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GUIDE TO THE BLEACHING OF PULP AND PAPER

Processes for the Bleaching of Vegetable Fibers in the Pulp and Paper Mill

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THE bleaching of vegetable fibers for papermaking has become in recent years not only an important but a widespread operation on the American Continent, and for obvious reasons. Pulpmakers especially are adopting bleaching methods in order to enhance the value of their product, thereby reaping an additional profit. It is therefore important that the different methods of bleaching fibers, whether these be derived from the acid or alkaline processes of manufacture, should be studied carefully to assure maximum economy not alone in the bleaching agent used, but, also, in all the factors involved in the operation as a whole. These factors so far as the bleaching operation itself is concerned are controlled largely by the character and purity of the fiber treated. Thus in the case of linen and cotton rag stock, the bleaching process is reduced to its simplest terms, in virtue of the comparative freedom of such stock from those foreign vegetable substances, which are acted upon and rendered soluble by the oxidizing or bleaching agent.

In the case of wood and other pulps such as straw, esparto, bamboo, bagasse, etc., the presence of foreign vegetable matter—other than cellulose—in somewhat larger quantity necessitates a more drastic treatment, resulting in a larger consumption of bleaching agent per unit of pulp treated and a greater proportionate loss of weight. In point of fact, these two factors—*viz.*: the consumption of bleaching agent and loss of weight—other conditions of the treatment being kept normal or nearly so—are a measure of the quality or purity of the pulp itself. This is understood by all practical pulpmakers and their constant aim is, or should be, so to adjust their manufacturing conditions that they can obtain a product which will conform to a minimum consumption of bleaching agent and minimum loss of weight.

The bleaching properties of a pulp depend upon the process by which it is prepared. As a general rule vegetable fibers prepared by the acid or sulphite process bleach more readily than those prepared by either of the alkaline methods, that is by either the "caustic soda" or "sulphate" methods . In all cases, no matter what process is in use, substances other than cellulose, as above stated, are left behind with the fiber, and it is these substances that are acted on by the bleaching agent and rendered soluble. It may be stated here that, of the three acid solutions—*viz.*: bisulphite of lime, magnesia and soda, it has been found in actual manufacturing practice, those of magnesia or soda yield a purer cellulose than that obtained with lime. And no doubt, this is due to the fact that the sulphur salts of magnesia and soda are much more soluble than those of lime.

The quality of the water used for washing the crude pulp has also 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 fiber, which absorb chlorine in proportion to their presence, and in order to avoid such precipitation calcareous water previously heated to boiling, or otherwise chemically treated for the removal of the lime and filtered, is frequently used. A similar precipitation of lime salts takes place when calcareous water is used for washing the pulp prepared by the alkaline process, the lime itself being precipitated either in the form of carbonate or sulphate by the alkali present, both of which cling to the fiber and carry down with them coloring organic matter, rendering 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, depend on many factors, the most important of which may be enumerated as follows:

1—The raw fibrous plant from which the pulp is prepared: Spruce, hemlock, balsam, pine and others, among the conifers; poplar, maple, birch, and others of the broadleafed trees; straw, esparto, bamboo, bagasse, etc., among the grasses and canes.

2—The process employed for manufacturing the cellulose or fiber, whether this be acid or alkaline, *i. e.*, soda or sulphite process.

3—The purity of the pulp obtained, controlled largely by the conditions under which the fiber is prepared, such as the amount, character and composition of the resolving chemicals used; the temperature employed;

and the time given to complete the process, together with 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 fiber.

5—The temperature at which the bleaching is carried out, chiefly with a view to accelerate 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 may be stated in general terms, first that it has been found in manufacturing practice, the greater the yield of fiber from unit weight of raw fibrous plant, no matter by what process this fiber has been made, the greater is the loss of weight of pulp operated upon, and the amount of bleaching agent required; and, second, that the dilution of the fiber 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 other in economy of bleach.

The oxidizing material universally employed in the pulp industry is chlorine in the form of bleaching powder (calcium hypochlorite) or an electrolyzed solution of common salt, for chlorine is unquestionably the cheapest bleaching agent known. Ozone has been applied, but failed to compete with chlorine on account of its cost; and although permanganates may in special cases be used to obtain a greater degree of whiteness than can be obtained with hypochlorites alone, yet, the use of a permanganate is scarcely admissible in the pulp and paper industry on account of the difficulty of removing the last traces of manganese from the fiber. Hydrogen peroxide is out of the question at the moment, owing to its cost.

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 fiber 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 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 papermills.

A still further advance was made when a series of

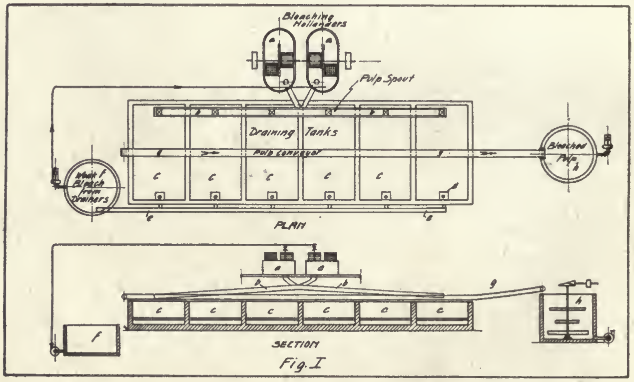

Fig. I

open concrete tanks were 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 fiber came up to the requisite degree of whiteness, 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 Fig. 1. The fiber 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° Fahr. 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 fiber 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

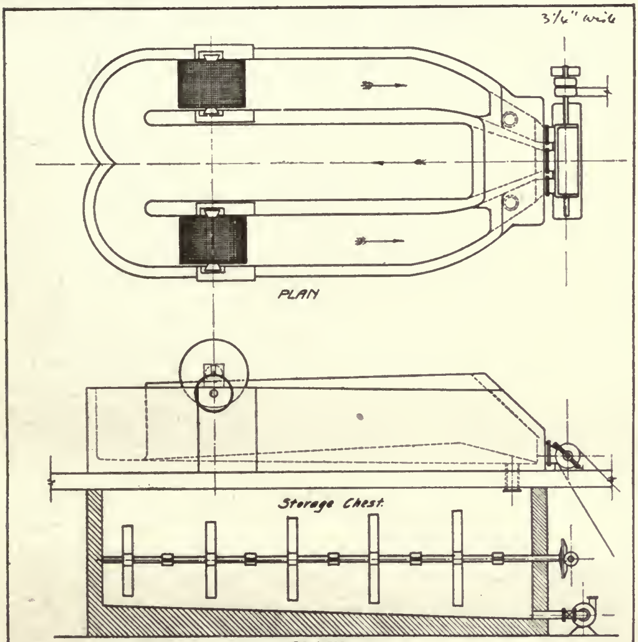

Fig. II.

to 3 percent density of stock is obtained from the pocher.

Bleaching apparatus were then designed fulfilling more perfectly the conditions for economy . The vessels or pochers were built of meunier work, or reinforced concrete, and the mixture of pulp, bleach liquor and water, kept in continued motion by means of an Archimedean screw or propeller, until the process of bleaching was practically completed. Such a system is illustrated in Fig. 2.

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 percent 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

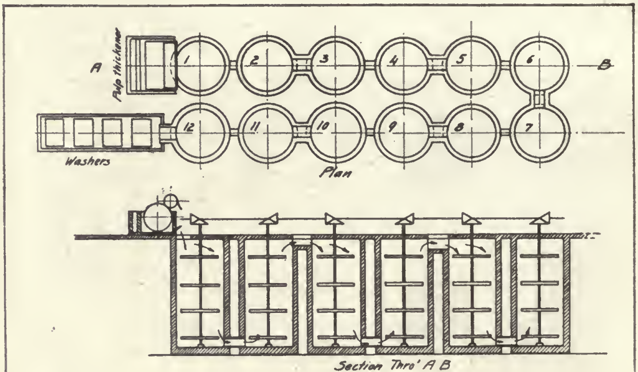

Fig III

into the chest beneath, from whence it is pumped to the washing and drying machines. The names of Kellner, Partington, Belmer, Hromadnik, and others are identified with bleaching engines and systems of this kind.

It has always been the aim of pulp manufacturers 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 the better of the two. The towers are usually concrete tanks, with or without conical bottoms, connected together by channels or passages as shown in Fig. 3, which illustrates the "continuous tank system" in use in many mills in America. 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, as shown in the section through *A B*. 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 percent stock can be handled, which in the opinion of many is too dilute to yield the most economical results in any continuous system.

Skjöld (*Svensk Pappers-Tidning,* 1905, No. 15, pp. 85-86) shows 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 to 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 50° Cent. (122° Fahr.) and bleaching powder solution of 3.5° Bé. 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° Fahr. The operations of this system are somewhat broken, and 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. 1277926), has overcome certain difficulties and has greatly simplified the continuous system. His apparatus is illustrated in Fig. 4, 5 and 6. All stock pipes, centrifugal pumps and agitators, are eliminated, the

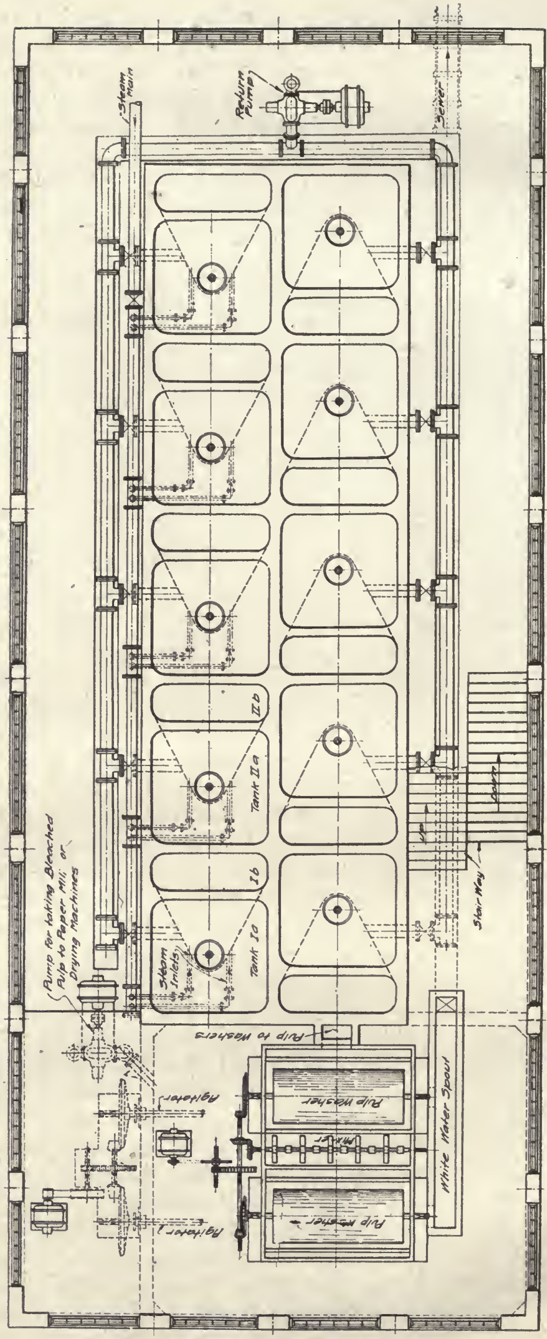

Fig. 4—Heiskanen's Method and Apparatus for Bleaching Pulp—Sectional Plan

inventor substituting for these propellers for mixing, agitating and circulating the stock through the whole system. These propellers are driven by small motors fixed on the upright shafts, or by overhead gearing, and as he attains a density of 6 to 8 percent 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 quantity 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 immediately below the propeller as shown in Fig. 5, 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 shown in Fig. 4 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 percent stock on an average; and that by so 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

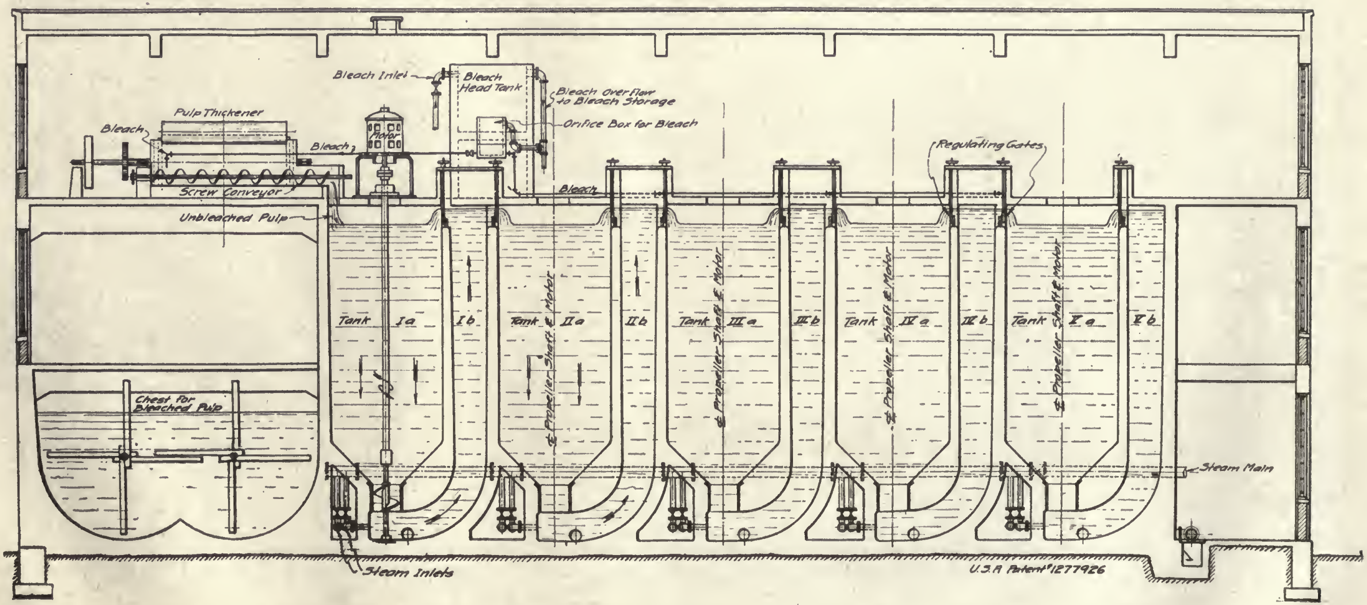

FIG. 5—Heiskanen's Method and Apparatus for Bleaching Pulp—Long Section Through First Line of Tanks

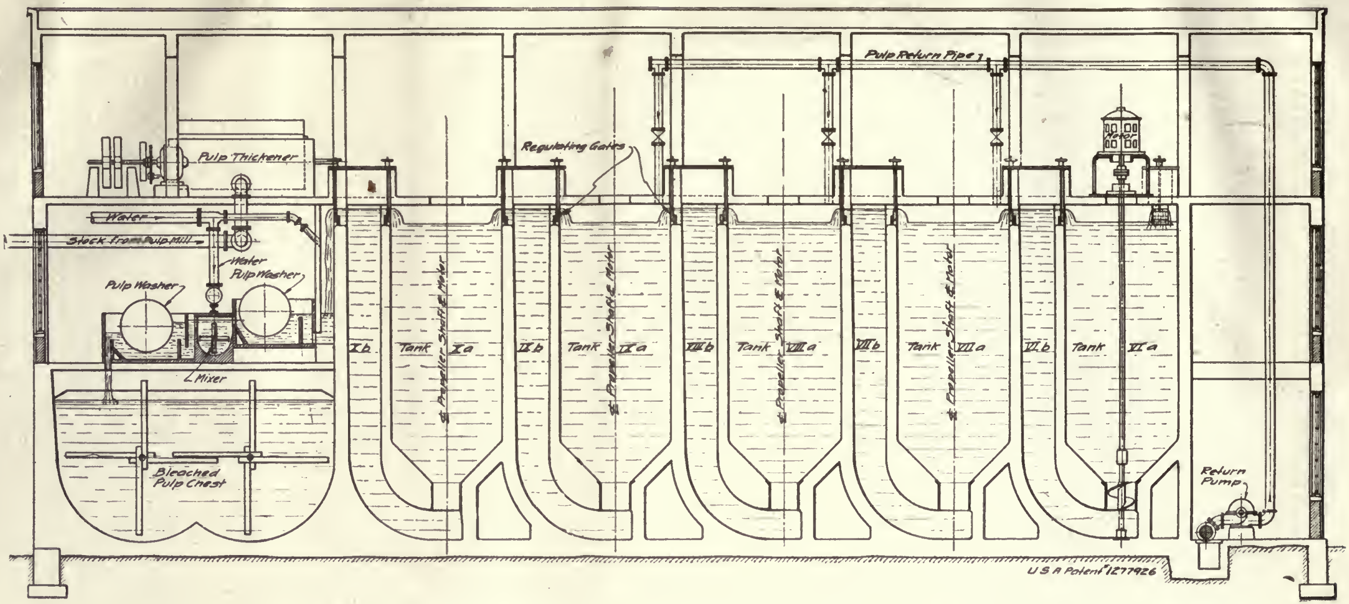

FIG. 6—Heiskanen's Method and Apparatus for Bleaching Pulp—Long Section Through Second Line of Tanks

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.

From the foregoing it is apparent that any economical system of bleaching must involve a high density of stock, primarily to economize steam for heating, and as this is a very important factor, I append my formula for calculating the amount required, which is applicable to every case for hot bleaching:

$$\frac{(W S + w' s' + w'' s'' + \ldots\ldots)\ (tf - ti)}{T - tf} = S$$

in which

S = ℔ of steam required.
W = Wt. of air-dry pulp in the charge, in ℔.
s = Sp. heat of air-dry pulp (0.65).
w′ = Wt. of water associated with the pulp, in ℔
s′ = Sp. heat of water (1.00).
w″ = Wt. of vessel in which pulp is bleached, in ℔.
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℔ 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° Fahr.; the final temperature tf, as 90, 100, 110 and 120° Fahr., and the total British thermal units in one pound of steam T as 1190, *i. e.*, steam at 110℔ pressure above atmosphere.

Density of Stock Pulp	Density of Stock Water	Water associated with 2000℔ air-dry pulp	Lbs. of steam required to heat the mixture containing 2000℔ air-dry pulp to 90° F.	100° F.	110° F.	120° F.
3%	97%	64666℔	1881	2421	3053	3699
4 "	96 "	48000 "	1427	1809	2282	2764
5 "	95 "	38000 "	1154	1442	1819	2203
6 "	94 "	31333 "	972	1197	1510	1830
7 "	93 "	26571 "	842	1023	1290	1562
8 "	92 "	23000 "	745	892	1125	1269

NOTE.—This table is based on the above formula but the weight of the apparatus w″ has been eliminated. Three percent should be added to the above quantities of steam in cols. 4, 5, 6 and 7 to allow for loss of heat by radiation.