occurred under him. As soon as these reports are compiled a copy is forwarded to each mill superintendent, thereby enabling him to keep a close survey of his operations.

The Bureau of Chemistry, periodically checks the operation of all inspectors, taking one inspector each week. In following these proceedings the paper inspectors are never informed as to who is being watched, which fact keeps them under a continuous surveillance in all their operations.

We will now return to the third set of samples: When received by the Department of Physical Tests, they are arranged in order of roll numbers and from these five strips are torn

12″ x 4″. Two of these strips are carefully noted as to color. formation and any other characteristics that apply to a good sheet of paper, by a practical paper man, who has served many years in the actual running of a machine and has officiated in various departments of the paper mill. Two sets of these strips are marked with the following data:—grade, weight and reel number—they are in turn forwarded to the General Manager and



TEST BUREAU

PAPER INSPECTION

Case No. C 44– Date Feb. 14-20

Mach. No. 1 Mill ______ Tour 11-7 Machine Tender Measgok

Reel	Time	Grade	Weight Stand	Weight Act	Mullen Stand	Mullen Act	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	12 [illegible]	[illegible]	80	82.6	80	68.2	.75	7.6	89	1½	1115	26
19	1 [illegible]	"	"	84.4	"	72–	.87	8.1	89	1½	1140	28
20	2 [illegible]	"	"	87–	"	65.8	.76	8.8	89	1½	1165	29
21	3 [illegible]	"	"	82.8	"	68–	.82	8.9	89	1½	1120	27
22	4 [illegible]	"	"	82.4	"	76.3	.91	8.3	89	1½	1113	26
23	5 [illegible]	"	"	82–	"	70.2	.86	8.7	89	1½	1108	26
24	6 [illegible]	"	"	81.8	"	69.7	.85	8.1	89	1½	1109	25
Average			80	8.33	80	68.	.83	8.4	89	1½	1125	27

REMARKS

Tested by [illegible] Figured by A. B. [illegible] App. [illegible]

Fig. 196.

to the General Superintendent. The remaining strip is tested on the Witham Tear Machine.

Until very recently the tearing quality of a sheet of paper could not be expressed by a numerical expression. This quality. all important in certain grades of paper, was left to the judgment of any person picking up the sheet. In the past the chief machine that has been available for determining the strength of a sheet of paper has been the Mullen Tester. We have found that frequently, although a paper may give a high Mullen test, it offers very little resistance to tear. In other words this Mullen Tester does not give the strength of the tearing qualities lengthwise of the sheet. Now with the introduction of Tear Machines a numerical expression can be obtained indicating the actual tearing resistance that the sheet may offer.

It has been found that in all tests involving the mechanical resistance of paper, it is essential (in cases requiring a great degree of accuracy) to take into consideration the influence of the hygroscopic moisture in the paper. With this point in view a Normal Air Humidifier can advantageously be installed but if no automatic device is added to control the temperature, the results will refer to Percentage Relative Humidity, and not to the Absolute Humidity.

After proper labelling, the two sets of samples prepared by the practical paper man are submitted to the General Superin-

........................Date.
Grade ....
Sample No. ....
Time ....
Mach. Tender ....
Cause for criticism ....
....
....
By ....

CRITICISM SHEET .... Date ....
Mr. .... Supt. .... Mill ....
Grade ....
Sample No. ....
Time ....
Machine Tender ....
Cause for criticism ....
....
Physical Testing Dept. .... Approved by ....
By ....Gen. Supt.

Fig. 197.

tendent and General Manager for further inspection. These particular examinations in conjunction with those of the practical paper man are of great utility, as an approximate estimate can be formed thereon. Unfortunately this inspection lacks the fundamental necessity of numerical expression, which must form the basis of any records when any particular point is disputed by equally experienced men representing different interests. The set of samples as received by the General Superintendent and Manager are given a thorough examination from a practical standpoint. With a long experience in "handling" paper, one is able to judge quality and value within a very few minutes. With the feeling of the sheet, the weight and ream weight are estimated. The drawing of the sheet of paper between the finger and the thumb will reveal the smoothness of the surface and its bulking qualities. By holding the sheet up to the light, and looking through it, one can see the nature of the beating, the length of the stuff, and the manipulation of the stuff upon the "wire."

With the practical tests carried out in this manner, if any question of doubt has arisen regarding the quality of any roll, the numerical figures that have been compiled by the Department of Physical Tests, covering all tests made by them, are analyzed and if the quality of the paper is questionable, a criticism sheet (Figure 197) is forwarded to the Mill Superintendent, stating whatever criticisms have occurred. In accordance with the criticism sheet, a reject slip (Figure 198) is sent to the Shipping Department, requesting that department to reject any paper that is under quality. In this manner no paper is allowed to leave

........................Date

No. of rolls Rej.......................

Made at .... Mill

Date ....

Grade .... Wt. ....

Roll No. ....

Cause for rejection

....

....

REJECTION NOTICE. Date..............

Mr. .... Supt. .... Mill

Reject the Following Rolls of Paper

Made at .... Mill .... Date Made

Grade ....

Weight ....

Roll No. ....

CAUSE FOR REJECTION ....

Signed .... Gen'l Supt.

Fig. 198.

PAPER INSPECTION
PHYSICAL TESTS FROM MANF'G. DEPT.

Date April [illegible], 19[illegible]

Mill	Grade	Weight Std	Weight Act	Weight % E	Moisture Std	Moisture Act	Moisture % E	Mullen Std	Mullen Act	Mullen % E	Wickham Std	Wickham Act	Wickham % E	Size Penetration Std	Size Penetration Act	Size Penetration % E	Production Std	Production Act	Production % E	Total Efficiency
	Allen Kraft	70	72.9	99.2	10	8.4	98.4	70	67.8	96.1	9.18	11.8	125.6		1800		12	13.2	110	105.8
	#1 Four Kraft	60	60.7	100	8	9.2	98.8	60	62.6	104.1					660		28	25.8	92.1	98.7
	Beaver Kraft	36	35.7	100	8	8.4	99.6	32	32.2	100.6	2.65	3.25	134		53		35	43	122.8	107.4
	Acme	31	31.4	100	8	8.1	99.9	19	19.8	104.2	1.8	2.1	116.6		48		37	37.1	102.7	104.6
	Bear	29	29.2	100	8	7.9	99.9	23	22.4	97.3	2.25	2.5	111.1		76		29	30.5	105.1	102.4 103.0
	Superb	38	37.7	100				29	27.7	95.5	2.95	3.6	122				5	6.1	120	109.3
	Beaver Kraft	35	35	100				32	31	96.8	2.8	3.35	119.6				9	9.4	104.4	105.2 107.2
	NonPareil	31.5	31.5	100	8	7.5	99.5	19.4	20	102	1.85	1.98	105.4				7	8.7	124.3	106.2
	Postum	28	28.0	100	8	7.8	99.6	15	17	113.3	1.65	1.85	119.3				18	20	111.1	108.7
	Moose	32.7	32.8	100	8	8	100	21	23	109.5	2.2	2.6	118.1				26	28.1	108	107.1 107.3

Formation O.K.

Total Efficiency of Combined Mills 104.1

Cleanliness Good

Remarks

Figured by F. [illegible]

Approved by

Fig. 199.

the mill until it has passed successfully through a thorough examination.

The daily data that is turned in each morning from the Department of Physical Tests, such as grade, weight, Mullen, moisture and size tests, tear, and production, is made up into the Daily Efficiency Chart (Figure 199). This chart in a condensed form shows the actual efficiency of each mill based on the various

PENALTY CHART FOR MOISTURE

PENALTY .1 OF 1% FOR EVERY .1 OF 1% OFF

Under Standard Moisture		Efficiency		Over Standard Moisture
8.0		100		8.0
7.0		99.9		8.1
7.8		99.8		8.2
7.7		99.7		8.3
7.6		99.6		8.4
7.5		99.5		8.5
7.4		99.4		8.6
7.3		99.3		8.7
7.2		99.2		8.8
7.1		99.1		8.9
7.0		99.0		9.0
6.9		98.9		9.1
6.8		98.8		9.2
6.7		98.7		9.3
6.6		98.6		9.4
6.5		98.5		9.5
6.4		98.4		9.6
6.3		98.3		9.7
6.2		98.2		9.8
6.1		98.1		9.9
6.0		98.0		10.0
5.9		97.9		10.1
5.8		97.8		10.2
5.7		97.7		10.3
5.6		97.6		10.4
5.5		97.5		10.5
5.4		97.4		10.6
5.3		97.3		10.7
5.2		97.2		10.8
5.1		97.1		10.9
5.0		97.0		11.0

To find Efficiency
Ex: Sheet with 7.5% Moisture = 99.5% Eff.

TB-6

Fig. 200.

Physical Tests. These reports are submitted to the Mill Superintendents who are found to take a great interest in them. In compiling the data on these charts, various penalties have been made depending upon the overrunning of our minimum standards. Figure 200 illustrates the Moisture Penalty Chart. Eight per cent has been taken as the standard percentage of moisture. The average moisture for each grade of paper in each mill is taken and for every .1 per cent above or under the standard (8 per cent) a penalty of .1 per cent is made for that grade.

Figure 201 is used as a Weight Penalty Chart. An allowance of 3 per cent is made for all grades and all weights either above or below the standard. If, after averaging the weight of a grade and making an allowance of 3 per cent the weights are still in excess or under, a penalty of .1 per cent for every .1 per cent is made.

Figure 202 indicates the various sizing qualities that are required of the different weight sheets. Again the average weight is obtained for each grade and the correspondng actual sizing in seconds. This is compared to the standard sizing for that weight sheet and penalized accordingly.

At the end of each week the daily charts are averaged and the data so obtained is indicated on the Weekly Efficiency Chart shown in Figure 203. Figure 204, known as Rejected Paper Penalty Chart, is based on the percentage of rejected paper based on the total production for the week. The percentage thus obtained is deducted from the total efficiency of the mill and the actual efficiency of the mill is denoted in red.

At the end of each month the total efficiencies of each week are added and averaged and plotted on a chart represented by Figure 205. There are other methods for presenting these weekly and monthly ratings. These are Mechanical Bar Charts manufactured by a concern dealing in such equipment. By means of various colored ribbons different units can be separated and quickly picked out by the mill men, thus enabling them to get the comparative rating between mills. If this outlay of mechanical bar charts appears expensive, the ordinary type of bars on blueprint paper will serve the same purpose.

This concludes the checking and methods of presentation of the daily work of the paper mill, the amount of paper produced, and the quality of workmanship. Further than this the Department of Physical Tests obtains from the Bureau of Chemistry data enabling them to present in somewhat similar form (as has already been explained) the efficiency of the various sulphite and ground wood mills.

Figure 206 indicates a daily efficiency chart covering the working of the ground wood mills. The information as shown by this chart gives for each individual unit the following:—total production; production per foot ahead; production per K. W.

PENALTY CHART FOR WEIGHTS

WEIGHT OF PAPER

Lbs. + −	25 26 27 28	29 30 31	32 33 34 35	36 37	38 39 40 41	42 43 44	45 46 47 48	49 50 51	52 53 54	55 56 57 58
.8	.0									
.9	.1	.0								
1.0	.2	.1	.0							
1.1	.3	.2	.1	.0						
1.2	.4	.3	.2	.1	.0					
1.3	.5	.4	.3	.2	.1	.0				
1.4	.6	.5	.4	.3	.2	.1	.0			
1.5	.7	.6	.5	.4	.3	.2	.1	.0		
1.6	.8	.7	.6	.5	.4	.3	.2	.1	.0	
1.7	.9	.8	.7	.6	.5	.4	.3	.2	.1	.0
1.8	1.0	.9	.8	.7	.6	.5	.4	.3	.2	.1
1.9	1.1	1.0	.9	.8	.7	.6	.5	.4	.3	.2
2.0	1.2	1.1	1.0	.9	.8	.7	.6	.5	.4	.3
2.1	1.3	1.2	1.1	1.0	.9	.8	.7	.6	.5	.4
2.2	1.4	1.3	1.2	1.1	1.0	.9	.8	.7	.6	.5
2.3	1.5	1.4	1.3	1.2	1.1	1.0	.9	.8	.7	.6
2.4	1.6	1.5	1.4	1.3	1.2	1.1	1.0	.9	.8	.7
2.5	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0	.9	.8
2.6	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0	.9
2.7	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.0
2.8	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1
2.9	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3	1.2
3.0	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4	1.3
3.1	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.4
3.2	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5
3.3	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7	1.6
3.4	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.7
3.5	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.8
3.6	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9
3.7	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0
3.8	3.0	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2	2.1
3.9	3.1	3.0	2.9	2.8	2.7	2.6	2.5	2.4	2.3	2.2
Exam	ple									
40 lb.	Sheet w	eighing	2 lbs. h	eavy						
Penal	ty = .8	of 1%								

TB-2

Fig. 201.

SIZE PENETRATION PENALTY CHART

Grade	Wt.	St'd.	100	99.8	99.6	99.4	99.2	99.0	98.8	98.6	98.4	98.2
A	36	45	5	6	7	8	9	10	11	12	13	14
	38	50	5	6	7	8	9	10	11	12	13	14
	42	55	6	7	8	9	10	11	12	13	14	15
	46	60	6	7	8	9	10	11	12	13	14	15
	52	70	7	8	9	10	11	12	13	14	15	16
	58	80	8	9	10	11	12	13	14	15	16	17
B	60	90	9	10	11	12	13	14	15	16	17	18
	70	110	11	12	13	14	15	16	17	18	19	20
	80	125	13	14	15	16	17	18	19	20	21	22
C	30	40	4	5	6	7	8	9	10	11	12	13
	35	45	5	6	7	8	9	10	11	12	13	14
	37	50	5	6	7	8	9	10	11	12	13	14
	40	60	6	7	8	9	10	11	12	13	14	15
	44	70	7	8	9	10	11	12	13	14	15	16
	50	75	8	9	10	11	12	13	14	15	16	17
D	30	30	3	4	5	6	7	8	9	10	11	12
	34	35	4	5	6	7	8	9	10	11	12	13
	36	37	4	5	6	7	8	9	10	11	12	13
	42	42	4	5	6	7	8	9	10	11	12	13
	50	50	5	6	7	8	9	10	11	12	13	14
E	30	45	5	6	7	8	9	10	11	12	13	14
	33	50	5	6	7	8	9	10	11	12	13	14
	35	70	7	8	9	10	11	12	13	14	15	16
	38	100	10	11	12	13	14	15	16	17	18	19
	40	110	11	12	13	14	15	16	17	18	19	20
	42	120	12	13	14	15	16	17	18	19	20	21
	45	130	13	14	15	16	17	18	19	20	21	22
F	38	50	5	6	7	8	9	10	11	12	13	14
	42	60	6	7	8	9	10	11	12	13	14	15
	46	70	7	8	9	10	11	12	13	14	15	16
	48	90	9	10	11	12	13	14	15	16	17	18

NOTE. Standard given in seconds
Figures to right of Standard Column indicate seconds over or under Standard for each weight
Standard in seconds

TB. 401

Fig. 202

hour; production per stone; tons per stone; pounds per cord of wood consumed; freeness of stock; hours down; total efficiency.

The freeness of ground wood stock is obtained by using

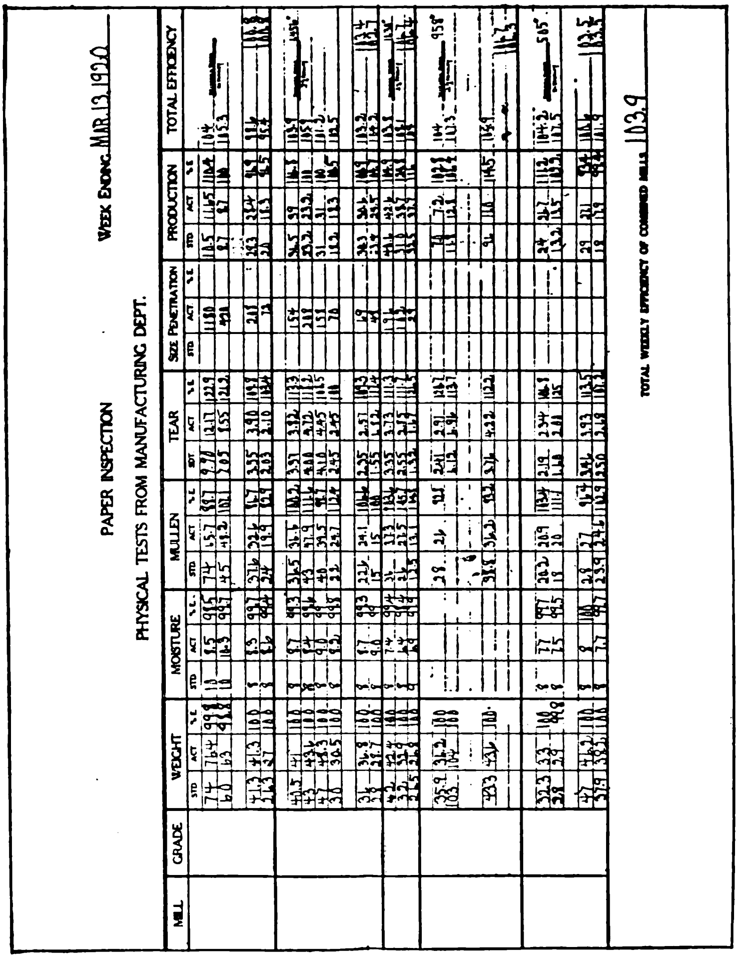


Fig. 203.

Scott's Freeness Tester and designates the nature of the stock whether slow, free or shievey.

All of this data not only serves as a systematic check upon mill operations and product made but also when presented in the right spirit serves as an incentive to the men.

Somewhat along the same lines, the Department of Physical

PENALTY FOR REJECTED PAPER

BASED ON PERCENT OF REJECTED PAPER FROM TOTAL PRODUCTION FOR THE WEEK

% Rejected Paper		% Efficiency
.25		99.5
.50		99.0
.75		98.5
1.00		98.0
1.25		97.5
1.50		97.0
1.75		96.5
2.00		96.0
2.25		95.5
2.50		95.0
2.75		94.5
3.00		94.0
3.25		93.5
3.50		93.0
3.75		92.5
4.00		92.0
4.25		91.5
4.50		91.0
4.75		90.5
5.00		90.0
5.25		89.5
5.50		89.0
5.75		88.5
6.00		88.0
6.25		87.5
6.50		87.0
6.75		86.5

TB-15

Fig. 204.

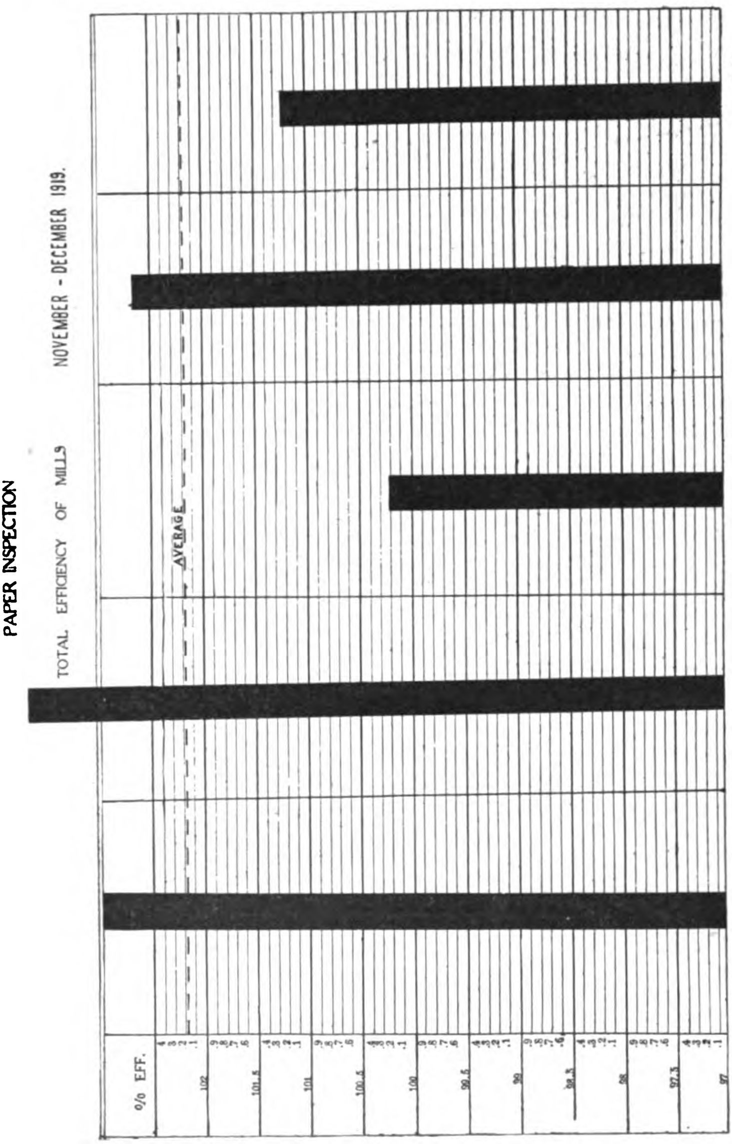


Fig. 205.

Tests traces the workings of the sulphite mills as shown in Figure 207 which includes the following:—total production; per cent screenings; quality of pulp; average filling time; quality of cooking acid; per cent reclamation; efficiency of chips; sulphur consumption; cooking time; production per digester; temperature of

GROUND WOOD MILLS DAILY EFFICIENCY CHART

/ DATE

Mill	Total Production			Production per Foot-head			Production per K. W. Hour			Tons per Stone			Lbs. per Cord			Freeness			Hours Downs		Cause of Shut Downs	Total Efficiency
	Std.	Act.	% E.	Std.	Act.	% E.	Std.	Act.	% E.	Std.	Act.	% E.	Std.	Act.	% E.	Std.	Act.	% E.	Grinder Number			
																			1			
																			2			
																			3			
																			4			
																			5			
																			6			
																			7			
																			8			

Remarks

Total Efficiency

Figured by:

Approved by:

Fig. 206.

UNION BAG & PAPER CORPORATION

SULPHITE MILLS

DAILY EFFICIENCY CHART

DATE April 20, 1920.

MILL	TOTAL PRODUCTION STD.	TOTAL PRODUCTION ACT.	TOTAL PRODUCTION % E.	PRODUCTION OF SCREENINGS % STD.	PRODUCTION OF SCREENINGS % ACT.	PRODUCTION OF SCREENINGS % % E.	QUALITY OF PULP STD.	QUALITY OF PULP ACT.	QUALITY OF PULP % E.	AVERAGE FILL TIME STD.	AVERAGE FILL TIME ACT.	AVERAGE FILL TIME % E.
FENIMORE	110	119.2	105	5	6.5	123	Good			50	56	89
CHEBOYGAN	55	55	100	5	7.4	108	Good			50	64	78

MILL	COOKING ACID: TOTAL STD.	TOTAL ACT.	TOTAL % E.	FREE STD.	FREE ACT.	FREE % E.	COMBINED STD.	COMBINED ACT.	COMBINED % E.	S RECLAMATION STD.	S RECLAMATION ACT.	S RECLAMATION % E.	EFFICIENCY OF CHIPS STD.	EFFICIENCY OF CHIPS ACT.	EFFICIENCY OF CHIPS % E.	SULPHUR CONSUMPTION STD.	SULPHUR CONSUMPTION ACT.	SULPHUR CONSUMPTION % E.
FENIMORE	450	434	94	335	319	95	115	113	100				40	40	100	250	250	100
CHEBOYGAN	450	446	[illegible]	335	339	100	115	107	93	70	70	100	70	82	117	260	259	100

MILL	COOKING TIME STD.	COOKING TIME ACT.	PROD. PER DIG. STD.	PROD. PER DIG. ACT.	TEMP. OF WATER	TEMP. OF GAS AFTER COOLING	TEMP. OF ACID TO DIG.	MOIS. IN CHIPS	NO. DIG.	HOURS DOWN	CAUSES	TOTAL % EFFICIENCY
FENIMORE	10:25	9:20	12.9	11.9	17°	60°	29°	24.7	1	–		101.
									2	10 Min	Wash out Digester	
									3	–		
									4	–		
CHEBOYGAN	10:25	10:50	12.9	11.3	12°	30°	23°	37.5	1	40 Min	Pipe Fitting	99.5
									2	90 Min	Belt Slipping	
									3			
									4			

REMARKS ______

TOTAL EFFICIENCY OF MILL 100.2

FIGURED BY ______ APPROVED BY ______

Fig. 207.

water: temperature of gas; temperature of acid to digester; moisture in chips; hours down; causes; total efficiency.

The above concludes the general routine work of the Depart-

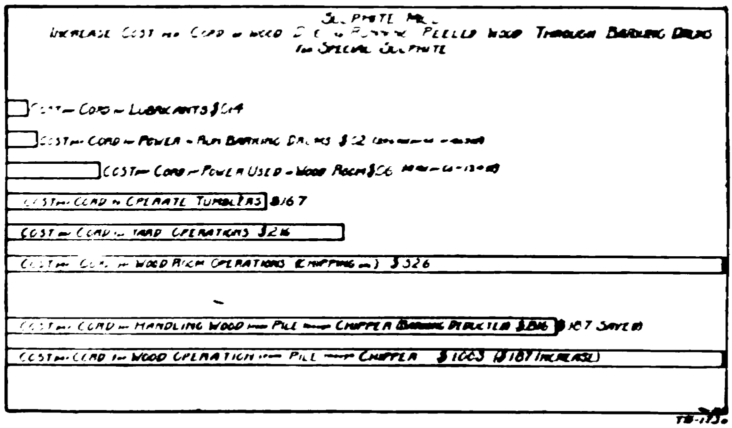


Fig. 208.

ment of Physical Tests in conjunction with the Bureau of Chemistry. Along with this work special mill tests are run in order to determine efficient cost, production and quality standards. Fig-

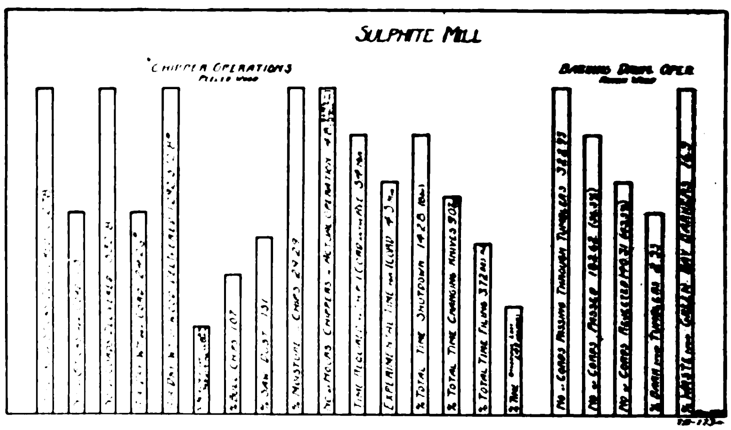


Fig. 209.

ures 208 to 215 inclusive show Graphic Analyses of some of these various tests. Moreover, competitors' papers are constantly tested in conjunction with one's own and samples are filed away under both bad and good storage conditions in order to ascertain relative per cent deterioration of the various grades of paper.

In testing one's own grades for deterioration of course it is essential to have all characteristics and data connected with the making of that sheet, in order that the test may be of any value. By this means quality of material is often proved to be below stand-

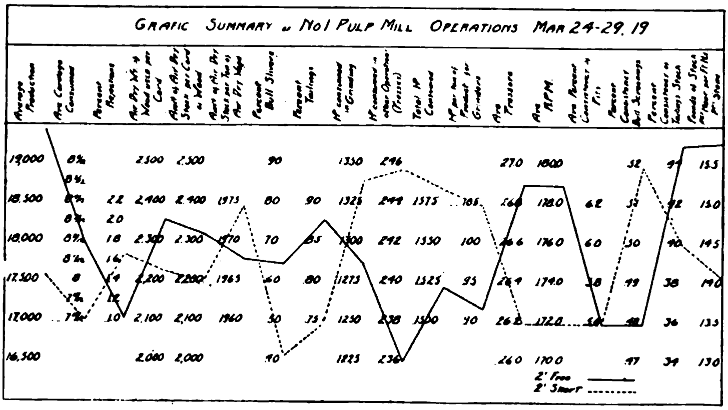


Fig. 210.

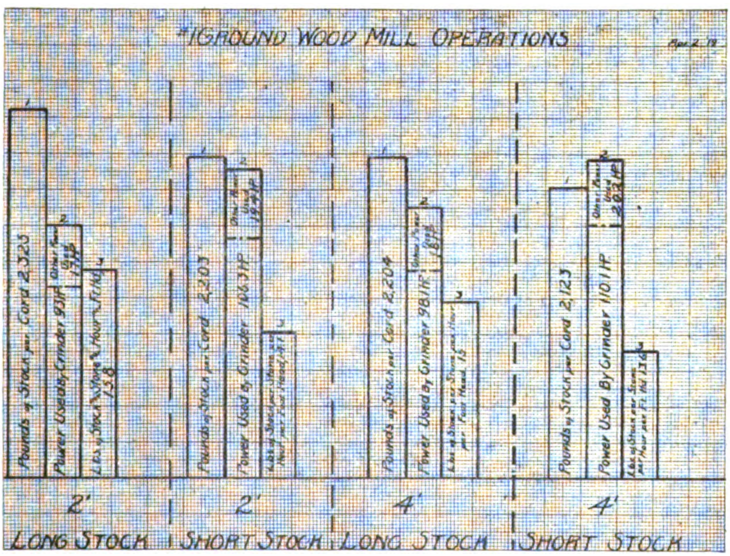


Fig. 211.

ard when stored under both poor and normal conditions, or again it may result in some change in the process of manufacture in an attempt to cure the evil.

The work outlined above is not of a very technical nature and one trained chemist assisted by several conscientious helpers can

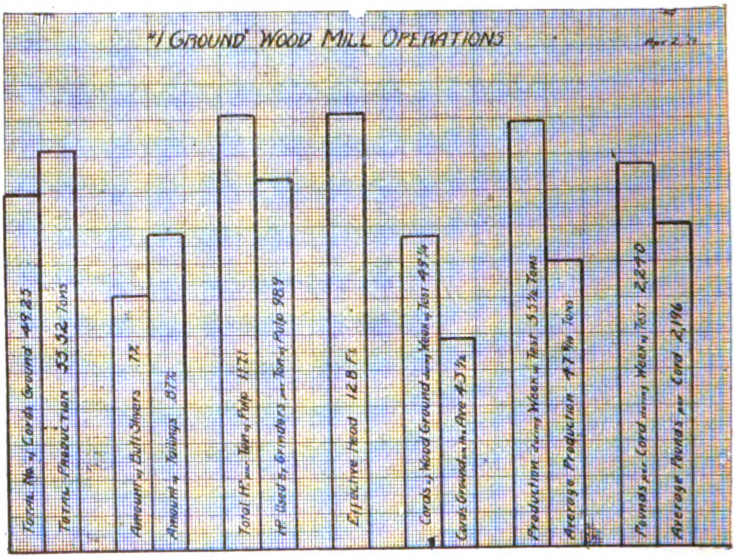


Fig. 212.

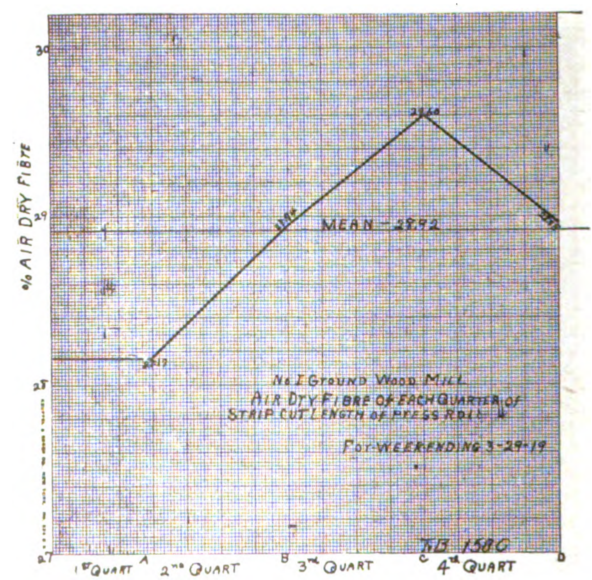


Fig. 213.

carry out this program to complete satisfaction. In connection with the Physical Tests Department, a good practical paper maker must be included in its personnel in order to pass judgment on various paper qualities that are not shown up by any mechanical,

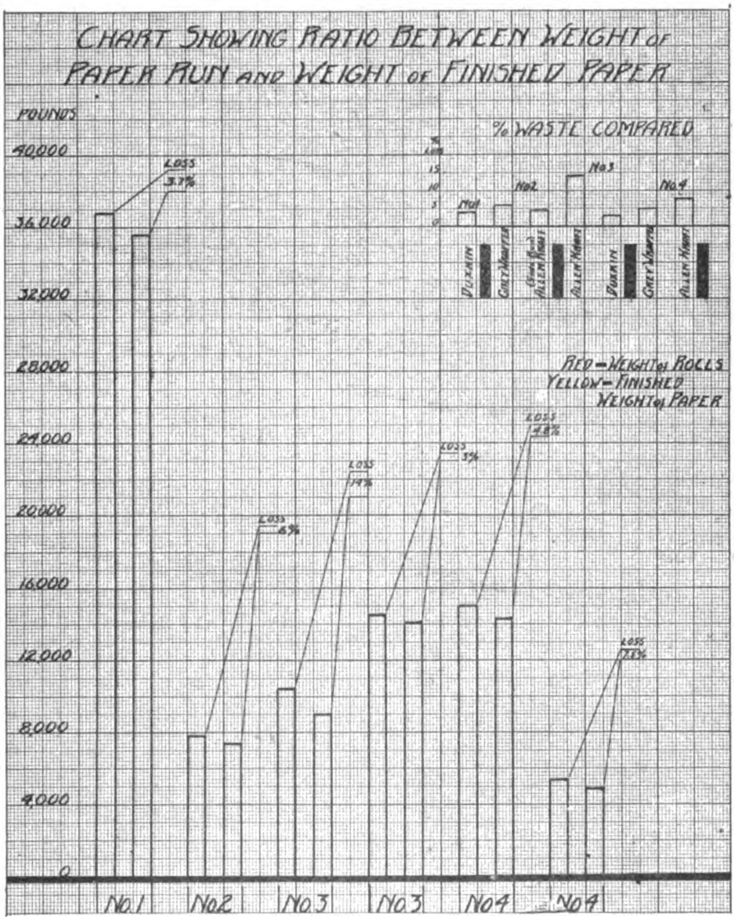


Fig. 214.

chemical, or physical tests. By the maintenance of such a department, properly supervised, the security obtained, not only for the good will of the company, but for all concerned, serves as an insurance or protection to all buyers. Of course, the system is not infallible, but it does minimize causes for error and shipment of inferior quality of goods, as well as wastefulness in manufacturing.

General Testing of Supplies.

Very little reliable information can be obtained from sales agents for various supplies for each agent has his own interests at stake, and it is his business to promote the sale of his material.

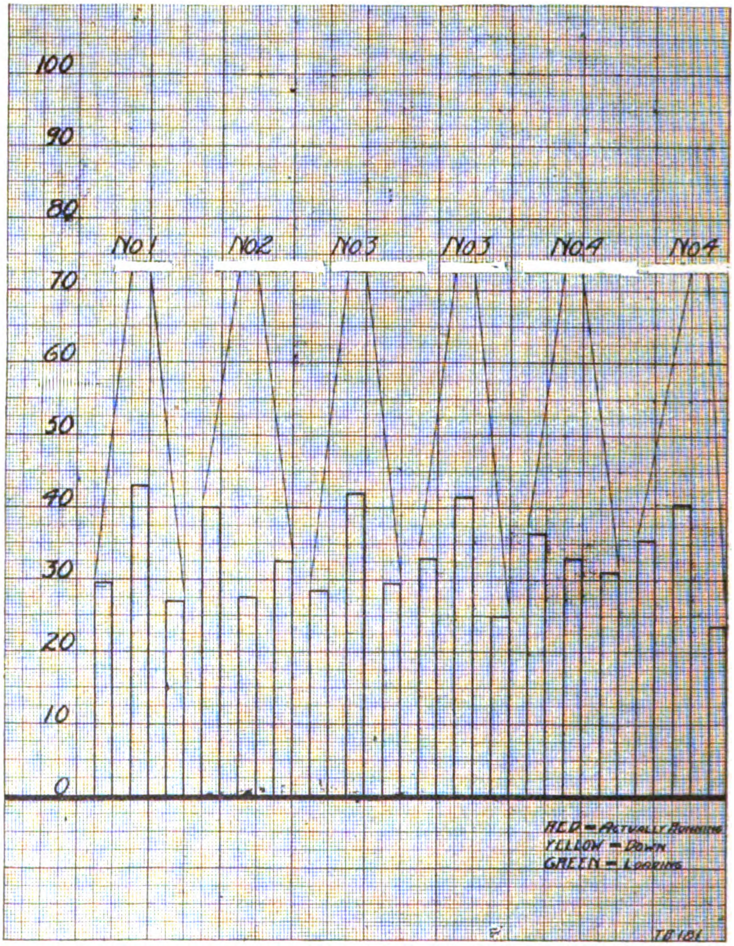


Fig. 215.—Chart showing percent. time down, percent. time loading cutters and percent. actual time cutters.

The necessity for testing therefore becomes apparent. In a large number of cases the best method is to put the article to practical use and keep accurate record of its service as in the case of wires, felts, etc.

In other cases we have chemical testing; also physical testing as strength of twine, belting, etc.

Meaning of the Word: Testing, in the broadest sense, means any method of procedure with the object of ascertaining facts about the thing, for example:

A car of coal is weighed in order to ascertain its weight more or less than the weight invoiced; this is testing its weight.

If a piece of clay is placed in the mouth in order to observe how it feels between the teeth; this is testing its grit.

If several felts, wires, etc., are used exactly under the same conditions and a record kept to see which gives the best service; this, also, is testing.

Weighing: The invoice weights of all kinds of material should be checked by weighing on accurate scales.

Testing Scales: All scales should be periodically tested as to the accuracy of their calculations.

The principle upon which paper is weighed is as follows: one pound = 16 ounces. 30 pounds therefore 30 x 16 = 480 ounces. If, therefore, the count basis is 480 sheets, one sheet of a 30 pound paper will weigh exactly 1 ounce so that a test weighing exactly 1 ounce be placed upon the scales instead of a sheet of paper it will register exactly 30 pounds on the 480 count. On the 500 count basis one sheet of a 30 pound paper will weigh 480-500 of one ounce or 96-100 of an ounce.

When test weights of exactly 1 ounce are placed upon these scales, one after another they should, therefore, register as follows:

Count	1	2	3	4	5 Oz.
480	30	60	90	120	150
500	31.25	62.50	93.75	125	156.25

Measuring: Measuring the dimensions of a thing is also a testing process. Measuring is sometimes connected with weighing as, for example, in the case of twine, exactly 1 pound may be weighed and measured so as to calculate the weight per 100 feet and thus get comparative weights for different makes or brands.

Counting is another method as in counting the mesh of a wire with a magnifying glass.

Testing of Belting: The various grades of belting depends to a large extent upon the composition of the friction used in their manufacture.

The highest grade of pure rubber gives the strongest and most durable friction while "recovered rubber" and inferior compositions give inferior tests and deteriorate rapidly.

To test—Cut 3 strips smoothly and evenly 1 in. in width, separate the ply for 1 inch or 2 inches by means of a knife in order to separate. Make a mark slightly beyond the point of separation and hang the strip by means of a clamp, etc.

Let the strip hang naturally. Pull with the hand till you reach the separation mark and take the time with a watch. The separation should not average more than 1 inch per minute, the average of the three strips being taken.

Some grades will only stand 5 or 6 pounds and are inferior; others will stand weights of 10 or 20 pounds.

Comparisons may be made by using the same weight (14 pounds) for all belts and calculate the rate of separation. Poor belting will separate quick under a 14 pound weight. By a systematic examination of every roll valuable information can be obtained as to different makes and brands.

The Drying Oven.

Tests for quantity of water or moisture in anything are among the most important class of testing, and a drying oven is an essential part of the equipment in every mill. These ovens may be either steam or electric. Good dealers in laboratory supplies carry both kinds and can suggest a suitable type.

Among the tests for water or moisture contained in materials we may mention the following:

Moisture of Pulp: Pulp both chemical and mechanical pulp such as sulphite, and soda and in fact any paper making pulp is tested for moisture and water by taking a sample, weighing it accurately bone dry and again weighing it. The loss in weight gives the amount of moisture or water in it and from the weights observed the percentages of water or moisture and the bone dry pulp are easily calculated.

It is ordinarily assumed that paper pulp after being dried bone dry and then left exposed to the air will absorb 10 per cent of its weight of moisture from the atmosphere.

This figure 10 per cent is a fairly approximate average, but, of course, the true amount of moisture absorbed from the air depends on the dryness or dampness of the weather which is constantly changing. At times when the air is very dry a bone dry pulp will not absorb anything like 10 per cent moisture while at other times when the atmosphere is very moist, it will absorb considerably more than 10 per cent. Under ordinary conditions during the year it is nearer to 9 per cent than to 10 per cent, but this again varies with the locality, for one locality during the year is different from another.

Calculating Dry Pulp: In our opinion the true basis for estimating the percentage of air dry material is the bone dry weight, but it makes no difference what percentage is added to this as long as the same percentage is uniformly adopted. 10 per cent. is as satisfactory as any although it may not represent the actual percentage of moisture absorbed in the majority of cases.

Moisture in Paper: The percentage of moisture in paper can also be readily determined by means of a drying oven. This is a very important test, being of much value in enabling one to regulate the drying of paper on a machine.

Newspaper when overdried is brittle and unsatisfactory, while if too much moisture is left in it the calendering produces a mottled smutty appearance, but such paper takes a superior finish to that which has been overdried.

As is well known, the best results are obtained when the paper is run as damp as possible without getting mottled or smutty in appearance.

Experiments have shown, in the case of newspaper, that the best degree of moisture is between 9 per cent and 11 per cent, on the average, 10 per cent.

This is the percentage which is added to "bone dry pulp" to convert it into air dry weight upon which calculations as to "production" and loss of raw material are based.

If paper is run (as is frequently the case) with only 7 per cent of moisture in it and calculations are based upon air dry pulp containing 10 per cent of moisture, there is, of course, a loss of raw material due to the paper being run too dry.

By running the paper damper not only is there a gain in the production but the quality of the paper that is run on the paper machine is more or less greatly improved.

Another bad effect of overdrying lies in the fact that overdried paper will absorb moisture from the atmosphere and increase in weight so that if a sample of paper fresh from the machine weighs 33 pounds it might readily take up sufficient moisture to be 34 pounds when tested by the customer and furnish grounds for complaint as to overweight.

The best method of testing the product of a paper machine for moisture is to take as large a sample as the scales can conveniently weigh, weigh the sample immediately and mark the weight on it. Then place it in the drying oven and allow it to remain until bone dry when it is again immediately weighed and the loss in weight calculated into percentage. If less than 10 per cent it shows that the paper has been run too dry on the machine. In case of many papers, such as heavy wrappers, much more than 10 per cent of water can be left in the paper. In all cases a sample of such paper will dry out and lose weight upon exposure to the atmosphere.

Moisture in Clay: The drying oven is also a convenient and accurate appliance for testing the moisture of many other substances. The best method for testing clay for moisture is as follows:

A tin pan is weighed accurately and its weight recorded. It is then filled level with clay and weighed again; the difference in weight is the weights of the clay taken for test. The pan is now placed in an oven until the clay is bone dry and again weighed. The loss in weight is due to water or moisture and is calculated into percentage.

In this connection it may be safe to state that the clay is a material which not only contains water in the form of dampness or moisture but also contains chemically combined water which cannot be expelled by drying in an oven.

This water forms a part of the clay and is not driven off by the heat of the drying oven or by the dryness of a paper machine but remains in the clay in the dried paper even if the paper is dried "bone dry." If some clay is put in a crucible and submitted to furnace heat, as in burning brick, this chemically combined water is expelled and the clay becomes hard like a brick and will no longer dissolve or "break down" into a fine powder when stirred with water. If pulverized, each small particle is hard and gritty and not soft and sticky like an unburnt clay is. It is this fact that renders clay so valuable in the manufacture of pottery. The combined water not being driven off to the slightest extent in the process of manufacture of paper it does not therefore enter into consideration at all in making moisture tests. All clay is more or less damp and it is simply the extent of the dampness which is of importance which is easily determined by drying in an oven as pulp or paper is dried.

Whatever percentage of dampness or moisture clay contains is so much loss for it is bone dry when the paper has passed over the dryers in the machine.

The fibres of paper or pulp when bone dry suck up or absorb moisture from the atmosphere, but dry clay may lie exposed to the atmosphere without absorbing any noticeable amount of moisture.

If, therefore, 100 pounds of damp clay containing 10 per cent moisture are furnished to a ton of paper the 10 per cent of moisture in the clay is all dried out and only 90 pounds of actual clay have been furnished in reality.

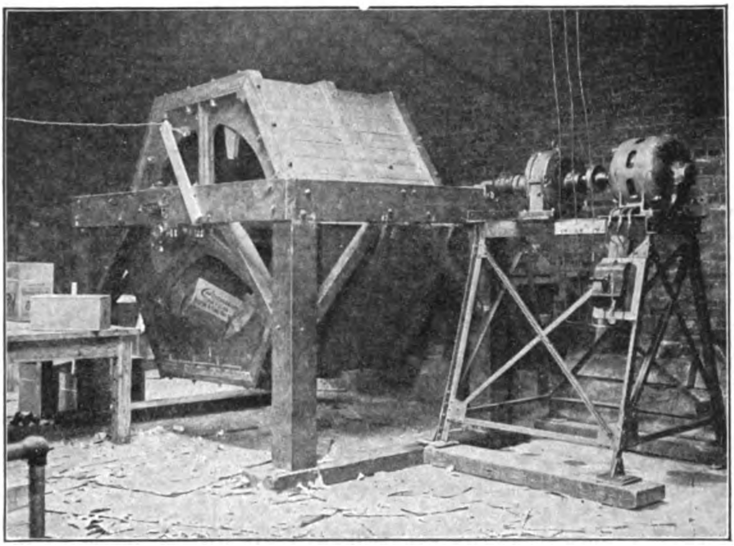
In testing the percentage of clay by paper all of the above features of clay must be taken into consideration and a sample of the clay itself must be tested as well as the sample of the paper used in order to obtain the correct and true results.

Testing for Retention of Clay: See under "Clay" in Chapter XII.

Moisture in Alum, Soda Ash, Lime, etc.: There are certain materials which absorb water or moisture from the atmosphere or which contains water chemically combined with the other constituents of the substance in such forms of combination that it cannot be dried out again by heating in a drying oven.

Alum, for example, contains a large amount of water which cannot be dried out of it even at high temperatures without decomposing the alum itself. At a high heat the alum melts or fuses without losing much water and if heated to a still higher degree, so as to drive off water, the alum is decomposed and the sulphuric acid is also driven off. There is, therefore, no method for estimating directly the quantity of water in alum. The percentages of all other ingredients can be determined accurately by tests and the water by difference.

Lime also absorbs moisture and carbonic acid from the atmosphere and becomes more or less "air slacked." Such moisture and acid cannot be driven off from the air slacked lime by heating in an oven, but it can be accurately determined by intense ignition of the lime, as no decomposition takes place and



Courtesy: Mellon Inst. of Industrial Research, Pittsburgh, Pa.

Fig. 215a.—Drum tester used for determining strength of fibre-board containers. The drum is rotated until the container breaks and the number of revolutions is recorded.

by ignition and air slacked lime is brought back to the original condition of the freshly burned lime.

Soda ash like lime absorbs moisture from the air and increases in weight, but the water absorbed can only be driven off completely by heating to a dull red heat. Some can be driven off in a drying oven but not all of it.

Moisture in Coal: Coal can be dried bone dry in a drying oven. Many times the coal delivered is quite wet and if cars are weighed a test for moisture is important to decide whether or not the full dry weight of the coal is delivered.

In conducting boiler tests the moisture in the coal used must also be determined and allowance made therefore.

Testing Stock: In determining the capacity of chests, concentration of liquid stock, etc., it is often desirable to test how much dry stock the liquid contains per cubic foot. This is best accomplished as follows:

Record the weight of a pie pan on the scales. Take exactly 1 quart of the liquid stock by means of an accurate quart measure. Pour this into a piece of cotton cloth and squeeze out as much of the water as possible. Transfer the stock from the cloth to the pie pan. Repeat this until the pan is about full recording the number of quarts necessary.

In the case of thick liquid stock one or two quarts may be enough while with thin stock a number of quarts must be taken to get a pan full. Care must be taken that no stock is lost during the operation.

The pie pan of wet stock is then placed in the drying oven and allowed to remain until it is bone dry. When it is taken out and weighed. It is well to put in again then weigh again, so that it is perfectly dry. The bone dry weight is calculated into air dry weight as usual by dividing by 90 and multiplying by 100. This gives the air dry weight of stock in the number of quarts measured out for the test, from which the weight in one quart is calculated.

The weight in one quart multiplied by 4 gives the weight in a gallon. The weight in one quart x 30 gives the weight in one cubic foot as there are 30 quarts to a cubic foot (exact figures 29.922 quarts).

XVIII. Paper Defects; their Cause and Cure.

Like all commercial products paper is liable to possess certain defects which cause trouble for the printers and other users of paper. It is incumbent upon a mill which wishes to hold the good will of the consumer to do everything possible to reduce the percentage of defective product to a minimum.

Fortunately, most of these defects fall into well defined classifications and the cause of them is well known in most cases and can be prevented by greater care on the part of the help and by the improvement of mechanical and chemical processes.

Slime Spots: These appear in paper as hard, shiny, discolored patches. They are caused by accumulations of slime forming somewhere in the preparation of the stock and getting onto the wire. Dirty beaters, dirty piping, dirty chests, headboxes, etc., are sure to produce this evil. It can be corrected by having all such equipment so designed that there is little opportunity for slime to accumulate, and then having it inspected at sufficiently frequent intervals that it will be thoroughly washed out when necessary. When a beater or chest is flushed out to remove slime the wash water should not be sent to the save-all system, but should go direct to the main sewer, otherwise the slime will just remain in the system and build up in total volume. The screens used with the paper machines are the worst offenders as to slime in the whole mill. The causes leading to the accumulation of slime in these screens and the steps to be taken to prevent it have been discussed already in connection with the section on screens in the chapter on the machine room, so it is not necessary to do more than refer the reader to that place. The discharge pipe leading from the screens is another bad place, which should be watched for slime.

In general slime can largely be prevented by taking certain precautions when the equipment is installed. Care should be taken to avoid all sharp corners in equipment and piping in which stock is to be handled. Such corners, when unavoidably present, should be filled in with fillets. Chests should be so designed that the currents created by the agitators reach every part of the chest, leaving no dead pockets in which the stock can stagnate and slime collect. All surfaces in contact with stock should be well finished and smooth. Roughness and irregularities afford lodging places for small particles which eventually grow into blobs of slime, fall off and pass into the stock furnished to the machine. The first step in preventing slime is to build all equipment in accordance with the above precautions. The second is to have frequent and regular wash-ups of all such equipment to get rid of what slime will inevitably form.

Hair Cuts: When a fibre of wool or sisal or some other harsh material gets into the sheet it will cut the paper as it goes through the calendar stack. This causes a great deal of trouble if the paper is being used for printing, and in fact for any use.

The sisal fibres are much the worst. They get into stock on account of sisal twine or rope being used for bundling in the finishing room. Pieces of this material get swept up with the broke and as the treatment of broke in the beater is of short duration the fibre goes into the stock in almost its original condition. Sometimes sisal gets into stock from bundles of pulp. One way to prevent this is not to allow the use of sisal twine. The second precaution is to see that no sweepings from the finishing room floor are put into the bin with the broke.

The wool fibres come chiefly from the washing of new felts, or from felts which have been newly napped. All wash water from this source should be run directly to the main sewer and under no circumstances allowed to go to the save-alls, which would lead to wool fibres in the white water and thus getting back into the stock.

There are certain other fibres which get into the stock from sweepings and miscellaneous causes, but according to an investigation of the matter made by a large printing company, more than three-quarters of all fibres causing hair-cuts in paper are either sisal or wool fibres. This investigation was made by examining all the offending fibres with a microscope and comparing them with standard slides showing known fibres.

Calender Cuts: Calender cuts are slits extending horizontally across the sheet, the paper along the line of the slit being glazed and discolored. These cuts will invariably cause the paper to break when used in a press or in any automatic machine. They are the result of careless supervision of the calenders. For instance, if anything makes the sheet go over from the dryers to the calender slack, there will be sure to be calender cuts. The sheet should go over just as tight as possible without straining it. Improper lubrication of the calenders may cause this. Another cause would be slipping of the belt driving the calender. If the calender rolls are crowding it is sure to produce calender cuts. Also if the sheet is a little thicker on one edge than on the other it will wallow as it goes down through the calender and this again will cause these cuts. The remedy in the case of each of the above causes of calender cuts is obvious and it only requires watchfulness and suitable regulation to eliminate these defects.

Calender Spots: These are due to little specks of paper that get on the sheet as it goes through the calender stack. They bruise the paper, glazing it slightly at the same time. These little scabs are largely due to wet ends, etc., going through the calender stack, after which the scabs of paper adhere to the rolls and go around again and again. Good calender doctors, well looked after, will do much to prevent this trouble, but it is bound to happen at times in spite of all precautions. However, in the case of an occurrence of this kind taking place, the stack ought to be well cleaned before the paper is put through again.

Crush Marks: Crush marks are distinguished by a curdled appearance in the paper. These marks are quite distinctive in appearance and cannot well be mistaken for any other form of defect once they are recognized. The cause of these marks is that the felt fills up with clay and other filler as well as with fine fibre. The water cannot get through the felt at this point and consequently is squeezed out as the felt and the paper pass through the press, spoiling the surrounding portions of the sheet. The cure for this is simply to keep the felts clean. Detailed instructions on the care of felts will be found in the chapter on the machine room.

Dandy Crush Marks: These marks also have a curdled appearance, but differ from the ordinary felt crush in not being localized but rather spreading over the whole surface of the sheet. These marks are caused by the too liberal use of water with the dandy roll, the roll wading in water which cannot get through the sheet in the usual manner. The best remedy is to use less water and more suction back of the dandy.

Coucher Crush Marks: Coucher crush marks are coarser than dandy crush marks and there are wide sepaations between the lumps of stock. These are caused by the suction boxes failing to take sufficient water out of the sheet, which may be due to too liberal use of water, to too slow stock or to imperfect operation of the suction boxes themselves, such as inadequate suction. It may also be due to the machine running too fast for the weight of paper being made. To prevent these marks it is advisable to find out which of the above causes is responsible and then adjust the operation of the machine so as to correct the fault.

Dandy Blisters: These blemishes look like a blister that has been raised up on the surface of the paper and then pressed down, causing a number of concentric wrinkles. The chief cause of these marks is a dandy roll that is filled up in places. This is especially so if the sheet is pretty dry under the dandy. A dandy roll that will run without trouble if supplied with a liberal amount of water will start to pick up if the water supply is decreased. The real cure for this trouble is to take the dandy off and clean it as described in the chapter on the machine room. However, some temporary relief may be secured by giving a little more water and this trouble can be lessened by keeping the showers used in connection with the dandy working evenly and perfectly.

Bubble Marks: When stock shows a tendency to foam, bubbles will frequently form on the wire which will break when they come over the suction boxes. The spot where the bubble was, will be deficient in actual fibres and consequently there will be a thin spot on the paper. These marks are usually quite perfectly circular, in which respect they differ from other marks which are usually irregular, and they are not noticeably curdled or wrinkled. With light tinted papers the bubbles will leave a distinct ring of concentrated color when they break. A steam shower or compressed air shower running across the sheet some distance back of the dandy will usually break these bubbles up. This shower should be sufficiently far back of the suction boxes that the shake will have a chance to fill up the places left thin by the breaking of the bubbles before the sheet passes over the suction boxes.

Froth Marks: These marks are due to large patches of froth or foam forming as the stock flows onto the wire. Sometimes a paper machine will be used at a much lower speed than the average of which such a machine is capable, owing to a variation in the weight of the paper being produced. The pump, however, is driven by a constant speed line and in comparison with the machine is racing at a very high speed, churning the stock up and causing it to foam. As the distance from the pump to the wire is small, the stock will go on the wire foaming, and this condition will be accentuated if there is anything in the stock peculiarly conducive to the cause of the foam. This can largely be avoided by introducing a drive for the pump, on a machine which is to be used at a variety of speeds, which will permit of the speed of the pump being varied.

A good shower right over the apron and slices will usually break down all the foam, but if foam persists in spite of this a little kerosene may be added to the stock in the beaters, or dropped into the pump box—2 or 3 drops a minute. This tends to keep foam down by forming a thin film on the surface of the stock. The shower should have 1/16-inch openings and a good pressure so as to create a fine needle stream. Alum will also tend to decrease the foam in most cases, although there are some cases where alum will positively increase foam, for instance, when certain pigments are used which react with alum so as to produce a gas.

Blemishes Caused by Drops of Water: Steam will condense on the roof of the machine room and drops of water will drip onto the wire. These marks are easily distinguished from bubble marks as they are irregular in outline although roughly circular. Sometimes the drop falls with sufficient force to make not only a mark but a hole. The cure for this evil is to have a ventilation system that will prevent condensation taking place. This is dealt with at length in the section on ventilation in the chapter on general design of pulp and paper mills.

Pitch Spots on Wire: These cause small holes in the paper.

The pitch fills up the meshes of the wire and no stock occupies this space and consequently no paper is formed. The cause of pitch goes right back to the nature of the wood used for pulp. Some woods naturally produce more pitch than others. It also depends on cooking conditions. The presence of gypsum or calcium sulphate in the cooking acid will tend to increase pitch, as the small granules of this material form nuclei around which pitch collects. This gypsum or calcium sulphate in the acid is due to improper burning of the sulphur to a large extent. This case is illustrative of the manner in which the various parts of a pulp and paper mill depend on each other. Troublesome holes in the paper may in this case be traced directly back to inefficiency in the sulphur burners. This subject is also touched in the chapters on the sulphite mill and acid plant.

The immediate cure for this evil is to thoroughly clean the wire. Sometimes a steam jet will soften the pitch and enable it to be washed out. Great care should be taken when removing pitch not to injure the wire. However, this is merely a temporary remedy. If pitch spots occur once they will occur again. The real cure is to thoroughly investigate the fundamental cause and attempt to cure that.

Lumps: Lumps or "slugs" are caused by little hard accretions of stock forming on the deckle strap or elsewhere and falling onto the surface of the sheet. Similar lumps are sometimes caused by fibres forming into knots on the under side of the screen plates and when they become heavy enough dropping off into the stock. This has been discussed in describing the construction and operation of screens in the chapter on the machine room. Almost anywhere that stock has a chance to churn around for any length of time not too violently such lumps will form.

These lumps will be pressed out forming blotches which interrupt the continuous strength of the paper and afford an opportunity for breaks, especially if near the edge.

A hole in the apron is another cause of such breaks. The tendency of the stock to run down through the hole will draw fibres into it which will be packed hard against the wire into a little knot. As soon as this is dislodged another will start to form and this hole will thus provide a constant source of these lumps, and the source may not be discovered until the holes wear large enough to be readily perceptible.

The cure for this class of troubles depends on the particular source. If it is the screens, the trouble probably is that the stock is standing too high in the vat. If the lumps are found to come from the deckle strap, the showers and poppets (or troughs through which the deckle straps pass) should be examined to see that they are exerting their proper cleansing functions. If a hole in the apron, the apron must be mended or replaced. A good sharp, clean shower back of the breast roll, under the apron, spraying water on the apron and the wire will help dispose of all such lumps if any are forming.

Wet Spots: Any bruise or depression in one of the press rolls will cause the paper which that spot comes in contact with to be somewhat wetter than the average. This wetness will not be removed by passing through the other presses, even by passing over the dryers in some instances, because it will always be a little wetter than the remainder of the sheet. If wet enough when it reaches the calenders such a wet spot will give rise to a blemish looking much like a slime spot, all the fibres being crushed and moulded together into a glazed blotch without strength and marring the look of the sheet. Obviously the cure is to repair the offending roll.

Sawdust Spots: Ground wood pulp, unless very carefully screened, will contain some sawdust. Moreover, in making sulphite pulp, sawdust frequently does not cook in the digesters, remaining hard and woody. By rights there should be no sawdust in the chips, if they are properly screened, but sometimes through carelessness or the use of poor equipment some sawdust gets into the digesters, and probably with the best practice there is always a little which has adhered to the chips in spite of all precautions.

These particles of sawdust will go right through with the stock into the beaters and into the paper machine. There they may form a blemish out of all proportion to their size, these marks sometimes being as large as a silver quarter. This is because the sawdust holds the sheet up off the dryers, letting it remain wet in a small circular area surrounding the piece of sawdust. When the sheet reaches the calenders this wet spot will be crushed in the manner described under the heading wet spots above. However, this sort of blemish can usually be distinguished from an ordinary wet spot as the sawdust or the trace it has left can usually be recognized in the center of the blemish.

The cure for this condition is more careful sawing, screening and chipping. However, if the screens on the paper machine are in good condition they should catch such particles, so that if sawdust spots are appearing it would be a good idea to look and see if the screen plates have not been bent by someone stepping on them or dropping a tool on them or pounding them too hard with a slapper.

Pin Holes: Sometimes a sheet of paper will display small glistening particles which fall out, leaving little pin holes when the sheet is crumpled. The glistening material is gypsum or calcium sulphate formed in the cooking acid on account of SO_3 being present in the sulphur gas. Therefore, the cure for this trouble goes right back to the sulphur burners, and for the details of this the reader should consult the chapter on the acid plant. Naturally this defect can only occur in papers containing sulphite stock.

Thin Streaks Due to Ridged Wire: If, for any reason, such as a lump of stock adhering to a carrying roll or the breast roll, the wire acquires a ridge, the stock will not form on this ridge, or at least will not form as thoroughly as on other portions and this will yield a thin strip reaching lengthwise of the sheet. There is no real permanent and sure cure for a ridged wire. In the hands of a careful operator a wire will not become ridged.

Thin Streaks Due to Seam of Wire: Sometimes the seam of the wire will fill up and make a thin streak. This sort of thin streak runs across the sheet. It is the result of a bungled job at seaming and there is really no cure for it. It is a case where the paper maker can learn from experience.

Blow Marks: Air will sometimes get under the paper as it passes into the pinch of the press rolls. This air will raise up the sheet in a sort of bubble, which will be ironed out as the sheet goes through the press. The air will make two paths or trails, one on each side of the bubble, just as will happen if you run a roller along a rubber tube full of air. These trails will leave marks on the paper which are easily recognized by their occurring in pairs.

When the bubble is pressed down it will overlap the remainder of the sheet at each side. The mark will thus finally appear as two thick, irregular blotches, running the length of the sheet, separated by a thin patch between them. One cure for this is to place a small very light felt covered roll on the paper after it has been carried across from the couchers to the first press. This roll will ride on the paper and insure it entering the pinch of the press level and free from air. This trouble cannot well occur on machines equipped with suction press rolls as the air is thoroughly drawn from under the sheet by suction. On the usual machine, however, there is no place for the air to escape to. This trouble is most likely to occur when the felt has just been washed and is so wet that air cannot pass through it. It is not a constantly occurring trouble and one may make a lot of paper without experiencing this difficulty, but we mention it so it will be recognized when it does take place.

The above, of course, are not all the possible defects that can occur in making paper. On such a complicated machine as a Fourdrinier paper machine new sets of circumstances are always happening which will lead to unexpected results. The thing to do is to get at the source of the trouble by a process of elimination, examining and dismissing the more to be expected sources of trouble first, one by one, before the more unlikely reasons are looked into. This is just as in finding out why an automobile refuses to go. One does not take the ignition system to pieces until one has ascertained if there is any gasoline in the tank. Defects may be very persistent and mysterious, but continued careful investigation will reveal the cause of all of them and when the cause is arrived at the defect can be remedied.

XIX. Personnel.

Now that the mechanical operations and the chemical and physical changes involved in the manufacture of pulp and paper have been thoroughly discussed it is necessary to consider another vital factor in paper making. There is nothing more essential in the conduct of a successful paper industry than an efficient operating force. A mill may have been designed by the most experienced and ingenious engineers, it may be equipped with all the latest and most efficient machinery regardless of expense, the raw materials may be of the best and highly trained chemists may be at hand to supervise each operation in accordance with the best scientific practice, and yet such a plant may barely struggle along on account of neglect of the human factors entering into paper production.

Co-operation in the Organization.

The personnel of a pulp and paper manufacturing concern means the entire assemblage of people from the president down to the most insignificant laborer who are in any way concerned with the necessary activities of the organization. The personnel of all pulp and paper concerns is much the same. First there are the general executives whose duty it is to supervise financing, manufacturing operations and future development, the purchase of raw materials, the general sales policies, etc. The vast number of those employed in such an industry never come in direct contact with these activities, but it should be remembered that if these large affairs are not attended to in a faithful and judicious manner all work further down the line would be of no avail. Next there come those in charge of various special departments, and between such executives there must be actual and intelligent co-operation if maximum efficiency is to be obtained in the concern as a whole. Such men are the sales manager, the advertising manager, the general purchasing agent, the chief chemist and finally—most important of all—the superintendent or mill manager or whatever it may be decided to call the man who is actually in charge of the manufacturing plant.

To illustrate the need of co-operation between these men, if the sales manager has no conception of the difficulties and intricacies of manufacture, it is obvious that he cannot market the concern's product in a very intelligent manner. He is hardly in a position to answer complaints, to accept or reject important orders which require immediate decision, or to direct the work of his subordinate salesman.

Similarly, the advertising manager is the man through whom the concern speaks to the public, or that section of the public where its customers and potential customers are found. It is self-evident that such a man cannot talk convincingly about something he knows nothing about. He must know the company's product from the wood pile to the finishing room.

If necessary co-operation between the purchasing department and the manufacturing department is lacking much needed supplies and equipment will not be on hand when needed, many unnecessary or unwise purchases will be made and much money and time will be wasted.

The necessity for the closest of relations between the chemical laboratory and the manufacturing department is too obvious to even comment upon. If the chemist is to be any good at all to the concern he must be familiar with every stage of the process of manufacture and also must be well informed on general trade conditions, the market in which the company's product is sold, what the competition is, etc.

Requisite Qualifications of a Superintendent.

The superintendent must display a nice balance of abilities. The principal qualities to be looked for in the ideal superintendent are:—

(1) Practical experience.
(2) Scientific and technical knowledge.
(3) Business sense.
(4) Ability to handle and get on with men.

Practical experience: This has no necessary relation to length of time spent in the industry. There are many men who have spent a lifetime in an industry and who know little more than when they began. It is the result of learning day by day and keeping one's mind open and not making the same mistake twice. However, other things being equal, a man's experience generally will increase as years pass and there are many tricks of the trade which only time can teach.

Scientific and technical knowledge: This does not necessarily imply training in a technical school or the scientific department of a university. It is the result of an alert, inquiring mind. In the course of years spent in an industry a man with the scientific trend of mind will find out *why* things are done. He will not be satisfied with the answer that they have always been done that way. A college training is an excellent thing for the man who knows how to use it after it is obtained. It opens the way to many short cuts to knowledge. However, it is no guarantee of technical ability and many of the most scientific men in the industry started without it. The truly scientific technical man is never done learning. He is always ready to consider new developments. In this he can be helped by the technical periodicals of which there are several excellent ones in the pulp and paper industry, by meetings of technical associations, etc. The dangerous stage is when a man thinks he knows enough about the industry. Just then someone is sure to get ahead of him. There is always more to learn about any industry, but especially about an industry involving such a variety of sciences as does paper manufacture.

Business sense: Cases where men who are scientific geniuses, and who have had a long experience in practical work, have failed absolutely in running the business end of an industry are too numerous to mention. An ideal superintendent must know something about ordinary business economics. He must realize that the final crucial test of any manufacturing operation is "Does it pay?" A wonderful product is of little practical value if it costs more to make than its sales department can possibly get for it. No one expects a mill superintendent to be a financier or a commercial genius, but he must have a grasp of the ordinary principles of business.

Ability to handle and get on with men: We will have so much to say on this subject later that we will dismiss it here with the comment that it is the most important requirement of all, because if a superintendent's men cannot or will not work with him he is automatically prevented from displaying his other abilities.

Co-operation Among the Employees

One of the most common causes of imperfect efficiency in pulp and paper manufacturing industries is lack of co-operation between the various departments of the concern. The most frequent cause for this lack of united effort is a too intensified rivalry between the different departments. Rivalry is an impulse that can be utilized to advantage if it can be kept under control. However, this is hard to do. Many superintendents make the mistake of over-encouraging rivalry in order to increase production and lower costs. In the end it does neither. The rivalry grows and in the end is replaced many times by an actual hatred.

Rivalry between departments is detrimental to the success of the mill in many ways. In attempting to cut down costs below those of a rival a foreman may release one or more of his men. His actual output of work may continue up to standard for a short period, but only on account of extra effort forced from the remaining men who soon become dissatisfied either through overwork or sympathy with their former fellow workmen. However, they realize that they are being driven to enable the boss to make a good showing. Dissatisfaction leads either to strikes or to indifferent work.

Foremen often refuse to help each other by lending help or tools in time of trouble. The rivalry between foremen will become so intense that one will delight to see the work of another suffer even if the whole plant is inconvenienced.

Rather than encouraging men to outdo each other it is better to teach that if the whole plant benefits, each man in it benefits and that therefore it is not only right, but good policy, to refrain from doing anything that will cut down general productiveness.

The relationship between men and their bosses plays a large part in the success of the paper mill. Every boss must have the good will of his men. This is true not only of department foremen, but also of the plant superintendent as well. The superintendent is the most important single individual in the personnel of the paper mill. He must keep the mill runing as a paying proposition. He must ever be on the watch to reduce unnecessary expenses. He must adjust labor troubles and settle disputes among the men. He represents the owners' interest in the concern. To be successful in all this he must have the hearty co-operation of all the men. This can only be secured in one way. This is by and through the sincere personal regard of his men.

Personal Relations between Superintendent and Men.

No superintendent can direct the operation of a mill with any hope of success if he is disliked by his men. Men will work under a superintendent whom they dislike, if they have to, but they will not give him all of which they are capable. They are bound to relax as soon as they are out of this direct observation. Some superintendents seek to govern the men through fear. Through fear a man may be made to work, but he cannot be made to work efficiently. The very dread which some superintendents inspire in their men causes the men to become nervous and incapable of doing good work. No man knows where the reprimand or sarcasm is going to strike next and suspicion and irritability soon prevails throughout the whole plant.

The superintendent should never misrepresent things. If he makes a promise he should do everything in reason to make good. If he cannot make good he should frankly tell the reason why.

Needless to say, the superintendent who wants the co-operation and respect of his men will have to be sociable and agreeable. This can be done in such a manner by a man of good judgment as not to lose the respect that he also must retain. It is a matter requiring some tact to retain proper respect and yet not to be cold and distant. Men should always be spoken to when they are met during working hours, or on the street, or anywhere else. The writer considers any man who works for him and is honest as a friend and to be treated as such both in and out of the mill. Some superintendents have more capacity than others for remembering names and little things about men, but it is a great help if a superintendent can remember something about each man so it will be evident when he speaks to him that he knows the man as an individual. One man likes to be questioned about his family and another about his garden or some other hobby, and if a man's relatives are ill he likes to have them inquired about. These things are little, but they have a powerful influence on the general atmosphere of a plant. However, unless the superintendent can maintain such relations naturally it is better not to attempt it at all. Insincerity is very apparent to workmen.

A superintendent should always believe what is told him by his men unless he is absolutely sure a man has prevaricated. In other words, a man gets the benefit of the doubt. If it is found that a man cannot be treated in this manner he may be considered a hopeless case and should be dropped out of the organization.

In this day and age men will not stand for bullying. The writer recollects having worked for men whom he constantly feared and could not trust. He never felt sure when he went home at night that he would not return the next day to find his place filled with some other man. It is impossible to do good work for an erratic and overbearing man of this type.

It is also bad policy ever to interfere with foremen. There is nothing a capable man so much resents as to be placed in charge of an operation and then to have the superintendent or manager issue instructions to some man under him. If the superintendent notices something obviously wrong he should go to the foreman, not to one of the workmen. This secures the confidence of both the foreman and the workmen.

The method used by some managers of going to workmen to get posted as to the details of operations is very disorganizing. The men feel that when they have a grievance they must go far up the line, even to the president of the company. They feel that they are getting more credit and it ends in making a mere figure-head of the foreman or superintendent.

A superintendent should discourage the carrying of tales to him by workmen. Men should be given to understand that they must settle all differences calling for adjustment with their immediate superiors.

It is bad to spy over men. It is not only objectionable, but futile. No system of spying could possibly be effective unless it involved much waste of time. Mills have to work nights as well as days and men have to be trusted to do their own work properly.

The writer has known superintendents who have made a practice of spying on their workmen at night, sometimes as late as one or two o'clock in the morning. When anything like that becomes known, the men lose all confidence in their superior and feel that they are branded as dishonest. It is well for a superintendent not to go near the mills at night unless in case a breakdown or some other exceptional circumstance. If it is necessary to go into the mills at night the workmen should be let know of it in some manner so that they will not think that it is spying.

Bullying, spying and overbearing conduct will make men secretive and much harm may be done in this manner. The writer has seen cases where the men were absolutely afraid to say anything about any accident that happened during the night and would even lie about them because they knew full well beforehand that without regard for the circumstances the superintendent would accuse them of sleeping or loafing on the job. In this way small accidents will stand unreported and may grow into serious matters. If a man feels that he is sure to be discharged or bullied for making a mistake (perhaps a very pardonable and natural one) he will invent some plausible story about it. If, however, conditions were otherwise and he was not afraid to explain about the mistake, the whole matter could be discussed and there would be small chance of that man making the same mistake again.

Development and Training of a Papermaker.

Progress is not quite as difficult nowadays as it was when the writer began his trade. At that time the paper and pulp industries were carefully guarded as more or less secret processes which was a great handicap to anybody undertaking to learn the business. For instance, the position of machine tender seemed to compare very favorably with the position of locomotive engineer. I mean by this that we had to wait until somebody died or grew too old to run his machine before we ever had an opportunity to be advanced to that position.

From the very beginning, or the bottom round of the ladder, up to the point of being a machine tender, there were all sorts of obstacles in my way. I was obliged to start in the machine room and do all of the dirty work. I lugged the drinking water, did the scrubbing, passed along the monkey wrenches, ran errands, hustled broke, and was not allowed to become too much interested in the skilled part of the work. For instance, if the paper broke on the machine and I asked the machine tender what broke it, he might tell me that the break came from the stuff chest, or it might be the fault of the pump in the basement or some other way of misleading me as to the real cause.

Perhaps this would be a good place right here to say that a young man who starts in to learn the paper business has not necessarily got to start in, in the machine room, but without influence it naturally follows that a young man must take a position wherever he can get it, whether he begins at the wood pile and works forward or at the finishing room and works back, or again in the machine room and works both ways. In any event he must cover the ground thoroughly in order to be proficient.

At this time also there were no unions to protect a man from unfair treatment or from ugly and overbearing superintendents. If I were asked to work even 48 hours consecutively without sleep, I did not dare to refuse because it would cost me my job.

Today this condition is far different. It is even against the law to compel a man or even to urge him to work beyond the specified hours fixed by the legislature. Men nowadays must be treated like human beings.

I worked for at least two years as roustabout, cutter man, third hand, winderman and finally back tender before I could get an opportunity to try my skill at operating a machine, and I would not have had a chance even then, had it not been for the fact that the machine tender wanted to go away on a vacation and there was no one else whom he would trust to take his place while he was gone, except myself. This merely broke the ice for me, but did not put me in more of a hopeful position for getting a machine, because there was still the obstacle of waiting for a dead man's shoes.

There is another phase to the question which has occurred to me repeatedly since I have been in charge of mills, which is that owing to my own experience I have been able to decide with some degree of accuracy as to whether an applicant is fitted for the position which he seeks.

Since pulp and paper manufacturing plants run day and night, it is necessary for one to become accustomed to night work, which is very unnatural. It does not require a stretch of imagination to know that this way of working one week nights and the next week days, will upset anybody's system. One cannot sleep in the daytime, nor can he eat rationally at night. It causes an upsetting of one's whole makeup, brings on dyspepsia, insomnia, and various unnatural tired and wornout feelings.

I have frequently had application from college men, young, robust, snappy fellows, who wished to learn the pulp and paper business. They were willing, so they said, to start in at the bottom, in fact they wanted to cover the ground thoroughly, and would take their turn with the rest, but there have been only one or two out of the many men whom I have started who have not fallen by the wayside.

First of all, we get intelligent young men right after their school course, unprepared to stand for any of the hard knocks and after having to sacrifice their health in many cases, go without sleep, and perhaps be knocked around, and having their intelligence insulted (so they think) by the rough characters they may come in contact with, they often give up. I mean *rough*, not in the sense that the paper makers themselves are particularly rough, but on account of the nature of the work which has to be covered during the man's advancement. There are various other reasons why a young man will drop out of the ranks during the journey from the bottom round of the ladder to the top.

Very frequently a young married man makes application. He starts in and finally makes the excuse that his wife does not want him to work nights. Then we frequently get young men who have absolutely no mechanical ingenuity or ideas. This condition is really hopeless. It is a well defined fact that it is useless to try to make a farmer out of a mechanic or to put a mechanic behind a plough.

The paper and pulp industry calls for a so many branches of work other than the mere matter of making paper that a case of this kind simply wastes the time of the employee and the employer; putting a man in charge of expensive machinery who has no idea of the care of such, is a very costly experiment. The man's judgment never is anywhere near correct and he makes very costly blunders and usually does not succeed after wasting possibly eight or ten years of his life.

The young men who start in the business who are more apt to succeed are those who are accustomed to rough and tumble work; have the determination to forge ahead; are not too sensitive as to their associates and are usually the boys who have had even a worse and a harder lot before they started in with the business, together with a natural trend for mechanics. You can imagine a bright, young man, with a college education, who makes a start in the paper business, how humiliated and insignificant he must feel to be ordered around, since he has been accustomed up to that time to polite treatment.

Then there is the intemperate young man. I had rather have a good, willing fellow that is reliable and temperate than to have one of the opposite type who might know very much more about the business. A willingness to obey orders and apply oneself to the learning of the business is a good asset.

There is just as much call for good, reliable conscientious and steady men today as there ever was. They have always been at a premium and always will be.

Then there is the disturber, whom we sometimes get into the organization. Their activities in an organization of men are as harmful as a rotten apple in the center of a barrel of good ones. They will do more towards disorganizing a crew of men in one month than can be put right in a year, and then it cannot be made right except when the cause is removed.

It is sometimes very hard to single out the person who is spreading unrest and discontent in your organization. These men have a faculty of covering their tracks to a great extent and have caused a great many bad disturbances.

Now some of these causes for disqualification of an employee can be charged directly to the individual himself, while others are inborn and cannot be remedied.

Finally the qualifications a man should have who desires to make paper and pulp manufacturing his life profession are:

First—Physical health.

Second—He must be absolutely honest and trustworthy.

Third—Willingess to undergo and put up with the various ordeals he must pass through, as he goes up the line towards promotion.

Fourth—He must have a natural trend toward the business, and be naturally mechanical.

Sixth—He must be a man who has a respect and deep interest for the success of his employer.

Seventh—He must be co-operative.

Eighth—He must be able to stand all of the disappointments and obstacles which he is bound to encounter and be willing to help and assist in any way that he can to further the interest of the company for which he works.

Ninth—He must have stick-to-it-ive-ness and the great desire to learn the business.

I call to mind an instance which happened in my own experience where I was eligible to the next position as machine tender, as I was the oldest employee in that department. I had been promised by the superintendent that I could be assured of the next place. After some time a vacancy occurred on one of the machines. I was perfectly sure that I would be given this position, but to my chagrin and disappointment the superintendent put his own son over my head, into the position that I thought rightfully belonged to me, as I had the superintendent's word of honor that I would get this position. I, of course, immediately quit, and by doing so, I lost ground. This display of temper and haste, without taking second thought, cost me a least one whole year of experience. This was one of the number of disappointments which a young man must put up with, as I saw later. If I had stayed I would not have lost my year's experience and would have been installed as machine tender before the year was out. I speak of this fact because I run across these conditions every day.

There is always an easy way to smooth out misunderstandings and difficulties, and there is a hard and rough way. I am satisfied that one cannot unravel and smooth out a misunder standing with men by bullying or insulting methods.

After organization is formed and things are running smoothly there may occur a vacancy. It may be the foreman for the yard operations; it may be foreman for the sawmill department, or some place where a man must have charge of a number of men. It will readily be seen that it is a difficult job which requires a great deal of careful study and observation to go into a crew of workmen and select a foreman to take a position as just described. A man may be perfectly competent to handle the job; he may say that he can get along with men; I may give him a position. The first thing I know some of his help come into the office with a story concerning his unjust treatment.

Some men, as soon as they are advanced a few steps, get so overbearing and feel that they are so much better than the men who work under them, that it is quite impossible to get along peaceably; they become arrogant, and overbearing and actually spoil their prospects for any position of trust or responsibility.

Every man must be capable of his job, from the superintendent to the broke hustler. The superintendent who does not know how to handle men cannot hope for success. Besides a thorough knowledge of papermaking, he must have tact and foresight, prudence and judgment. This is true of the foreman also. Every man in the plant must have a thorough knowledge of his job and he must be physically able to perform its duties. If through deficient knowledge or physical incapacity a man depends upon others to help him perform his duties, somebody's work is bound to suffer and the efficiency of the mill is consequently lowered. No man should be called upon to do work of which he is incapable. He may attempt it, he may almost succeed, but in the end his attempt will prove a decrease in the mill efficiency.

The working conditions of the mill must be favorable in order to keep the personnel up to standard. The truly efficient workman will not work in a mill which does not meet the condition to which he has been accustomed in other mills. The men all appreciate the little consideration which their employers grant them and more than repay the small cost by their greater efficiency of the work. To sum up—each man in the paper mill's personnel must be a man capable of his job, a man satisfied with his job, a man loyal to his job.

Machine Tender.

The machine tender is responsible for the operation of his machine and the quality of the paper turned out by it. He directs the work of the back tender, third hand and other machine help, although the more detailed supervision of these men is largely in charge of his assistant, the back tender.

The machine tender should encourage the back tender to observe his manner of tending the machine so that he—the back tender—can assume those duties whenever occasion may so demand.

The machine tender is responsible for starting the machine. His immediate concern is the wire, which must be free from slime and otherwise ready for the stock to flow onto it. When the machine tender is perfectly sure that the wire is in proper condition he begins furnishing up the vats, screens, pump box, head box, save-alls, etc. It is his function to decide when the stock is to be allowed to flow onto the wire. From that point on the back tender carries the paper through the presses and over the dryers. While this is being done the machine tender inspects the screens, suction boxes, deckle straps, couch roll and presses and other parts of the wet end and takes particular notice whether his sheet is level or not, which can be especially well noted at the couch roll, and makes whatever minor adjustments may be necessary. He is guided in this by the weigh sheet which the back tender tears off, weighs and brings to him as soon as the dry paper is going through the calenders. When this is all done, and everything at the wet end is running smoothly he should take a general look over the dry end to see everything is all right.

The Back Tender.

The back tender is to the machine tender what the first mate it to the captain of a vessel. He is largely responsible for the third hand and other help around the machine. By devoting proper time and attention to the training of these men so that he can rely on them to accomplish their work in a quiet, efficient manner without constant directions being shouted to them, he can leave just that much time and attention free for acquiring the further knowledge that will be necessary before he can aspire to the position of machine tender.

Similarly, the more the back tender can devote his time to routine matters and the supervision of the other help, the more time the machine tender can give to inspecting the machine and seeing that everything is in the best working condition, determining the cause of irregularities, etc.

The chief responsibility devolves on the back tender in connection with breaks. He must see that the other help are in their proper places to take the paper after he personally has passed it over the dryers, etc. During wash-ups the back tender should be responsible for the washing of the felt, being assisted by the other help, and the machine tender being free to look after the wire, etc.

When starting the machine, after the machine tender has let the stock flow onto the wire the back tender takes the sheet through the presses and over the dryers, watching to see that the dryers are hot enough to thoroughly dry the sheet before it is led through the calender stack. The third hand should be allowed to perform this work from time to time under the direct supervision of the back tender, who should take care to see that he does not do it in such a manner that his hand is in danger of getting caught in the presses or dryers.

If the dryers are working properly, the back tender next runs the sheet through the calender stack or stacks making sure that the doctors are clean so as to prevent calendar spots, and seeing that the calender is properly lubricated so that there is no slacking back, which is the chief cause of calender cuts, one of the most objectionable defects in paper.

It is also his duty to see that the paper is going over from the calenders to the reel properly, so as not to cause rolls with hard and soft spots on the reel. We have already spoken of the harm this does in the chapter on the finishing room.

The back tender should see that the floor around the machine is kept in an orderly manner and not encumbered with broke, spears, tools or rubbish or sloppy with stocks, etc. An untidy floor has been the cause of many an accident.

All the time the back tender should be learning as much as possible of the machine tender's art and should be teaching his own to the third hand. In this way he is preparing himself for advancement and training a man to take his own place.

The back tender needs to be a man of resourcefulness and able to think quickly in an emergency. It is a responsible position, but one full of opportunity for usefulness and for future advancement.

Third Hand.

Just as the back tender is an understudy for the machine tender, so is the third hand an understudy for the back tender, that is, he should be if he is ambitious and capable. The third hand should assist the back tender and machine tender generally in washing up and in renewing felts, wires and jackets. By so doing he will learn much about the duties of the men immediately above him.

Making splices at places indicated by the back tender is a job usually relegated to the third hand, and it is a very important job from the point of view of the company's customers. Crushes, calender spots, slime spots, etc., have to be cut out and a neat splice made and a flag inserted in the roll to mark the location of the splice.

The third hand's prospects for advancement are largely dependent on his avidity for work. It depends on the man himself whether he will be looking for opportunity and always finding some way of being useful to the machine tender and back tender, or whether he will merely do what is absolutely demanded of him.

Beaterman.

The position of beaterman is a very responsible one in all mills, and one where a great deal of science can be applied if the man will take the trouble to learn from observation. He should see that color, size and alum are added in the proper order, and at sufficient intervals of time for the best results to be obtained, not all dumped in so as to get the work done as soon as possible. He should supervise the furnishing of lap stock, seeing that the beater help open out the laps properly and that the roll does not jump as the laps go under. He is responsible for the condition of the roll and bed plate, the keeping of the beater in a clean condition (free from slime, etc.) and the entire conduct of the operation. Therefore he must watch the appearance and feel of the stock most carefully, regulating the roll as may be necessary to secure the proper result, in accordance with the general instructions of the superintendent, and his own judgment.

Industrial Bureau.

The past few years has brought forth the need of maintaining within the pulp and paper manufacturing concern a department to look after the welfare of the employees and to serve as a medium between the management heads and the employees themselves. The problem, however, is to decide just how far to go with this sort of work. For instance it is reasonable to suppose that a company employing from 300 to 500 or possibly 1,000 men on the payroll can not afford to go into this as deeply as mills employing from 20,000 to 40,000 and incidentally using men speaking several languages. The name applied to such a department is usually termed an Industrial or Employment Bureau.

Regardless of how large the personnel of the Bureau may be the following two main divisions of activity must be kept in mind:

1. Getting Workers; 2. Keeping Workers.

Getting workers necessarily includes the following:

1. Getting applicants from among whom to select the workers. 2. Interviewing, selecting, examining and investigating the applicants. 3. Developing labor sources from within the plants.

The above, of course, furnishes but a very much simplified sketch of what the work of this first division might consist of.

Keeping workers might include some of the following ideas:

1. Accurate enrollment details; 2. Intelligent introduction of workers to the conditions of employment to their supervisors; 3. Analyses of enrollment of details—age, sex, nationality, intelligence and experience; special qualifications, kind of work at which started; supervision, rate, hours, physical conditions peculiar to the individual; 4. Quiet and tactful follow-up of every new employee to determine the accuracy of placement, satisfaction with work, attitude of co-workers; 5. Familiarity with progress of every employee through watching records of attendance, production, wages, transfers and suggestions offered; 6. Investigation of reports of dissatisfaction.

In order to carry out the above work the Chief of this Industrial Bureau, that he may carry his work out both for the benefit of the organization that he represents and the employees themselves, must be acquainted with the following details:

1. General policies and supervising personnel of the industry and physical working conditions; 2. Conditions, hours and rates of neighboring and competing industries; 3. The number and kind of workers needed by the industry; 4. Kind of work to be done; 5. Conditions of work; 6. Hours, regularity and permanency of work; 7. Kind, amount and frequency of reward.

In the present stage of agitation it has become quite necessary to employ such a medium for watching the hiring of men. In large corporations where the hiring lies entirely in the hands of numerous foremen, graft, favoritism and autocratic power often result and men discharged in one department for being agitators may be promptly picked up by another foreman who may at the time be short of help. Few manufacturers have a real live Employment Department. The old system of letting the foreman hire men regardless of experience and qualifications

Form [illegible]

APPLICATION FOR EMPLOYMENT No.............

WITH

Note—Application for employment must be made out and signed personally by applicant in ink. Each question must be answered in full.

Name in full (no initials).......................... Married or single?.............. White or colored?..............

Address: Street and Number .... City or Town .... State ....

Position desired.......................... Wages expected per Hr. / Wk............ Could report for work....days after engagement

Date of Birth.......................... Year.................. Height.................. Weight.............. Lbs.

Birthplace: City or Town .... State or Country .... Have you been naturalized?.......... Date..........

What languages do you speak?.......................... Have lived in United States......years

Grammar School attended .... No. of years.............. Year of graduation..............

High School attended .... No. of years.............. Year of graduation..............

Technical School attended.......................... No. of years....... Year of graduation......... Degree.......

Give below four employers to whom we can refer. [Read note at bottom of this blank.]

Time Employed (Give Month & Year)	Name and address of Employer	Name of Foreman	Kind of Work Done	Wages Received	Reason for Leaving
From	Name			$........	
To present date	Address			Per	
From	Name			$........	
To	Address			Per	
From	Name			$........	
To	Address			Per	
From	Name			$........	
To	Address			Per	

Were you ever employed by this Company?......... If so, where and when?..........................

Give names of your relatives in this Company's employ ....

State condition of your health.......................... Have you any chronic ailment?..........................

Are you ruptured?.............. Have you ever had tuberculosis?.......... Fits or epilepsy? .... Rheumatism?..............

Explain fully your defects in sight, speech, hearing or limb ....

....

Give below: Full Names of living Relatives and their Home Addresses

Wife or Husband	
Children	
Father	
Mother	
Grandparents	
Brothers	
Sisters	

In case of my illness, etc., notify..........................

I certify that my answers to the above questions are true, and I also agree that said questions and answers shall form the basis of my employment.

Date.......................... 191 Telephone No.............. Sign here ☞ ....

Fig. 216.

is, and always will be, a big expense as well as the least efficient way of securing productive labor. The management that permits the old system to continue either through ignorance or fear gives no attention to working conditions of the employees, the very backbone of the industry, and the employees continue to growl and agitate trouble at the smallest disturbance. Before installing a system of this nature the writer encountered these difficulties daily. Oftentimes men fired in one department for being radical agitators have in a short time returned to be hired by another foreman, unknowingly, of course, as he had no adequate means for investigating the past of this particular workman. Frequently problems dealing with the welfare and betterment work and industrial education are handled by the same bureau.

As previously stated it is often a hard question to decide just what the powers of this department are to be—whether the employment manager will have the sole right to select, hire or fire workers: whether the foremen can have the right to decline to accept workers selected by the employment department: whether the rights of transfer should lie in the hands of the foremen or the employment bureau.

The powers of such a department are, therefore, largely dependent upon the nature of the plant—in specialized work with a tightly woven working organization these powers might lie entirely in the hands of the Industrial Bureau with advantage to all parties concerned. In organizations, however, where operations are widely diffused and varied, as is the case in most pulp and paper mills, it is best to adopt an intermediate plan. One organization employing 1,500 men has an Industrial Bureau consisting of a Chief and two alert assistants. The forms adopted and the powers of this department will be lightly touched upon.

Figure 216—Shows a usual form of employment blank. All men seeking positions, no matter to whom they apply, are directed to the Industrial Bureau where they are interviewed by the Chief of the Bureau. The applicants are then requested to fill out this application form which is by no means elaborate and cumbersome and contains all the data essential for the purpose. In conjunction with this form is used a follow-up slip on each applicant to verify the statements made by the applicant by writing to his former employers. This form is illustrated by Figure 217.

Each morning all Superintendents demanding help, call the Industrial Bureau stating the type of man wanted and nature of jobs. The Chief of the Bureau then looks over his files containing the waiting lists and selects the men suitable for the jobs in question. This man then reports to the Bureau and is given a slip illustrated in Figure 218. Also, if the Mill Superintendent has the right to pick out a man, he is furnished with the form shown by Figure 219. The man with this form must report to the Industrial Bureau, where he will properly enroll and then report to his Superintendent.

The man then reports to the Superintendent who generally accepts him. If he has any reasons for not accepting the man he has the right to reject him but must first state his reasons for so doing.

We now have the man installed on the payroll. It is the

SMITH & JONES PAPER CO.

....
(Place & Date)

....

....

Dear Sir:

........................of........................

applicant for a position with us as ....
has given your name as a reference, and claims to have been employed by you

As ....................FROM.................TO..............
RATE..................CHECK NO...........................
......................DEPT. FOREMAN....................

USING REVERSE SIDE, kindly advise if information given above is correct and whether you can recommend the applicant as to ability, character and disposition. Any further information will be appreciated and treated as confidential.

Very truly yours,

....

....

I authorize you to furnish the information requetsed

....
Signature of Applicant

....
Witness

Fig. 217.

duty of the Chief of the Industrial Bureau to see that the man is content with his job. Special provisions are made to educate the foreigners in elementary English. The application of ef-

SUPERINTENDENT'S NOTICE OF REGISTRATION

______________ 192

Mr.______________________ Sup't______________________ Mill

Mr.______________________ No.______________________

has registered with the Industrial Bureau.

Signed______________________
Industrial Bureau

Fig. 218.

ficiency on record system has a gratifying effect on the workers when properly applied. It minimizes the opportunities for display of favoritism, a practice that is often abused by foremen in positions where they can recommend wage increases. It places all the employees on an equal basis, as far as opportunities for increase are concerned, and it puts the wage increase problem squarely up to the workers. By this means and others for keeping in close touch with the workmen, the highest type of efficiency can be obtained; for it is only when working under such favorable conditions that the ordinary worker can put heart

SUPERINTENDENT'S ENGAGEMENT CARD

To Paymaster ____________________

Name ____________________ Card No. ________

Local Address ____________________

Date Engaged ____________ As ____________

For Dep't ____________________

Rate ____________ Week Per Hour ____________

Old No. ________ Signature of Employee ____________

Reason ____________________

Approved | Reported for Week

____________ Sup't ________ M. ________ 192

Approved by General Superintendent ____________

Fig. 219.

and soul into his work. The neglected worker usually becomes indifferent, drifts or stays in a rut. Welfare work with the intention of increasing the home life of the worker will often bring an improved state of affairs. One of the most practical ways to supplant an employee's indifference with interest and enthusiasm is to sell him as many shares in the stock of the

DEPARTMENT TRANSFER

To Paymaster: 192

Name .... No. ....

Local Address .... Place of Birth .... Age ....

Was transferred this day from .... Department

to .... Department to be Employed

as .... at rate of .... per ....

Present Rate .... Present Occupation ....

Approved:

.... General Superintendent .... Industrial Bureau

Reported for work this day at .... M. New No. ....

Date .... 192 .... Foreman.

Fig. 220.

company as he cares to buy. There are various ways of selling the stock, such as the installment plan, or by organizing saving funds which will be used to buy stock as soon as they have reached a high enough mark.

By following out such methods the man takes an interest and works for the benefit of the company, and under most conditions will soon be ready for a transfer or promotion. In such an event the mill superintendent (in conjunction with the Industrial Bureau) arranges a transfer for this man to a better job, in which case the form represented by Figure 220 is made out and filed, copies going to both the paymaster and the Industrial Bureau. If it is purely a matter of rerating, a card such as Figure 221 is filled in the two departments.

INDUSTRIAL BUREAU

....................192

Name.................... No....................

ReRated.................... 192....................

New Rate.................... Per Hour....................

Old Rate.................... Per Hour....................

Explanation....................

....

....

.... Mill, Factory—Department....................

.... Superintendent

Approved:.................... General Superintendent

....

Fig. 221.

If under these conditions of good protection by the Industrial Bureau, a man fails to qualify for his position, shows a tendency to be an agitator, then he is discharged. He is given Form 222, properly filled out, and submits same to the paymaster, who then

REMOVAL FROM PAYROLL

TO PAYMASTER: 192

Please Pay.................... No....................

Occupation.................... In full to and including 192

(To be filled out by Paymaster)	AMOUNT	
Week ending....................		
Week ending....................		
Paid on Acc't....................		
Net Am't Due....................		

Has all Co. property been surrended?....................

Foreman must fill out Green copy of this blank and send same promptly to Industrial Service Department.

Checked by....................

Approved: Signed

....

Fig. 222.

pays the man in full. At the same time Figure 223, properly filled out, is filed by the Industrial Bureau for further reference on the adaptability of the worker. This form, as indicated, is of a confidential nature.

In the event of a man wishing to leave for good reasons—not dissatisfaction—the above forms are also made out as in any other instance.

In order that the Industrial Bureau may be able to obtain further statistics for compiling charts Form 224 is made out daily by the clerks of each respective mill.

At the end of each week the Industrial Bureau hands to the management Form 225 containing a generalized summary of the data obtained by them during the week. This form enables one to trace the labor conditions throughout the plant, and any

REMOVAL RECORD—[Confidential]

To Industrial Service Department: 192

Name .... **No.** ....

Occupation .... In full to and including 192

Discharged-Dropped-Suspended-Left ....192 .... **Dep't**
(Cross out words not used)

Nationality .... **Age** ....

Reason [In full] ....

....

[1] Do you expect to reinstate? .... [2] Ability ....

[3] Character? .... [4] Deportment? ....

[5] Would you re-employ in your Dep't? .... [6] Do you think it advisable to re-employ elsewhere? .... [7] Industrious? ....

[8] Satisfied with shop conditions and pay? ....

Approved: Signed

.... Sup't

Fig. 223.

ABSENTEE REPORT

Mr. ____________ Dep't ____________ Date ____________ 192

Please report the following Absences and return to the Industrial Bureau at once

Employee Number	NAME	Excused	Not Excused	Absence Satisfactory	Absence Not Satisfactory	REMARKS

Fig. 224.

radical changes can be immediately spotted and taken care of. From this data the Industrial Bureau graphically shows the Labor Maintenance and Turnover figures for various periods.

All of these various forms are kept in a neatly arranged folder so that all statistics relative to one man are always available and easily found when properly filed. The face of this folder is represented by Form 226.

INDUSTRIAL BUREAU

—Week Ending ____________

	Fenimore Sulphite	Fenimore Paper	Allen Paper	Allen Pulp	Allen Finishing	Paper Handlers	Stock Handlers	Bag Factory	Cartage Barn	Power House	R. & E.	No. 5 Paper	No. 1 Pulp	Store	G. Expense		TOTAL
1—Average No. on Roll																	
2—Total Exits																	
3—Total Entrances																	
4—Transfers																	
5—Change Rate (Increase)																	
6—Change Rate (Decrease)																	
7—Applications																	
8—Absentees Investigated																	
9—Absentees Without Notice																	
10—Laid Off, No Work																	
11—Released																	
12—Accidents																	
13—Hours Lost, Account Accidents																	

Notes:

____
Industrial Bureau

____

Fig. 225.

EMPLOYMENT BUREAU

Name: ____________

Began	Clock No.	Rate	Dept.	Work	Date: Transfer'd	Date: Rate Changed	Date: Released	Reason

Fig. 226.

Labor Turnover.

Labor Turnover is the result of many causes, dissatisfaction of the employee, inefficiency of the employee, activities of agitators, etc.

This Turnover measured in dollars is generally estimated from $25 to $150 per employee measured by the following:

1. Placing of employees in departments where they are not adapted to the nature of the work.
2. Decreased production while learning.
3. Cost of time involved while teaching the new operator.
4. Breakage and spillage of material and machines as a result of inexperience on the part of the operator.

In studying this proportion of labor turnover, we find several important factors. These have developed much discussion among those who have studied this problem. The students of the question may be divided into four principal groups:

1. Those who use terminations as a basis for figuring labor.
2. Those who use replacements as a basis.
3. Those who use payroll figures.
4. Those who use attendance figures.

From the above the only conclusion apparent is that no definite formula has yet been established by any standard committee for computing this labor turnover. Moreover all the various applications have their merits and demerits.

Talbot has devised a method which he terms Labor Maintenance. Briefly stated we record:

Annual growth.
Periodic growth.
Specific growth.

Annual growth requires additions to the working force to be retained indefinitely. Periodic growth needs added workers at the beginning of the busy season to be laid off later at its close. Specific growth also requires temporary help.

The accompanying chart, Figure 227, shows such conditions as related above. In the background are sketched the numbers of persons at work week by week. At the base above the zero line, are sketched in solid lines the number of men taken on, and below the zero line, also in solid lines, are sketched the number of men let out. To gain a fairly accurate conception of change of personnel throughout other divisions of the same organization, similar charts should be for each. Charts of this nature made in a continuous sequence prove almost invaluable in tracing the growth or decline of each main department, in that they present the annual growth, seasonal fluctuations, and also demonstrate clearly the unnecessary changes taking place during the height of production.

This form is made out weekly and filed in the Industrial Bureau and serves as a guide or check to the form which we

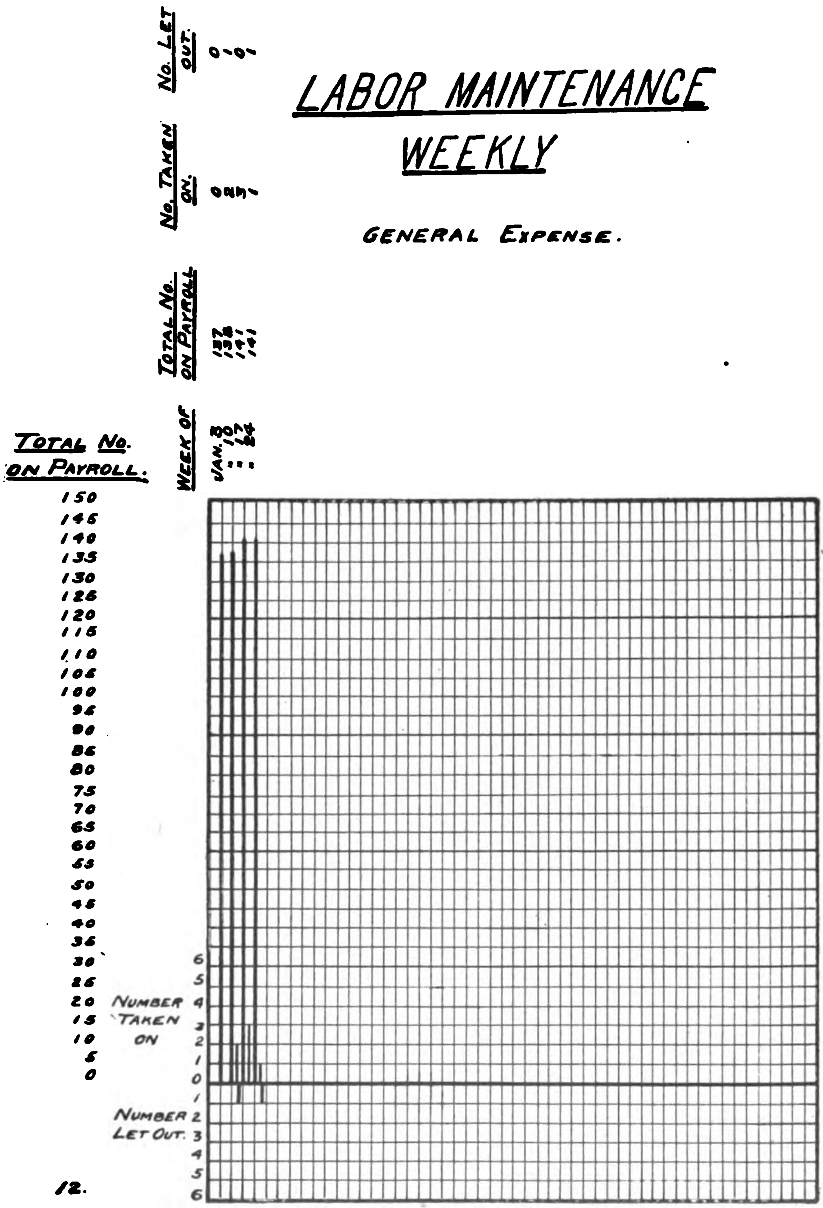

LABOR MAINTENANCE
WEEKLY
GENERAL EXPENSE.
No. LET OUT.
No. TAKEN ON.
TOTAL No. ON PAYROLL
WEEK OF
TOTAL No. ON PAYROLL.
NUMBER TAKEN ON
NUMBER LET OUT.
12.

Fig. 227.

will now describe, which is placed monthly on the desk of the chief executive of the company. Unlike the chart mentioned this form, Figure 228 is a summarized account for all departments for a period of one month. In this form several main features are brought out:

1. Average number on payroll.
2. Fluctuation factor.
3. Per cent Turnover.

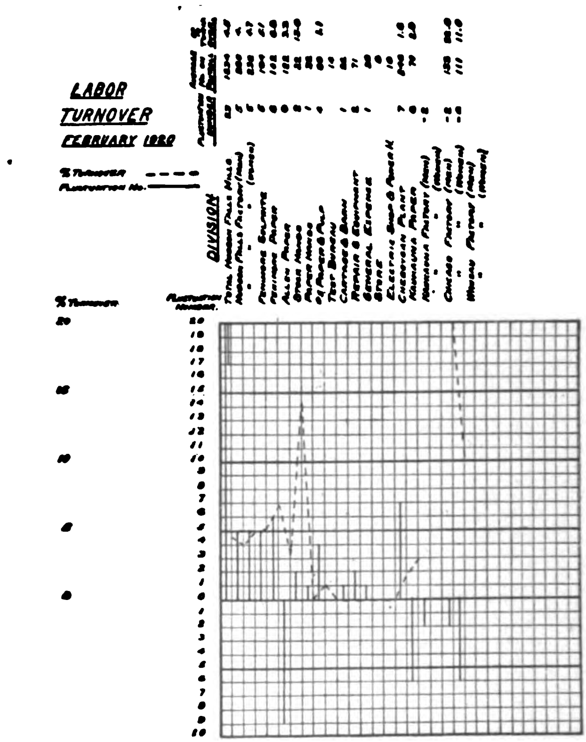


Fig. 228.

Item one, the average number of men on the payroll is self-explanatory.

Item two, the fluctuation factor, shows the rise or decrease in the personnel of each department. For example: referring to Form 228, using the first notation "total of all mills," we have the following statistics obtained from the Industrial Bureau:

Average Number on Payroll, 1,234.

Total taken in, 78.

Total let out, 55.

In this particular instance we have 78 men taken on and 55 men let out, showing 55 complete cycles. It is this factor, and the average number on the payroll, that we use as a basis for figuring the percentage turnover. The difference between numbers taken on and number let out we designate as the "Fluctuation Factor," in the case it is positive—23 men. These facts are then plotted on Form 228—the heavy black line indicating the Fluctuation Factor, and the dotted line the percentage Labor Turnover. By means of such a form the executive at a glance can trace the labor conditions throughout the plant. In the event that the turnover is relatively high, he looks up the report form shown in Figure 227, in order to find out just what trend affairs have taken.

The above forms are open to criticism, like all other forms that are in use, but for this particular line of work they have shown themselves to be useful and valuable to the executive.

Graphic Reports.

The present managers of corporations, mostly men who have risen through the ranks and have become thoroughly familiar to the relationships that one department bears to another, have an enormous task that daily confronts them. Important decisions must oftentimes be made at a moment's notice, without opportunity or time, for a voluminous amount of correspondence and calculation. As a result, Graphic Records, practically unknown a few years ago, have become generally adopted as a proper medium for the quick presentation of facts in nearly all large industries. There are many forms and appliances for the presentation of these facts, almost all of which are applicable to any industry, according to what the management may desire.

To the trained mind, the analytical mind, these graphic charts, when properly and honestly compiled, furnish a medium whereby he develops himself at the same time that his job is growing bigger. He need not spend or waste time looking over a group of figures but he has presented to him a picture of what he wishes to see. It may be only a line, it may be a group of lines, or it may be a series of images, but in all instances there is some one feature made a pronounced factor, enabling him to grasp the trend of affairs in the space of a few minutes of time. This visual picture becomes a fixed factor in the mind of that executive, whereas the group of figures would soon fade into oblivion.

If from the above it is seen that charts help to visualize the trend of affairs that they tend to fix facts in the mind of the individual, and moreover do not necessitate the expenditure of a large amount of money, then it certainly seems logical that charts are worth while. Even if the executive is not of the analytical mind, then it is to his advantage that he adopt this comparatively easy method for the presentation of facts. These charts may be made flexible, covering many operations over an unlimited period. Direct and indirect labor costs can be traced with production and estimated sales; costs of running various departments from year to year showing seasonal fluctuations; comparative quality of various articles; departmental facts; sales, etc. All of these facts regardless of the nature of the business can be made in a presentable form.

This work should be in charge of a conscientious and reliable man (not necessarily a technical man), for once the system has been put in operation the work is quite elementary. The facts, however, must be honestly presented or otherwise the work is detrimental to the executive. It is the function of this man to collect for the business all the data and facts which would be of any assistance to the executive, the officers and department heads. A concern doing a business of $1,000,000 per year or over should have a large room for the doing of such work.

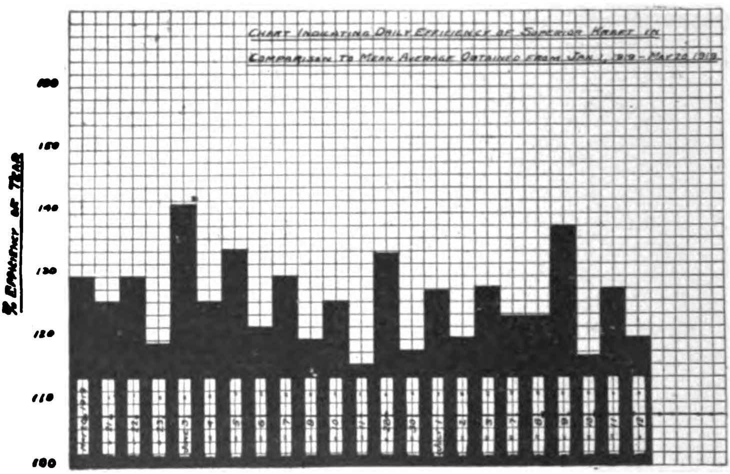


Fig. 229.

It should be called the Record Room, and be an adjunct to the Manager, giving him all the data portraying the running conditions for which he is responsible. Definite rules should be made that originals should not be taken from the record room, but duplicates or blue prints should be obtained. Only by following that rule will the system prove its worth. Of course, it is needless to say, that adequate facilities must be given for filing of the completed charts. This room should be accessible to all department heads and those immediately connected with the various operations, in order that they may keep in touch with affairs and thereby realize the advantages of such a system.

The nature of the data that can be compiled in this chart form is of course dependent upon the industry, its size, and the financial backing of the Manager or President. In operations covering the manufacture of paper we have adopted several forms, some of which illustrate but one fact, others covering period of one week, others monthly, etc.

First of all let us consider charts illustrating tests on qual-

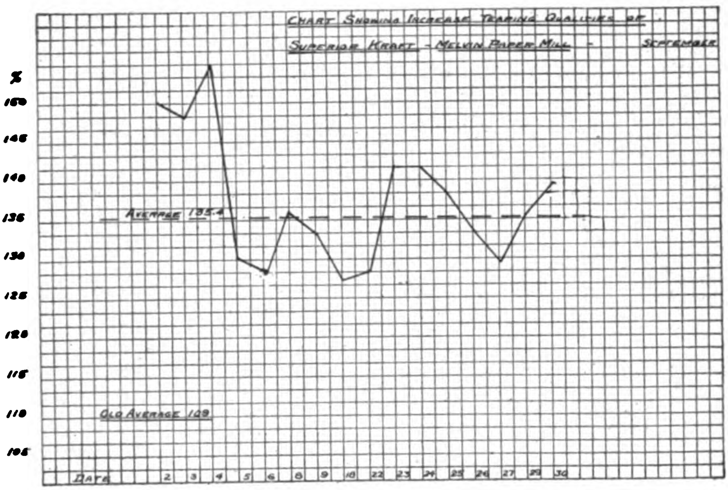


Fig. 230.

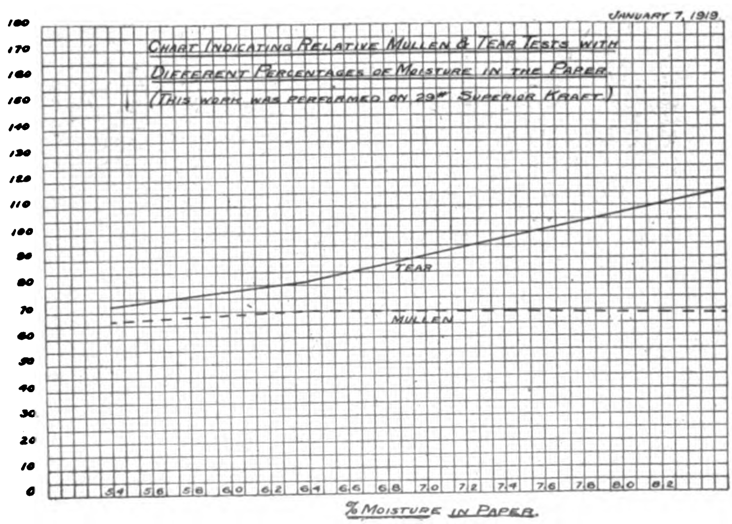


Fig. 231.

ity of paper between various grades in some instances, and also variations from day to day on the same grade.

Figure 229 illustrates the fluctuation in quality of a standard grade of paper. This chart is made out on a bar principle,

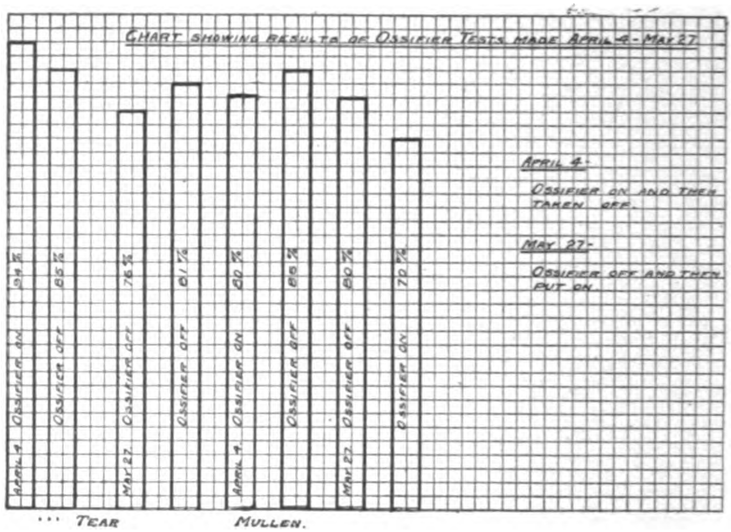


Fig. 232.

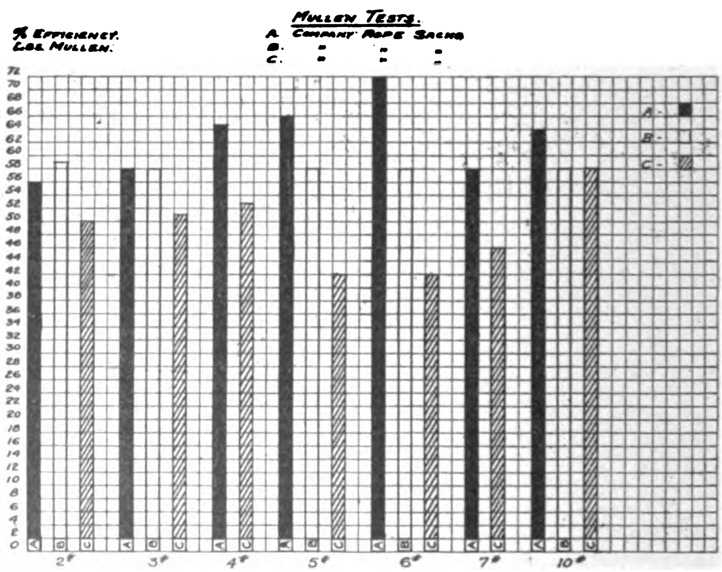


Fig. 233.

and the various heights of column readily visualize to the observer just how that particular grade of paper has been running from time to time.

Figure 230 is a chart illustrating the same facts, but by the use of a single line, instead of a series of bars. This, of course, consumes less time in the making but it is generally conceded by those who make use of such charts that the bar principle is better, where but one factor is being indicated.

Figure 231 involves two factors illustrating the influence of moisture in a sheet of paper, where the tearing resistance of the paper is emphasized. In this chart we have two lines, one for tear, and the other for the Mullen test plotted by means of two factors, one the moisture contained in the sheet of paper, and the other, the values of the two tests, Tear and Mullen, each taken individually. At a glance an operator can ascertain the relative importance of moisture in a sheet of paper by noting the rise of the tear line, with increased moisture content contained in the sheet.

Figure 232 like Figure 231 illustrates two varying factors but presented in the form of bars. The choice between these two different forms must be left to the preference of executive.

Figure 233 shows the comparative rating of different sizes for three different manufacturers. The bar principle here is undoubtedly the best presentable form, for here we have each distinct group of sizes separated, with the varying heights of columns, plainly discernible to the observer.

Figure 234 presents a type already described but upon a different form of chart. This form is quite valuable and has found a wide application which will be described later when costs are taken up. On this form of chart not only a graphic form can be presented but actual figures can be neatly typewritten in, thereby indicating all the data, a picture and figures at the same time.

Figure 235 is an interesting chart showing the increased amount of alum at one mill as compared with another on a monthly basis covering a combination of years and months. This chart is interesting in that these two mills make practically the same grades of paper. A superintendent receiving such a graphic analysis will readily see that something is wrong and will proceed to correct the cause of the discrepancy.

Figure 236 involves principles already mentioned but presents an interesting viewpoint in that reasons for rejection of paper are discernible, and amounts of rejection are shown.

Figure 237 again illustrates another point that we constantly watch—the variations in sulphur consumption between two sulphite mills.

This is only one of many forms that illustrate the fluctuations between the workings of sulphite mills. Free, total and combined acids, with resulting quality of finished pulp; steam pressure; temperature; and all the various stages of the process, when tabulated in such a form, often bring a quick decision to the executive who would frequently be lost if all this data were presented to him in a tabulated form, or as miscellaneous groups of figures.

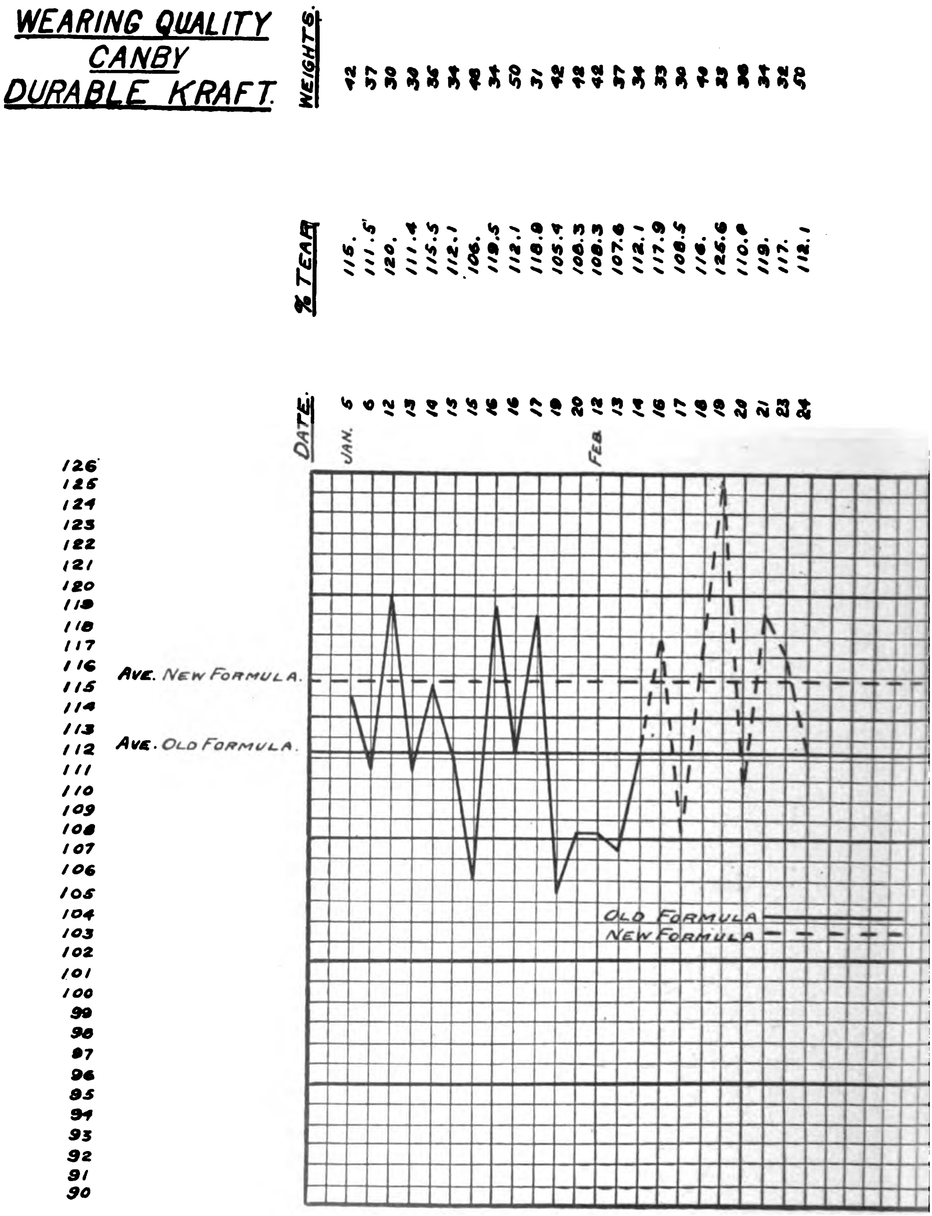

WEARING QUALITY
CANBY
DURABLE KRAFT.
WEIGHTS.
% TEAR
DATE.
JAN.
FEB.
AVE. NEW FORMULA.
AVE. OLD FORMULA.
OLD FORMULA
NEW FORMULA

Fig. 234.

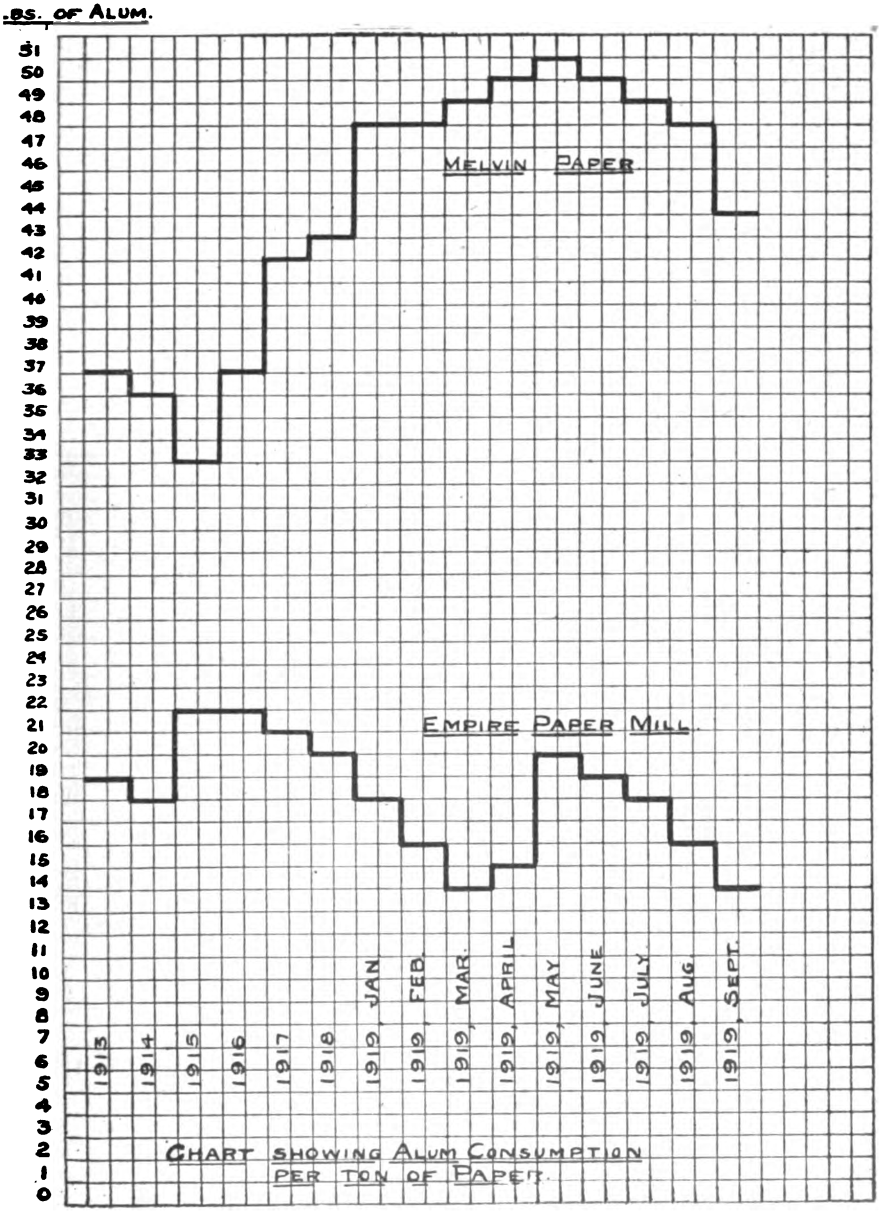

LBS. OF ALUM.
MELVIN PAPER.
EMPIRE PAPER MILL.
1913
1914
1915
1916
1917
1918
1919 JAN.
1919 FEB.
1919 MAR.
1919 APRIL
1919 MAY
1919 JUNE
1919 JULY
1919 AUG.
1919 SEPT.
CHART SHOWING ALUM CONSUMPTION PER TON OF PAPER.

Fig. 235.

Figure 238 is a chart showing mean average consumption of coal per ton of product for period of six months, quickly bringing out important facts. This is a simple form of chart but

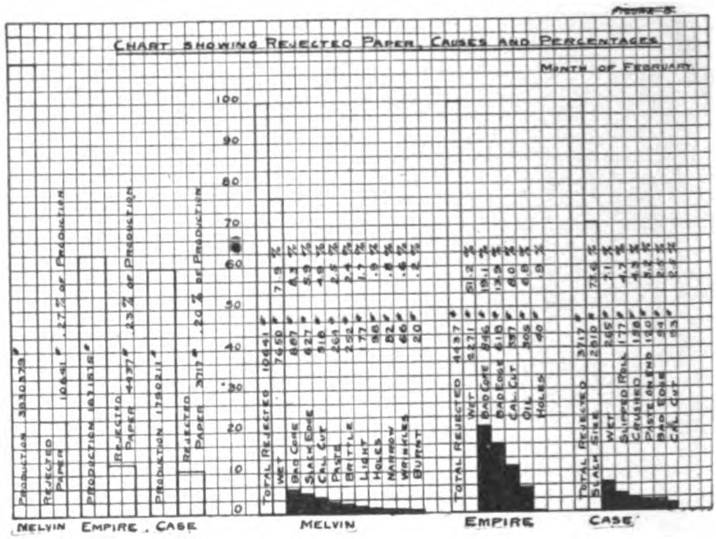


Fig. 236.

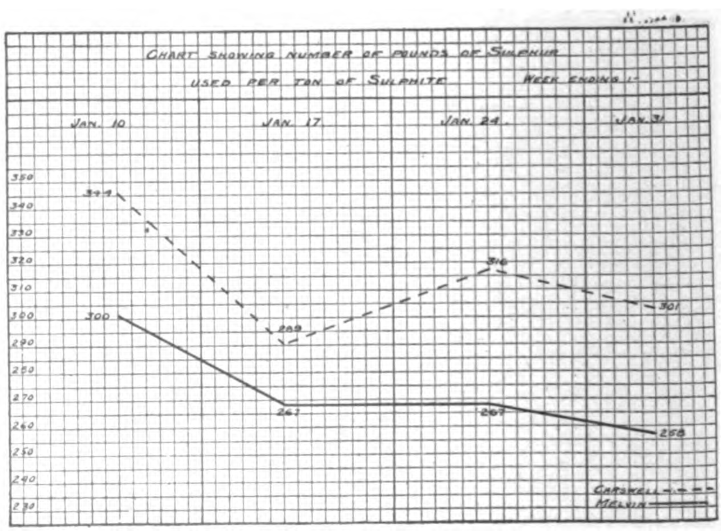


Fig. 237.

the facts are there nevertheless and will serve the purpose of a more intricate form that would take more time to make, and more time to analyze.

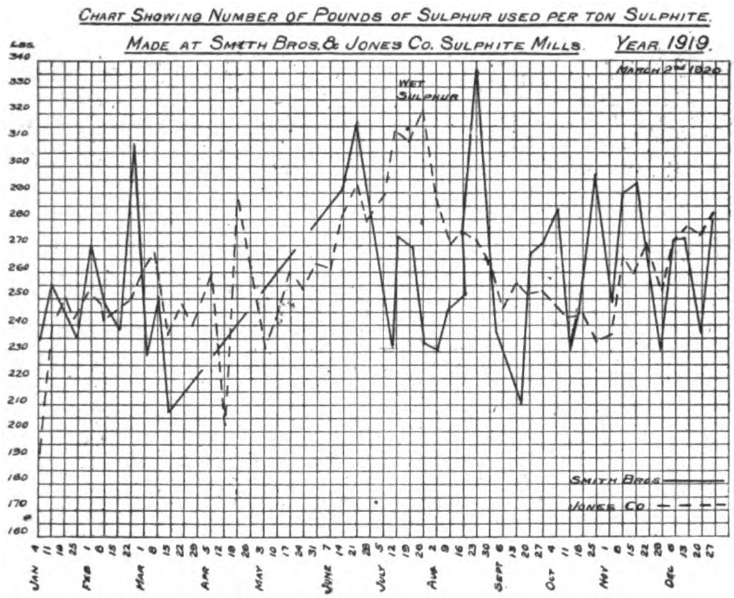


Fig. 237a.

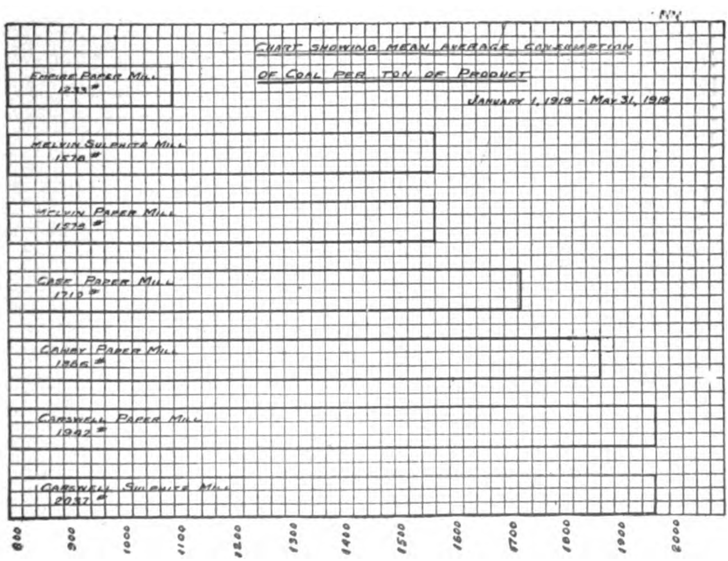


Fig. 238.

We have covered briefly in a general way charts that can be made useful to the executives of a pulp and paper mill, covering general mill operations, quality, etc. We will now give

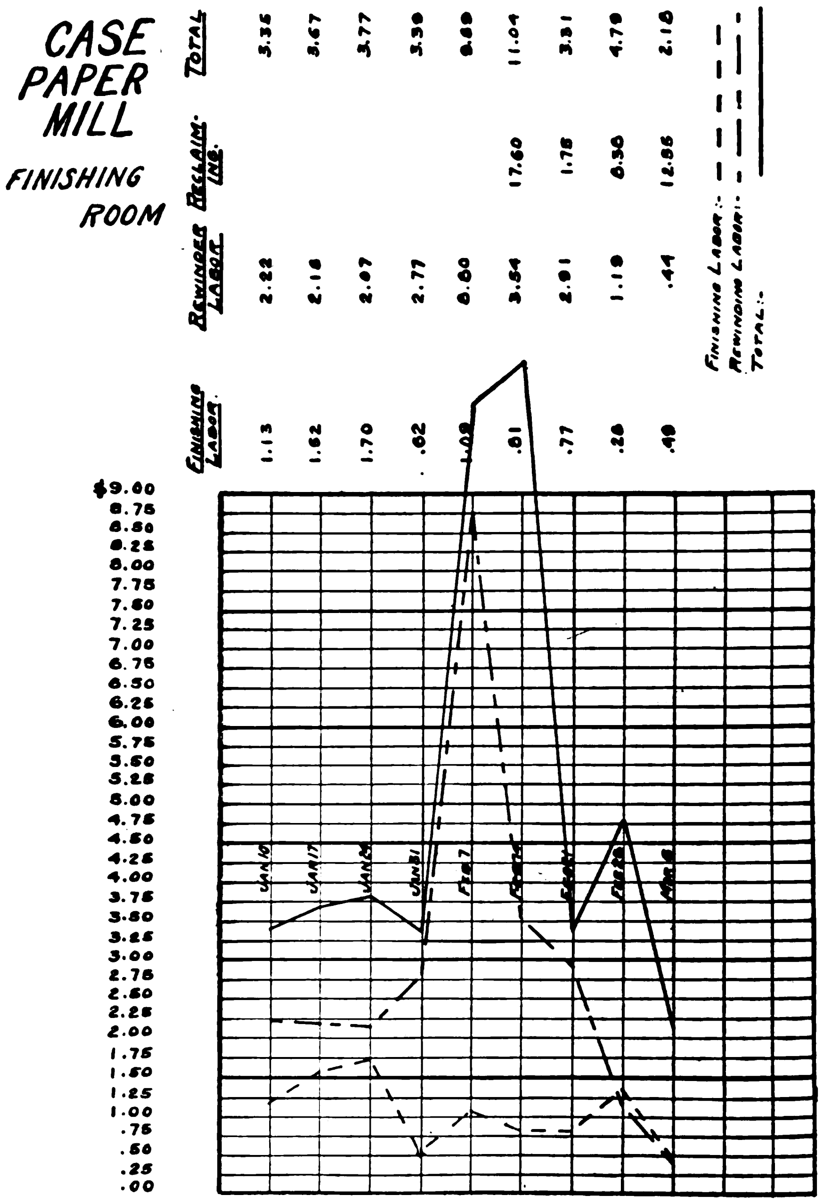

CASE PAPER MILL
FINISHING ROOM
TOTAL
RECLAIMING
REWINDER LABOR
FINISHING LABOR
3.35
3.67
3.77
11.04
2.18
17.60
12.55
2.22
2.18
2.77
.44
1.13
1.62
1.70
.62
.77
FINISHING LABOR:-
REWINDING LABOR:-
TOTAL:-
$9.00
8.75
8.50
8.25
8.00
7.75
7.50
7.25
7.00
6.75
6.50
6.25
6.00
5.75
5.50
5.25
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
.75
.50
.25
.00

Fig. 239.

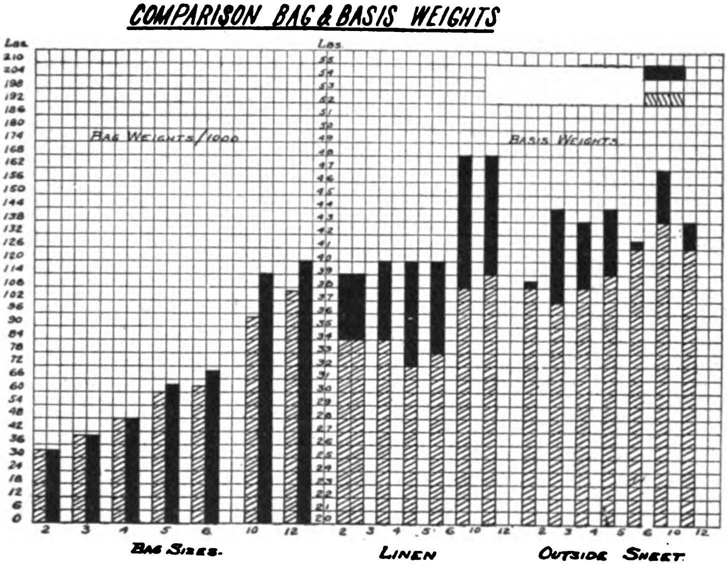


Fig. 240.

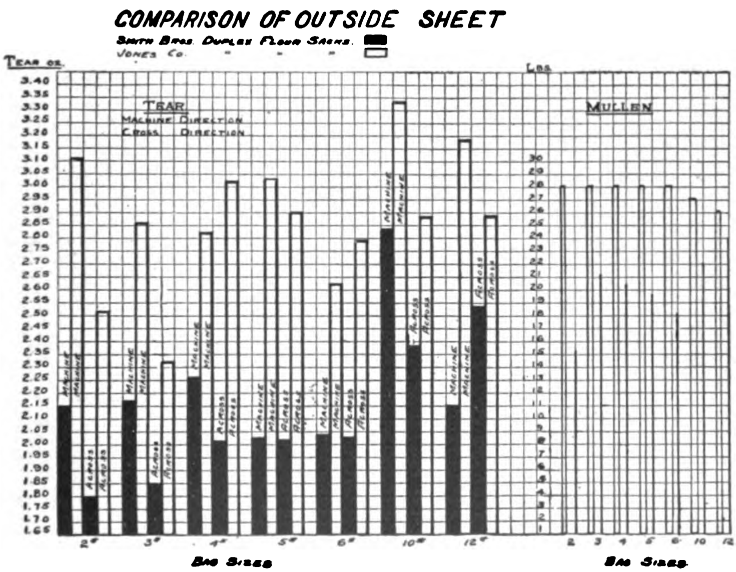


Fig. 241.

in a brief form a digest on various cost charts, data of which must come from the Accounting Department and be put into the hands of a reliable man for further interpretations and presentation.

Figure 239 shows cost of roll finishing in one Finishing Room. This chart, by means of three lines, shows quite plainly the cost of these various operations from week to week. This chart if it

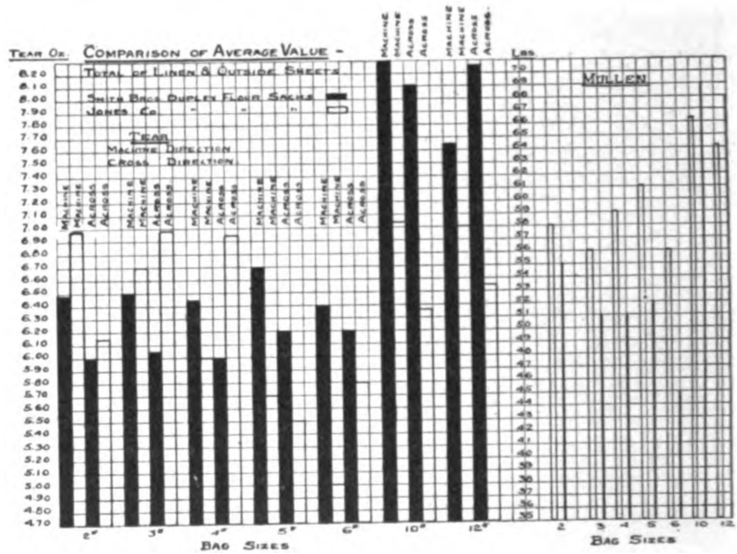


Fig. 242.

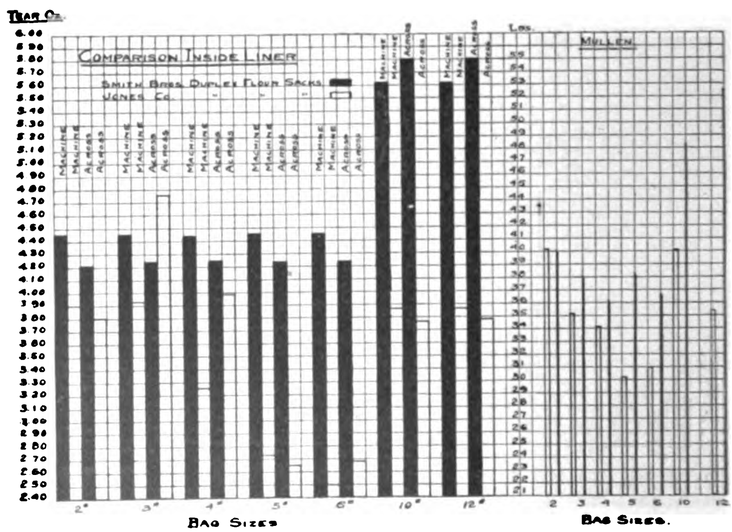


Fig. 243.

is to cover a period of one year should be made out in a form with 52 divisions in order to properly cover the 52 weeks of the year. Following are illustrations of various forms of cost charts covering weekly and monthly periods for one year. These cover direct costs, indirect costs, various departmental costs as explained by the titles. These charts show fluctuations month to month. If made on tracing paper or transparent cross-section sheets these forms can be superimposed (a chart for 1919 can be placed over one for 1918) covering some one operation, and the trend of affairs grasped in that manner.

We have but slightly touched on this subject, but hope to have given some ideas as to the applications of graphic charts to the pulp and paper industry. It is quite evident that very valuable information can be obtained in a short space of time, enabling the executive to make rapid decisions relative to all

AVERAGE COMPARISON ON TOTAL.

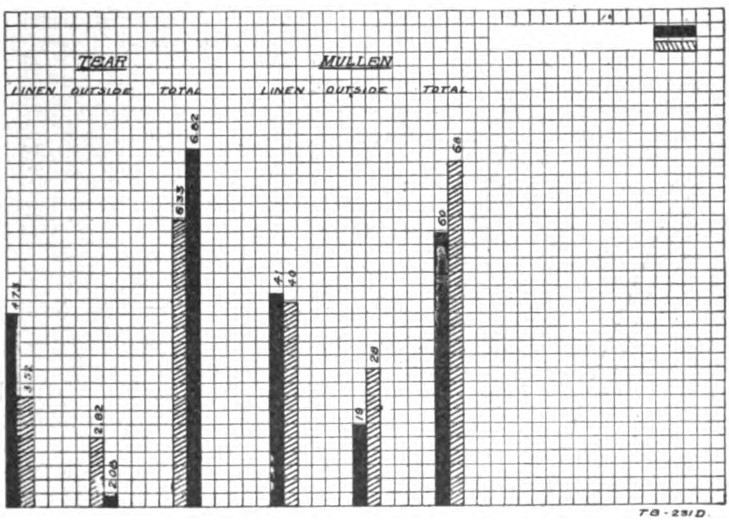


Fig. 244.

branches of the industry. Further, by means of a Technical Bureau daily checks and test runs can be made plotted in a presentable form and put in the mills for the benefit of the men. How this is done is described in the chapter on testing. These records are invaluable when presented in the proper form (not as a means of criticism but as a mean of arousing interest between individuals and units) so that the men will regard this as playing or scoring in a game. It has been necessary to reproduce all the charts in this book in simple black and white, but in actual work we use different colored lines, columns, etc., although various kinds of dotted lines will do just as well. There is nothing about these charts peculiar to the paper industry. Chemical plants, smelters, machine shops, department stores, banks and all kinds of plants and offices use them constantly.

XX. Useful Data and Tables.

TRADE CUSTOMS

General Rules and Regulations Governing the Sale of Book Papers.

MINIMUM BASIC WEIGHTS without extra charge.

COATED BOOK two sides	25 x 38—70
COATED BOOK one side	25 x 38—60
S & SC BOOK	25 x 38—50
ENGLISH FINISH BOOK	25 x 38—45
M. F. BOOK	25 x 38—45
EGGSHELL BOOK	25 x 38—45

For LIGHT WEIGHT COATED PAPERS add 5 cents per hundred pounds for each pound below the minimum basis mentioned, down to 60 pound for Coated two sides and 50 pound for Coated one side. Any papers lighter than these weights are subject to special price.

For LIGHT WEIGHT UNCOATED PAPERS add 5 cents per hundred pounds for each pound light down to 40 pound and 10 cents per 100 pounds for each pound light from 40 pound to 30 pound basis.

EXTRA CHARGE for colors—other than White or Natural.

On special sizes and weights, 5,000 pounds minimum amount without extra charge.

On COATED PAPERS a variation in weight not exceeding 5 per cent over or under, shall constitute a good delivery, and such papers shall be billed as ordered. The same applies to UNCOATED PAPERS except that if variation is in excess of 2½ per cent below the ordered weight, paper is to be billed at actual weight.

On SPECIAL MAKING ORDERS variation in amounts shall be accepted as follows:—

COATED:	1 — 2½ Tons	20% Over
	2½— 5 "	15% "
	5 —10 "	10% "
	Over—10 "	5% "
UNCOATED:	1— 2 Tons	15% Over or Under
	2— 5 "	10% " " "
	5—20 "	5% " " "
	20 " and Upward	3% " " "

SPECIAL TRIMMING OR PACKING is subject to additional charge.

ALL CLAIMS for damaged papers must be reported immediately in order that the paper may be inspected before it is cut or printed.

Trade Customs for Coated Cardboards.

1—STANDARD THICKNESSES.

Coated Blanks		Tough Check		Translucents		Railroads	
2 ply	.012	2 ply	.012	2 ply	.008	2 ply	.012
3 "	.015	4 "	.018	3 "	.010	4 "	.018
4 "	.018	6 "	.024	4 "	.012	6 "	.024
5 "	.021	8 "	.030	5 "	.015	8 "	.030
6 "	.024						
8 "	.030						
10 "	.036	Thick China					
12 "	.042						
14 "	.048		.011				

2—VARIATION IN THICKNESS.

.008 to .029—.001 above or below ordered thicknesses.
.030 to .042—.002 above or below ordered thicknesses.
.043 and heavier 5% above or below ordered thicknesses.

3—STANDARD STOCK SIZES.

For Railroads, Tough Check, Thick China and Blanks—22 x 28.

For Translucents—22½ x 28½.

4—STANDARD STOCK COLORS.

For Railroads and Tough Check.

Blue, Buff, Coral, Green, Orange, Red, Salmon, Yellow. In addition to White and Black.

For Thick China Add: Gray, Pearl.

For Translucents and Tinted Litho. Blanks: add

Flesh, Green, India Tint, Pearl, Primrose, Rose. In addition to White.

5—SPECIAL SIZES AND THICKNESSES.

(a) Minimum quantity at base price for sizes which cut without waste from Standard Stock rolls will be not less than the equivalent of 5,000 sheets 22 x 28. Smaller quantities may be made at a price commensurate with the increased cost.

(b) Minimum quantity at base price for odd sizes and thicknesses which will not cut without waste from Standard Stock rolls will be not less than the equivalent of 10,000 sheets 22 x 28. Smaller quantities may be made at a price commensurate with the increased cost.

6—MINIMUM STOCK ORDERS.

Minimum quantity at base price of stock items will be not less than one standard case. Add not less than 10% for broken cases.

7—SPECIAL COLORS.

Minimum quantity at base price for odd colors will be not less than equivalent of 25,000 sheets 22 x 28 single coated one side. Smaller quantities may be made at a price commensurate with the increased cost.

8—OVER-RUNS AND UNDER-RUNS.

All special orders subject to over-run of 10%; where maximum quantity is specified, an under-run of 10% will constitute a good delivery.

9—CLAIMS.

All claims must be made promptly upon receipt and examination of goods. No claims can be allowed on goods which have been cut or printed.

Trade Customs for Wrapping Paper.

All orders for wrapping paper are accepted for wrapping purposes only, unless otherwise specifically stated.

All wrapping paper will be made on a basis of 24 x 36—480 sheets only.

All wrapping paper to be billed actual scale weight, including twine and wrappers with a leeway of five per cent (5%) over or under ordered weight. Wood or iron cores billed by weight or piece and returnable if agreed. Paper cores to be weighed with the paper and not returnable.

No paper to be made one weight and stenciled another.

Tissues.

STANDARD BASIS: White Tissue, 20 x 30, 480 sheets, 7 pounds to the ream. Manila Tissue, 24 x 36, 480 sheets, 10 pounds to the ream.

OVER-RUNS AND UNDER-RUNS: On orders for special sizes or colors, ten per cent (10%) above or below the quantity ordered to be considered a good delivery and accepted by purchaser.

MISCELLANEOUS CONDITIONS: All paper heavier than 10 pounds to the ream, 24 x 36, 480 sheets, to be sold by the pound, weight to include wrappers and twine. Any size ordered, not exceeding 1½ inches smaller than regular sizes to be charged for as regular sizes. Regular sizes are 24 x 36; 20 x 30; 15 x 20; 30 x 40, and 11 x 15.

The limit in weight for Tissue Paper shall be 17 pounds to the ream, 24 x 36, 480 sheets. Paper made in excess of this weight shall be classified as light weight Manila.

Bonds, Ledgers, Writings, etc.

1. On special sizes, not less than 10 per cent additional price for lots of less than one ton. The following sizes may be considered as regular:

FLATS AND BONDS

14 x 17	26 x 34	17 x 26
17 x 28	19 x 24	18 x 23
28 x 34	24 x 38	23 x 36
16 x 21	19 x 26	21 x 33
21 x 32	26 x 38	30 x 38
16 x 26	19 x 28	20 x 28
17 x 22	28 x 38	28 x 40
22 x 34	19 x 30	28 x 42½
22 x 25½		

LEDGERS

14 x 17	21 x 32	18 x 46
17 x 28	16 x 42	19 x 24
28 x 34	17 x 22	19 x 48
15 x 19	22 x 34	24 x 38
19 x 30	18 x 23	20 x 28
16 x 21	23 x 36	28 x 40

LOOSE-LEAF

16¼ x 21¼	22 x 38	23 x 24½
17¾ x 22¾	22½ x 22½	23¼ x 28½
19¼ x 24¼	22½ x 28½	24½ x 24½
29¼ x 28½	22½ x 34	24½ x 28½
21½ x 31½	22¾ x 25¾	24½ x 29
22 x 34	22¾ x 35½	24½ x 36½
		24½ x 38½

Any of the above sizes not regularly stocked by the mill in the grade ordered may be considered special sizes, but these and any other sizes may be considered regular if stocked by the mill or buyer, but all special orders for sizes other than those mentioned, unless regularly stocked, shall be billed at 10 per cent additional in lots less than one ton.

2. On special colors, or colors not regularly made in the grade ordered, less than ton lots, not less than 10 per cent additional price. One ton and less than two tons, not less than 5 per cent additional. Two tons and over open.

Under rules Nos. 1 and 2 the quantities mentioned are understood to be the quantities named in the original order or inquiry and not the quantities that may be arrived at by adding the 10 or 15 per cent over-run provided for under rule No. 4. For example, an order for say 1900 pounds is an order for less than one ton and is to be billed and accepted at the 10 per cent advance, although when made, the allowed over-run may make the shipment aggregate more than 2000 pounds.

Under this rule (rule No. 2) mills may make in any established grade for a customer buying said grade regularly, without additional charge, such colors as may be decided upon as constituting the regular colors of such customer's line.

3. On all Writing Papers; namely, Fines, Flats, Ledgers, Bonds, Linens and Typewriter papers, there shall be a differential between the price of white and colors in said grades and lines.

4. On special orders of one ton or less, over- and under-runs not greater than 15 per cent to be taken by customer. On orders for more than one ton, over- and under-runs not greater than 10 per cent to be taken by customer.

5. Orders for less than a full package, not less than 25 per cent additional. A full package shall be construed as that number of sheets which it is the custom of the mill to use in wrapping and selling the item of paper in question.

This does not apply to orders for one or more full packages and a fraction; for example, an order for 3¼ packages.

6. No paper made one weight and stenciled another.

7. The average actual weight, including wrappers, not to exceed 2½ per cent above or below the nominal weight. Paper within this range to constitute a good delivery and to be billed at the nominal weight. The above to be based on items of one size and weight on individual invoices.

8. No claims allowed after paper is cut, ruled, or printed.

Experience has shown that exceptional cases occasionally arise where the fault is clearly with the mill and where an absolutely literal enforcement of rule No. 8 would work injustice and hardship to the merchants. It is, therefore, understood that mills will enforce the spirit of this rule, deciding exceptional cases upon their merits and according to the rules of equity.

9. No paper of private watermarks or brands to be supplied for sampling purposes, nor allowance made on account of watermarks or brands.

10. All "make and hold" orders must specify an ultimate date for shipment, at which date goods are to be billed and the invoices taken to account by customer whether ordered shipped or not.

11. Where unruled paper is to be cut and folded in ream bundles or quarter ream and pound packages, the paper in the flat shall first be charged for at the regular flat price. In addition 1 cent per pound shall be charged for each pound of pound packages shipped, or ¾ cent per pound for package of a quarter ream or more.

12. A charge of not less than 1½ cents per pound to be made for feint ruling, such as letterheads, etc., and not less than 2½ cents per pound for struck ruling, such as billheads, statements, etc. This charge is to apply on paper basis 17 x 22-16, and over; 13 pound paper to be charged on the basis of 16 pound, and on papers of less than 13 pound weight, the charge to be at the option of the mill doing the work.

13. There shall be a minimum cutting charge of ½ cent per pound wherever the regular sizes and weights of unruled paper of the mill are to be cut to smaller sizes.

(a) This minimum charge of ½ cent per pound to be made when cutting any regular size containing not less than 336 square inches (16 x 21) down to and including a size containing not less than 84 square inches (8 x 10½); a charge of 1 cent per pound to be made for cutting sheets containing less than 84 square inches down to and including a sheet containing 42 square inches.

(b) When cut to small sizes, the charge shall be the same whether the packages are sealed, banded or merely divided by markers.

14. Paper shipped untrimmed is to be billed at proportionate weight, and there shall be no allowance made for paper untrimmed instead of trimmed, nor unsealed instead of sealed, nor for both.

Paper such as Envelope paper, sold on basis of cut and trim on the machine to be considered as trimmed paper.

15. Merchants, manufacturers or converters desiring special watermarks for their customers must pay the cost of dandy roll, and no credit will be given on account of the number of cases ordered.

16. Members shall not sell private watermarks and brands for less than they sell the mill marks and brands of the same grade.

17. For weights lighter than basis sixteen pounds 17 x 22, 500 sheets, an additional price to be charged. All Bond and Writing paper basis 15, 14, 13 pound folio to be charged for at ream prices, 16 pound basis.

18. New orders for Bonds and Linens, Flat Writings and Ledgers will be entered and manufactured only in conformity with the following list of substances on pages 148 and 149.

For convenience in merchandising, reams will be marked (in addition to their respective substances) with their approximate weights, the table to be used being that compiled by the National Paper Trade Association and embodied in their request under date of April 17, 1917.

The substance may be omitted from the reams on private watermarks or brands, if so requested by the owner thereof.

(a) Intermediate substances carry same ream price as next higher substance. Trade Custom No. 17 governs on substances below 16.

(b) Trade Custom No. 1 governs on Odd sizes.

(c) Beginning October 1, 1918, this Trade Custom shall apply to all grades of Writing Paper from above 10 pound folio basis, to and including 44 pound folio basis. Exception: Grades below No. 2 Rag Envelope.

Cover Papers

1. On standard lines of Cover Papers, the following shall be considered "regular" sizes and substances—all others shall be considered "special."

A. Regular Sizes—
20 x 26
23 x 33 and multiples thereof.
B. Regular Substances—
20 x 26—25, 35, 40, 50, 65, 80, 90
23 x 33—36½,— — 73, 95, — —

Intermediate substances carry same ream price as the next higher substance. Below Substance 25 the same ream price as Substance 25.

Sizes other than 20 x 26 made to substance weights and figuring a fractional pound would be billed to the nearest half-pound.

2. Any size not listed in Paragraph 1 shall be interpreted as special. Special sizes may be cut from standard size rolls in less than ton quantities, but at an additional price of not less than 10 per cent.

3. On special colors, or colors not regularly made in the grade ordered, ton lots not less than 15 per cent additional price. Less than ton lots not less than 25 per cent additional price.

4. On special orders for one ton or less, 15 per cent over- or under-run to be accepted as a commercial delivery. On orders for more than one ton over-runs or under-runs not greater than 10 per cent to be accepted as a commercial delivery.

5. Orders for less than a full package, not less than 25 per cent additional.

A full package shall be construed as that number of sheets which it is the custom of the mill to use in wrapping and selling the item of paper in question. When ordered in conjunction with a full package, this aditional charge will be made.

6. No paper to be made one weight and stenciled another. Paper to be marked by manufacturers the ream weight ordered, and there shall be no evasion by substituting letters or symbols for figures.

7. The average actual weight, including wrappers, not to exceed 2½ per cent above or below the nominal weight. Paper within this weight to constitute a good delivery, and to be billed at nominal weight. The above to be based on items of one size, weight and color on individual invoices.

8. No claims allowed after paper is cut or printed.

Experience has shown that exceptional cases occasionally arise where the fault is clearly with the mill and where an absolutely literal enforcement of rule No. 8 would work an injustice and hardship to the merchant. It is, therefore, understood that mills will enforce the spirit of this rule, deciding exceptional cases upon their merits and according to the rules of equity.

TABLE OF COMPARATIVE WEIGHTS

Book Papers

25 x 38	40	50	60	70	80	90	100	120
22 x 32....	30	37	44½	52	59½	....	74	....
24 x 36....	36	45	55	64	73	82	91	....
25 x 38....	40	50	60	70	80	90	100	120
26 x 29....	32	40	48	56	63	72	79	95
25 x 40....	....	....	63	74	84	95	105	126
26 x 40....	44	55	66	77	88	....	110	....
28 x 42....	50	62	74	86	99	111	124	149
28 x 44....	52	65	78	90	104	117	130	156
29 x 45....	....	....	82	96	110	124	137	165
29 x 52....	64	80	96	112	126	144	158	190
30½ x 41....	53	66	79	92	105	118	132	158
32 x 44....	60	74	89	104	119	133	148	178
33 x 46....	64	80	96	112	128	144	160	192
34 x 44....	63	79	95	110	126	....	157	....
35 x 45....	66	83	100	116	133	149	166	199
36 x 48....	72	90	110	128	146	164	182	218
38 x 50....	80	100	120	140	160	180	200	240
41 x 61....	106	132	158	184	210	236	264	316
42 x 56....	100	124	148	172	198	222	248	298
44 x 56....	104	130	156	180	208	234	260	312
44 x 64....	120	148	178	208	238	266	296	356

Wrapping Paper Sizes

Scale of weights equal to 24 x 36

24 x 36..	15	20	25	30	35	40	50	60	70	80	90	100	125	150
12 x 18..	4	5	6	8	9	10	13	15	18	20	23	25	31	38
15 x 20..	5	7	9	10	12	14	17	21	24	28	31	35	43	52
18 x 24..	8	10	13	15	18	20	25	30	35	40	45	50	63	75
20 x 30..	10	14	17	21	24	28	35	42	49	56	63	69	87	104
22 x 32..	12	16	20	24	29	33	41	49	57	65	73	81	102	122
26 x 36..	16	22	27	33	38	43	54	65	76	87	98	108	135	163
30 x 40..	21	28	35	42	49	56	69	83	97	111	125	139	174	208
36 x 40..	25	33	42	50	58	67	83	100	117	133	150	167	208	250
40 x 48..	33	44	56	67	78	89	111	133	156	178	200	222	278	333
48 x 52..	43	58	72	87	101	116	144	173	202	231	260	289	361	433
48 x 64..	53	71	89	107	124	142	178	213	249	284	320	356	444	533

TABLE SHOWING REVISED WEIGHTS WHICH THE NATIONAL PAPER TRADE ASSOCIATION, UNDER DATE OF APRIL 17, 1917, REQUESTS THE MANUFACTURERS TO MARK ON REAMS OF BONDS AND LINENS, FLAT WRITINGS AND LEDGER PAPERS MADE TO SUBSTANCES.

	SUBSTANCE								
	No. 13	No. 16	No. 20	No. 24	No. 28	No. 32	No. 36	No. 40	No. 44
14 x 34...........	16½	20½	25½	30½	35½	40½	46	51	56
16 x 21...........	11½	14½	18	21½	25	28½	32½	36	39½
16 x 26...........	14½	18	22	26½	31	35½	40	44½	49
16 x 42...........	23	29	36	43	50	57	65	72	79
16¼ x 21¼.........	12	15	18½	22	26	29½	33	37	40½
17 x 22...........	13	16	20	24	28	32	36	40	44
17 x 26...........	15½	19	23½	28½	33	38	42½	47½	52
17 x 28...........	16½	20½	25½	30½	35½	40½	46	51	56
17 x 44...........	26	32	40	48	56	64	72	80	88
17 x 56...........	33	41	51	61	71	81	92	102	112
17¾ x 22¾.........	14	17½	21½	26	30	34½	39	43	47½
18 x 23...........	14½	17½	22	26½	31	35½	40	44½	48½
18 x 46...........	29	35	44	53	62	71	80	89	97
19 x 24...........	16	19½	24½	29½	34	39	44	49	53½
19 x 26...........	17	21	26½	31½	37	42½	47½	53	58
19 x 28...........	18½	23	28½	34	40	45½	51	57	62½
19 x 30...........	20	24½	30½	36½	42½	49	55	61	67
19 x 48...........	32	39	49	59	68	78	88	98	107
19¼ x 24¼.........	16	20	25	30	35	40	45	50	55
19¼ x 28½.........	19	23½	29½	35	41	47	53	58½	64½
20 x 28...........	19½	24	30	36	42	48	54	60	66
20 x 56...........	39	48	60	72	84	96	108	120	132
21 x 32...........	23	29	36	43	50	57	65	72	79
21 x 33...........	24	29½	37	44½	52	59½	66½	74	81½
21½ x 31½.........	23½	29	36	43½	50½	58	65	72½	79½
22 x 25½.........	19½	24	30	36	42	48	54	60	68
22 x 34...........	26	32	40	48	56	64	72	80	88
22 x 38...........	29	36	44½	53½	62½	71½	80½	89½	98½
22½ x 22½.........	17½	21½	27	32½	38	43½	48½	54	59½
22½ x 28½.........	22½	27½	34½	41	48	55	61½	68½	75½
22½ x 34..........	26½	32½	41	49	57½	65½	73½	82	90
22¾ x 25¾.........	20½	25	31½	37½	44	50	56½	62½	69
22¾ x 35½.........	28	34½	43	52	60½	69	77½	86½	95
23 x 24½.........	19½	24	30	36	42	48	54	60½	66½
23 x 28...........	22½	27½	34½	41½	48	55	62	69	76
23 x 31...........	25	30½	38	45½	53½	61	68½	76	84
23 x 34...........	27	33½	42	50	58½	67	75½	83½	92
23 x 36...........	29	35	44	53	62	71	80	89	97
23¼ x 28½.........	23	28½	35½	42½	49½	56½	64	71	78
24 x 38...........	32	39	49	59	68	78	88	98	107
24 x 48...........	40	49½	61½	74	86	98½	111	123	135½
24½ x 24½.........	21	25½	32	38½	45	51½	58	64	70½
24½ x 28½.........	24½	30	37½	45	52½	59½	67	74½	82
24½ x 29..........	24½	30½	38	45½	53	61	68½	76	83½
24½ x 36½.........	31	38½	48	57½	67	76½	86	95½	105
24½ x 38½.........	33	40½	50½	60½	70½	80½	91	101	111
26 x 32...........	29	36	44	53	62	71	80	89	98
26 x 33...........	30	36½	46	55	64	73½	82½	92	101
26 x 34...........	31	38	47	57	66	76	85	95	104
26 x 38...........	34	42	53	63	74	85	95	106	116
27 x 40...........	37½	46	58	69½	81	92½	104	115½	127
28 x 34...........	33	41	51	61	71	81	92	102	112
28 x 38...........	37	46	57	68	80	91	102	114	125
28 x 40...........	39	48	60	72	84	96	108	120	132
28 x 42½.........	41½	51	63½	76½	89	102	114½	127½	140
30 x 38...........	40	49	61	73	85	98	110	122	134
31 x 53...........	57	70½	88	105½	123	140½	158	175½	193½
34 x 44...........	52	64	80	96	112	128	144	160	176

AVERAGE COST OF PRODUCTION PER TON OF PAPER FOR 39 PRINCIPAL BOOK-PAPER MILLS, 1915 AND 1916

	1915	1916	Increase, 1916 over 1915	Per cent of increase
Tons produced	644,902	772,532	127,630	19.79
Stock:				
Soda pulp	$13.08	$14.30	$1.22	9.33
Sulphite	17.01	18.81	1.80	10.58
Waste paper	5.79	7.65	1.86	32.12
Fillers	2.28	2.21	[1].07	[1]3.07
Alum	.68	.84	.16	23.53
Rosin	.48	.72	.24	50.00
Color	.24	.48	.24	100.00
Miscellaneous	1.12	1.61	.49	43.75
Total	40.68	46.62	5.94	14.60
Conversion:				
Labor	8.68	9.63	.95	10.94
Fuel	2.88	3.25	.37	12.85
Repairs	1.59	1.56	[1].03	[1]1.89
Wires, felts, belting, and lubricants	1.31	1.43	.12	9.16
Packing and shipping	1.42	1.58	.16	11.27
Miscellaneous	1.29	1.52	.23	17.83
Total	17.17	18.97	1.80	10.48
General expense:				
Taxes and insurance	.69	.73	.04	5.80
Administrative	1.70	1.80	.10	5.88
Total	2.39	2.53	.14	5.86
Factory cost, without depreciation	60.24	68.12	7.88	13.08
Depreciation	2.00	1.75	[1].25	[1]12.50
Total cost	62.24	69.87	7.63	12.26

[1] Decrease.

PERCENTAGE OF TOTAL COST OF PRODUCING PAPER OF 39 PRINCIPAL BOOK-PAPER MILLS ATTRIBUTABLE TO PARTICULAR ITEMS, 1915 AND 1916.

	1915	1916	Increase 1916 over 1915
Tons produced	644,902	772,532	127,630
Stock:	*Per cent.*	*Per cent.*	*Per cent.*
Soda pulp	21.02	20.47	[1]0.55
Sulphite	27.33	26.92	[1].41
Waste paper	9.30	10.95	1.65
Fillers	3.66	3.16	[1].50
Alum	1.09	1.20	.11
Rosin	.77	1.03	.26
Color	.39	.69	.30
Miscellaneous	1.80	2.31	.51
Total	65.36	66.73	1.37
Conversion:			
Labor	13.95	13.78	[1].17
Fuel	4.63	4.65	.02
Repairs	2.55	2.23	[1].32
Wires, felts, belting, and lubricants	2.10	2.05	[1].05
Packing and shipping	2.28	2.26	[1].02
Miscellaneous	2.08	2.18	.10
Total	27.59	27.15	[1].44
General expense:			
Taxes and insurance	1.11	1.04	[1].07
Administrative	2.73	2.58	[1].15
Total	3.84	3.62	[1].22
Factory cost, without depreciation	96.79	97.50	.71
Depreciation	3.21	2.50	[1].71
Total cost	100.00	100.00	......

[1] Decrease.

COST OF PRODUCTION PER TON OF PAPER OF 39 PRINCIPAL BOOK-PAPER MILLS, BY MILLS, 1915 AND 1916

1915

Mill number	Stock					Conversion			General expense, including depreciation	Total cost
	Soda pulp	Sulphite	Waste paper	Miscellaneous	Total	Labor	Miscellaneous	Total		
1......	$15.37	$13.66	$2.41	$3.55	$34.99	$6.38	$5.11	$11.49	$3.86	$50.34
2......	13.24	19.32	....	3.65	36.21	5.84	5.41	11.25	3.75	51.21
3......	6.82	21.00	5.74	2.66	36.22	5.32	5.90	11.22	4.62	52.06
4......	25.68	7.51	....	3.43	36.62	6.07	7.39	13.46	3.91	53.99
5......	23.62	8.74	....	3.13	35.49	7.65	7.80	15.45	3.75	54.69
6......	13.34	16.97	4.25	3.44	38.00	7.86	6.05	13.91	4.10	56.01
7......	18.43	15.37	.23	4.11	38.14	7.77	7.53	15.30	3.51	56.95
8......	17.20	18.29	....	3.85	39.34	7.22	6.29	13.51	4.17	57.02
9......	5.78	19.86	4.19	7.76	37.59	7.20	8.83	16.03	5.32	58.94
10......	....	2.21	26.10	5.33	33.64	12.70	9.72	22.42	4.33	60.39
11......	13.27	22.69	.12	3.61	39.69	9.08	8.28	17.36	3.62	60.67
12......	....	22.40	9.70	5.56	37.66	7.74	9.30	17.04	6.10	60.80
13......	6.77	14.06	14.27	3.99	39.09	12.26	7.02	19.28	3.47	61.84
14......	12.16	19.18	7.77	3.98	43.09	6.21	7.91	14.12	4.91	62.12
15......	35.67	....	2.15	4.23	42.05	9.44	7.23	16.67	4.03	62.75
16......	32.88	2.37	2.45	3.76	41.46	10.80	6.92	17.72	4.09	63.27
17......	5.72	16.59	14.40	5.88	42.59	8.31	8.02	16.33	4.44	63.36
18......	4.80	11.48	17.67	4.71	38.66	12.04	6.92	18.96	5.79	63.41
19......	28.73	6.66	2.72	3.98	42.09	9.26	8.18	17.44	4.02	63.55
20......	20.91	11.36	10.44	3.96	46.67	6.32	6.98	13.30	4.17	64.14
21......	16.91	10.35	13.26	4.79	45.31	8.11	7.14	15.25	4.08	64.64
22......	....	21.49	9.94	9.05	40.48	10.46	10.66	21.12	4.56	66.16
23......	12.11	17.22	....	4.81	34.14	17.65	8.51	26.16	6.03	66.33
24......	12.90	29.52	.05	5.35	47.82	7.09	7.16	14.25	4.79	66.86
25......	16.84	13.05	11.70	4.62	46.21	8.79	8.01	16.80	4.23	67.24
26......	1.27	16.66	20.26	5.74	43.93	10.81	8.66	19.47	4.06	67.46
27......	4.98	12.46	19.84	5.68	42.96	11.39	8.24	19.63	5.45	68.04
28......	....	28.14	10.61	3.88	42.63	11.40	9.39	20.79	5.26	68.68
29......	16.59	12.69	10.44	5.68	45.40	11.73	7.52	19.25	4.11	68.76
30......	8.78	17.95	9.19	6.75	42.67	13.76	10.31	24.07	4.30	71.04
31......	....	21.67	9.75	8.87	40.29	15.24	10.80	26.04	5.19	71.52
32......	4.06	25.75	13.18	4.77	47.76	8.89	10.32	19.21	4.77	71.74
33......	18.59	14.67	.36	8.61	42.23	12.22	14.06	26.28	3.40	71.91
34......	15.27	17.08	10.98	5.47	48.80	11.76	10.34	22.10	4.26	75.16
35......	14.20	15.04	13.06	4.91	47.21	11.96	12.10	24.06	4.16	75.43
36......	12.96	14.76	9.13	7.94	44.79	6.67	19.19	25.86	7.20	77.85
37......	9.00	37.91	1.71	4.32	52.94	8.98	10.77	19.75	5.90	78.59
38......	11.38	25.14	3.60	8.24	48.36	12.29	12.24	24.53	8.18	81.07
39......	11.62	17.78	4.43	6.20	40.03	19.66	16.44	36.10	6.24	82.37
Average.	13.08	17.01	5.79	4.80	40.68	8.68	8.49	17.17	4.39	62.24

COST OF PRODUCTION PER TON OF PAPER OF 39 PRINCIPAL BOOK-PAPER MILLS, BY MILLS, 1915 AND 1916—Continued

1916

Mill number	Stock					Conversion			General expense, including depreciation	Total cost
	Soda pulp	Sulphite	Waste paper	Miscellaneous	Total	Labor	Miscellaneous	Total		
1......	$28.88	$4.74	....	$3.81	$37.43	$6.72	$6.33	$13.05	$4.63	$55.11
2......	16.56	15.34	$2.58	3.73	38.21	7.08	6.01	13.09	3.97	55.27
3......	13.00	23.77	....	3.41	40.18	6.31	5.21	11.52	4.11	55.81
4......	16.86	18.58	....	3.55	38.99	7.55	7.18	14.73	4.65	58.37
5......	19.51	13.66	.08	4.65	37.90	9.52	7.99	17.51	3.11	58.52
6......	24.92	9.93	....	3.53	38.38	7.86	7.85	15.71	4.46	58.55
7......	14.95	19.01	6.05	3.66	43.67	7.76	6.49	14.25	4.57	62.49
8......	32.36	....	1.12	7.02	40.50	10.75	7.78	18.53	3.60	62.63
9......	31.44	5.79	.61	4.88	42.72	11.44	6.60	18.04	3.51	64.27
10......	18.26	19.56	.06	3.69	41.57	10.72	9.14	19.86	3.33	64.76
11......	....	20.83	8.80	9.53	39.16	7.93	12.00	19.93	5.80	64.89
12......	7.95	25.86	11.52	3.56	48.89	6.42	7.29	13.71	4.85	67.45
13......	13.66	28.66	.39	6.46	49.17	8.09	8.48	16.57	4.37	70.11
14......	26.52	10.90	11.84	4.21	53.47	6.23	7.46	13.69	3.40	70.56
15......	4.82	14.92	22.75	5.57	48.06	11.51	7.04	18.55	5.39	72.00
16......	20.78	12.29	15.91	5.66	54.64	7.99	7.50	15.49	3.56	73.69
17......	5.10	28.35	8.47	9.33	51.25	7.29	10.58	17.87	4.69	73.81
18......	27.76	13.54	3.32	4.60	49.22	11.45	9.61	21.06	3.63	73.91
19......	10.70	26.89	9.64	4.33	51.56	7.91	9.30	17.21	5.48	74.25
20......	....	27.24	16.33	4.60	48.17	11.81	10.34	22.15	4.50	74.82
21......	....	25.90	14.06	8.18	48.14	13.07	10.35	23.42	3.78	75.34
22......	....	20.38	19.18	6.46	46.02	12.68	12.48	25.16	4.26	75.44
23......	10.59	18.22	15.18	6.81	50.80	11.06	10.62	21.68	3.36	75.84
24......	....	1.62	42.64	5.53	49.79	12.87	10.87	23.74	3.88	77.41
25......	5.42	19.11	23.25	5.03	52.81	11.96	9.78	21.74	3.05	77.60
26......	20.83	14.03	.33	12.86	48.05	13.61	13.57	27.18	3.02	78.25
27......	7.14	18.01	24.33	6.07	55.55	9.47	9.95	19.42	3.38	78.35
28......	20.01	17.80	14.35	4.84	57.00	9.20	8.75	17.95	3.47	78.42
29......	16.29	17.32	14.51	6.33	54.45	13.23	8.34	21.57	3.69	79.71
30......	1.50	20.80	25.07	6.94	54.31	12.77	10.42	23.19	3.69	81.19
31......	17.56	15.31	17.88	5.36	56.11	11.53	10.58	22.11	3.51	81.73
32......	8.75	39.95	.84	6.17	55.71	9.90	11.82	21.72	4.72	82.15
33......	18.17	19.16	13.42	6.66	57.41	11.27	11.06	22.33	3.42	83.16
34......	6.94	15.79	26.50	8.04	57.27	14.05	10.07	24.12	5.18	86.57
35......	14.36	26.77	2.12	9.92	53.17	14.04	13.32	27.36	7.75	88.28
36......	17.73	19.31	3.57	5.99	46.60	17.08	18.22	35.30	6.57	88.47
37......	23.21	24.40	....	6.03	53.64	16.04	14.50	30.54	5.40	89.58
38......	5.12	29.06	21.79	5.26	61.23	10.59	11.53	22.12	8.86	92.21
39......	15.79	21.70	12.33	8.92	58.74	11.52	19.58	31.10	7.48	97.32
Average.	14.30	18.81	7.65	5.86	46.62	9.63	9.34	18.97	4.28	69.87

AVERAGE COST OF PRODUCTION PER TON OF COATED PAPER FOR 6 COATING MILLS, 1915 AND 1916

	1915	1916	Increase, 1916 over 1915	Per cent of increase
Tons produced	83,024	100,920	17,896	21.56
Stock:				
Paper	$42.54	$53.58	$11.04	25.95
Clay	3.26	3.25	[1].01	[1].31
Casein	7.56	9.68	2.12	28.04
Satin white	1.92	1.73	[1].19	[1]1.90
Miscellaneous	2.59	4.77	2.18	84.17
Total	57.87	73.01	15.14	26.16
Conversion:				
Labor	9.75	11.63	1.88	19.28
Fuel	2.01	2.06	.05	2.49
Repairs	1.43	1.52	.09	6.29
Belting and lubricants	.12	.12	......	......
Packing and shipping	2.72	3.01	.29	10.66
Miscellaneous	.31	.25	[1].06	[1] 19.35
Total	16.34	18.59	2.25	13.77
General expense:				
Taxes and insurance	.49	.53	.04	8.16
Administrative	1.54	2.02	.48	31.17
Total	2.03	2.55	.52	25.62
Factory cost, without depreciation	76.24	94.15	17.91	23.49
Depreciation	1.75	1.50	[1].25	14.29
Total cost	77.99	95.65	17.66	22.64

[1] Decrease.

PERCENTAGE OF TOTAL COST OF PRODUCING COATED PAPER OF 6 MILLS ATTRIBUTABLE TO PARTICULAR ITEMS, 1915 AND 1916

	1915	1916	Increase, 1916 over 1915
Tons produced	83,024	100,920	17,896
Stock:	*Per cent.*	*Per cent.*	*Per cent.*
Paper	54.55	56.02	1.47
Clay	4.18	3.40	[1] .78
Casein	9.69	10.12	.43
Satin white	2.46	1.81	[1] .65
Miscellaneous	3.32	4.98	1.66
Total	74.20	76.33	2.13
Conversion:			
Labor	12.50	12.16	[1] .34
Fuel	2.58	2.15	[1] .43
Repairs	1.83	1.59	[1] .24
Belting and lubricants	.15	.13	[1] .02
Packing and shipping	3.49	3.15	[1] .34
Miscellaneous	.40	.26	[1] .14
Total	20.95	19.44	[1] 1.51
General expense:			
Taxes and insurance	.63	.55	[1] .08
Administrative	1.98	2.11	.13
Total	2.61	2.66	.05
Factory cost, without depreciation	97.76	98.43	.67
Depreciation	2.24	1.57	[1] .67
Total cost	100.00	100.00	0.00

[1] Decrease.

AVERAGE COST OF PRODUCTION PER TON OF SODA PULP FOR 16 MILLS, 1915 AND 1916

	1915	1916	Increase, 1916 over 1915	Per cent of increase
Tons produced	266,807	319,623	52,816	19.80
Stock:				
Wood	$13.24	$13.46	$0.22	1.66
Soda ash and soda	1.98	2.38	.40	20.20
Bleach	3.07	2.89	[1].18	[1]5.86
Lime	1.90	1.99	.09	4.74
Miscellaneous	.05	.08	.03	60.00
Total	20.24	20.80	.56	2.77
Conversion:				
Labor	5.29	5.96	.67	12.67
Fuel	4.03	4.48	.45	11.17
Repairs	1.45	1.73	.28	19.31
Felts, wires, belting, and lubricants	.31	.33	.02	6.45
Miscellaneous	.76	.81	.05	6.58
Total	11.84	13.31	1.47	12.42
General expense:				
Taxes and insurance	.40	.41	.01	2.50
Administrative	1.08	1.20	.12	11.11
Total	1.48	1.61	.13	8.78
Factory cost, without depreciation	33.56	35.72	2.16	6.44
Depreciation	1.50	1.25	[1].25	[1]16.67
Total cost	35.06	36.97	1.91	5.45

[1] Decrease.

PERCENTAGE OF TOTAL COST OF PRODUCING SODA PULP OF 16 MILLS ATTRIBUTABLE TO PARTICULAR ITEMS, 1915 AND 1916

	1915	1916	Increase, 1916 over 1915
Tons produced	266,807	319,623	52,816
Stock:	*Per cent.*	*Per cent.*	*Per cent.*
Wood	37.76	36.41	[1] 1.35
Soda ash and soda	5.65	6.44	.79
Bleach	8.76	7.82	[1] .94
Lime	5.42	5.38	[1] .04
Miscellaneous	.14	.21	.07
Total	57.73	56.26	[1] 1.47
Conversion:			
Labor	15.09	16.12	1.03
Fuel	11.49	12.12	.63
Repairs	4.14	4.68	.54
Felts, wires, belting, and lubricants	.88	.89	.01
Miscellaneous	2.17	2.19	.02
Total	33.77	36.00	2.23
General expense:			
Taxes and insurance	1.14	1.11	[1] .03
Administrative	3.08	3.25	.17
Total	4.22	4.36	.14
Factory cost, without depreciation	95.72	96.62	.90
Depreciation	4.28	3.38	[1] .90
Total cost	100.00	100.00	0.00

[1] Decrease.

AVERAGE COST OF PRODUCTION PER TON OF SULPHITE FOR 9 MILLS, 1915 AND 1916

	1915	1916	Increase, 1916 over 1915	Per cent of increase
Tons produced	179,419	203,003	23,584	13.14
Stock:				
Wood	$18.87	$18.80	[1] $0.07	[1] 0.37
Sulphur and pyrites	2.71	2.56	[1] .15	[1] 5.54
Bleach	3.11	3.15	.04	1.29
Lime	.48	.48	.00	.00
Miscellaneous	.01	.28	.27	2,700.00
Total	25.18	25.27	.09	.36
Conversion:				
Labor	5.54	5.65	.11	1.99
Fuel	2.73	2.84	.11	4.03
Repairs	1.58	1.59	.01	.63
Felts, wires, belting, and lubricants	.36	.39	.03	8.33
Miscellaneous	.72	.75	.03	4.17
Total	10.93	11.22	.29	2.65
General expense:				
Taxes and insurance	.43	.51	.08	18.60
Administrative	1.08	1.87	.79	73.15
Total	1.51	2.38	.87	57.62
Factory cost, without depreciation	37.62	38.87	1.25	3.32
Depreciation	1.50	1.25	[1] .25	[1] 16.67
Total cost	39.12	40.12	1.00	2.56

[1] Decrease.

PERCENTAGE OF TOTAL COST OF PRODUCING SULPHITE OF 9 MILLS ATTRIBUTABLE TO PARTICULAR ITEMS, 1915 AND 1916

	1915	1916	Increase, 1916 over 1915
Tons produced	179,419	203,003	23,584
Stock:	*Per cent.*	*Per cent.*	*Per cent.*
Wood	48.24	46.86	[1] 1.38
Sulphur and pyrites	6.93	6.38	[1] .53
Bleach	7.95	7.85	[1] .15
Lime	1.23	1.20	[1] .00
Miscellaneous	.02	.70	.68
Total	64.37	62.99	[1] 1.38
Conversion:			
Labor	14.16	14.08	[1] .08
Fuel	6.98	7.08	.10
Repairs	4.04	3.96	[1] .08
Felts, wires, belting, and lubricants	.92	.97	.05
Miscellaneous	1.84	1.87	.03
Total	27.94	27.96	.02
General expense:			
Taxes and insurance	1.10	1.27	.17
Administrative	2.76	4.66	1.90
Total	3.86	5.93	2.07
Factory cost, without depreciation	96.17	96.88	.71
Depreciation	3.83	3.12	[1] .71
Total cost	100.00	100.00	0.00

[1] Decrease.

PERCENTAGE OF TOTAL COST OF PRODUCING NEWS-PRINT PAPER ATTRIBUTABLE TO PARTICULAR ITEMS — UNITED STATES AND CANADIAN MILLS COMBINED — 1913-1916 (FIRST HALF).

Item	1913	1914	1915	First half 1916
Stock	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sulphite	24.41	23.69	23.66	23.36
Ground wood	34.71	34.97	34.67	34.30
Fillers	1.18	1.14	1.20	.80
Alum	.52	.54	.63	.63
Sizing	.35	.30	.28	.21
Miscellaneous	1.72	1.85	2.26	1.96
Total	62.89	62.49	62.70	61.26
Conversion:				
Labor	10.20	10.17	10.16	.999
Felts	2.57	2.48	2.35	2.51
Wires	1.16	1.08	1.24	1.36
Belting	.28	.33	.30	.30
Lubricants	.26	.26	.25	.22
Repairs	3.97	3.91	3.29	3.54
Fuel	6.39	6.36	6.35	7.28
Power and water rentals	.76	.90	1.14	1.08
Miscellaneous	3.37	3.55	3.56	3.60
Total	28.96	29.04	28.64	29.88
General expense:				
Taxes and insurance	1.19	1.36	1.18	1.33
General and administrative	1.82	1.92	2.00	1.96
Total	3.01	3.28	3.18	3.29
Depreciation	5.14	5.19	5.48	5.57
Total cost	100.00	100.00	100.00	100.00

COST OF MANUFACTURE PER TON OF NEWS-PRINT PAPER FOR PRINCIPAL UNITED STATES MILLS, 1915-1916 (FIRST HALF)

Mill No.	Stock				Total conversion	General expenses	Depreciation	Total cost
	Sulphite	Ground wood	Miscellaneous	Total				
1915:								
1	$7.23	$9.00	$1.62	$17.85	$5.06	$1.11	$1.75	$25.77
2	6.52	8.96	.61	16.09	8.46	.38	1.75	26.68
3	8.18	8.73	1.65	18.56	5.55	1.08	1.75	26.94
4	6.90	8.59	.68	16.17	9.21	.39	1.75	27.52
5	6.36	10.85	1.80	19.01	7.78	.77	1.74	29.30
6	7.48	10.26	1.25	18.99	7.77	1.97	1.72	30.45
7	7.20	11.17	1.42	19.79	8.42	.90	1.48	30.59
8	5.39	12.78	1.52	19.69	8.43	1.20	1.49	30.81
9	6.69	12.46	1.43	20.58	7.41	1.55	1.48	31.02
10	9.22	12.35	1.59	23.16	6.27	1.17	1.45	32.05
11	7.02	10.70	.31	18.03	10.95	1.38	1.75	32.11
12	6.82	11.45	1.61	19.88	9.95	.64	1.75	32.22
13	7.08	12.33	.74	20.15	10.24	.51	1.75	32.65
14	4.91	11.56	1.40	17.87	12.25	1.34	1.75	33.21
15	5.94	11.43	1.59	18.96	11.51	1.23	1.75	33.45
16	7.03	14.37	2.08	23.48	8.16	.60	1.66	33.90
17	6.10	14.03	1.65	21.78	10.12	.87	1.71	34.48
18	8.55	12.70	.77	22.02	8.99	1.82	1.75	34.58
19	8.16	12.68	2.28	23.12	8.93	1.41	1.64	35.10
20	6.06	13.07	2.04	21.17	11.15	1.09	1.74	35.15
21	8.40	10.53	.82	19.75	11.77	1.90	1.75	35.17
22	6.93	16.03	2.01	24.97	8.01	.69	1.53	35.20
23	6.72	15.41	1.58	23.71	8.85	1.04	1.69	35.29
24	6.80	13.18	1.80	21.78	11.34	.99	1.74	35.85
25	10.04	11.78	2.69	24.51	8.77	1.37	1.41	36.06
26	6.61	14.87	1.70	23.18	10.73	1.12	1.75	36.78
27	9.13	14.09	3.07	26.29	8.22	.99	1.49	36.99
28	8.59	14.03	.83	23.45	10.81	1.34	1.40	37.00
29	9.44	11.70	1.57	22.71	11.05	1.97	1.37	37.10
30	8.52	13.79	.90	23.21	10.64	1.64	1.75	37.24
31	7.79	12.75	1.58	22.12	11.38	2.72	1.46	37.68
32	12.44	12.78	1.63	26.85	8.85	1.80	1.64	39.14
33	4.55	16.63	2.43	23.61	13.35	1.84	1.75	40.55
34	8.44	14.43	2.19	25.06	14.37	1.57	1.75	42.75
35	10.69	13.73	.90	25.32	16.18	1.16	1.75	44.41
Average	7.47	11.63	1.39	20.49	9.00	1.03	1.69	32.21

COST OF MANUFACTURE PER TON OF NEWS-PRINT PAPER FOR PRINCIPAL UNITED STATES MILLS, 1915-1916 (FIRST HALF)—Continued

Mill No.	Stock				Total conversion	General expenses	Depreciation	Total cost
	Sulphite	Ground wood	Miscellaneous	Total				
1916 (first half):								
1.........	$7.70	$8.18	$1.21	$17.09	$5.36	$.73	$1.75	$34.93
2.........	7.41	8.71	1.27	17.39	5.96	.71	1.75	25.81
3.........	6.70	9.08	.04	15.82	9.31	.50	1.75	27.38
4.........	7.51	8.39	.91	16.81	9.13	.52	1.75	28.21
5.........	6.13	11.35	1.51	18.99	6.30	1.90	1.49	28.68
6.........	6.48	10.67	1.07	18.22	8.17	.82	1.74	28.95
7.........	4.32	13.87	.74	18.93	7.93	2.03	1.45	30.34
8.........	7.12	8.80	.22	16.14	10.73	1.75	1.75	30.37
9.........	5.82	13.44	1.65	20.91	7.43	1.27	1.48	31.09
10.........	6.95	9.81	1.71	18.47	9.09	2.02	1.75	31.33
11.........	5.87	11.79	.90	18.56	10.39	.71	1.75	31.41
12.........	8.12	11.00	.40	19.52	8.39	1.78	1.75	31.44
13.........	7.01	11.30	.40	18.71	11.28	.74	1.75	32.48
14.........	4.80	12.21	1.10	18.11	11.63	1.12	1.75	32.61
15.........	6.71	10.43	1.15	18.29	11.65	1.15	1.75	32.84
16.........	6.61	11.71	1.65	19.97	9.69	1.58	1.75	32.99
17.........	7.72	13.06	1.06	21.84	8.93	.79	1.46	33.02
18.........	6.96	14.02	1.42	22.40	8.63	.68	1.70	33.41
19.........	6.02	13.74	1.08	20.84	11.14	.92	1.75	34.65
20.........	9.49	11.93	2.51	23.93	8.98	1.28	1.34	35.53
21.........	8.02	14.16	1.11	23.29	9.61	1.08	1.75	35.73
22.........	7.97	10.92	.73	19.62	12.66	1.73	1.75	35.76
23.........	6.65	16.55	1.13	24.33	9.04	.85	1.56	35.78
24.........	7.93	13.01	.51	21.45	10.75	1.84	1.75	35.79
25.........	8.34	12.73	1.33	22.40	11.38	.90	1.75	36.43
26.........	8.61	11.69	2.30	22.60	10.68	1.99	1.39	36.66
27.........	8.35	13.37	.76	22.48	11.53	1.29	1.38	36.68
28.........	9.52	12.89	3.62	26.03	8.17	1.41	1.49	37.10
29.........	7.67	12.76	1.85	22.28	12.84	1.06	1.75	37.93
30.........	7.39	14.66	1.38	23.43	12.22	1.15	1.75	38.55
31.........	7.04	13.68	3.10	23.82	12.73	2.00	1.48	40.03
32.........	13.07	11.89	2.55	27.51	9.68	1.75	1.69	40.63
33.........	8.75	15.22	1.22	25.19	15.76	1.32	1.75	44.02
34.........	11.32	16.59	1.68	29.59	14.46	1.14	1.75	46.94
Average.	7.33	11.33	1.09	19.75	9.40	1.08	1.70	31.93

PERCENTAGE OF TOTAL COST OF PRODUCING SULPHITE ATTRIBUTABLE TO PARTICULAR ITEMS — UNITED STATES AND CANADIAN MILLS COMBINED — 1913-1916 (FIRST HALF).

Item	1913	1914	1915	First half 1916
Stock:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sulphur	10.38	10.35	10.21	9.77
Lime and limestone	2.65	2.49	2.46	2.39
Wood	54.69	54.28	55.53	56.36
Total	67.72	67.12	68.20	68.52
Conversion:				
Labor	11.32	11.38	10.85	10.30
Felts	.31	.32	.34	.40
Wires	.07	.06	.06	.10
Belting	.39	.36	.26	.32
Lunbricants	.09	.09	.09	.08
Repairs	5.61	5.43	5.15	5.36
Fuel	8.20	7.80	7.33	7.77
Power and water rentals	1.24	2.09	2.00	1.91
Miscellaneous	1.84	1.77	2.06	2.01
Total	29.07	29.30	28.14	28.25
General expense:				
Taxes and insurance	1.25	1.28	1.24	1.26
General and administrative	1.96	2.30	2.42	1.97
Total	3.21	3.58	3.66	3.23
Total cost [1]	100.00	100.00	100.00	100.00

[1] Exclusive of depreciation.

PERCENTAGE OF TOTAL COST OF PRODUCING GROUND WOOD ATTRIBUTABLE TO PARTICULAR ITEMS—UNITED STATES AND CANADIAN MILLS COMBINED—1913-1916 (FIRST HALF).

Item	1913	1914	1915	First half 1916
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Wood	65.04	64.86	67.11	68.85
Conversion:				
Labor	16.38	16.11	15.00	14.12
Stones	.86	.94	.82	.92
Felts	.57	.57	.55	.57
Wires	.19	.19	.21	.27
Belting	.45	.43	.35	.34
Lubricants	.24	.22	.20	.17
Repairs	5.83	5.62	5.07	4.65
Power and water rentals	3.87	4.21	4.20	3.98
Miscellaneous	2.11	2.25	2.43	2.28
Total	30.50	30.54	28.83	27.30
General expense:				
Taxes and insurance	1.86	1.78	1.46	1.49
General and administrative	2.60	2.82	2.60	2.36
Total	4.46	4.60	4.06	3.85
Total cost [1]	100.00	100.00	100.00	100.00

[1] Exclusive of depreciation.

QUANTITIES AND PROPORTIONS OF MATERIALS, EXCLUSIVE OF COLORS AND SOME MISCELLANEOUS ITEMS, USED IN 1916 BY 3 EASTERN AND 5 MICHIGAN COMPANIES.

Materials	Three eastern companies (production, 291,953 tons)			Five Michigan companies (production, 89,015 tons)		
	Quantity	Pounds used per ton of paper produced	Proportions of materials used	Quantity	Pounds used per ton of paper produced	Proportions of materials used
	Tons		*Per cent*	*Tons*		*Per cent*
Soda pulp	138,910	952	40.1	6,949	156	5.7
Sulphite	120,730	827	34.9	26,140	587	21.7
Waste paper	10,063	69	2.9	[1] 71,031	[1] 1,596	[1] 58.9
Clay, agalite and talc	67,223	460	19.4	9,885	222	8.2
Alum	5,980	41	1.7	4,851	109	4.0
Rosin	3,310	23	1.0	1,799	41	1.5
Total	346,216	2,372	100.0	120,655	2,711	100.0

[1] Includes a small proportion of rags.

AVERAGE COST OF MANUFACTURE PER TON OF NEWS-PRINT PAPER FOR UNITED STATES AND CANADIAN MILLS, 1913-1916 (FIRST HALF)

Item	United States				Canada				United States and Canada Combined			
	1913	1914	1915	First half 1916	1913	1914	1915	First half 1916	1913	1914	1915	First half 1916
Number of mills	30	35	35	34	7	9	11	10	37	44	46	44
Tons produced	944,363	1,043,530	1,025,461	539,836	226,538	347,308	432,406	219,511	1,170,901	1,390,838	1,457,867	759,347
Stock:												
Sulphite	$8.02	$7.64	$7.47	$7.33	$7.97	$7.68	$7.01	$6.74	$8.01	$7.65	$7.33	$7.16
Ground wood	12.07	12.03	11.63	11.33	8.54	9.06	8.65	8.47	11.39	11.29	10.75	10.50
Fillers	.41	.38	.38	.29	.29	.34	.35	.30	.39	.37	.37	.25
Alum	.15	.15	.18	.17	.25	.23	.22	.26	.17	.17	.19	.19
Sizing	.11	.08	.10	.07	.16	.13	.07	.06	.12	.09	.09	.06
Miscellaneous	.59	.65	.73	.63	.47	.45	.63	.51	.56	.60	.70	.60
Total	21.35	20.93	20.49	19.75	17.68	17.89	16.93	16.34	20.64	20.17	19.43	18.76
Conversion:												
Labor	3.49	3.51	3.41	3.34	2.75	2.60	2.54	2.36	3.34	3.28	3.15	3.06
Felts	.80	.75	.68	.69	1.03	.96	.83	.95	.84	.80	.73	.77
Wires	.37	.35	.37	.43	.39	.34	.42	.40	.38	.35	.38	.42
Belting	.09	.11	.10	.10	.10	.09	.08	.07	.09	.11	.09	.09
Lubricants	.08	.08	.07	.06	.12	.10	.08	.07	.09	.08	.08	.07
Repairs	1.35	1.34	1.05	1.19	1.09	1.04	.94	.84	1.30	1.26	1.02	1.08
Fuel	2.04	2.03	1.97	2.25	2.35	2.13	1.96	2.18	2.10	2.05	1.97	2.23
Power and water rentals	.22	.27	.56	.33	.36	.36	.35	.33	.25	.29	.35	.33
Miscellaneous	.98	.98	.99	1.01	1.64	1.63	1.38	1.33	1.11	1.15	1.10	1.10
Total	9.42	9.42	9.00	9.40	9.83	9.25	8.58	8.53	9.50	9.37	8.87	9.15
General expenses:												
Taxes and insurance	.42	.50	.43	.50	.26	.26	.21	.19	.39	.44	.37	.41
Administrative	.54	.57	.60	.58	.86	.76	.66	.65	.60	.62	.62	.60
Total	.96	1.07	1.03	1.08	1.12	1.02	.87	.84	.99	1.06	.99	1.01
Cost, not including depreciation	31.73	31.42	30.52	30.23	28.63	28.16	26.38	25.71	31.13	30.60	29.29	28.92
Depreciation	1.69	1.66	1.69	1.70	1.69	1.72	1.73	1.72	1.69	1.68	1.70	1.71
Total cost	33.42	33.08	32.21	31.93	30.32	29.88	28.11	27.43	32.82	32.28	30.99	30.63

AVERAGE COST OF MANUFACTURE PER TON OF SULPHITE FOR UNITED STATES AND CANADIAN MILLS, 1913-1916 (FIRST HALF)

Item	United States				Canada				United States and Canada Combined			
	1913	1914	1915	First half 1916	1913	1914	1915	First half 1916	1913	1914	1915	First half 1916
Number of mills	19	21	22	20	5	7	9	8	24	28	31	28
Tons produced	305,531	321,533	326,093	195,647	63,349	111,930	142,959	77,219	368,880	433,463	469,052	272,866
Stock:												
Sulphur	$3.14	$3.13	$2.97	$2.79	$3.38	$3.09	$3.04	$2.97	$3.18	$3.13	$3.00	$2.84
Lime and limestone	.90	.88	.84	.82	.39	.39	.45	.38	.81	.75	.72	.70
Wood	17.27	16.84	17.16	17.42	14.27	15.07	14.32	13.82	16.76	16.38	16.29	16.40
Total	21.31	20.85	20.97	21.03	18.04	18.55	17.81	17.17	20.75	20.26	20.01	19.94
Conversion:												
Labor	3.67	3.76	3.51	3.39	2.49	2.49	2.44	2.00	3.47	3.43	3.18	3.00
Felts	.10	.10	.09	.11	.09	.09	.11	.13	.10	.10	.10	.12
Wires	.02	.02	.02	.03	.01	.01	.01	.02	.02	.02	.02	.03
Belting	.13	.13	.09	.12	.07	.05	.04	.04	.12	.11	.08	.09
Lubricants	.03	.03	.03	.03	.02	.02	.02	.01	.03	.03	.03	.02
Repairs	1.79	1.75	1.68	1.80	1.41	1.32	1.12	.94	1.72	1.64	1.51	1.56
Fuel	2.36	2.14	2.08	2.28	3.25	2.97	2.32	2.22	2.51	2.35	2.15	2.26
Power and water rentals	.35	.63	.59	.53	.50	.66	.59	.63	.38	.63	.58	.55
Miscellaneous	.49	.48	.52	.52	.92	.68	.79	.75	.56	.54	.60	.59
Total	8.94	9.04	8.61	8.81	8.76	8.29	7.44	6.74	8.91	8.85	8.25	8.22
General expenses:												
Taxes and insurance	.41	.45	.43	.43	25	.21	21	21	.38	.39	.36	.37
Administrative	.54	.71	.69	.51	.88	64	.75	73	.60	.69	.71	.57
Total	.95	1.16	1.12	.94	1.13	.85	.96	.94	.98	1.08	1.07	.94
Total cost [1]	31.20	31.05	30.70	30.78	27.93	27.69	26.21	24.85	30.64	30.19	29.33	29.10

[1] Exclusive of depreciation which on the average would be about $1.17 per ton of sulphite.

AVERAGE COST OF MANUFACTURE PER TON OF GROUND WOOD FOR UNITED STATES AND CANADIAN MILLS, 1913-1916 (FIRST HALF)

Item	United States				Canada				United States and Canada Combined			
	1913	1914	1915	First half 1916	1913	1914	1915	First half 1916	1913	1914	1915	First half 1916
Number of mills	45	50	50	47	7	10	11	10	52	60	61	57
Tons produced	698,222	770,017	844,815	511,243	216,151	328,460	406,960	187,707	914,373	1,098,478	1,251,775	698,950
Stock:												
Wood	$9.51	$9.32	$9.57	$9.41	$7.03	$7.30	$7.34	$7.45	$8.92	$8.72	$8.85	$8.88
Conversion:												
Labor	2.43	2.36	2.18	2.05	1.66	1.71	1.55	1.20	2.25	2.16	1.98	1.82
Stones	.12	.14	.12	.11	.11	.09	.08	.13	.12	.13	.11	.12
Felts	.08	.08	.09	.09	.08	.07	.07	.05	.04	.08	.07	.07
Wires	.03	.03	.03	.04	.02	.02	.02	.02	.03	.02	.03	.04
Belting	.07	.07	.05	.05	.05	.03	.04	.03	.06	.06	.05	.04
Lubricants	.03	.03	.03	.02	.03	.03	.03	.02	.03	.03	.02	.02
Repairs	.91	.87	.78	.68	.44	.48	.43	.38	.80	.76	.67	.60
Power and water rentals	.54	.58	.57	.52	.49	.53	.53	.50	.53	.56	.55	.51
Miscellaneous	.28	.31	.31	.31	.31	.29	.33	.26	.29	.30	.32	.30
Total	4.49	4.17	4.16	3.87	3.19	3.25	3.06	2.58	4.19	4.10	3.80	3.52
General expense:												
Taxes and insurance	.30	.28	.23	.22	.12	.13	.12	.10	.25	.24	.19	.19
Administrative	.33	.39	.33	.27	.44	.37	.37	.41	.36	.38	.34	.31
Total	.63	.67	.56	.49	.56	.50	.49	.51	.61	.62	.53	.50
Total cost [1]	14.63	14.46	14.29	13.77	10.78	11.05	10.89	10.54	13.72	13.44	13.18	12.90

[1] Exclusive of depreciation which on the average would be about $0.55 per ton of ground wood.

AMERICAN PULPWOODS *

By Otto Kress[1], Sidney D. Wells[2] and Vance P. Edwards[3]

Forest Products Laboratory, Madison, Wisconsin

The Forest Products Laboratory, Madison, Wis., has in the past received frequent requests as to the suitability of various woods for pulp and paper production and it has therefore seemed advisable to prepare for publication some of the available data on this subject The laboratory has carried on an extended investigation over a period of more than ten years and has collected experimental pulping data on practically all the possible species of American pulp woods. These data, in so far as the chemical pulps are concerned, have mainly been obtained from experimental cooks made in the Forest Products Laboratory, Madison, Wis., in 100-pound semi-commercial digesters, and from studies made on the resulting pulps. It has been found, however, that the general cooking conditions, yield, bleach, consumption, etc., as determined by experimental trials for pulp made from any given wood, compare quite favorably with the results obtained in commercial practice. The data for the various mechanical pulps were obtained from the experiments carried on at the ground-wood laboratory, Wausau, Wis., where a commercial-sized grinder equipment was installed by the Forest Products Laboratory in co-operation with the American Paper and Pulp Association.

The yield of pulp from any given wood depends directly upon the specific gravity of the wood or weight per cubic foot, and the pulping method employed. By varying the severity of the pulping treatment, both yield and bleach consumption are changed. For example, white spruce sulphite pulp prepared for the manufacture of newsprint paper would show an entirely different yield and bleach consumption from bleached white spruce pulp prepared for use in a white bond paper. It is, therefore, evident that the character and use of the pulp will largely decide the severity of the cooking operation. Certain woods, such as western larch, containing a high percentage of galactan, which is water-soluble, will show a decreased yield by either mechanical or chemical pulping.

Pulping data have been given for woods such as red and white oak, white ash and certain other woods not because we consider these species suitable for pulp purposes, but because the information was available. Many wood-using plants produce considerable tonnage of slabs and mill waste of woods not especially suitable for pulp production, and are interested in a possible outlet for this waste. In some cases, at their direct request, pulping trials have been made on woods known to be unsuitable for pulping purposes. The various woods have been listed, giving the

* From: "The Paper Industry," Chicago, Ill.

[1] Much of the data used in this report has been collected at a previous date by Henry E. Surface of our laboratory, but not for publication. We also wish to acknowledge the contributions of Edwin Sutermeister, R. C. Cooper, G. C. McNaughton, C. K. Textor and S. E. Lunack, who, while in the employ of the Forest Service, made some of these cooks.

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[3] Engineer in Forest Products.

official name as recognized by the Forest Service, also the common names in use and the range covering the growth of that particular species This information has been taken directly from the "Check List of the Forest Trees of the United States," by George B. Sudworth.

In considering the pulping and other data given for the various woods, attention is drawn to the following points:

1. The weights of wood given are for bone-dry material per solid cubic foot. This is obtained by multiplying the specific gravity of the over-dried wood based on the green volume by 62.3 lbs. (the weight of a cubic foot of water).

2. The fiber lengths as given are the average of all the available data taken from the Forest Service investigations and from other sources. Many of the measurements given are the results of averages of thousands of determinations; in other cases from only a few determinations.

3. The yield figures represent the yield of bone dry screened and unbleached pulp per hundred cubic feet of solid bone-dry wood. It is our opinion that in general the ordinary cord of 128 cubic feet of rossed wood piled 4x4x8 feet closely approximates 100 solid cubic feet of wood. To convert the yields on bone-dry basis to air-dry pulp containing 10 per cent moisture, divide the yield by 0.9

The yield data are based on results obtained from experimental runs made under very favorable conditions. The pulp logs on arrival at the laboratory are barked, sawed into convenient size and any wood containing knots and decayed spots is rejected. The chips are carefully sorted and are far more uniform in size and moisture content than can be obtained in commercial practice unless the mills operate under more favorable conditions than ordinarily exist. Further, each cook representing an individual experiment, it is possible to press, shred, sample and screen the pulp with fewer mechanical losses than is feasible in handling the pulp in commercial practice from the blow pit to the wet machine or to the finished paper.

4. The comparison of the character and uses of the various pulps that may be obtained from the different woods offers certain difficulties. It has, therefore, been decided to consider white spruce as the standard wood for pulping by the sulphite, sulphate and mechanical processes and to compare the pulp that might be obtained from any given wood by this process of pulping with the pulp obtained from white spruce. Aspen wood has likewise been adopted as the standard for reduction by the soda process, and soda pulps from other woods will be compared with it.

No figures have been given on the bleaching of the sulphate pulps as we do not know of any mills making bleached sulphate pulp in this country at the present time. By this we do not mean to imply that sulphate pulp cannot be economically bleached, but this is not the present mill practice.

Further, no data are given on the possible soda pulping of the various firs, pines, hemlocks, larch, tamarack and other woods that can be reduced by the sulphate process. The laboratory has made extensive pulping trials on the reduction of these woods by the soda process and it is, of course, recognized that this process can be and is at present employed to a limited extent for reduction of certain of these woods. In general, the soda process can be used for reduction of any wood suitable for the production of sulphate pulp, where the stock is not to be bleached and where strength is of primary consideration. These soda pulps from coniferous woods could, of course, through a severe pulping treatment, be bleached with a reasonable bleach consumption.

No figures have been given for bleach consumption. It has appeared advisable to compare the ease of bleaching for any given pulp with the standard white spruce sulphite and aspen soda pulp.

The data given must, of course, be interpreted with the understanding that the figures and results are based on experimental pulping trials. We believe that it may be of interest if used with this reservation for comparing the character and yields of pulps that may be expected from different woods.

BLACK SPRUCE—Picea mariana. Wt. 23 lb Fiber 2.6 m. m.
Range—Newfoundland to Hudson Bay and northwestward to the Mackenzie river; southward in Michigan, Wisconsin, Minnesota, and in the eastern mountains to North Carolina and Tennessee.
Common Names—Black Spruce (N. H., Vt., Mass., R. I., N. Y., Pa., W. Va., N. C., S. C., Wis., Mich., Minn., Ont. Eng.); Double Spruce (Me., Vt., Minn.); Blue Spruce (Wis.); Spruce (Vt.); White Spruce (W. Va.); Yew Pine (W. Va.); Juniper (N. C.); Spruce Pine (W. Va., Pa.); He Balsam (Del., N. C.); Epinette Jaune (Quebec); Water Spruce (Canada, Me.).
Sulphite Pulp
Yield 1,050 lb. Easily bleached.
Easily pulped—excellent strength and color.
Possible Uses—Same as white spruce.
Sulphate Pulp
Yield 1,150 lb.
Character and Uses—Similar to White Spruce.

BLUE SPRUCE—Picea parryana. Wt. 23 lb. Fiber 2.8 m. m.
Range—Central Rocky Mountain region—Colorado, Utah and Wyoming.
Common Names—Parry's Spruce, (Utah); Blue Spruce, (Colo.); Spruce Balsam (Colo., Utah); White Spruce (Colo., Utah); Silver Spruce (Colo.); Colorado Blue Spruce (Colo.); Prickly Spruce (lit.).
Sulphite Pulp
Yield 1,050 lb. Easily bleached.
Easily pulped—excellent strength and color.
Possible Uses—Same as white spruce.
Sulphate Pulp
Yield 1,150 lb.
Character and Uses—Similar to white spruce.

ENGELMANN SPRUCE—Pica engelmanni. Wt. 21 lb. Fiber 2 m. m.
Range—Northern Arizona and through the Rocky Mountain region to British Columbia.
Common Names—Engelmann's Spruce (Utah); Balsam (Utah); White Spruce (Oreg., Colo., Utah, Idaho; White Pine (Idaho); Mountain Spruce (Mont.); Arizona Spruce (Cal. lit.).
Sulphite Pulp
Yield 990 lb. Easily bleached.
A little hard to pulp—excellent strength. Excellent color.
Possible Uses—Same as white spruce.
Sulphate Pulp
Yield 1,000 lb.
Character and Possible Uses—Similar to white spruce..
Mechanical Pulp
Yield 2,100 lb.
Character—Strong fiber of good color.
Possible Uses—Same as white spruce.

RED SPRUCE—Picea rubens. Wt. 24 lb. Fiber 3.7 m. m.
Range—Nova Scotia to North Carolina and Tennessee. Range imperfectly known.
Common Names—Red Spruce; Yellow Spruce (N. Y.); North American Red Spruce (foreign lit.).
Sulphite Pulp
Yield 1,080 lb. Easily bleached.
Easily pulped—good strength—excellent color.
Possible Uses—Same as white spruce.
Sulphate Pulp
Yield 1,150 lb.
Character—High-grade strong fiber.
Possible Uses—Same as white spruce.
Mechanical Pulp
Yield 2,400 lb.
Character—Excellent color and strength.
Possible Uses—Similar to white spruce.

SITKA SPRUCE—Picea sitchensis. Wt. 24 lb. Fiber 3.5 m. m.
Range—Coast region (extending inland about fifty miles) from Alaska to northern California (Mendocino County).
Common Names—Tideland Spruce (Cal., Ore., Wash.); *Menzies' Spruce; Western Spruce; Great Tideland Spruce* (Cal. lit.).
Sulphite Pulp
Yield 1,080 lb. Easily bleached.
Easily pulped——excellent strength and color.
Possible Uses—Same as white spruce.
Sulphate Pulp
Yield 1,150 lb.
Character and Uses—Similar to white spruce.
Mechanical Pulp
Yield 2,040 lb.

Character—Slightly grayish color.
Possible Uses—Similar to white spruce.

WHITE SPRUCE—Picea canadensis. Wt. 24 lb. Fiber 2 8 m m.
Range—Newfoundland to Hudson Bay and northwestward to Alaska; southward to Northern New York, Michigan, Wisconsin, Minnesota, South Dakota, Montana, and British Columbia.
Common Names—White Spruce (Vt., N. H., Mass., N. Y., Wis., Mich., Minn., Ont.); Single Spruce (Me., Vt., Minn.); Bog Spruce (New Eng.); Skunk Spruce (Wis., Me., New Eng., Ont.); Cat Spruce (Me., New Eng.); Spruce (Vt.); Pine (Hudson Bay); Double Spruce (Vt.).
Sulphite Pulp
Yield 1,030 lb. Easily bleached.
Easily pulped—excellent strength—excellent color.
Possible Uses—White spruce is considered the standard sulphite pulpwood and is used for news, wrapping, book, high-grade printings, etc.
Sulphate Pulp
Yield 1,150 lb.
Character—Very strong fine fiber.
Possible Uses—Highest grade of kraft paper and strong fiber board.
Mechanical Pulp
Yield 2,400 lb.
Character—Excellent color and strength.
Possible Uses—For practically every purpose where groundwood pulp is required.

ALPINE FIR—Abie lasiocarpa. Wt. 21 lb. Fiber ——.
Range—Rocky Mountain region from Colorado to Montana and Idaho, and westward through northern Oregon and northward to Alaska (latitude 60 degrees).
Common Names—Sub-Alpine Fir (Utah); Balsam (Colo., Utah, Idaho, Oreg.); White Fir (Idaho, Mont.); White Balsam; Oregon Balsam-tree (Cal.); Pumpkin-tree Alpine Fir; Mountain Balsam (mountains of Utah and Idaho); Downcone Fir (lit.); Downy-cone Sub-Alpine Fir (Cal. lit.).
Sulphite Pulp
Yield 1,010 lb. Easily bleached.
Easily pulped—good strength—excellent color.
Possible Uses—As a substitute for white spruce.
Sulphate Pulp
Yield 1,050 lb.
Character and long fiber. Excellent strength.
Possible Uses—Same as white spruce.
Mechanical Pulp
Yield 2,070 lb.
Character—White fiber, fair strength.
Possible Uses—Same as white spruce.

AMABALIS FIR—Abie amabalis. Wt. 22 lb. Fiber ——.
Range—From British Columbia (Fraser river and southward in the Cascade mountains) to Washington and Oregon.
Common Names—Red Fir; Red Silver Fir (Western Mountains); Fir (Cal.); Lorely Fir (Cal. lit.); Lorely Red Fir (Cal. lit.); Amabalis or Lovely Fir (Cal. lit.); "Larch" (Oreg. Lumbermen).
Sulphite Pulp
Yield 1,060 lb. Easily bleached.
Easily pulped—fair strength—excellent color..
Possible Uses—As a substitute for white spruce.
Sulphate Pulp
Yield 1,100 lb.
Character—Long fiber, excellent strength.
Possible Uses—Same as white spruce.
Mechanical Pulp
Yield 1.870 lb.
Character—Long fiber of excellent strength; color slightly grayish.
Possible Uses—Same as white spruce.

BALSAM FIR—Abie balsamea. Wt. 21 lb. Fiber 2.7 m. m.
Range—From Newfoundland and Labrador to Hudson Bay and northwestward to Great Bear Lake region, and south to Pennsylvania (and along high mountains to Virginia), Michigan and Minnesota.
Common Names—Balsam Fir (N. H., Vt., Mass., R. I., N. Y., Pa., W. Va., Wis., Mich., Minn., Nebr., Ohio, Ont.; Eng. cult.); Balsam (Vt., N. H., N. Y.); Canada Balsam (N. C.); Balm of Gilead (Del.); Balm of Gilead Fir (N. Y., Pa.); Blister Pine (W. Va.,); Fir Pine (W. V.); Firtree (Vt.); Single Spruce (N. Bruns. to Hudson Bay); Silver Pine (Hudson Bay) Sapin (Quebec); Cho-koh-tung= "Blisters" (N. Y. Indians)
Sulphite Pulp
Yield 970 lb. Easily bleached.
Easily pulped—good strength—excellent color.
Possible Uses—As a substitute for white spruce.
Sulphate Pulp
Yield 1,010 lb.
Character— High grade kraft fiber.
Possible Uses—Same as white spruce.

Mechanical Pulp
Yield 1,910 lb.
Character—Good fiber length, strong and good color.
Possible Uses—Same as white spruce

Grand Fir—Abies Grandis Wt. 23 lb Fiber 3.2 m. m.
Range—Coast region from Vancouver Island to California (Mendocino County), and from Washington and Oregon to Northern Idaho and Montana.
Common Names—White Fir (Cal., Oreg., Idaho); Silver Fir (Mont., Idaho); Yellow Fir (Mont., Idaho); Oregon White Fir (Cal.); Western White Fir; Grand or Oregon White Fir (Cal. lit.); Great California Fir (lit.).
Sulphite Pulp
Yield 890 lb. Easily bleached.
Easily pulped—fair strength—excellent color.
Possible Uses—As a substitute for white spruce.
Sulphate Pulp
Yield 1,140 lb.
Character—Good strong grade of kraft pulp.
Possible Uses—Same as white spruce.
Mechanical Pulp
Yield 1,950 lb.
Character—Good fiber, color and strength.
Possible Uses—Same as white spruce.

Noble Fir—Abies nobilis. Wt. 22 lb. Fiber ——.
Range—Washington (coast mountains in southwestern part of state; Olympic Mountains on Solduc river; from Mount Baker southward in the Cascade Mountains) to Oregon (Browder Ridge on headwaters of McKinzie river in Lane County). Range at present but little known.
Common Names—Red Fir (Oreg.); "Larch" (Oreg. lumbermen); Noble Fir (Oreg.); Big tree; Feather Red Fir (Cal. lit.); Noble or Brocted Red Fir (Cal. lit.); Tuck Tuck (Pacific Indians).
Sulphite Pulp
Yield 1,010 lb. Easily bleached.
Easily pulped—poor strength—excellent color.
Possible Uses—As a substitute for white spruce.
Sulphate Pulp
Yield 1,080 lb.
Character—Good quality of strong pulp.
Possible Uses—Same as white spruce.
Mechanical Pulp
Yield 1,920 lb.
Character—Very long strong fiber—good color.
Possible Uses—Same as white spruce.

Red Fir—Abies magnifica. Wt. 23 lb. Fiber ——.
Range—Southern Oregon (Cascade Mts.) and California (Mount Shasta and along the western slope of Sierra Nevada Mountains).
Common Names—Red Fir (Cal.); California Red-bark Fir (Cal.); Magnificent Fir (Cal. lit.); California Red Fir (Cal. lit.); Golden Fir (Cal. lit.).
Sulphite Pulp
Yield 1,080 lb. A little hard to bleach.
Easily pulped—good strength—fair color.
Possible Uses—As a substitute for white spruce.
Sulphate Pulp
Yield 1,150 lb.
Character—Good strong fiber.
Possible Uses—Same as white spruce.
Mechanical Pulp
Yield 1,915 lb.
Character—Pinkish color—fair strength.
Possible Uses—As a substitute for white spruce.

White Fir—Abies Concolor. Wt. 22 lb. Fiber 3.5 m. m.
Range—Oregon (Siskiyou Mountains) to Southern California (San Bernardino County); Northern Arizona and New Mexico to Colorado and Utah (Wasatch Mountains).
Common Names—White Fir (Cal., Idaho, Utah, Colo.); Balsam Fir (Cal., Idaho, Colo.); Silver Fir (Cal.); Balsam (Cal.); White Balsam (Utah); Bastard Pine (Utah); Balsam-tree (Idaho); Black Gum (Utah); California White Fir (Cal.); Colorado White Fir (Cal. lit.); Concolor Silver Fir (Eng. lit.).
Sulphite Pulp
Yield 950 lb. Easily bleached.
Easily pulped—good strength—good color.
Possible Uses—As a substitute for white spruce.
Sulphate Pulp
Yield 1,100 lb.
Character—Good strong grade of kraft pulp.
Possible Uses—Same as white spruce.
Mechanical Pulp
Yield 2,010 lb. Satisfactory color—fair strength—good fiber.
Possible Uses—As a substitute for white spruce.

Douglas Fir—Pseudotsuga taxifolia.
Washington and Oregon. Wt. 28 lb. Fiber and 4.4. m. m.
Montana and Wyoming—Wt. 25 lb. Fiber ——.

Range—From the Rocky Mountain region (in United States) and northward to central British Columbia; Pacific Coast.
Common Names—Red Fir (Oreg., Wash., Idaho, Utah, Mont., Colo.); Douglas Spruce (Cal., Colo.. Mont.); Douglas Fir (Utah, Oreg., Colo.); Yellow Fir (Oreg., Mont., Idaho, Wash.); Spruce (Mont.); Fir (Mont.); Oregon Pine (Cal, Wash., Oreg.); Red Pine (Utah, Idaho, Colo); Puget Sound Pine (Wash.); Douglas-tree; Cork-barked Douglas Spruce.
Sulphite Pulp
Yield 850 lb. Difficult to bleach. Hard to pulp. Fair strength—poor color.
Possible Uses—Few.
Sulphate Pulp
Yield 1,170 lb.
Character—Good grade of kraft pulp but not as strong as white spruce.
Possible Uses—Similar to white spruce.

HEMLOCK—Tsuga canadensis. Wt. 24 lb. Fiber 3.0 m. m.
Range—Nova Scotia to Minnesota (Carleton County), Wisconsin, Michigan, and southward in the Atlantic region along the mountains to Northern Alabama (Winston County) and Georgia.
Common Names—Hemlock (Me., N. H., Vt.. Mass., R. I., Conn., N. Y., N. J., Pa., Del., Va., N. C., S. C., Ky., Wis., Mich., Minn., Ohio, Ont.); Hemlock Spruce (Vt., R. I., N. Y., Pa., N. J., W. Va., N. C., S. C., England, cult.); Spruce (Pa., W. Va.); Spruce Pine (Pa., Del., Va., N. C., Ga.); Oh-neh-tah= "Greens on the stick" (N. Y. Indians); Canadian Hemlock (lit.); New England Hemlock (lit.).
Sulphite Pulp
Yield 1,080 lb. A little hard to bleach.
Not easily pulped. Good strength—fair color.
Possible Uses—As a substitute for white spruce.
Sulphate Pulp
Yield 2,030 lb.
Character—Good strong pulp.
Possible Uses—Similar to white spruce.
Mechanical Pulp
Yield 2,030 lb.
Character—Pinkish color—short fiber.
Possible Uses—As a substitute for white spruce.

WESTERN HEMLOCK—Tsuga heterophylla. Wt. 23 lb. Fiber 2.7 m. m.
Range—Alaska to Idaho and Montana and southward (in the Cascade and coast ranges) to California (Marin County).
Common Names—Hemlock Spruce (Cal.); Western Hemlock (Cal.); Hemlock (Oreg., Idaho, Wash.); Western Hemlock Spruce (lit.); California Hemlock Spruce; Western Hemlock Fir (Eng.); Prince Albert's Fir (Eng.); Alaska Pine (Northwestern lumbermen).
Sulphite Pulp
Yield 1,050 lb. Easily bleached.
Easily pulped—good strength—fair color.
Possible Uses—Same as white spruce.
Sulphate Pulp
Yield 1,100 lb.
Character—Good strong fiber.
Possible Uses—Similar to white spruce.
Mechanical Pulp
Yield 2,160 lb.
Character—Good strength and fiber—grayish color.
Possible Uses—Similar to white spruce.

TAMARACK—Larix laricina. Wt. 31 lb. Fiber 2.6 m. m.
Range—From New Foundland and Labrador to Northern Pennsylvania, Northern Indiana, Illinois, Central Minnesota, and northwestward to Hudson Bay (Cape Churchill, Great Bear Lake, and Mackenzie River) (in Arctic Circle).
Common Names—Larch (Vt., Mass., R. I., Conn., N. Y. N. J., Pa., Del., Wis., Minn. Ohio, Ont.); Tamarack. (Me., N H., Vt.. Mass., R. I., N. Y., N. J., Pa., Ind., Ill., Wis., Mich., Minn., Ohio, Ont.); Hackmatack (Me. H. H. Mass., R. I., Del., Ill., Minn., Ont.); American Larch (Vt., Wis. nurserymen); Juniper (Me., N. Bruns. to Hudson Bay); Black Larch (Minn.); Epinette Rouge (Quebec); Ka-neh-tens="The leaves fall" (Indians N. Y.); Red Larch, Mich.); Hacmack, (lit.).
Sulphite Pulp
Yield 1,270 lb. Difficult to bleach.
Difficult to pulp—good strength—poor color.
Possible Uses—Low grade wrappings.
Sulphate Pulp
Yield 1,400 lb.
Character—strong, tough pulp.
Possible Uses—Similar to white spruce.
Mechanical Pulp
Yield 2,620 lb.
Character—Short fibered and gray color.
Possible Uses—As a substitute for white spruce.

WESTERN LARCH—Larix occidentalis. Wt. 28 lb. Fiber 2.6 m. m.
Range—Southern British Columbia (south of latitude 53 degrees) and south in the Cascade Mountains to the Columbia River and to Western Montana; also

in Blue Mountains of Washington and Oregon.
Common Names—Tamarack (Oreg.); Hackmatack; Larch (Idaho, Wash., etc.); Red American Larch; Western Hamarack; Western Larch (Eng.); Great Western Larch (Cal. lit.).
Sulphite Pulp
Yield 1,200 lb. Difficult to bleach. Difficult to pulp—poor strength and color.
Possible Uses—Low grade wrappings.
Sulphate Pulp
Yield 1,290 lb.
Character—Good quality of kraft fiber.
Possible Uses—Same as white spruce.
Mechanical Pulp
Yield 2,100 lb.
Character—Brown color, short fiber and fair strength.
Possible Uses—Where a medium quality of ground-wood will answer the purpose.

Jack Pine—Pinus divaricata. Wt. 24 lb. Fiber 2.5 m. m.
Range—New Brunswick to New Hampshire and west through Great Lake and Hudson Bay (southern shores) region to Great Bear Lake, Mackenzie river, and Rocky Mountains; south into Northern Maine, Northern New York, Northern Indiana and Illinois, and Central Minnesota.
Common Names—Scrub Pine (Me., Vt., N. Y., Wis., Mich., Minn., Ont.); Gray Pine (Vt., Minn., Ont.); Jack Pine (Mich., Minn. Canada); Prince Pine (Ont.); Black Jack Pine (Wis); Black Pine (Minn.); Cypress (Quebec to Hudson Bay); Canada Horn-cone Pine (Cal. lit); Chek Pine; Sir Joseph Bank's Pine (Eng.); "Juniper" (Canada); Banksian Pine (lit.).
Sulphite Pulp
Yield 1,080 lb. Very difficult to bleach.
Not easily pulped—fair strength—poor color.
Pulp shivey and full of pitch.
Possible Uses—Mechanical difficulties when running this pulp over the paper machine prevent its use.
Sulphate Pulp
Yield 1,150 lb.
Character—Very strong, tough fiber.
Possible Uses—Similar to white spruce.
Mechanical Pulp
Yield 2,130 lb.
Character—Gray, somewhat soft, good strength, pitchy, poor finish.
Possible Uses—Medium grades of ground wood.

Loblolly Pine—Pinus Tæda. Wt. 30 lb. Fiber 3.0 m. m.
Range—South Atlantic and Gulf States from New Jersey (Cape May), Southern Delaware and West Virginia (Wood, Mineral, Hampshire, and Hardy counties) to Central Florida (Cape Malabar and Tampa Bay) and west to Eastern Texas (Colorado River; in Bastrop County); northward into Southeastern Indian Territory, Arkansas, and southern border of middle and West Tennessee.
Common Names—Loblolly Pine (Del., Va., N. C., S. C., Ga., Ala., Fla., Miss., La., Tex., Ark.); Oldfield Pine (Del., Va., N. C., S. C., G., Ala., Fla., Miss., La., Tex., Ark.); Torch Pine (Frog. lit.); Rosemary Pine (Va., N. C., in part); Slash Pine (Va., N. C, in part); Longschat Pine (Del.); Longshucks (Md., Va.); Black Slash Pine (S. C.); Frankincense Pine (lit.); Short-leaf Pine (Va., N. C., S. C., La.); Bull Pine (Texas and Gulf region); Virginia Pine; Sap Pine (Va., N. C.); Meadow Pine (Fla.); Cornstalk Pine (Va.); Black Pine (Va.); Foxtail Pine (Va., Md.); Indian Pine (Va., N. C.); Spruce Pine (Va., in part); Bastard Pine (Va., N. C.); Yellow Pine North Ala., N. C.); Swamp Pine (Va., N. C.); Longstraw Pine (Va., N. C., in part).
Sulphite Pulp
Yield 1,140 lb. Difficult to bleach.
Easily pulped—good strength and color.
Possible Uses—As a substitute for white spruce.
Sulphate Pulp
Yield 1,420 lb.
Character—Strong but coarse fiber.
Possible Uses—Similar to white spruce.
Mechanical Pulp
Yield 2,450 lb.
Character—Short fiber and very pitchy.
Possible Uses—Only when mixed with better grades of ground-wood fibers.

Lodgepole Pine—Pinus murrayana. Wt. 24 lb. Fiber 2.3 m. m.
Range—From Alaska (Yukon river) and southward through interior British Columbia; the mountains of Washington and Oregon to California (Sierra Nevada Mountains to San Jacinto Mountains); plateau east of the Rocky Mountains (latitude 56) and south through the Rocky Mountain region to New Mexico and Northern Arizona. Also Coast region from Alaska to California (Mendocino County).
Common Names—Tamarack (Wyo., Utah., Mont., Cal.); Prickly Pine (Utah); White Pine (Mont.); Black Pine (Wyo.); Lodgepole Pine (Wyo., Mont., Idaho); Spruce Pine (Colo., Idaho, Mont.); Tamarack Pine (Cal.); Murray Pine (Cal. lit.); Scrub Pine; Knotty Sand Pine (Oreg.); Bolander's Pine; Henderson's Pine; North Coast Scrub Pine (Cal. lit.).

Sulphite Pulp
Yield 1,080 lb. A little hard to bleach.
Easily pulped. Excellent strength and color.
Possible Uses—As a substitute for white spruce.
Sulphate Pulp
Yield 1,120 lb.
Character and Uses—Same as white spruce.
Mechanical Pulp
Yield 2,140 lb.
Character and Uses—A little pitchy but otherwise similar to white spruce.
Note—The Lodgepole pine which grows in the lowlands in the coastal region is very similar to jack pine. The Rocky Mountain region lodgepole pine, however, contains much less pitch and is to be preferred for sulphite and mechanical pulps.

LONGLEAF PINE—Pinus Palustris. Wt. 34 lb. Fiber 3.7 m.m.
Range—Coast region, from Southern Virginia (Norfolk) to Florida (Tampa Bay and Cape Canaveral) to Eastern Texas (Trinity River); northward in Alabama to the northeastern part of the State (Clay and Walker counties) and Northwestern (boarder counties) Georgia.
Common Names—Longleaved Pine (Va., N. C., S. C., Ga., Ala., Fla., Miss., La., Tex,); Southern Pine (N. C., Ala.. Miss., La.); Yellow Pine (Del., N. C., S. C., Ala., Fla., La., Tex.); Turpentine Pine (N. C.); Rosemary Pine (N. C.); Brown Pine (Tenn); Hard Pine (Ala, Miss., La.); Georgia Pine (general, Del.); Fat Pine (Southern States); Southern Yellow Pine (general); Southern Hard Pine (general); Southern Heart Pine (general); Southern Pitch Pine (general); Heart Pine (N. C. and South Atlantic region); Pitch Pine (Atlantic region); Longleaved Yellow Pine (Atlantic region); Longstraw Pine (Atlantic region); North Carolina Pitch Pine (Va., N. C.); Georgia Yellow Pine (Atlantic region); Georgia Heart Pine (general); Georgia Longleaved Pine (Atlantic region); Georgia Pitch Pine (Atlantic region); Florida Yellow Pine (Atlantic Region); Texas Longleaved Pine (Atlantic region).
Sulphite Pulp
Yield 1,840 lb. (crude pulp). Cannot be bleached.
Very poor color. In general, this wood cannot be considered satisfactory for sulphite pulp.
Possible Uses—Few.
Sulphate Pulp
Yield 1,600 lb.
Character—Strong but coarse fiber.
Possible Uses—Similar to white spruce.

NORWAY PINE—Pinus resinosa. Wt. 27 lb. Fiber 3.7 m. m.
Range—From Newfoundland and along the northern shores of St. Lawrence Gulf to Northern Ontario (north of Abitibi Lake) to Southern Manitoba (near southern end of Lake Winnipeg); southward through the Northern States to Massachusetts (Middlesex County), Pennsylvania (Chester County), Northeastern Ohio (north of Cleveland), Central Michigan (Saginaw), Northern Wisconsin (Oshkosh and Eau Claire) and Northeastern Minnesota.
Common Names—Red Pine (Vt., N. H., N. Y., Wis., Minn., Ont.); Norway Pine (Me., N. H., Vt., Mass., N. Y., Wis., Mich., Minn., Ont.); Hard Pine (Wis.); Canadian Red Pine (Eng.).
Sulphate Pulp
Yield 1,350 lb.
Character and Possible Uses—Similar to white spruce.

PITCH PINE—Pinus rigida. Wt. 29 lb. Fiber ——.
Range—From Southern New Brunswick (St. Johns river) to Eastern Ontario (north shore of Lake Ontario and lower Ottawa River) and southward in the Atlantic region to Southern Virginia (Norfolk) and along the mountains to Northern Georgia (Atlanta); west to Western New York (Ithaca); Northeastern Pennsylvania, Eastern Ohio (border counties south of Canton) and Kentucky, Eastern Tennessee (to Cumberland Mountains).
Common Names—Pitch Pine (Vt., N. H., Mass. R. I., Conn., N. Y., N. J., Pa., Del., W. Va., N. C., S. C., Ga., Ohio, Ont., Md., Eng.);Longleaved Pine (Del.); Longschat Pine (Del.); Black Norway Pine (N. Y.) Hard Pine (Mass.); Yellow Pine (Pa.); Black Pine (N. C.); Rigid Pine (Eng. lit.); Sap Pine (lit.).
Sulphate Pulp
Yield 1,430 lb.
Character and Uses—Similar to white spruce.

SAND PINE—Pinus clausa. Wt. 29 lb. Fiber ——.
Range—Coast of Alabama (Baldwin County) and Western Florida (to Pease Creek) east coast of Florida from St. Augustine to Halifax River.
Common Names—Sand Pine (Fla., Ala.); Oldfield Pine (Fla.); Florida Spruce Pine ((Ala.); Scrub Pine (Fla.); Spruce Pine (Fla.); Upland Spruce Pine (Fla.).
Sulphite Pulp
Yield 1,300 lb. Difficult to bleach, and shivey.
Easily pulped—fair strength—good color.
Possible Uses—As a substitute for white spruce.
Sulphate Pulp
Yield 1,220 lb.
Character and Uses—Similar to white spruce.

SCRUB PINE—Pinus virginiana. Wt. 26 lb. Fiber 2.8 m.m.
Range—From New York (Staten Island) to South Carolina (Aiken River) and

Northern Alabama (Winston, Cullman, and Dekalb counties); west into Southern Indiana, to middle Tennessee (Putnam County).

Common Names—Jersey Pine (N. J., Pa., Del., N. C., S. C.); Scrub Pine (R. I., N. Y., Pa., Del., N. C., S. C., Ohio); Short Shucks (Md., Va.); Shortshat Pine (Del.); Spruce Pine (N. J., N. C.); Shortleaved (N. C.); Cedar Pine (N. C.); River Pine (N. C.); Nigger Pine (Tenn.); New Jersey Pine (lit.).

Sulphite Pulp

Yield 1,000 lb.

Difficult to bleach, easily pulped and good color.

Possible Uses—As a substitute for white spruce.

Sulphate Pulp

Yield 1,250 lb.

Character—Strong but coarse fiber.

Possible Uses—Similar to white spruce.

SUGAR PINE—Pinus lambertiana. Wt. 23 lb. Fiber 4.1 m.m.

Range—Coast region from Oregon (head of Mackenzie and Rogue rivers) to California (Sierra Nevada Mountains and coast ranges to Santa Lucia Mountains; San Bernardino and Cuyamac Mountains).

Common Names—Sugar Pine (Cal., Oreg.); Big Pine; Shade Pine (Cal.); Great Sugar Pine; Little Sugar Pine; Gigantic Pine (Cal. lit.); Purple-coned Sugar Pine.

Sulphite Pulp

Yield 1,010 lb. A little difficult to bleach.

Easily pulped. Poor strength—fair color.

Possible Uses—Dark colored wrappings.

Sulphate Pulp

Yield 1,150 lb.

Character and Uses—Similar to white spruce.

WESTERN YELLOW PINE—Pinus ponderosa. Wt. 24 lb. Fiber 3.6 m.m.

Range—From British Columbia (interior south of latitude 51°), and Dakota (Black Hills region), southward in the Pacific and Rocky Mountain region to Western Texas and Mexico.

Common Names—Yellow Pine (Cal., Colo., Mont., Idaho, Utah, Wash., Oreg.); Bull Pine (Cal., Wash., Utah, Idaho, Oreg.); Big Pine (Mont.); Longleaved Pine (Utah, Nev.); Red Pine; Pitch Pine; Southern Yellow Pine; Heavy-wooded Pine (Eng.); Western Pitch Pine; Heavy Pine (Cal.); Foothills Yellow Pine; Sierra Brownbark Pine; Montana Black Pine (Cal. lit.); "Gambier Parry's Pine" (Eng. lit.).

Sulphite Pulp

Yield 1,130 lb. Difficult to bleach, shivey.

Not difficult to pulp. Very poor strength and color.

Possible Uses—Few.

Sulphate Pulp

Yield 1,100 lb.

Character—Fine, high grade, very strong, and tough fiber.

Possible Uses—Same as white spruce.

Mechanical Pulp

Yield 2,060 lb.

Character—Fibers are long, coarse and soft, creamy color and somewhat pitchy.

Possible Uses—Where a medium quality of ground wood will answer the purpose.

WHITE PINE—Pinus strobus. Wt. 22 lb. Fiber 3.8 m.m.

Range—From Newfoundland (White Bay region) and along the northern shores of St. Lawrence Gulf to Northern Ontario (near Abitibi and Nipigon lakes), Southern Manitoba (near southern end of Lake Winnipeg); southward through Northern and Eastern Minnesota, northeastern (Mitchell county) and eastern border of Iowa (to Scott County), Northern (counties) Illinois, southern shores of Lake Michigan, Southern Michigan (north of Allegan, Eaton, and St. Clair counties), Northeastern and Eastern (border counties) Ohio, and along the Allegheny Mountains to Northern Georgia, Tallulah Falls).

Common Names—White Pine (Me., N. H., Vt., Mass., R. I., Conn., N. Y., N. J., Pa., Del., Va., W. Va., N. C., Ga., Ind., Ill., Wis., Mich., Minn., Ohio, Ont., Nebr.); Weymouth Pine (Mass., S. C.); Soft Pine (Pa.); Northern Pine (S. C.); Spruce Pine (Tenn.).

Sulphite Pulp

Yield 1,210 lb. Difficult to bleach.

Difficult to pulp. Fair strength, but shivey and poor color.

Possible Uses—Few.

Sulphate Pulp

Yield 1,100 lb.

Character—Excellent strength and color.

Possible Uses—Similar to white spruce.

Mechanical Pulp

Character—Good strength and color, but pitchy.

Possible Uses—Similar to white spruce.

INCENSE CEDAR—Libocedrus decurrens. Wt. 23 lb. Fiber 2 m.m.

Range—From Oregon (North Fork of Sanitam River and southward on the Western slopes of the Cascade Mountains through California (Western slopes of Sierra Nevada Mountains and coast ranges from southern border of Mendocino

County to San Bernardino. San Jacinto, and Cuyamaca Mountains); Western Nevada; Lower California (Mount San Pedro Martir.)
Common Names—White Cedar (Cal., Oreg.); Cedar (Cal., Oreg.); Incense Cedar (Cal., Oreg.); Post Cedar (Cal., Nev.); Juniper (Nev.) Bastard Cedar (Cal., Wash.); Red Cedar; California Post Cedar (Cal. lit.).
Sulphite Pulp
Yield 830 lb. Difficult to bleach.
Good strength—poor color.
Possible Uses—Few.
Sulphate Pulp
Yield 950 lb.
Character—Dark colored, strong and hard fiber.
Possible Uses—As a substitute for white spruce.

BALD CYPRES—Taxodium distichum. Wt. 27 lb. Fiber 3.3 m.m.
Range—From Southern Delaware (Sussex County and southward in the coast region) to Florida (Mosquito Inlet and Cape Romano); westward in the Gulf coast region of Texas (Devils del' River); and northward through Louisiana, Arkansas, and Eastern Mississippi and Tennessee, Southeastern Missouri, Western and Northwestern Kentucky, Southern Illinois, and Southwestern Indiana (Knox County).
Common Names—Bald Cypress (Del., N. C., S. C., Ala., La., Fla., Tex., Ark., Mo., Ill., Ind.); White Cypress (N. C., S. C., Fla., Miss.); Black Cypress (N. C., S. C., Ala., Tex.); Red Cypress (Ga., Miss., La., Tex.); Swamp Cypress (La.); Cypress (Del., N. C., S. C., Fla. Miss., Ky., Mo., Ill.); Deciduous Cypress (Del., Ill., Tex.); Southern Cypress (Ala.);
Sulphite Pulp
Yield 1,160 lb. Very difficult to bleach.
Difficult to cook—poor strength and color.
Possible Uses—Few.
Sulphate Pulp
Yield 1,350 lb.
Character—Fiber long but tender.
Possible Uses—As a substitute for white spruce.

REDWOOD—Sequoia sempervirens. Wt. 23 lb. Fiber 5.5 m.m.
Range—From the southern borders of Oregon (on Chetco River (about six miles from mouth, and on Winchuck River) and southward in the coast region (twenty to thirty miles inland) through California (to Salmon Creek Canyon, twelve miles south of Punta Gorda, Monterey County).
Common Names—Sekuoia (Cal.); Coast Redwood (Cal.); Redwood (Cal. and Am. lit.); California Redwood (Eng. lit.).
Sulphite Pulp
Yield 920 lb. Difficult to bleach.
Easily pulped—fair strength—dark colored.
Possible Uses—Low grade wrappings.
Sulphate Pulp
Yield 950 lb.
Character—Long fibered but tender.
Possible Uses—As a substitute for white spruce.

WHITE ASH—Franxinus americana. Wt. 34 lb. Fiber 1.2 m.m.
Range—From Nova Scotia and Newfoundland to Florida and westward to Ontario and North Minnesota, Eastern Nebraska, Kansas, Indian Territory, and Texas (Trinity River).
Common Names—White Ash (Me., N. H., Vt., Mass., R. I., Conn., N. Y., N. J., Del., Pa., Va., W. V., N. C., S. C., Ga., Fla., Ala., Miss., La., Tex., Ky., Mo., Ill., Ind., Iowa, Kansas, Nebr., Mich., Ohio, Ont., Minn., N. Dak.. Wis.); Ash (Ark., Iowa, Wis., Ill., Mo., Minn.); American Ash (Iowa); Franc-Frene (Quebec); Cane Ash (Ala, Miss., La.).
Sulphite Pulp
Yield 1,530 lb. A little hard to bleach.
Easily pulped. Very weak. Poor color.
Possible Uses—Few.
Soda Pulp
Yield 1,350 lb.
Character—Very difficult to reduce and bleach.
Possible Uses—Few.

ASPEN—Populus tremuloides. Wt. 23 lb. Fiber 1 m.m.
Range—Southern Laborador to Hudson Bay (southern shores) and northwestward to the MacKenzie River (near mouth and Alaska (Yukon River); southward to Pennsylvania (mountains), Northeastern Missouri, Southern Nebraska, and throughout the western mountains to Northern New Mexico and Arizona and Central California; Lower California (San Pedro Matir Mountains) and Mexico (mountains to Chicuahua).
Common Names—Aspen (N. H., Mass., R. I., Conn., N. Y., N. J., Pa., Del., Ill., Ind., Wis., Mich., Minn., N. Dak., Nebr., Ohio, Ont., Oreg., Utah, Idaho, Nev., Mont., Colo., Cal.); Quaking Asp (N. Y., Pa., Del., Cal., N. Mex., Idaho, Colo., Ariz., Ill., Iowa., Minn., Mont., Nebr., Utah, Oreg., Nev.); Mountain Asp (Mont.); American Aspen (Vt.); Aspen Leaf (Pa.); White Poplar (Mass.); Trembling Poplar (Minn., Colo.); American Poplar (Minn., Colo.); Poplar (Vt., N. Y., Ill., Ind., Minn., Mont.); Popple (Wis., Iowa, Mont.); Tremble (Quebec); Trembling Aspen (Iowa); Aspen Poplar (Cal., Mont.).

Sulphite Pulp

Yield 1,30 lb. Easily bleached.

Easily pulped—very weak—excellent color.

Possible Uses—Used with longer fibered stock for better grade of papers.

Soda Pulp

Yield 1,080 lb.

Character—Soft and short fibered—easily bleached.

Possible Uses—When bleached and mixed with longer fibered bleached stock is well adapted for book, envelope, and high grade printings.

Mechanical Pulp

Yield 2,170 lb.

Character—Short fibered, poor strength, good color, but may have black specks present.

Possible Uses—As a filler when used with longer fibered stocks.

COTTONWOOD—Populus deltoides. Wt. 23 lb. Fiber 1.3 m.m.

Range—From Quebec (Lower Maurice River) and Vermont (Lake Champlain) through western New England and New York, Pennsylvania (west of Alleghenies), Maryland, and Atlantic States to Western Florida and west to the Rocky Mountains from Southern Alberta to Northern New Mexico.

Common Names—Cottonwood (N. H., Vt., Mass., R. I., N. Y., N. J., W. Va., N. C., Ala., Fla., Miss., La., Tex., Cal., Ky., Mo., Ill., Wis., Kans., Nebr., Iowa, Minn., Mich., Ohio, Ont., Colo., Mont., N. Dak.); Big Cotton wood (Miss., Neb.); Yellow Cottonwood (Ark., Iowa, Neb.); Cotton-tree (N. Y.); Carolina Poplar (Pa., Miss., La., N. Mex., Ind., Ohio); Necklace Poplar Texas, Colo.); Vermont Poplar (Vt.); Whitewood (Iowa); Broad-leaved Cottonwood (Colo.).

Sulphite Pulp

Yield 1,035 lb. Easily bleached.

Easily pulped—very weak. Excellent color.

Possible Uses—Same as aspen.

Soda Pulp

Yield 1,030 lb.

Character Soft and easily bleached.

Possible Uses—Same as aspen.

Mechanical Pulp

Yield 2,180 lb.

Character—short fibered, weak, good color.

Possible Uses—As a filler when used with longer fibered stocks.

BASSWOOD—Tilia americana. Wt. 21 lb. Fiber 1.1 m.m.

Range—New Brunswick to Virginia and (along Allegheny Mountains) to Georgia and Alabama (mountains); west (in Canada) to Lake Superior (eastern shores) and to Lake Winnipeg (southern shores) and Assiniboine River (in United States), to Eastern Dakota, Eastern Nebraska, Kansas, Oklahoma, and Eastern Texas.

Common Names—Basswood (Me., N. H., Vt., R. I., Mass., Conn., N. Y., N. J., Del., Pa., W. Va., D. C., N. C., S. C., Ga., Ala., Miss., La., Ark., Ky., Ill., Ind., Iowa, Wis., Mich., Ohio, Ont., Neb., Kan., Minn., N. Dak.); American Linden (Me., N. H., R. I., N. Y., Pa., Del., N. C., Miss., Ohio, Ill., Neb., N. Dak., Ont., Minn.); Linn (Pa., Va., W. Va., Ala., La., Ill., Ind., Ohio, Mo., Iowa, Kans., Nebr., Wis., S. Dak.); Linden (Vt., R. I., Pa., W. Va., Nebr., Minn.); Limetree (R. I., N. C., S. C., Ala., Miss., La., Ill.); Whitewood (Vt., W. Va., Ark., Minn., Ont.); Beetree (Vt., W. Va., Wis.); Black Limetree (Tenn.); Smooth-leaved Limetree (Tenn.); White Lind (W. Va.); Wickup (Mass.); Yellow Basswood (Ind.); Lein (Ind.).

Soda Pulp

Yield 1,020 lb.

Character Soft and easy bleaching.

Possible Uses Similar to aspen.

PAPER BIRCH Betula papyrifera. Wt. 34 lb. Fiber 1.2 m.m.

Range- From Labrador to Hudson Bay (southern shores), Great Bear Lake, Yukon River and coast of Alaska; southward to New York (Long Island) and Northern Pennsylvania, Central Michigan, and Minnesota, Northern Nebraska (Bluffs of Niobrara River), Dakota (Black Hills), Northern Montana, and Northwestern Washington (near Seattle).

Common Names- Paper Birch (N. H., Vt., Mass., R. I., Conn., N. Y., Wis., Mich., Minn., Ont.); Canoe Birch (Me., Vt., N. H., R. I., Mass., N. Y., Pa., Wis., Minn., Ont.); White Birch (Me., N. H., Vt., R. I., N. Y., N. J., Wis., Minn., Mich., Nebr., Ont.); Silver Birch (Minn., N. Y.); Large White Birch (Vt.); Boleau (Quebec).

Sulphite Pulp

Yield 1,500 lb. Difficult to bleach.

Easily pulped poor strength and color.

Possible Uses—Few.

Soda Pulp

Yield 1,350 lb.

Character—More difficult to reduce than aspen—soft, easily bleached.

Possible Uses Similar to aspen.

Mechanical Pulp

Yield 3,000 lb.

Character Pinkish color—short fiber and poor strength.

Possible Uses—As a filler with long fibered stocks.

YELLOW BIRCH—Betula lutea. Wt. 34 lb. Fiber 1.5 m.m.
Range—From Newfoundland and along the northern shores of St. Lawrence Gulf to Abitibi Lake and Rainy River; southward to Northern Minnesota and through the Northern States to Eastern Tennessee, North Carolina and Delaware.
Common Names—Yellow Birch (Me., N. H., Vt., Mass., Conn., R. I., N. Y., N. J., Pa., N. C., S. C., Ill., Mich., Wis., Minn., N. Dak., Ont.); Gray Birch (Vt., R. I., Pa., Mich., Minn.); Swamp Birch (Minn.); Silver Birch (N. H.); Merisier (Quebec); Merisier Rouge (Quebec).
Sulphite Pulp
Yield 1,590 lb. Easily bleached.
Easily pulped—very weak—good color.
Possible Uses—Same as aspen.
Soda Pulp
Yield 1,360 lb.
Character—More difficult to reduce than aspen—soft, easily bleached.
Possible Uses—Same as aspen.

CHESTNUT—Castanea dentata. Wt. 25 lbs. Fiber 1.0 m.m.
Range—From Southern Maine to Northwestern Vermont (Winooski River), Southern Ontario, and Southern shores of Lake Ontario to Southeastern Michigan; southward to Delaware and Southeastern Indiana, and on the Allegheny Mountains to Central Kentucky and Tennessee, Central Alabama, and Mississippi.
Common Names—Chestnut (Me., N. H., Vt., Mass., R. I., Conn., N. Y., N. J., Del., Md., Va., W. Va., N. C., Ga., Ala., Miss. Ky., Mo., Mich., Ont.); O-hea-yah-taf="Prickly Bur" (Indiana, N. Y.).
Sulphite Pulp
Not pulped.
Soda Pulp
Yield (on extracted chips) 950 lb.
Character—Soft, easy bleaching, and a little hard to cook.
Possible Uses—Similar to aspen. Unextracted wood can be pulped but is very difficult to reduce and bleach.

CUCUMBER-TREE—Magnolia acuminata. Wt. 27 lb. Fiber 1.3 m.m.
Range—From Western New York through Southern Ontario to Southern Illinois and south in the Appalachian Mountains to Southern Alabama (Stockton) and Northeastern Mississippi (Meridian); Central Kentucky and Tennessee (near Nashville and eastern part of State); Northeastern, Southern and Southwestern Arkansas.
Common Names—Cucumber-tree (R. I., Mass., N. Y., Pa., D. C. (cult.), N. C., S. C., Ala., Miss., La., Ark., Ky., W. Va., Ohio, Ind., Ill.); Mountain Magnola (Miss., Ky.); Cucumber (W. Va.); Black Lin (W. Va.); Magnolia (Ark.); Pointed-leaved Magnolia (lit.).
Soda Pulp
Yield 1,200 lb.
Character—A little harder to reduce and bleach than aspen.
Possible Uses—Same as aspen.

BLACK GUM—Nyssa sylvatica. Wt. 30 lb. Fiber 1.7 m.m.
Range—From Maine (Kennebec River) to Florida (Kissimmee River and Tampa Bay) and west to Southern Ontario. Southern Michigan (up to Gratiot County), Southeastern Missouri, and Texas (Brazos River).
Common Names—Black Gum (N. J., Pa., Del., Va., W. Va., N. C., S. C., Ga., Ala., Fla., Miss., La., Tex., Ill., Ind.); Sour Gum (Vt., Mass., R. I., N. Y., N. J., Pa., Del., Va., W. Va., S. C., Fla., Tex., Ohio, Ind., Ill.); Tupelo (Mass., R. I., N. J., Del., S. C., Ala., Fla., Miss., Tex., Ill., Ohio); Pepperidge (Vt., Mass., R. I., N. Y., N. J., S. C., Tenn., Mich., Ohio, Ont.); Wild Peartree (Tenn.); Yellow Gumtree (Tenn.); Gum (Md.) Stinkwood (W. Va.) Tupelo Gum (Fla.)
Soda Pulp
Yield 1,300 lb.
Character—Soft; a little harder to cook and bleach than aspen.
Possible Uses—Similar to aspen.
Mechanical Pulp
Yield 2,610 lb.
Character—Very short, but tough fiber, very white color.
Possible Uses—As a filler with longer fibered stocks.

COTTON GUM—Nyssa aquatica. Wt. 29 lb. Fiber 1.6 m.m.
Range—Coast region from Southern Virginia to Northern Florida, and through the Gulf States to Texas (Nueces River); northward through Arkansas, West Tennessee and Kentucky, Southern and Southeastern Missouri to Southern Illinois lower Wabash River).
Common Names—Large Tupelo (Ala., La., Tex.); Tupelo Gum (Ga., Ala., Miss., La.); Sour Gum (Ark., Mo.); Swamp Tupelo (S. C., La.); Cotton Gum (N. C., S. C., Fla.); Tupelo (N. C., S. C.); Wild Olivetree (La.); Olivier à grandes feuilles (La.) Olive tree (Miss.).
Sulphite Pulp
Yield 1,160 lb. Easily bleached.
Easily pulped. Poor strength—fair color.
Possible Uses—Same as aspen.
Soda Pulp
Yield 1,200 lb.
Character—Soft, but harder to bleach than aspen.
Possible Uses—Similar to aspen.

RED GUM—Liquidambar styraciflua. Wt. 27 lb. Fiber 1.6 m.m.
Range—From Connecticut (Fairfield County) to Southeastern Missouri and Arkansas; south to Florida (Cape Canaveral and Tampa Bay) and Texas (Trinity River).
Common Names—Sweet Gum (Mass., R. I., N. Y., N. J., Pa., Del., Va., W. Va., N. C., S. C., Ga., Ala., Fla., Miss., La., Tex., Ark., Ky., Mo., Ill., Ind., Ohio); Liquidamber (R. I., N. Y., Del., N. J., Pa., La., Tex., Ohio, Ill.); Red Gum (Va., Ala., Miss., Tex., La.); Gum (Va.); Gumtree (S. C., La.); Alligator-wood (N. J.); Bilsted (N. J.); Starleaved Gum; Satin Walnut (lumber markets).
Sulphite Pulp
Yield 1,190 lb. Difficult to bleach.
Easily pulped—very poor strength—dark colored.
Possible Uses—Few.
Soda Pulp
Yield 1,080 lb.
Character—A little more difficult to reduce than aspen.
Soft and hard to bleach.
Possible Uses—Same as aspen.

RED OAK—Quercus rubra. Wt. 35 lb. Fiber 1.5 m m.
Range—Nova Scotia and Southern New Brunswick through Quebec and along the north shores of Lake Huron to near Lake Namekagon; south to Middle Tennessee and Virginia, and along the Appalachian Mountains to Northern Georgia; west to Eastern Nebraska, Central Kansas.
Common Names—Red Oak (Me., Vt., N. H., Mass., R. I., N. Y., N. J., Pa., Del., Va., W. Va., N. C., S. C., Ga., Ark., Mo., Ky., Ill., Ind., Iowa, Nebr., Kans., Mich., Minn., S. Dak., Ont.); Black Oak (Vt., Conn., N. Y., Wis., Iowa, Nebr., S. Dak., Ont.); Spanish Oak (Pa., N. C.).
Sulphite Pulp
Yield 1,600 lb. Easily bleached.
Easily pulped. Very weak—poor color.
Possible Uses—Few.
Soda Pulp
Yield 1,400 lb.
Character—Very difficult to pulp and bleach.
Possible Uses—Few.

WHITE OAK—Quercus alba. Wt. 37 lb. Fiber 1.5 m.m.
Range—From Southern Maine to Southwestern Quebec and through Central and Southern Ontario, lower peninsula of Michigan and Southern Minnesota to Southeastern Nebraska and Eastern Kansas; south to Northern Florida and Texas Brazos river).
Common Names—White Oak (Me., N. H., Vt., Mass., R. I., Conn., N. Y., N. J., Pa., Del., Va., W. Va., N. C., S. C., Ala., Fla., Ga., Miss., La., Tex., Ky., Mo., Ohio, Ill, Ind., Kans., Nebr., Mich., Wis., Minn., S. Dak. (cult.), Iowa, (Ont.); Stave Oak (Ark.).
Soda Pulp
Yield 1,480 lb.
Character—Difficult to pulp and bleach.
Possible Uses—Few.

SYCAMORE—Plaxtanus occidentals. Wt. 29 lb. Fiber 1.7 m.m.
Range—Southeastern New Hampshire and southern Maine to northern Vermont and Lake Ontario (Don River, near north shores of the lake); west to eastern Nebraska and Kansas, and south to northern Florida, central Alabama and Mississippi, and Texas (Brazos river and thence south to Devils river).
Common Names—Sycamore (Vt., N. H., Mass., Conn., R. I., N. Y., N. J., Pa., Del., Va., W. Va., N. C., S. C., Ga., Fla., Ala., Miss., La., Tex., Ky., Ark., Mo., Ill., Ind., Iowa, Kansas, Nebr., Mich., Wis., Ohio, Ont.); Buttonwood (Vt., N. H., R. I., Mass., N. Y., N. J., Pa., Del., S. C., Ala., Miss., La., Tex., Ark., Mo., Ill., Nebr., Mich., Minn., Ohio, Ont.); Button balltree (Mass., R. I., Conn. N. Y., N. J., Pa., Del., Miss., La., Mo., Ill., Iowa, Mich., Nebr., Ohio); Buttonball (R. I., N. Y., Pa., Fla.); Planetree (R. I., Del., S. C., Kans., Nebr., Iowa); Water Beech (Del.); Platane (La.); Cotonier (La.); Bois puant (La.) Oo-da-te-cha-wun-nes="Big stockings" (Indians, N. Y.).
Soda Pulp
Yield 1,300 lb.
Character—Soft, easily bleached.
Possible Uses—Similar to aspen.

BLACK WILLOW—Salix nigra. Wt. 21 lb. Fiber 0.8 m.m.
Range—New Brunswick to southern Florida and west to eastern Dakota, Nebraska, Kansas, Oklahoma, southern Arizona, and south into Mexico. In California Sacramento River to Arizona.
Common Names—Black Willow (N. H., Vt., R. I., N. Y., Pa., Del., S. C., Fla., Ala., Miss., La., Tex., Ariz. Cal., N. Mex., Utah, Ill., Wis., Mich., Minn., Nebr., Kan., Ohio, Ont., N. Dak.); Swamp Willow (N. C., S. C.); Willow (N. Y., Pa., N. C., S. C., Miss., Tex., Cal., Ky., Mo., Nebr.).
Sulphite Pulp
Yield 1,150 lb. Easily bleached.
Easily pulped. Very weak—excellent color.
Possible Uses—Same as aspen.

Soda Pulp
Yield 950 lb.
Character—Soft and easily bleached.
Possible Uses—Similar to aspen.

BEECH—Fagus atropunicea. Wt. 36 lb. Fiber ——.
Range—Nova Scotia to Lake Huron (north shores) and northern Wisconsin; south to western Florida and west to southeastern Missouri and Texas (Trinity River).
Common Names—Beech (Me., N. H., Vt., Mass., R. I., Conn., N. Y., N. J., Pa., Del., Va., W. Va., N. C., S. C., Ga., Ala., Fla., Miss., La., Tex., Ark., Ky., Mo., Ohio, Ill., Ind., Mich., Nebr., Minn., Ont.); Red Beech (Me., Vt., Ky., Ohio); White Beech (Me., Ohio, Mich.); Ridge Beech (Ark.).
Soda Pulp
Yield 1,530 lb.
Character—Slightly more difficult to reduce than aspen—soft, easily bleached.
Possible Uses—Same as aspen.

AVERAGE WEIGHTS OF SPECIES OF WOOD

In making the weight determinations given in the following table, the U. S. Forest Products Laboratory used small, clear specimens secured from the top 4 feet of the 16-foot butt logs of typical trees. Wood thus selected probably averages a trifle heavier than the wood in ordinary ties, structural timbers, poles and posts. Such large pieces usually include the pith, or are taken from top logs, where relatively light weight material is frequently encountered.

Species and Locality		Weights		
		Kiln-dry (1)	Air-dry (2)	Green (3)
DECIDUOUS				
		Pounds per cubic foot		
Alder, red	Snohomish Co., Wash.	27	28	46
Ash, Biltmore	Overton Co., Tenn.	38	39	45
" black	Ostonagon Co., Mich.	34	36	53
" "	Marathon Co., Wis.	34	35	52
" blue	Bourbon Co., Ky	39	41	46
" green	Richland Parish, La.	38	39	47
" "	New Madrid Co., Mo.	40	42	49
" Oregon	Lane Co., Oregon	37	39	46
" pumpkin	New Madrid Co., Mo.	36	37	46
" white	Stone Co., Ark.	41	42	47
" "	Oswego Co., N. Y	41	44	51
" "	Pocohontas Co., W. Va.	37	38	46
Aspen	Rusk Co., Wis.	26	27	47
" Largetooth	Sauk Co., Wis.	26	27	43
Basswood	Potter Co., Pa.	26	27	41
"	Marathon Co., Wis.	24	25	41
Beech	Hendricks Co., Ind.	43	45	56
"	Potter Co., Pa.	41	43	54

Note—(1) About 8 per cent moisture.
(2) About 12 or 15 per cent moisture. Average condition reached without artificial heating by material sheltered from precipitation. North Central States.
(3) Average green material.

Species and Locality		Weights		
		Kiln-dry	Air-dry	Green
Deciduous		Pounds per cubic foot		
Birch, paper	Rusk Co., Wis.	37	38	51
" sweet	Potter Co., Pa.	45	47	59
" yellow	Potter Co., Pa.	43	45	56
" "	Marathon Co., Wis.	43	44	59
Buckeye, yellow	Sevier Co., Tenn.	24	25	49
Buckthorn, cascara	Lane Co., Oregon	35	36	50
Butternut	Sauk Co., Wis.	25	26	45
"	Sevier Co., Tenn.	27	28	47
Cherry, black	Potter Co., Pa.	34	36	46
" wild red	Sevier Co., Tenn.	27	28	33
Chestnut	Baltimore Co., Md.	29	30	53
"	Sevier Co., Tenn.	29	30	56
Chinquapin, western	Lane Co., Oregon	31	32	61
Cottonwood	Pemiscot Co., Mo.	28	29	49
" black	Snohomish Co., Wash.	23	24	46
Cucumber tree	Sevier Co., Tenn.	33	34	50
Dogwood (flowering)	Sevier Co., Tenn.	52	34	65
" western	Lane Co., Oregon	45	47	55
Elder, pale	Douglas Co., Oregon	36	37	65
Elm, cork	Marathon Co., Wis.	43	44	53
" "	Rusk Co., Wis.	43	45	53
" slippery	Hendricks Co., Ind.	42	43	53
" "	Sauk Co., Wis.	36	37	56
" white	Potter Co., Pa.	33	35	53
" "	Marathon Co., Wis.	32	33	45
Greenheart	S. A.	60	62	72
Gum, black	Sevier Co., Tenn.	35	36	45
" blue	Alameda Co., Cal.	52	54	70
" red	New Madrid Co., Mo.	..	35	46
" "	Pemiscot Co., Mo.	34	36	54
Blackberry	Hendricks Co., Ind.	38	39	47
"	Sauk Co., Wis.	36	38	51
Haw, pear	Sauk Co., Wis.	47	49	63
Hickory, big shellbark	Sardis, Miss.	47	49	62
" " "	Napoleon, Ohio	55	57	65
" bitternut	Napoleon, Ohio	47	49	64
" mockernut	Sardis, Miss.	47	49	62
" "	Chester Co., Pa.	53	55	65
" "	Webster Co., W. Va.	..	..	62
" nutmeg	Sardis, Miss.	42	43	61
" pignut	Sardis, Miss.	48	50	62
" "	Napoleon, Ohio	51	53	64
" "	Chester Co., Pa.	52	54	65
" "	Webster Co., W. Va.	55	57	63
" shagbark	Sardis, Miss.	47	49	63
" "	Napoleon, Ohio	51	54	64
" "	Chester Co., Pa.	45	47	63
" "	Webster Co., W. Va.	50	52	65
" water	Sardis, Miss.	44	46	69
Holly, American	Sevier Co., Tenn.	39	40	57
Hornbean	Rusk Co., Wis.	35	36	60
Laurel, California	Douglas Co., Oregon	38	39	54
" mountain	Sevier Co., Tenn.	47	49	62
Locust, black	Sevier Co., Tenn.	48	49	58
" honey	Hendricks Co., Ind.	49	51	65
" "	Pemiscot Co., Mo.	42	44	60

Species and Locality		Weights		
		Kiln-dry	Air-dry	Green
Deciduous		Pounds per cubic foot		
Madrona	Butte Co., Cal	42	43	66
"	Douglas Co., Oregon	46	48	59
Maple, Oregon	Snohomish Co., Wash	32	34	47
" red	Marathon Co., Wis	37	38	54
" "	Potter Co., Pa	34	36	49
" silver	Sauk Co., Wis	32	34	46
" sugar	Hendricks Co., Ind	41	43	54
" "	Potter Co., Pa	42	44	58
" "	Marathon Co., Wis	42	44	56
Magnolia (evergreen)	Winn Parish, La	34	35	62
Oak, bar	Sauk Co., Wis	43	45	61
" California black	Butte Co., Cal	37	38	64
" " "	Douglas Co., Oregon	39	40	68
" canyon live	Butte Co., Cal	54	56	71
" chestnut	Sevier Co., Tenn	45	46	62
" cow	Winn Parish, La	48	50	65
" laurel	Winn Parish, La	45	47	65
" Pacific post	Douglas Co., Oregon	48	50	69
" post	Stone Co., Ark	46	47	60
" "	Winn Parish, La	47	49	66
" red	Stone Co., Ark	43	45	66
" "	Hendricks Co., Ind	42	44	64
" "	Richland Parish, La	48	50	67
" "	Sevier Co., Tenn	41	42	61
" Spanish (lowland)	Winn Parish, La	47	49	67
" " (highland)	Winn Parish, La	40	42	62
" swamp white	Hendricks Co., Ind	50	52	69
Oak, tanbark	Willits, Cal	43	44	66
Oak, water	Winn Parish, La	43	45	63
" white	Stone Co., Ark	44	46	59
" "	Hendricks Co., Ind	46	47	61
" "	Richland Parish, La	46	48	57
" "	Winn Parish, La	46	47	63
" willow	Winn Parish, La	43	46	67
" yellow	Stone Co., Ark	43	43	63
" "	Marathon Co., Wis	40	42	62
Osage orange	Morgan Co., Ind	54	56	62
Pecan (hickory)	Pemiscot Co., Mo	45	47	61
Persimmon	Pemiscot Co., Mo	51	53	63
Rhododendron, great	Sevier Co., Tenn	39	40	62
Sassafras	Sevier Co., Tenn	31	32	44
Serviceberry	Sevier Co., Tenn	52	54	61
Silverbell tree	Sevier Co., Tenn	31	32	44
Sourwood	Sevier Co., Tenn	39	40	53
Sugarberry	Pemiscot Co., Mo	35	36	46
Sumach, staghorn	Sauk Co., Wis	32	34	61
Sycamore	Hendricks Co., Ind	34	35	61
"	Sevier Co., Tenn	35	36	53
Tulip tree	Sevier Co., Tenn	27	28	59
Tupelo	St. John the Baptist Parish, La	35	37	66
Umbrella, Fraser	Sevier Co., Tenn	30	31	47
Walnut, black	Kentucky	37	39	52
Willow, western black	Douglas Co., Oregon	30	31	51
" black	Sauk Co., Wis	25	26	51
" "	Pemiscot Co., Mo	26	27	47
Witch hazel	Sevier Co., Tenn	45	46	59

Species and Locality		Weights		
		Kiln-dry	Air-dry	Green
CONIFERS		Pounds per cubic foot		
Cedar, incense	Lane Co., Oregon	23	24	49
" "	Weed, Cal	..	..	41
" Port Orford	Douglas Co., Oregon	30	31	39
" western red	Missoula Co., Mont	21	22	24
" " "	Snohomish Co., Wash	23	24	30
" white	Shawano Co., Wis	21	21	28
Cypress, bald	Pemiscot Co., Mo	28	29	47
" "	St. John the Baptist Parish, La	33	34	51
" yellow	Lane Co., Oregon	28	29	53
Douglas fir	Plumas Co., Cal	30	31	40
" "	Humboldt Co., Cal	32	33	40
" "	Johnson Co., Wyo	31	32	34
" "	Lane Co., Oregon	35	36	39
" "	Chehalis Co., Wash	31	32	36
" "	Lewis Co., Wash	35	37	41
" "	Washington and Oregon	..	..	37
" "	Missoula Co., Mont	28	29	33
Fir amabilis	Deer, Ore	..	..	53
" "	Snohomish Co., Wash	26	27	36
" Alpine	Grand Co., Colo	22	23	28
" balsam	Rusk Co., Wis	24	25	45
" grand	Missoula Co., Mont	28	29	37
" "	Douglas Co., Oregon	26	27	52
" noble	Multnomah Co., Oregon	27	28	31
" white	Madera Co., Cal	25	26	56
Hemlock,	Sevier Co., Tenn	31	32	46
"	Marathon Co., Wis	24	25	49
" black	Missoula Co., Mont	30	32	45
" western	Chehalis Co., Wash	28	29	41
" "	Gray's Harbor & Buckley, Wash	30	31	40
Larch, western	Missoula Co., Mont	37	39	51
" "	Stevens Co., Wash	33	34	42
Pine, Cuban	Nassau Co., Fla	43	45	53
" jack	Barron Co., Wis	29	30	50
" Jeffrey	Plumas Co., Cal	27	28	47
" loblolly	Nassau Co., Fla	37	39	54
" lodgepole	Grand Co., Colo	27	28	33
" "	Gallatin Co., Mont	27	28	47
" "	Granite Co., Mont	29	30	41
" "	Jefferson Co., Mont	28	29	39
" "	Johnson Co., Wyo	27	28	37
" longleaf	Nassau Co., Fla	43	44	51
" "	Bogalusa, La	41	42	56
" "	Lake Charles, La	42	43	45
" "	Tangipahoa Parish, La	39	41	54
" "	Hattiesburg, Miss	38	40	42
" pitch	Sevier Co., Tenn	35	36	54
" pond	Nassau Co., Fla	38	40	49
" Norway	Shawano Co., Wis	32	34	42
" shortleaf	Malvern, Ark	35	36	45
" "	Bogalusa, La	38	39	56
" sugar	Madera Co., Cal	25	27	50

Species and Locality		Weights		
		Kiln-dry	Air-dry	Green
Conifers		Pounds per cubic foot		
Pine, Table-Mountain	Sevier Co., Tenn	36	37	54
" western white	Missoula Co., Mont	29	30	59
" " yellow	Coconino Co., Arizona	25	26	44
" " "	Madera Co., Cal	28	29	53
" " "	Douglas Co., Colo	28	29	49
" " "	Stevens Co., Wash	..	..	36
" " "	Missoula Co., Mont	27	28	51
" white	Shawano Co., Wis	26	27	39
Redwood	Humboldt Co., Cal	23	24	36
"	Mendocino Co., Cal	26	27	39
Spruce, Engelmann	San Miguel Co., Colo	22	23	48
"	Grand Co., Colo	24	25	30
" red	Coos Co., N. H	28	29	32
" "	Sevier Co., Tenn	27	28	35
" Sitka	Chehalis Co., Wash	25	26	33
" white	Coos Co., N. H	25	26	28
" "	Rusk Co., Wis	29	30	35
Tamarack	Shawano Co., Wis	37	38	47
Yew, western	Snohomish Co., Wash	43	45	54

TABLE FOR COMPARING DIFFERENT SYSTEMS OF ALKALIMETRY FOR CAUSTIC SODA

Caustic Soda is sold on its strength in Na_2O, as indicated in the New York and Liverpool Test column below.

The price is always based on 60% Caustic, with a proportionate addition for the higher percentages.

No. 1	No. 2	No. 3	No. 4
Caustic Soda Sodium Hydrate NaOH Per Cent	Actual Alkali Sodium Oxide Na_2O Per Cent	Newcastle Test Sodium Oxide Na_2O Per Cent	N. Y. & Liv. Sodium Oxide Na_2O Per Cent
74.83	58.0	58.76	59.87
75.48	58.5	59.27	60.38
76.12	59.0	59.77	60.90
76.77	59.5	60.28	61.42
77.40	60.0	60.79	61.93
78.05	60.5	61.30	62.45
78.70	61.0	61.80	62.97
79.35	61.5	62.31	63.48
80.00	62.0	62.82	64.00
80.65	62.5	63.32	64.52
81.29	63.0	63.83	65.03
81.94	63.5	64.33	65.55
82.58	64.0	64.84	66.06
83.23	64.5	65.35	66.58
83.87	65.0	65.85	67.10
84.52	65.5	66.36	67.61
85.16	66.0	66.87	68.13
85.81	66.5	67.37	68.65
86.45	67.0	67.88	69.16
87.10	67.5	68.39	69.68
87.74	68.0	68.89	70.19
88.39	68.5	69.40	70.71
89.03	69.0	69.91	71.23
89.67	69.5	70.41	71.74
90.30	70.0	70.92	72.26
90.95	70.5	71.43	72.77
91.60	71.0	71.93	73.29
92.25	71.5	72.44	73.81
92.90	72.0	72.95	74.32
93.55	72.5	73.45	74.84
94.19	73.0	73.96	75.35
94.84	73.5	74.47	75.87
95.48	74.0	74.97	76.39
96.13	74.5	75.48	76.90
96.77	75.0	75.99	77.42
97.32	75.5	76.49	77.94
98.06	76.0	77.00	78.45
98.71	76.5	77.51	78.97
99.35	77.0	78.01	79.49
100.00	77.5	78.52	80,00

TABLE FOR COMPARING DIFFERENT SYSTEMS OF ALKALIMETRY FOR SODA ASH

The following table gives the chemical and commercial equivalents for the different kinds of alkali. On the continent of Europe, alkali is sold by its strength in carbonate of soda (Na_2CO_3), as per column No. 1 of table. In England, alkali is sold nominally on its strength in actual alkali (Na_2O), as per column No. 2 of table, but actually on the so-called "Newcastle Test" of the actual alkali, as per column No. 3 of table. In the United States, the commercial standard for 75 years has been the New York and Liverpool Test for actual alkali, as per column No. 4 of table.

No. 1	No. 2	No. 3	No. 4
Soda Ash Sodium Carbonate Na_2CO_3 Per Cent	Actual Alkali Sodium Oxide Na_2O Per Cent	Newcastle Test Sodium Oxide Na_2O Per Cent	N. Y. & Liv. Sodium Oxide Na_2O Per Cent
79.51	46.5	47.11	48.00
80.37	47.0	47.62	48.51
81.22	47.5	48.12	49.03
82.07	48.0	48.63	49.54
82.93	48.5	49.14	50.06
83.78	49.0	49.64	50.58
84.64	49.5	50.15	51.09
85.48	50.0	50.66	51.61
86.34	50.5	51.16	52.12
87.19	51.0	51.67	52.64
88.05	51.5	52.18	53.16
88.90	52.0	52.68	53.67
89.76	52.5	53.19	54.19
90.61	53.0	53.70	54.70
91.47	53.5	54.20	55.22
92.32	54.0	54.71	55.74
93.18	54.5	55.22	56.25
94.03	55.0	55.72	56.77
94.89	55.5	56.23	57.29
95.74	56.0	56.74	57.80
96.60	56.5	57.24	58.32
97.45	57.0	57.25	58.83
98.31	57.5	58.26	59.35
99.16	58.0	58.76	59.87
100.00	58.5	59.27	60.38

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