

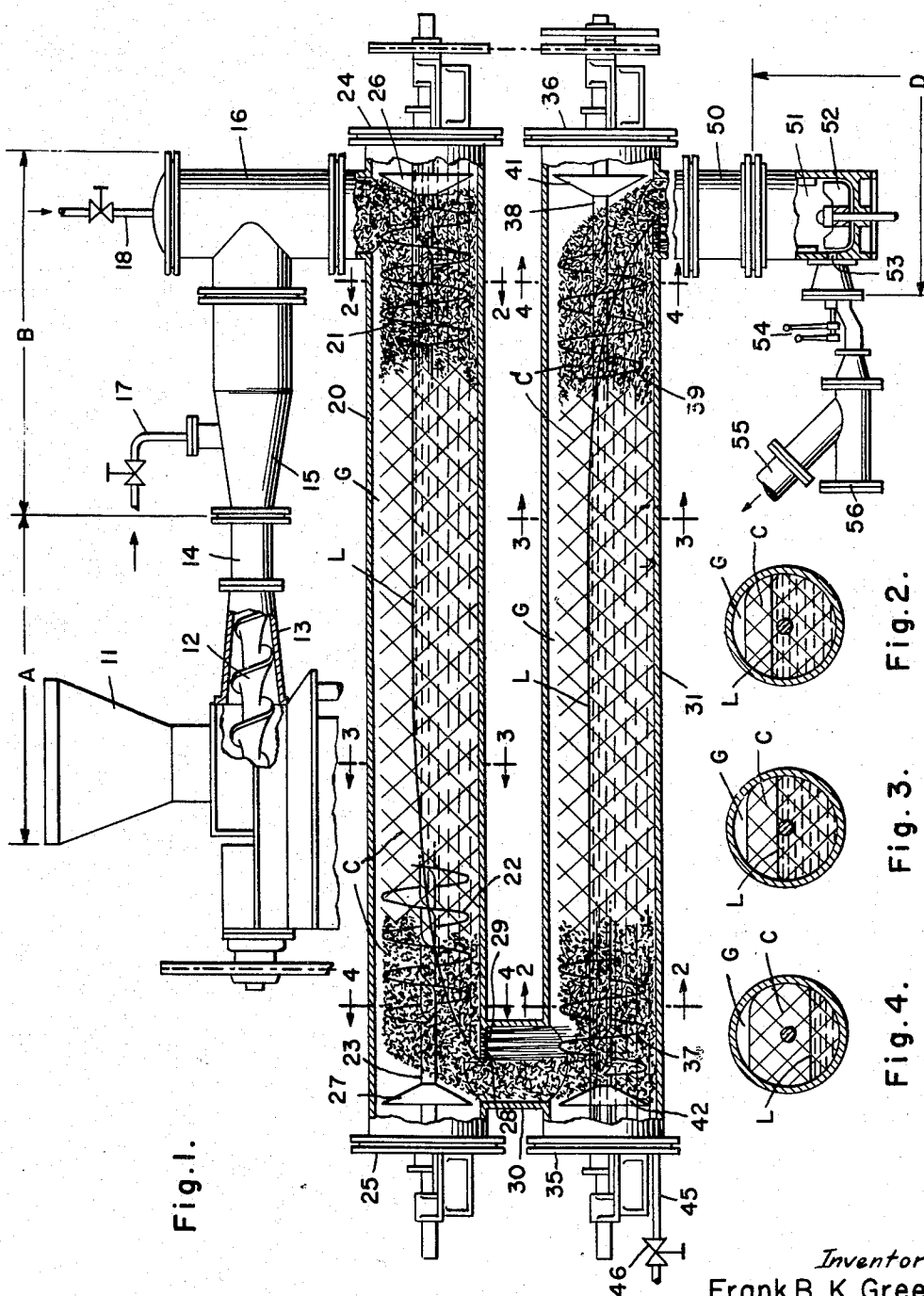
Dec. 6, 1960

F. B. K. GREEN
PAPER MACHINERY

2,963,086

Filed Sept. 22, 1955

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

Fig. 5.

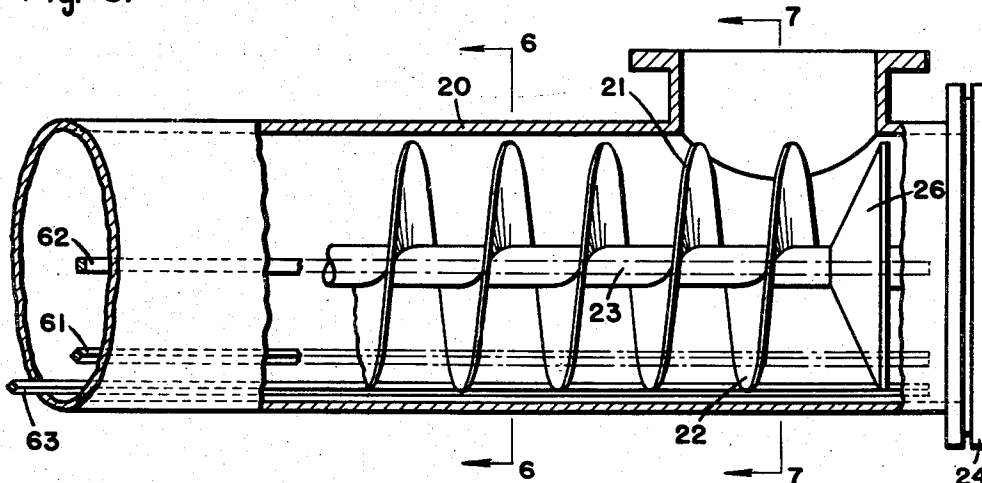


Fig. 6.

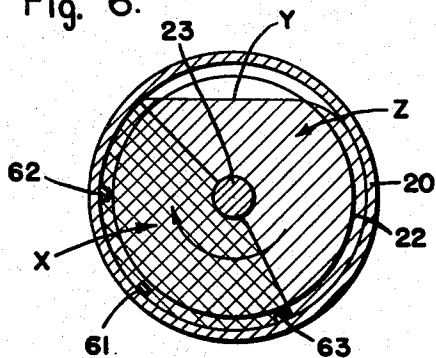


Fig. 9.

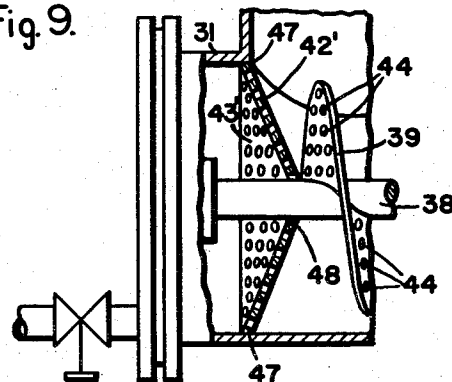


Fig. 7.

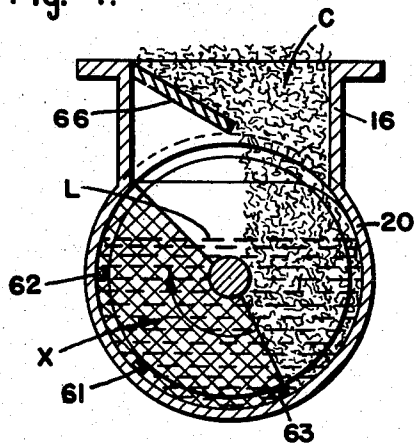
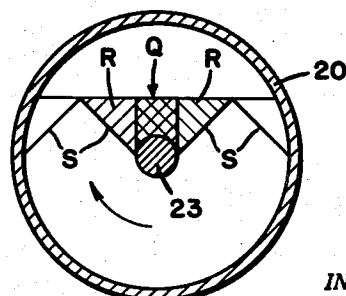


Fig. 8.



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Fig. 10

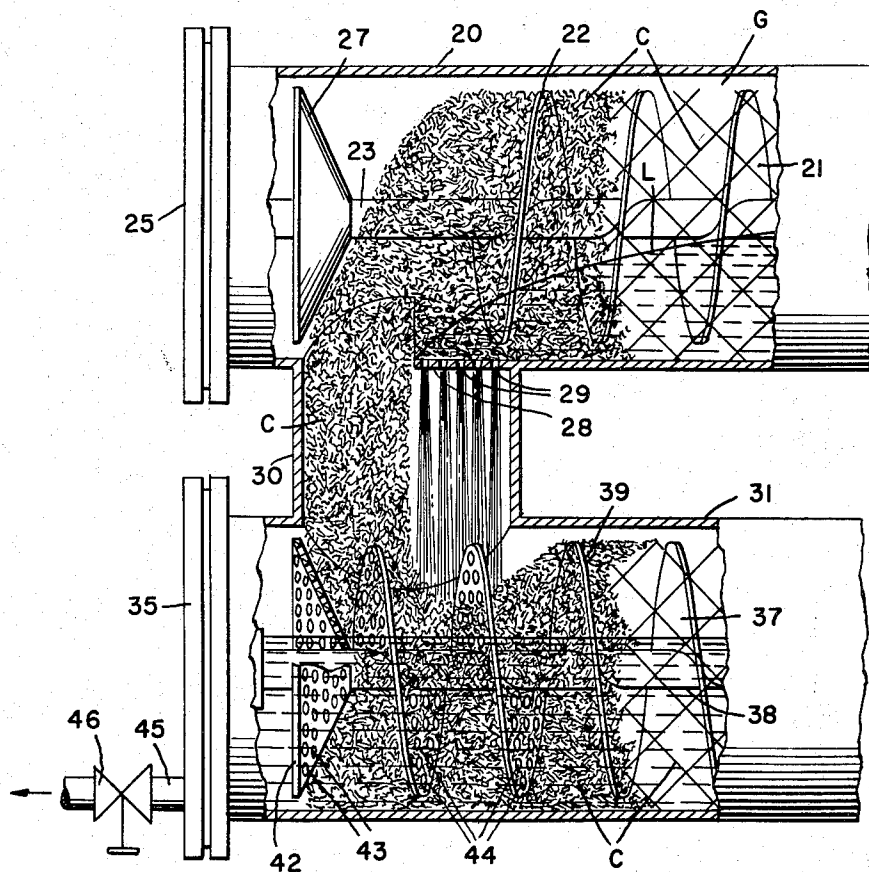
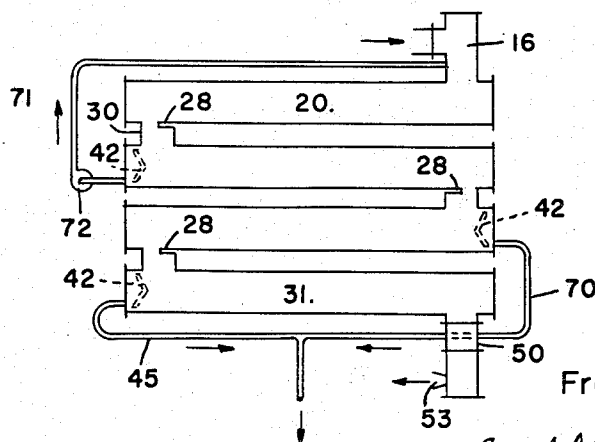


Fig. 11



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3 Claims. (Cl. 162—237)

This invention relates to the digestion of lignocellulosic fibrous material for rendering the ligneous and other fiber-encrusting contaminants amenable to removal so that cellulosic fibers can be obtained in a form that lends itself to making them into paper, paperboard, nine point and related products.

Such fibrous material as wood-chips, for instance, is digested or cooked in chemical liquor capable of rendering the ligneous constituents water-soluble. The cooking is done in digesters while under heat and pressure with the wood-chips submerged in the digestant liquor. The digesters are filled and emptied periodically on a batch basis. Efforts have been made to carry out such digestion on a continuous basis, and one process and apparatus that has proven successful is shown in the Beveridge and Kehoe Patent No. 2,422,522 issued June 17, 1947, and assigned to the assignee of this application. The inventions of that patent proposed that the wood-chips be forcibly fed to a heat-and-pressure conduit-like flowpath embodied in a plurality of superposed substantially horizontal tubes or pipes with a vertical connection therebetween. In each pipe was a screw conveyor for progressing the chips along the pipe in a controlled and uniform manner while in non-submergence but subject to digestive or cooking treatment in a gaseous environment from which the chips were discharged after being defibrated while hot and under pressure. In that digesting apparatus, and in its normal operation, the horizontal pipes were rarely filled with chips being treated to an elevation higher than the axis of the pipe, so it is a major object of this invention to devise ways and means whereby those pipes can be substantially filled with chips being treated, and thereby to increase the effective capacity of that apparatus.

However, certain kinds of pulp having a relatively high cellulosic content as compared with the residual ligneous content (called low-yield pulps) heretofore have been made usually in batch digesters where the chips are maintained constantly in submergence in the cooking liquor. In batch digesters penetration of the chips by the cooking liquor is retarded by the packed condition of the chips in their relatively fixed position while liquor is circulated over them, so another object of this invention is to move the chips repeatedly and continually with respect to each other as well as to the cooking liquor.

An additional object is to move the chips through a digester from submergence to emergence and return so that they are exposed during the digestion period to submergence in the cooking liquor and to emergence in the chemical-bearing gaseous atmosphere above the liquid-level of the liquor. And a corollary to this object is to be able to exercise control of the frequency and duration of the alternate submergence and emergence.

Still another object is to devise ways and means for carrying out the submergence and emergence of the chips while in a continuous digester embodying a succession of substantially horizontal material-supporting pipes or tubes

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while avoiding harmful cascading of the chips and without the use of liquor-damming devices as such.

A still further object is to render some of the ligneous fiber-encrusting contaminants water-soluble but not actually simultaneously dissolved by having the liquor act on the chips while non-submerged, that is, emerged. The cooking liquor's purpose is to react with these encrustations to render them water-soluble, but when the chips are cooking in submergence, as rapidly as the encrustants are rendered soluble, they are dissolved; so by the practice of this invention, some of the encrustants, while in emergence, are rendered soluble and thereafter they are dissolved when submerged, whereas others of the encrustants, while in submergence, are both rendered soluble and concurrently dissolved.

Reference is also made to Kehoe et al. Patent No. 2,616,802, issued November 2, 1952 to the assignee of this application, which discloses a method and applications whereby steam-softened chips are fragmentized while in a mobilized turbulent mass thereof in gaseous suspension followed by a final sizing of these fragments by projecting them threadingly through a size-controlling orifice. In order to do this, the steam-softened chips must not be in submergence, so it is another object of the present invention to devise ways and means for combining this type of fragmentizing and size-controlling discharge with digestion treatment of the chips by the alternate liquor submergence and emergence thereof that is one of the objects of this invention.

Additional objects and advantages will be apparent from the following description, the accompanying drawings and the appended claims.

In the drawings:

Fig. 1 is a view partly in side elevation and partly broken away in vertical section showing continuous digesting apparatus constructed in accordance with the invention;

Figs. 2, 3 and 4 are somewhat diagrammatic cross-sectional views taken on the lines 2—2, 3—3 and 4—4 respectively of Fig. 1;

Fig. 5 is an enlarged and somewhat diagrammatic fragment of Fig. 1;

Fig. 6 is a somewhat diagrammatic view taken generally as indicated by the line 6—6 of Fig. 5;

Fig. 7 is a view similar to Fig. 6 taken generally on the line 7—7 of Fig. 5;

Fig. 8 is a further diagrammatic view similar to Fig. 6;

Fig. 9 is a fragmentary section showing a modification of the construction in Fig. 1;

Fig. 10 is an enlarged and somewhat diagrammatic view showing the left-hand end of the apparatus of Fig. 1; and

Fig. 11 is a diagrammatic illustration of apparatus similar to that of Fig. 1 but incorporating additional digesting tubes.

In the embodiment of the invention shown in the drawings, and particularly Fig. 1, there is a feed hopper 11 to which chips, or other ligno-cellulosic material to be treated, are supplied. Chips are forced from the bottom of the hopper by a motivated feed-screw feeding means 12, through a feeding-in section A comprising a pipe 13 of progressively decreasing diameter connected to an intermediate pipe 14 of uniform diameter which in turn is connected to another pipe 15 of enlarging diameter leading to a T-piece 16. Steam is delivered to the feeding-in section as by valved pipe 17, and liquor is delivered to the feeding-in section as by the valved pipe 18, so that it is sprayed into the T-piece 16. In the drawings, the parts included in the A bracket comprise the feeding-in section while the parts included in the B bracket are often called collectively the pre-heater.

The vertical T-piece 16, down which chips have free-

fall, leads to a pipe or tube 20 which is sufficiently horizontal to be material-supporting; that is, chips remain in it by gravity. This tube has within it a driven screw conveyor 21 with usual screw flights 22 on a central shaft 23 supported from the closure ends 24 and 25 of the tube adjacent the closure end and carried by the shaft 23 is a conical deflector disk 26, coned toward the length of the tube 20, to keep the chips away from the bearing of the shaft 23, and a similar coned deflector disk 27, but oppositely directed, is carried by the shaft 23 adjacent the other closure end 25 of the pipe. At the end of the tube 20 opposite its inlet from the T-piece 16 is an outlet connection 30 sufficiently vertical so that chips have free-fall therethrough. Projecting into the mouth of the free-fall connection 30 is an open-ended shelf-like plate 28, having perforations 29 therein, which form a strainer means for a purpose hereinafter described.

The free-fall connection 30, while comprising the discharge outlet from the tube 20, also comprises the feed-inlet to a subjacent tube 31 which is in all respects similar to the tube 20, except that it can be oppositely directed as shown. It has one closure end 35, and an opposite closure end 36, in which are rotatably supported a screw conveyor 37 having a shaft 38 and screw flights 39. At the right-hand end of the tube 31 there is a deflector disk 41 like deflector disk 26 of pipe 20 and for the same purpose, but the deflector disk 42 which corresponds to deflector disk 27 in tube 20 differs in that it has perforations 43 (Fig. 10) for liquor-drainage purposes. And also for drainage purposes, the first few screw flights (at the left) on conveyor 37 in pipe 31, adjacent the draining deflector disk 42, have perforations 44. In the left-hand closure end 35 of tube 31 is a drainage pipe 45, valved at 46.

In Figs. 1 and 10, the strainer disks 42 are shown carried by the shaft 38 of the screw conveyor, but under certain circumstances it is advantageous to have the strainer disk fixed, as shown at 42' in Fig. 9. Here the disk 42' with its perforations 43' is fixed to the periphery of the bore of the tube 31, as at 47. At the apex, the disk 42' has a hole or bore 48 through which shaft passes with ample clearance so as not to bind.

The tube 31 has a free-fall outlet connection 50 at its opposite end which may lead to another material-supporting tube with a screw conveyor in it, constructed generally like tube 31, and this arrangement of vertically spaced tubes connected by free-fall connections can be multiplied so that there are as many as four (see Fig. 11) or more such tubes. However, for simplicity purposes, only two are shown.

The lowermost tube discharges through its free-fall connection 50 into a chip-fragmentizing discharge section indicated generally by the lines leading to the letter D. This fragmentizing discharge section is shown and described in the previously mentioned patent of Kehoe, et al., No. 2,616,802. In essence, it comprises a closed-bottomed chamber 51 into which steam-softened chips fall where they encounter an intensely rapidly moving bladed impeller 52 whose rapidity of motion renders the softened chips into a highly turbulent, mobilized mass in substantially gaseous suspension, such that there results an initial fragmentation of the chips. These fragments are then projected through a particle-size controlling orifice 53, partly by the force of the impeller and partly by the stream of steam issuing therethrough. The size of the orifice is controlled by regulating devices 54 and the final fragmentized particles are discharged to the atmosphere through pipe 55. Pipe 56 is merely for clean-out purposes. In this, and the other figures, the chips are indicated collectively and separately by the letter C, the liquor in the pipes, hereinafter to be described, or perhaps rather the liquid-level thereof, by the letter L, and the steam or other atmosphere over the liquor, by the letter G.

Since a main feature of this invention is to treat the

chips to alternate submergence in digesting liquor and emergence therefrom, such liquor is pondingly held in pipe 20 with a liquid-level about as shown in Fig. 1, wherein it is fairly level at the right-hand end or feed-in end; but at the outlet or left-hand end, the liquid-level follows more or less a parabolic curve. Figs. 2, 3 and 4 are cross-sectional views so in each the relation of liquid to superposed gaseous environment can be seen. At the inlet end of the tube, it is desired that the liquid-level of the liquor be above the level of the shaft 23, whereas at the left-hand end, it is to be below it, and this relationship changes progressively as the outlet end of the tube is reached. This result is due apparently to the fact that while the liquor in the pipe 20 forms in effect one general pool or pond, actually it is divided into a succession of individualized or component pools or ponds, with each pool being held between two adjacent screw flights, so one is separated from its next-door neighbor by a rotating substantially vertical flight. The flights have a limited clearance from the inner periphery of the pipe 20, as can be seen in Fig. 8, but with the chips compacted between the flights, due to their turning, there is a certain flow-retarding effect set up by them which prevents too much flow of liquor past the bottom of the flights. Some takes place but not much, so the liquid-level gradually decreases as can be seen from Figs. 2, 3 and 4. Of course, at the outlet end of pipe 20, the liquid-level goes to nothing as shown because of the flow of liquor over and down from the bottom edge of the pipe 20 through the free-fall connection 30. Thus, at the inlet end of the tube, each hydraulically connected compartment made between two adjacent flights has more liquor in it than gas, and at the outlet end, each compartment has in its more gas than liquor.

In order to obtain maximum through-put for the apparatus, it is important to assure that even when the pipe is filled to maximum capacity with chips, the chips will advance through the pipe at the proper rate with minimum tendency toward rotation with the conveyor screw in such manner as to cause plugging of the pipe, and the present invention accomplishes this desired result. Referring to Fig. 7, with the screw rotating clockwise as shown, the effect of the screw in cooperation with the forces of gravity is to cause compaction of the chips into an area X represented by the double cross hatching. The sloping top or inner surface of the area X remains fairly constant at all loadings of the tube at or above the lowest operating conditions for which the unit is designed providing that proper advance of the chips axially of the tube is maintained, and the outer surface of area X is shown as extending circumferentially of the tube from a position below its horizontal center line on the downwardly moving side of the screw to a position above the horizontal center line on the upwardly moving side of the screw.

The plugging tendency of the chips referred to above appears to depend upon the frictional relation between the chips on the one hand and both the inner surface of the tube casing and the flights of the conveyor screw.

When the unit is less than half full, the weight of the chips between the screw flights is supported by the casing, and the friction between the chips and the inner surface of the casing is sufficiently greater than the friction between the chips and the screw flights that the chips will not turn with the flights but will advance axially of the tube as the flights pass through them. However, such loading conditions result in a low capacity throughput for the apparatus, and when the capacity is increased by filling the tube to any level above the top of the screw shaft, two other forces come into play which upset the friction balance in the unit in favor of the rotating screw.

The first of these additional forces is illustrated in the diagram in Fig. 8. The chips lying directly above the screw shaft 23 and represented by the double cross-

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hatched area Q are supported substantially directly by the screw shaft and are therefore subjected to the rotating motion of the screw. As the depth of this area Q increases, so will the weight of the chips therein and also the rotating force effective thereon. In addition, the chips which lie in the areas R located between the area Q and the angles of repose, represented by the lines S, are supported in part by the chips in the area Q and thus further increase the downward load on the screw shaft. Fig. 8 therefore demonstrates the fact that the weight of the chips supported by the wall of the casing does not increase in direct proportion to the total weight of the chips present in the tube when the chip level rises above the horizontal center line of the tube.

The second additional force derives from the fact that while the chips resting on the bottom of the tube directly on its vertical center line are supported by the tube wall, as the helix of the screw flight develops in the direction of rotation and the chips increase in depth, the weight of the chips supported by the flight increase because of the inclining face of the flight inherently present. This additional weight also favors the rotating force, which increases to a greater extent proportionately upon increased loading than does the weight supported by the casing.

To recapitulate: when the tube is less than half full, almost all of the weight of the chips is supported by the tube casing, and the friction balance favors the casing. When the chips fill the tube above the top of the screw shaft, then the shaft and the screw flight supports the weight of some of the chips, thus proportionately reducing the load which is supported by the casing. This weight supported by the screw is also subjected to rotation of the screw, and this apparently creates enough total friction to cause the chips to rotate as a mass with the screw rather than to advance through the tube, thus effectively plugging the tube.

In accordance with the present invention, it has been determined that the proper frictional conditions for maintained axial advance of the chips under conditions of high loading, as well as for the desired rotational movement of the chips for repeated submergence in the digesting liquor and emergence therefrom, are established by the provision of a plurality of spline bars extending lengthwise of the tube and projecting inwardly from the inner surface of the tube casing within the area X. Since the top surface of the area X remains essentially constant as previously noted, the center of this area remains similarly constant and appears to be located below center and approximately midway between the vertical and horizontal center lines of the tube on the upwardly moving side of the screw. For this reason, one spline bar 61 is desirably located at this 45° position as shown in Fig. 6. A second spline bar 62 should be located above spline 61 within the area X, and the position of this spline on the horizontal center line as shown in Fig. 6 has been found to give the desired results in operation by offering additional resistance to rotation of the chips with the screw.

When the level of the chips in the tube rises above the screw shaft 23, the uppermost chips tend to be conveyed over to the downwardly moving side of the screw, particularly those chips lying in the area correspondingly to the area Q in Fig. 8, and these chips fill the single cross hatched area Z in Fig. 6. The position on the inner wall of the tube casing where the areas X and Z meet appears to remain practically constant, and it also appears that when the level of chips in the tube reaches the point at which the chips begin to travel over the top of the screw shaft, the forces in the area X are at a maximum. If, therefore, a third spline bar 63 is located at the lower junction of the areas X and Z, further increase in the chip level will not alter the forces in the area X. The proper location for the spline 63 appears to be between the

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vertical center line and the adjacent 45° position on the downwardly moving side of the screw, with preferred results having been obtained with this spline 22.5° from the vertical as shown in Fig. 6. The splines 61—63 should run substantially the entire length of the tube, and the compacting or compressing action of the rotating screw in combination with the resisting or retarding action of the splines aids in the disintegration of the chips in a long cook.

The pattern assumed by the chips in the tube as described in connection with Fig. 6 is of special importance at the position immediately below the inlet to the uppermost tube 20 because of its relation to the fresh material being supplied to the tube from the inlet. Referring to Fig. 7, since the chips assume the sloping pattern in the area X for the reasons described, if the fresh chips fall on to the upwardly moving side of the screw, they tend to stay in such position. As a result, those of these chips lying above the liquor level at the inlet end of the tube may not be submerged in liquor for a considerable time, especially if the unit is running at low capacity.

In contrast to the condition just described, if the fresh chips fall on to the downwardly moving side of the screw, they are received initially in an area of minimum chip concentration and maximum liquor level, so that at least the majority of the fresh supply of chips will be caused to pass through a pond of liquor before reaching the area X. As shown in Fig. 7, this desired result is accomplished by providing in the inlet connection 16 an inclined baffle 66 arranged to direct the incoming chips to fall tangentially into the tube 20 on the downwardly moving side of the conveyor screw. This arrangement is especially desirable when the unit is running at high capacity, since it assures immediate submergence in liquor of the maximum amount of fresh chips, and thereafter all the chips will rotate slowly with the screw as they progress axially through the tube for thorough submergence in the digesting liquor.

A somewhat different directional problem exists at the free-fall connection from each tube to the next lower tube, which is illustrated for tubes 20 and 31 in Fig. 10. Since the connection 30 leads at right angles into the tube 31 similarly to a T piece, if the chips are free to fall directly through the connection 30 as soon as they reach it, they tend to pile up in pipe 31, and then as the flights of the conveyor screw bite into this pile, undesirable shearing of the chips can take place between the flights and the lower edge of the connection 30. This result is prevented in accordance with the invention by the provision of the plate 28, which acts as a deflector to direct the chips toward the far side of the connection 30 as shown in Fig. 8.

With this arrangement including a deflector as shown at 28, the chips falling through the connection 30 have time in which to flatten out and rearrange themselves before they can be carried by the screw flights to the junction between the connection 30 and the pipe 31, and shearing of the chips at this junction is thus prevented. With the plate 28 perforated as shown, the liquor can drain through the perforations 29 for temporary segregation from the chips as both fall into the pipe 31, and the liquor thus will spray over the chips as they have been rearranged in the lower tube. In addition, the use of this deflector plate 28 results in increasing the effective length of each tube and hence increases the cooking time for the same size and operating speed of the unit. In other words, the deflector plate adds its own axial length to the distance the chips must travel both in the tube in which the deflector plate is mounted and also in the adjacent lower tube.

It is desirable under certain conditions to have a minimum amount of liquor in the final tube. This is particularly true when the fragmentizing type of discharger D is to be used, for there the chips have to be frag-

mentized in gaseous suspension so they should have a minimum of liquor with them. To the end of de-watering the chips, it is possible to drain or suck off the liquor from the chips by the means shown in Fig. 10. That is, the deflector disk 42 is perforated and so are the first few end flights of the screw, which permits the liquor to be sucked out from that end of the tube 31 through the conduit 45 which is to be connected to a pump, if desired.

Fig. 11 shows how the liquor can be drawn off through conduit 45 from the left-hand end of the bottom tube and also from the right-hand end of the adjacent upper tube, through connecting conduit 70. In the event that it is desired to recirculate some of the liquor, this can be done from the left-hand end of the second tube in Fig. 11 to the T-piece 16, by means of conduit 71 and its pump 72. Since the liquor can be held back and ponded as described herein, more liquor can thus be added and used.

Operation

Chips or other ligno-cellulosic material to be treated are supplied to the feeding-in section A, namely to the hopper 11, from whence screw feeder 12 forced the chips into the preheater B, while compacting the chips into the form of plugs which plug the intermediate pipe 14 for minimizing escape past the plug of the heat and pressure within the flow-path housed by the conduit comprising the digesting tubes 20 and 31 with their free-fall connections 16, 30 and 50. The plug tends to expand as it enters the pipe 15 with its increased diameter, especially as it encounters there saturated steam supplied through pipe 17. By the time the chips reach the T-piece 16, they have become substantially disintegrated from their plug form, so that they are in effect individualized again. It is important to get a proper concept of the relative sizes of the chips and the horizontal tubes such as 20. The tubes may be 24 inches in diameter and in some cases are as large as 36 inches. On the other hand, a wood chip ranges from the size of a silver half-dollar to a dollar although somewhat thicker at times, and the size of the chips is roughly indicated in the drawings by the small wavy lines. They are compressed clingingly into a mass, but rather than continue the showing of the massed chips, broad cross-hatching has been used instead so as not to obscure the liquid-level of the ponded liquor in the pipes.

In falling down the T-piece 16, the chips are subjected to a spray of strong digesting liquor which comes in through the pipe 18. The chips then fall into the inlet end (right-hand end) of tube 20 in a tangential manner with respect to the screw conveyor flights 22, as shown in Fig. 7, whereupon they begin their passage along the tube 20. Their transit of tube 20 is accurately controlled to be uniform and as to total time by the speed of rotation of the screw conveyor 21. The quantity of liquor supplied through pipe 18 is controlled to give the desired amount of liquor flowing through tube 20 to present a liquid-level L about as shown in Fig. 1. Due to the splines inwardly projecting from the inner periphery of the tube 20, the chips in the tube do not rotate unitarily with the screw conveyor as they would tend to do if the splines were absent but are submerged in the liquor pool and then caused to emerge into the gaseous steam-bearing atmosphere overlying the liquor.

The liquor-level progressively decreases as the left-hand end of the tube is reached, as shown in Fig. 1, and more particularly in Figs. 2, 3 and 4. Thus near the right-hand or inlet end of tube 20 more of the chips are submerged in liquor than are exposed in the overlying gaseous atmosphere, whereas at the left-hand end, the reverse is true, and the transition from right-hand end to left-hand end, is progressive from one relationship to the other. The splines assure alternate squeezed submergence and unsqueezed emergence of the chips in the tube so that it is not possible for some chips to remain in submergence while others remain in the gaseous atmosphere.

An important function of the splines 61—63 is to increase the friction between the inner periphery of the tube and the chips. The splines cause this increase in friction to a degree such as to overbalance the friction between the chips and the screw flights for inducing squeezing, compression or compaction of chips between themselves so that their tendency to lifting by the flights is retarded, and the chips are rearranged compressively in their mutual contact with each other. The splines help also to assure the presence of chips in the space between the outer edges of the screw flights and the inner periphery of the tubes where such chips form the flow-retarding but liquor-permeable seal for keeping a pool of flowing liquor between flights and yet having the adjacent pools in hydraulic flow-through communication.

As the chips reach the left-hand or outlet end of tube 20, they fall while segregated from the liquor which is strained off through strainer plate 28. The segregated chips have time to flatten out and rearrange themselves so that no pile of them develops in the inlet end of tube 31, whereupon the screw conveyor 37 of that tube can pick them up and advance them to the free-fall connection 50, either to another lower tube, like 20 or 31 but finally to the fragmentizing zone D. In the latter, the steam-softened digested and dewatered chips are initially fragmentized in the chamber 51 due to the action of the bladed impeller 52 which renders them into a turbulent mobilized gaseous suspension, from whence they are discharged through an orifice 53 to pipe 55 and thus sized as to the diameter—all fragmentation being along the lines of natural cleavage of the chips.

In a satisfactory embodiment, the digesting tubes were 35 inches in inside diameter, and the screw conveyor had a pitch of 12 inches with a diameter of 33 inches and was rotated at a speed ranging from 1 to 2 r.p.m. The splines 61—63 were $\frac{3}{8}$ inch square so there was a clearance of $\frac{1}{8}$ inch between them and the screw flights. Center to center distance between free-fall connections was 21 feet. The quantity of digestant liquor was from 3 to 4 parts liquor to 1 part of wood chips. It was found possible to hold liquor flowing through the pipe at any depth desired and this was governed solely by the rate at which the liquor was fed. Enough steam was used to maintain in the entire treatment conduit a temperature of from 212° F. up to 375° F. and a superpressure appropriate to the temperature to prevent boiling. Wood chips vary in diameter from about $\frac{3}{8}$ to $\frac{3}{4}$ inch. The digestant liquor may be a solution of caustic soda in a concentration of from 4% to 15%. And solutions of other chemicals usable are sodium sulfite, sodium carbonate, and the like.

Features of advantage of this invention include the submerging of compression-induced contacting chips in digestant liquor followed by emergence in the steam-bearing atmosphere above the liquor while not so compressed. One effect of this is that after the chips are covered with and somewhat penetrated by the liquor, they are raised out of it into the super-pressure super-temperature steam atmosphere where air is thus removed from the chips so that when they are again submerged, more liquor can penetrate the chips to do its work of removing the ligneous encrustations on the cellulosic fibers. The progress of the chips along the digesting tubes is carefully controlled by the screw conveyor and their spiralized motion from submergence to emergence is also carefully controlled by the splines projecting inwardly from the inner wall of the tubes. Then the relative position of the chips is repeatedly changed and rearranged in each compartment between adjacent flights by the expedient of the splines and by the expedient of the free-fall of the chips down the free-fall connections from tube to tube, and at the same time the rearrangement of the liquor is also assured by the segregation of the liquor from the chips during this free-fall by means of the straining perforated plate means at the exit end of the tubes.

Further assurances of the control of the chips is given by the subdividing of the pool of liquor into component pools each with its own superposed gaseous atmosphere. The component pools are horizontally separated by the rotating vertical screw conveyor flights but the component pools are retained in peripheral hydraulic connection due to the permeable seal of chips in the flow passages between the splines and the inner wall of the tube and past the conveyor flights. This arrangement gives downstream flow of liquor from an upstream component pool to its next downstream neighbor but without letting too much liquor escape past the flight to drain the pool of its liquor. In this manner the liquor is maintained in the tube without the use of dams per se. The liquid-level of the liquor is maintained in the tube so that it is higher in the inlet end of the tube and lower in the exit end of the tube, with the liquid-level assuming the shape more or less like that of a parabolic curve. This is helpful because the chips get the greatest depth of submergence at the inlet end of the tube and the greatest extent of gaseous atmosphere at the exit end.

This progressive transition from relatively great submergence to relatively great emergence seems to be very advantageous. The tangential feed of chips from the first free-fall connection into the uppermost tube seems to facilitate the spiralizing of the chips in the latter, for otherwise there is a definite disturbance of forward flow of the chips. The liquor draw-off straining means provided at the end of some tubes is of advantage in removing excess liquor from the chips before they go to the fragmentizing discharger wherein they must be fragmentized in a gaseous environment preparatory to being discharged through the size-controlling discharge orifice. And, of course, by maintaining the horizontal digesting tubes substantially full of chips at all times, the through-put or treatment capacity of such a digester is maximized over those of a similar type wherein the tubes are maintained only partially filled with chips.

This application is a continuation-in-part of my application Serial No. 420,033, filed March 31, 1954 as a continuation-in-part of my application Serial No. 261,278, filed December 12, 1951, both of which prior applications are now abandoned.

While the methods and forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise methods and forms of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. In continuous digesting apparatus of the character described for cellulosic material, comprising a pair of vertically spaced generally horizontally extending tubes each having an inlet in the top thereof and an outlet in the bottom thereof spaced axially from said inlet, means supporting said tubes with said inlet of the lower said tube vertically aligned with said outlet of the upper said tube, a connection extending vertically from said upper tube outlet to said lower tube inlet, means for introducing said cellulosic material into said upper tube through said inlet, and means for supplying digesting liquor to said upper tube for movement therethrough with said cellulosic material, the combination of a conveyor screw extending lengthwise of each said tube, means for rotating each said screw in the direction to advance said cellulosic material lengthwise of said tubes to said outlets thereof for free fall therethrough, and the improvement comprising a baffle mounted in fixed position at the upper end of said connection and extending across a portion thereof nearest said inlet of said upper tube for directing said free falling material toward the portion of said connection furthest from said outlet of said lower tube to minimize shearing of said material between said

screw in said lower tube and the lower end of said connection.

2. In continuous digesting apparatus of the character described for cellulosic material, comprising a pair of vertically spaced generally horizontally extending tubes each having an inlet in the top of one end thereof and an outlet in the bottom of the opposite end thereof, means supporting said tubes with said inlet of the lower said tube vertically aligned with said outlet of the upper said tube, a connection extending vertically from said upper tube outlet to said lower tube inlet, means for introducing said cellulosic material into said upper tube through said inlet, and means for supplying digesting liquor to said upper tube for movement therethrough with said cellulosic material, the combination of a conveyor screw extending lengthwise of each said tube, means for rotating each said screw in the direction to advance said cellulosic material lengthwise of said tubes to said outlets thereof while tending in cooperation with gravity to compact said material in each said tube in an area extending from a position between the horizontal and vertical center lines of said tube on the downwardly moving side of said screw therein to a position between said horizontal and vertical center lines on the upwardly moving side of said screw, spline bars within said area of each said tube and secured to the inner surface of said tube for cooperation with said screws to resist the tendency of the compacted cellulosic material toward rotation with said screws and thereby to cause axial advance of said material to the adjacent said outlet for free fall therethrough and to provide an area of minimum compaction of said material including and below said horizontal center line on the downwardly moving side of said screw, the improvement comprising means in said inlet of said upper tube for directing said material introduced therethrough toward the downwardly moving side of said upper screw and away from the upwardly moving side thereof to effect delivery of said material initially into said area of minimum compaction, and means covering a portion of the upper end of said connection nearest said inlet of said upper tube for directing said free falling material toward the portion of said connection furthest from said outlet of said lower tube to minimize shearing of said material between said screw in said lower tube and the lower end of said connection.

3. In continuous digesting apparatus of the character described for cellulosic material, comprising a pair of vertically spaced generally horizontally extending tubes each having an inlet in the top thereof and an outlet in the bottom thereof spaced axially from said inlet, means supporting said tubes with said inlet of the lower said tube vertically aligned with said outlet of the upper said tube, a connection extending vertically from said upper tube outlet to said lower tube inlet, means for introducing said cellulosic material into said upper tube through said inlet, and means for supplying digesting liquor to said upper tube for movement therethrough with said cellulosic material, the combination of a conveyor screw extending lengthwise of each said tube, means for rotating each said screw in the direction to advance said cellulosic material lengthwise of said tubes to said outlets thereof for free fall therethrough, the improvement comprising, a baffle mounted in fixed position at the upper end of said connection and extending across a portion thereof nearest said inlet of said upper tube for directing said free falling material toward the portion of said connection furthest from said outlet of said lower tube to minimize shearing of said material between said screw in said lower tube and the lower end of said connection, and said baffle including a plate member having substantially vertical perforations therethrough to cause said liquor to drain therethrough onto said material in said lower tube.

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