United States Patent [19]

Wilson et al.

[11] **3,814,246**

[45] **June 4, 1974**

[54] **METHOD FOR CENTRIFUGALLY REMOVING LIQUID FROM A MIXTURE**

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[73] Assignees: **Fiberfuge Company,** Denver, Colo.; **Centrifugal and Mechanical Industries, Inc.,** St. Louis, Mo. ; a part interest to each

[22] Filed: **Aug. 20, 1971**

[21] Appl. No.: **173,657**

Related U.S. Application Data

[62] Division of Ser. No. 752,022, Aug. 12, 1968, Pat. No. 3,642,139.

[52] **U.S. Cl.** **210/78,** 210/79, 210/213, 210/374, 210/380

[51] **Int. Cl.** **B04b 3/04**

[58] **Field of Search** 210/77, 78, 79, 213, 374, 210/380, 68

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Primary Examiner—Samih N. Zaharna
Assistant Examiner—F. F. Calvetti
Attorney, Agent, or Firm—Duane Burton

[57] **ABSTRACT**

A method and apparatus for continuously removing, through a centrifuging operation, liquid from a mixture including therein a cellulose fiber pulp of organic origin which is used or could be used in the making of paper. The method involves impinging the mixture upon a rotating screen surface to form a layer of lightly compacted, relatively porous, fibrous material thereon and passing a portion of liquid through said porous layer of material and through said screen followed by effecting a further removal of the liquid from said mixture by cleaning said screen surface by moving the edge of a transportating member adjacent said screen surface while simultaneously producing and maintaining a mass of densely compacted, relatively impervious, fibrous material between said edge and said screen and using said mass to remove continuously from said screen surface fibrous material deposited thereon, and rolling, wringing and redepositing said fibrous material upon said screen surface while passing additional liquid through said screen and moving said fibrous material along said screen surface. The mixture is centrifuged at a force varying within a range between approximately 70 and 650 times the force of gravity. The fibrous material passing with the liquid through the screen is recovered by impinging the liquid-fibrous material upon the surface of a second screen. The method may also be used with a mixture containing fibers which are relatively short in length by adding to said mixture a predetermined quantity of fibers having a relatively long length. The apparatus comprises a hollow, rotatably mounted screen means, a scroll member rotatably mounted concentrically within said screen means, and means for rotating the scroll member at a predetermined angular velocity differential relative to the angular velocity of rotation of the screen means. The screen means preferably has a circularly shaped inner surface and a plurality of openings formed therethrough, the minimum dimension of said openings, taken in a direction generally normal to the longitudinal axis of said openings, varying within a range of not less than approximately 0.3 millimeters nor more than approximately 3 millimeters. The scroll member has a plurality of helical flights formed on the surface thereof so constructed and arranged to prevent fibrous material from "bridging" between adjacent flights. This construction and arrangement includes helical flights disposed to form an included angle with a plane disposed perpendicular to the longitudinal axis of the scroll member not more than approximately 65°, and perpendicularly spacing each flight from an adjacent flight by an amount equalling at least approximately 0.03 and preferably 0.04 times the inner circumference of the screen means. The clearance between the edge of each flight and the inner surface of the screen means adjacent the end into which the mixture is supplied to the apparatus equals approximately not more than 0.004 times the inner diameter of the screen means. A relationship exists between certain structural parts of the apparatus whereby, upon operation thereof, the fibrous material is retained upon the inner surface of the screen means at least approximately 1½ seconds and preferably about 3 seconds.

13 Claims, 17 Drawing Figures

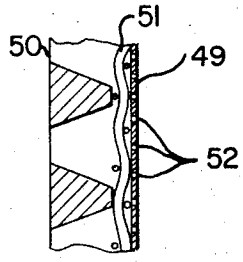

51
50
49
52

Fig. 2

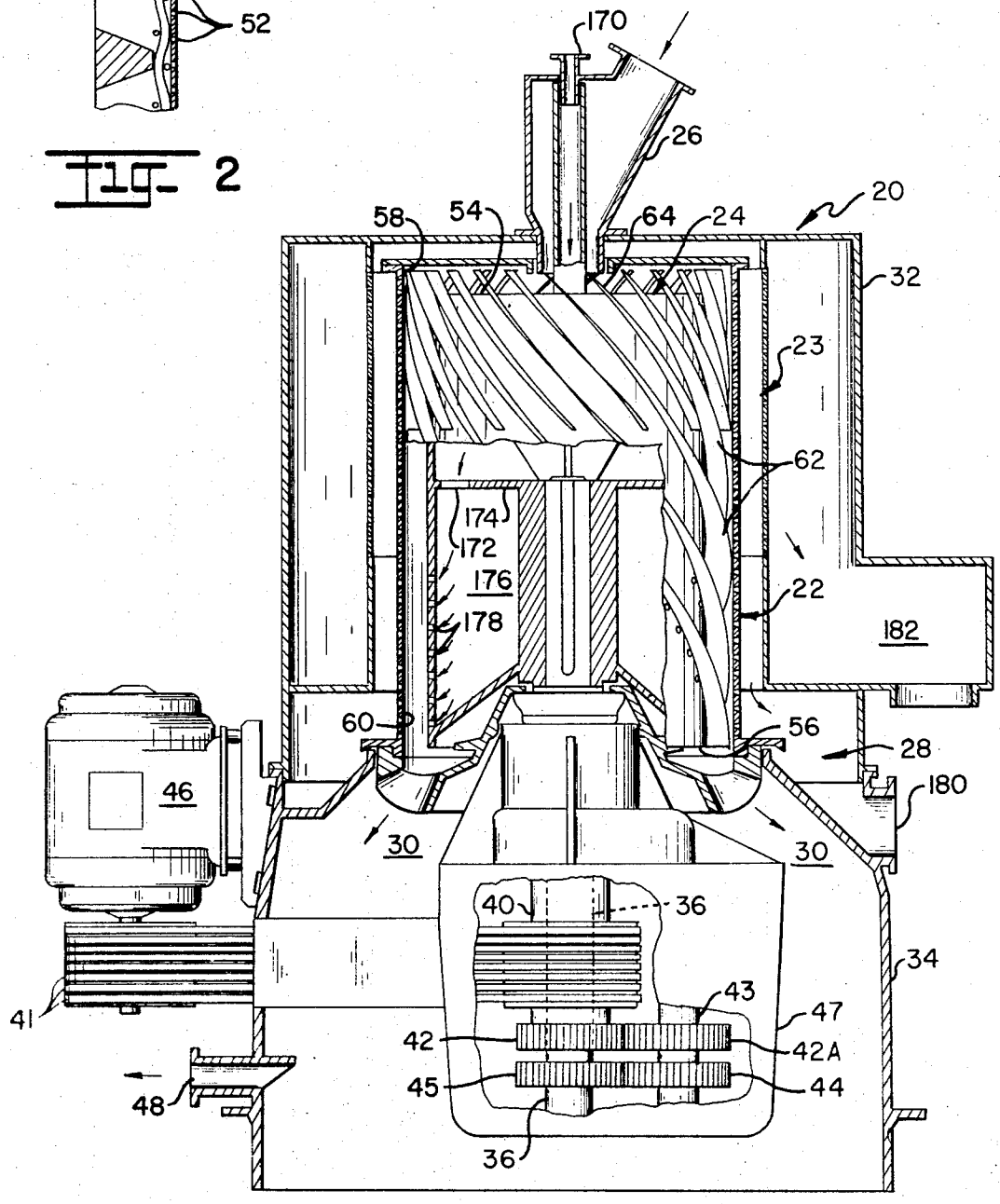

170
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Fig. 1

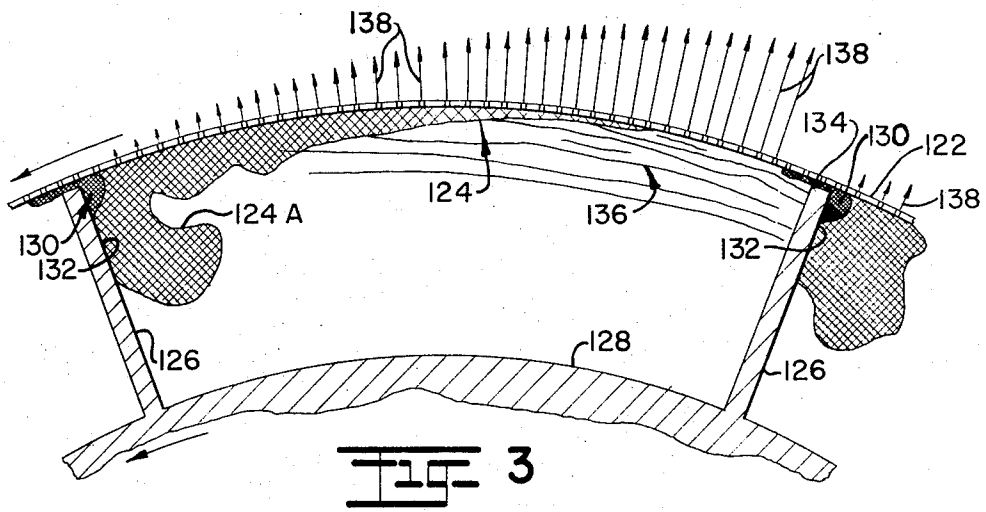


FIG 3

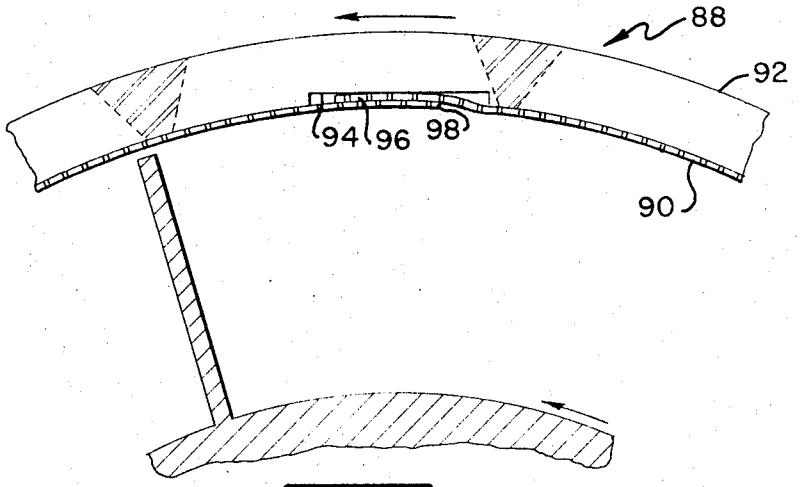


FIG 4

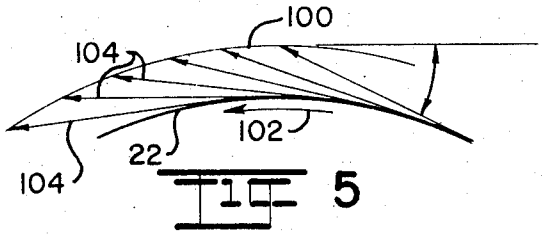


FIG 5

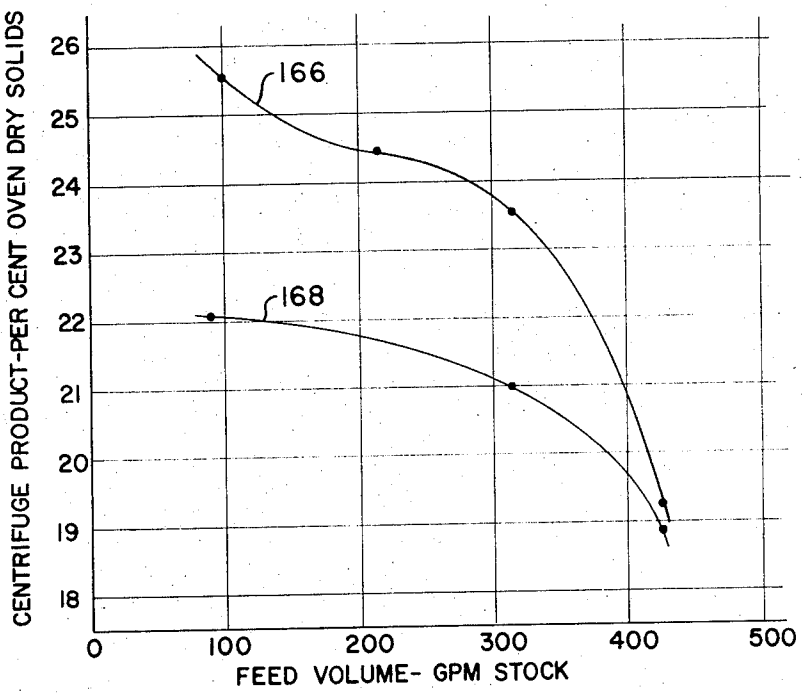


FIG 17

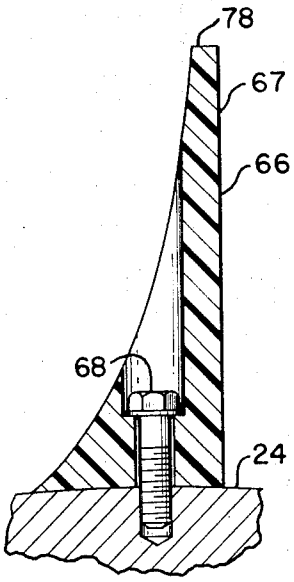


FIG 6

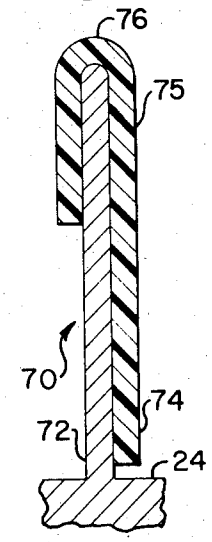


FIG 7

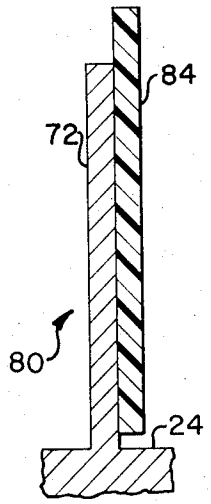


FIG 8

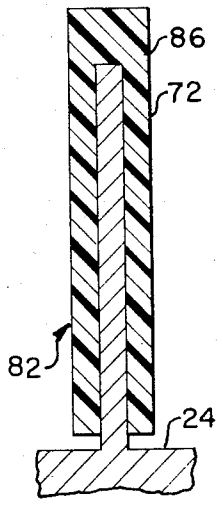


FIG 9

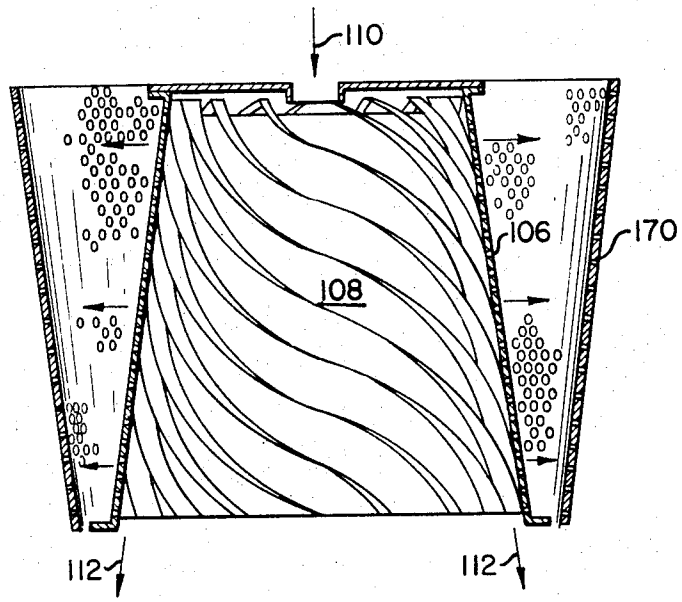


Fig. 10

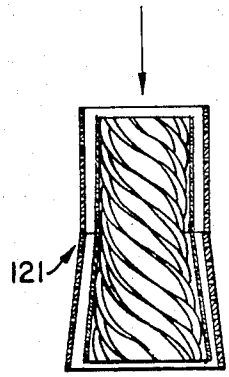


Fig. 13

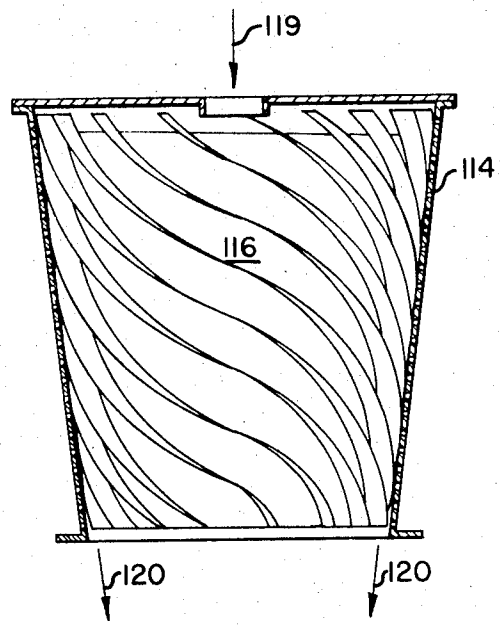


Fig. 11

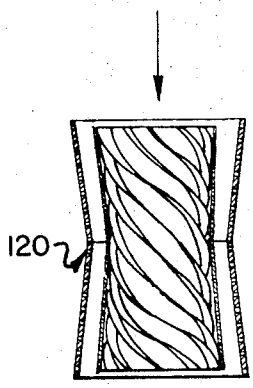


Fig. 12

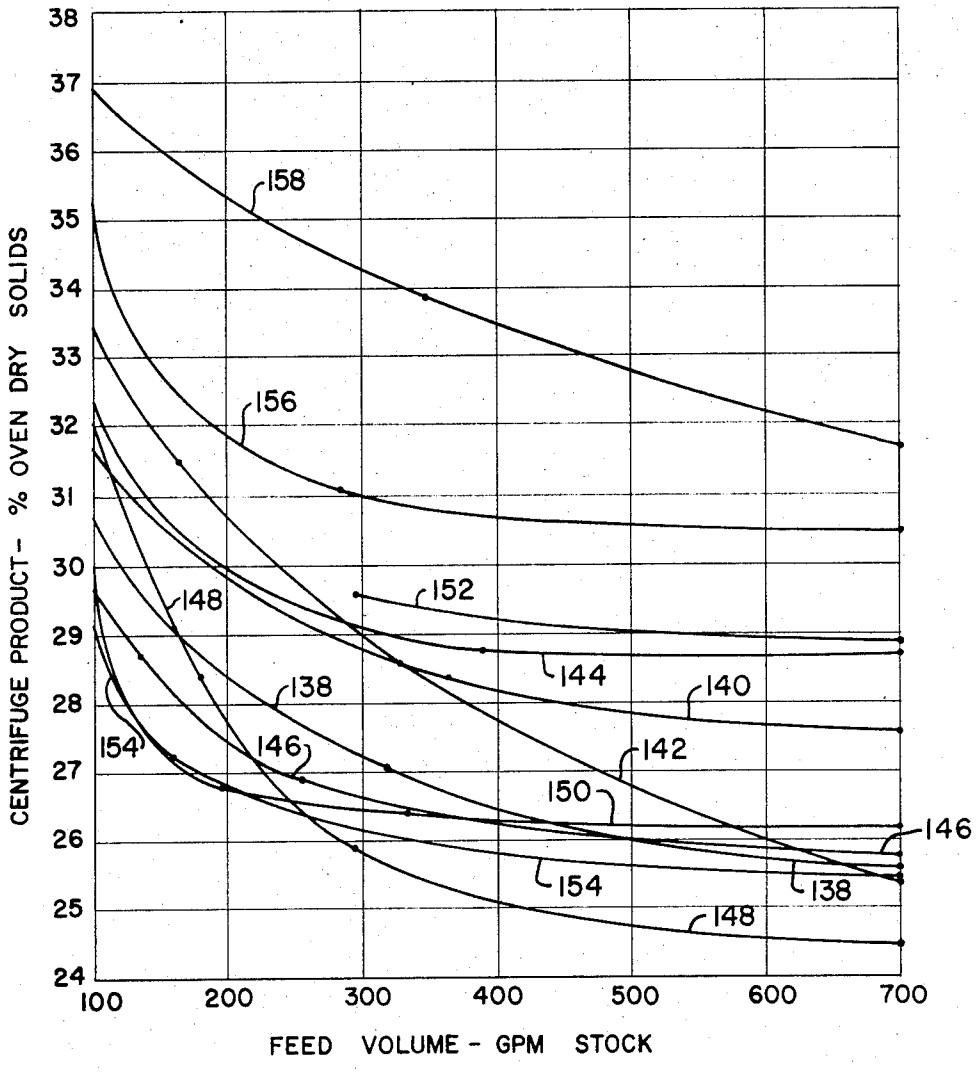

CENTRIFUGE PRODUCT - % OVEN DRY SOLIDS
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
100
200
300
400
500
600
700
FEED VOLUME - GPM STOCK
158
156
148
152
144
140
138
154
146
142
150
146
154
138
148

FIG 14

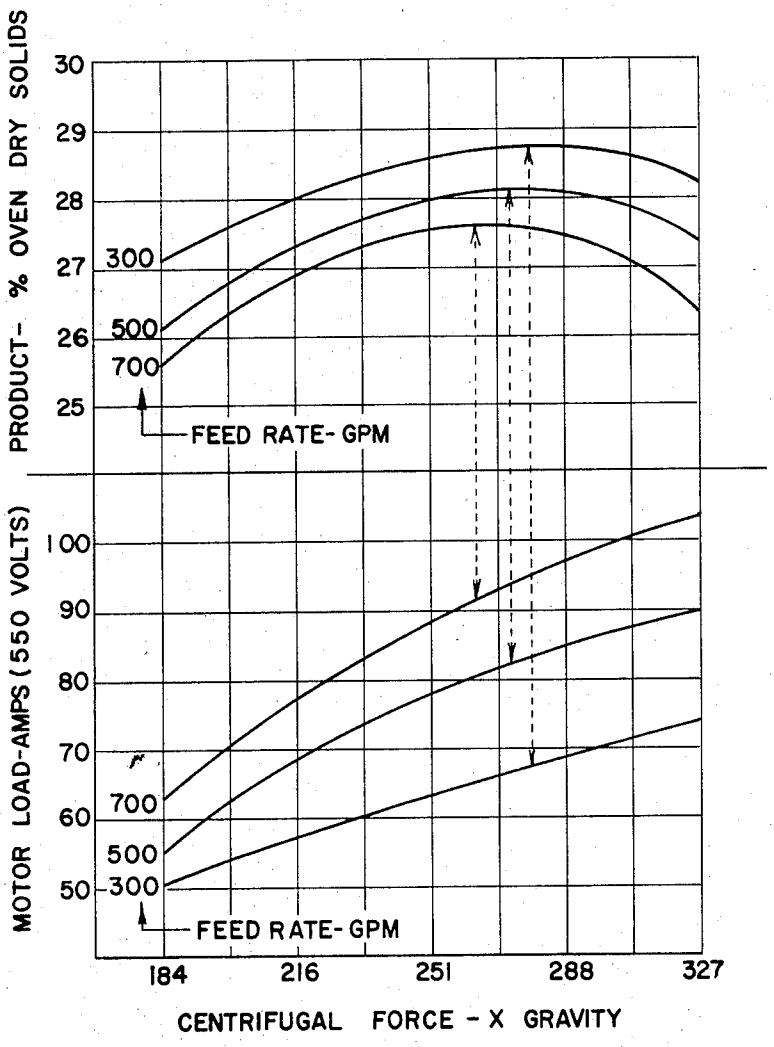

PRODUCT- % OVEN DRY SOLIDS
30
29
28
27
26
25
300
500
700
FEED RATE- GPM
MOTOR LOAD-AMPS (550 VOLTS)
100
90
80
70
60
50
700
500
300
FEED RATE- GPM
184
216
251
288
327
CENTRIFUGAL FORCE - X GRAVITY

Fig. 15

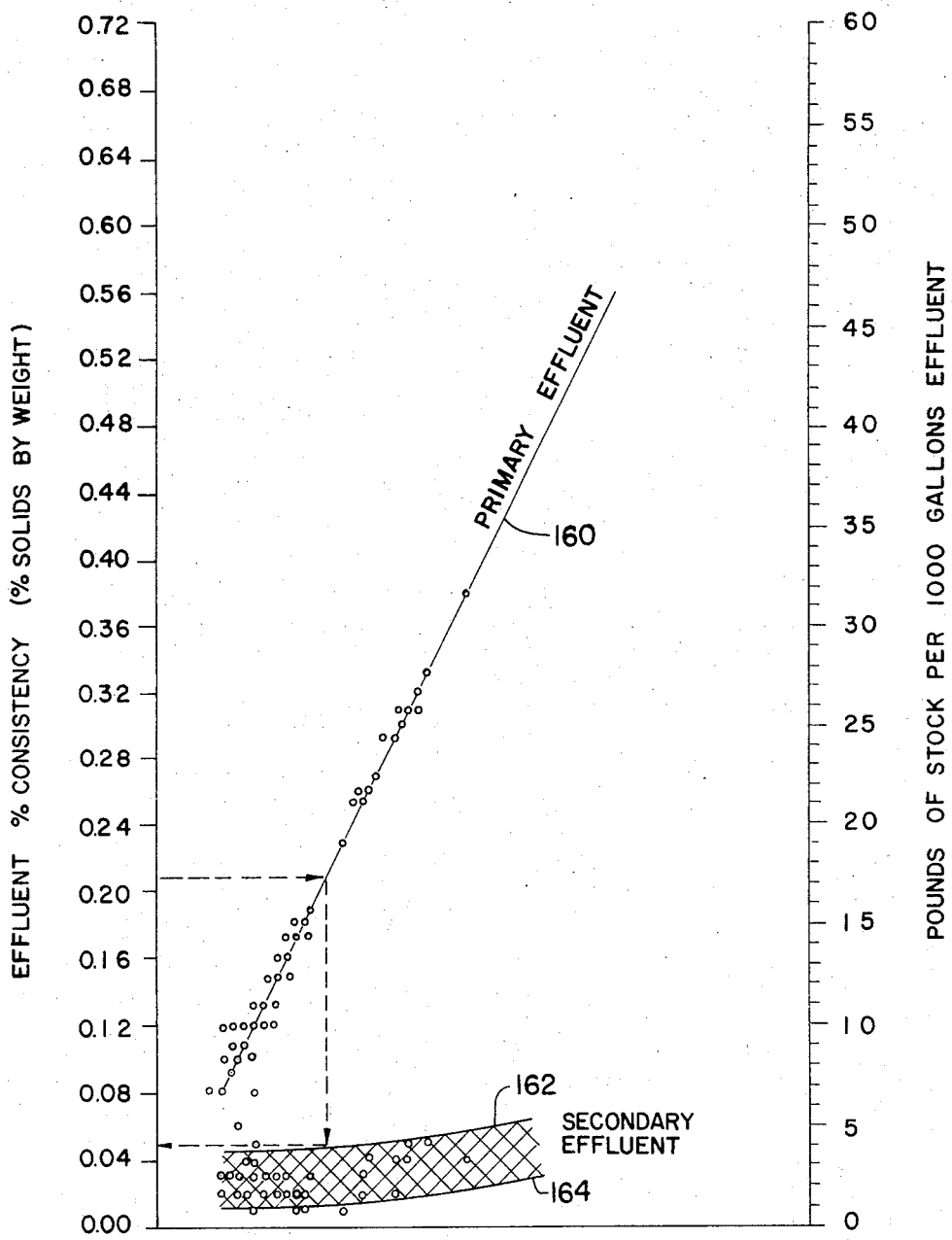

EFFLUENT % CONSISTENCY (% SOLIDS BY WEIGHT)
0.72
0.68
0.64
0.60
0.56
0.52
0.48
0.44
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.08
0.04
0.00
60
55
50
45
40
35
30
25
20
15
10
5
0
POUNDS OF STOCK PER 1000 GALLONS EFFLUENT
PRIMARY EFFLUENT
160
162
SECONDARY EFFLUENT
164

FIG. 16

METHOD FOR CENTRIFUGALLY REMOVING LIQUID FROM A MIXTURE

This is a division of application Ser. No. 752,022, filed on Aug. 12, 1968 now U.S. Pat. No. 3,642,139.

BACKGROUND OF INVENTION

In the process of producing pulp requisite to the making of paper and paper type products, most cellulose fiber pulp of organic origin is mechanically thickened from a dilute form, as low as one-half of 1 percent to 5 percent consistency (percent by weight of fibrous solids contained in the mixture) to a thickened form as high as 6 percent to 40 percent consistency, anywhere from four to ten times before ending up as a product from which paper can be made. Since cellulose fiber pulps originate from different organic species and from different chemical or mechanical processes, they exhibit varying physical characteristics typical of which is the ability to dewater. For example, in a given type of dewatering equipment, different pulps will dewater to a range of consistency, hence the use of ranges of percent solids herein.

At the present time in the United States approximately 40 million tons of cellulose fiber pulp of organic origin, and which is useful in the papermaking industry, are produced each year. However, due to the fact that a pulp may be processed or cycled a number of times before ending up as a finished product, liquid is extracted from as much as 3 to 20 billion tons of dilute pulp mixture in the United States alone each year. It will therefore be apparent that the method of such removal is a formidable problem deserving of technical attention and efforts to accomplish dewatering, thickening or washing in a more economical or expeditious manner. Further, as in any washing system employing a counter-current action involving several repeated steps of dewatering, repulping and subsequent dewatering, there are numerous advantages inherent in dewatering to the highest possible consistency. Although it is generally recognized that where applicable a centrifuge is an efficient mechanical device to use for removing liquid from a mixture, with the exception of the invention herein described and with the exception of solid bowl types of centrifuges which are used to thicken to low consistency paper and pulp mill wastes consisting of relatively fiber free mixtures containing fillers such as clay, starch, titanium oxide and other extraneous particulate (not fibrous) types of solids, not a single continuous type of centrifuge is known to be used in the United States or elsewhere to remove liquid from any dilute form of fibrous pulp material useful in the making of paper or similar cellulose fiber products.

The types of appurtenances being used to remove liquid from fibrous pulp material in dilute form are presses, gravity and vacuum filters, stationary, vibrating, rotating, or traveling screens, and hybrids of any combination of these. Presses are categorized into types including screw presses, disc presses, belt presses and roll presses. The production capacity of these presses is greatly enhanced through the use of an apparatus which increases the consistency of the material before same is fed to any of the presses and, thus, presses are frequently used in combination with such an apparatus. Screw presses are disadvantageous since

the fibers often become permanently kinked and entangled with each other producing dense fiber bundles. The existence of dense fiber bundles in pulp makes such pulp relatively undesirable for the manufacture of quality paper thereby decreasing the value of pulp dewatered in this manner. Although the consistency of pulp produced by presses is relatively high, approximately 30 percent or more, it is generally recognized that presses are disadvantageous from the acquisition cost thereof as compared to their production capacity and, also, frequently from a maintenance viewpoint.

There are two general types of filters — namely, gravity filters and vacuum filters. The gravity filter comprises a cylindrically shaped screen rotatably mounted within a vat. The pulp mixture is fed into the vat. The major portion of the liquid within the mixture passes through the screen surface into the center of the circularly shaped screen where same is withdrawn. The fibrous material is retained on the outer surface thereof and is removed through the use of scrapers or the like. The vacuum filter is similar to a gravity filter but has the interior of these cylindrical screens exposed to a vacuum source for the purpose of increasing the rate of liquid flow through the screen surface. Because of the high air-liquid flow through the vacuum filter, the vacuum source is for economic reasons usually obtained by means of a barometric leg. To obtain the barometric leg the vacuum filter must be installed in a position considerably elevated above normal ground level. The gravity filter is capable of handling pulp of approximately one-half of 1 percent to 1½ percent consistency to produce a pulp of approximately 6 percent to 7 percent consistency. A vacuum filter, with suitable accessories such as pressure rolls and the like, is capable of handling pulp of approximately one-half of 1 percent to 1½ percent consistency to produce a pulp of 10 percent to 15 percent consistency.

An example of a hybrid device used to thicken pulp, and which is a combination of filter and roll press, comprises four vertically disposed drums located about a central point and each of which is disposed in rotating contact with two other drums. The walls of the drums are perforated and covered by screen plates. The four drums comprise two pairs of drums, each drum of each pair cooperating with the other drum of said pair. The pulp mixture is fed into the pressurized area circumscribed by the four drums and some of the liquid passes through the screen surfaces into the center of each drum depositing a layer of fiber on the surface of each drum. The fiber then passes between the surfaces of both of the pairs of cooperating drums. Due to the squeezing action exerted upon the fiber as same passes between said drums, an additional portion of the liquid is removed from the fiber. Although this hybrid device may be used to process pulp of consistencies lower than 9 percent to 12 percent, such use is normally avoided due to the substantial reduction in efficiency resulting thereof.

A typical screen type thickening device is the side hill screen which is essentially a screen surface disposed at a diagonal to the horizontal plane and having the mixture flowing over the upper surface thereof. Some of the liquid flows through the openings in the screen surface and is thereby separated from the mixture. This particular device, although being relatively inexpensive, is also relatively inefficient in increasing the consistency of the pulp being processed therethrough.

Centrifugal screening devices are used in the paper making industry to remove shives and other foreign particles from liberated fibers. Such devices are not used to thicken the fibrous pulp but instead are designed to remove foreign material from pulps having a consistency of approximately 2 percent or less.

Although considerable effort has been expended in the past to produce a centrifugal apparatus capable of removing liquid from a cellulose fiber pulp of organic origin which is used in or useful in making paper, all such efforts have been relatively unsuccessful. Generally, prior art methods and apparatuses involving the centrifuging of a cellulose pulp as aforedescribed, have been unacceptable for commercial use due to the extremely small amounts of pulp that can be processed therethrough. There are a number of reasons why prior art methods and apparatuses involving centrifuging of pulp have not been successful. One of the problems encountered involved the utilization of a satisfactory screen surface. If the diameter of the screen openings were made too large, there would be too great a loss of fiber through the screen and, additionally, the tendency for the screen to "blind" increases with an increase in the size of screen openings. Thus, attempts were made to centrifuge pulp while using thin screen surfaces having very small openings. However, screens having small sized openings and a nominal percentage of open area were too fragile; thus, the use of such a screen member was disadvantageous since it had an extremely short life of sometimes only a few hours.

Another problem encountered with centrifuges was that of preventing the fibrous material from "bridging" between adjacent flights whereby fibrous material no longer passed through the apparatus.

The basket angles of prior art centrifugal devices used in attempts to dewater fibrous pulps of organic origin utilized in the paper making industry were such that excessive gravity forces were produced in a direction downward of the screening surface with a resultant loss of control of dilute pulp within the rotating basket.

Gravity forces developed by prior art centrifugal dewatering devices utilized in attempts to thicken the paper pulps, were of sufficient magnitude so as to frequently form a thin, relatively impervious layer of fiber so close to the screen surface that the co-rotating scrapers were unable to reach and remove this dense fiber layer from the rotating screen surface. Additionally, pulp dewatering was greatly restricted due to blockage of the screen surface by the dense layer of fibers.

Although prior art centrifuges were unacceptable for removing liquid from a cellulose pulp as aforedescribed, tests show that the already poor performance thereof was further reduced when low consistency pulp mixtures were fed to the centrifuge. In addition to the foregoing, attempts to remove liquid from ground wood or short fibered pulp by centrifuging same were totally unsatisfactory.

SUMMARY OF THE INVENTION

It has been found that each of the foregoing disadvantages of the prior art methods and apparatuses for removing liquid from a cellulose pulp of organic origin which is useful in the paper making industry through centrifuging of same can be overcome through the use of the method and apparatus of the subject invention.

The method of this invention comprises the steps of impinging a cellulose pulp of organic origin which is useful in the paper making industry upon a rotating screen surface to form a layer of lightly compacted, relatively porous fibrous material thereon and passing a portion of the liquid through the porous layer of material and the screen, and effecting a further removal of the liquid from said pulp by cleaning said screen surface by moving the edge of a transporting member adjacent the screen surface while simultaneously producing and maintaining a mass of densely compacted, relatively impervious, fibrous material adjacent one side of said edge of said transporting member and between said surfaces and using said mass to remove continuously said layer of fibrous material from said screen surface, and rolling, wringing and redepositing said fibrous material upon said screen surface while passing additional liquid through said screen and moving said fibrous material along said screen surface. The fibrous material is subjected to said centrifugal force for a predetermined period of time of at least approximately one and one-half seconds or longer. The centrifugal apparatus of this invention comprises a hollow, rotatably mounted screen means of predetermined length having an inner surface which, in cross-section, forms with a line disposed normal to the longitudinal axis of said screen means an included angle varying between approximately 75 and 105° and is preferably formed at an angle of approximately 90°, said screen means having a plurality of openings formed therethrough, the minimum dimension of said openings, taken in a direction generally normal to the longitudinal axis thereof, varying within a range of not less than approximately 0.3 millimeters to not more than approximately 3 millimeters; a rotatably mounted scroll member concentrically mounted within said screen means, said scroll member having a plurality of helical flights formed on the surface thereof, at a predetermined angle of inclination each flight having an edge and a fibrous material engaging surface, the distance separating said edge of each flight and the inner surface of said screen means adjacent at least a first end of said screen means equalling approximately not more than 0.004 times the inner diameter of the screen means, the surface of said flight being smoother than the inner surface of said screen means, the flights being so constructed and arranged to prevent bridging of fibrous material between adjacent flights; means for rotating said scroll member at a predetermined angular velocity differential relative to the angular velocity of rotation of said screen means; the relationship between the length of the screen means, the amount of angular velocity, the angle of inclination of said helical flights and the smoothness of the flight surfaces being maintained such that, during operation of the apparatus, the fibrous material is retained upon the inner surface of the screen means at least approximately one and one-half seconds; feed inlet means; liquid receiving means; and fibrous material receiving means.

Accordingly, one of the principal objects of this invention is to provide an improved method and apparatus for continuously removing liquid from a cellulose pulp of organic origin which is useful in the paper making industry by centrifuging same.

Another object of this invention it to provide a method of continuously removing liquid from a low

consistency organic cellulose pulp mixture by centrifuging same.

Another object of this invention is to provide a method of continuously removing liquid from a cellulose fiber mixture of organic origin comprising the step of subjecting the cellulose fiber mixture to a centrifugal force varying within a range between approximately 70 and 650 times the force of gravity by impinging said mixture against a rotating screen surface until a portion of the liquid contained within said mixture passes through said screen, and effecting a further removal of liquid from said mixture and passing same through said screen by continuously removing said fiber from said screen surface, rolling and wringing said fiber, and redepositing same upon said screen surface while moving said fiber along said screen surface.

Another object of this invention is to provide an improved method as aforedescribed in which the mixture is centrifuged at an accelerative force varying within a range of approximately 100 to 550 times the force of gravity.

Another object of this invention is to provide an improved method as aforedescribed in which the mixture is centrifuged at an accelerative force varying within a range between approximately 140 and 450 times the force of gravity.

Another object of this invention is to provide an improved method as aforedescribed including the step of recovering substantially all of the fiber passing with the liquid through said screen by impinging said liquid-fibrous material mixture upon the surface of a second screen.

Another object of this invention is to provide an improved method as aforedescribed in which the step of impinging said liquid-fibrous material upon the surface of said second screen includes moving said material toward the surface of said second screen at an angle obliquely disposed with respect to the surface of said second screen.

Another object of this invention is to provide an improved method as aforedescribed including the step of treating or washing said fibrous material with a liquid or treating said fibrous material with a gas following the removal of substantially all of the liquid that is to be removed therefrom and moving substantially all of said gas along with said fibrous material.

Another object of this invention is to provide a method of centrifugally removing liquid from a mixture including therein a fibrous material the fibers of which are relatively short in length, as characterized as being produced by a two or three pass stone or refiner groundwood process, said method comprising the steps of adding to said mixture a predetermined quantity of fibers which are relatively long in length, impinging said mixture upon a rotating screen until substantially all of the fibrous material contained therein forms a layer on said surface while passing a portion of said liquid through said screen, and effecting a further removal of the liquid from said mixture by cleaning said screen by moving the surface of a transporting member adjacent said screen surface while simultaneously producing and maintaining a mass of densely compacted, relatively impervious fibrous material adjacent one side of said member and between said surfaces and passing additional portions of liquid through said screen, the quantity of fibers having a relatively long length being sufficient to effect the producing and maintaining of said mass of densely compacted, relatively impervious fibrous material.

Another object of this invention is to provide a centrifugal apparatus for removing liquid from a mixture, said apparatus including a hollow, rotatably mounted screen means and a scroll member rotatably mounted concentrically within said screen means, said screen means including an inner screen member and an outer encompassing perforated basket, said scroll member having a plurality of helical flights formed on the surface thereof, the improvement comprising a generally longitudinally extending recess formed on the inner surface of said basket, said screen member being formed from a layer of material and having opposite ends thereof secured together in overlapping relation, said overlapping ends being disposed within said recess whereby the inner surface of said screen member is substantially smooth throughout the peripheral extent thereof.

Another object of this invention is to provide a centrifugal apparatus for removing liquid from a mixture having a fibrous material therein, said apparatus including a hollow, rotatably mounted screen means and a scroll member rotatably mounted concentrically within said screen means, said screen means including an inner screen member and an outer encompassing perforated basket, said scroll member having a plurality of helical flights formed on the surface thereof, the improvement comprising a second screen means mounted generally concentrically of and in spaced apart relation to said screen means and exteriorly thereof.

Another object of this invention it to provide a centrifugal apparatus as aforedescribed in which said second screen means is stationarily mounted.

Another object of this invention is to provide a centrifugal apparatus as aforedescribed in which the inner surface of the second screen means is conically shaped.

Another object of this invention is to provide a centrifugal apparatus for continuously removing liquid from a cellulose pulp of organic origin which is useful in the paper making industry, said apparatus comprising a hollow, rotatably mounted screen means of predetermined length, said screen means having an axially extending inner surface preferably substantially constant in radius and having a first and second end, said screen means having a plurality of openings formed therethrough, the minimum dimension of said openings, taken in a direction generally normal to the longitudinal axis thereof, varying within a range of not less than approximately 0.3 millimeters to not more than approximately 3 millimeters, a rotatably mounted scroll member concentrically mounted within said screen means, said scroll member having a first and second end, said first and second ends being disposed, respectively, adjacent said first and second ends of said screen means, said scroll member having a plurality of helical flights formed thereon at a predetermined angle of inclination, each flight having an edge and a fibrous material engaging surface, the perpendicular distance separating each edge of flight and the inner surface of said screen means adjacent at least said first end thereof equalling approximately not more than 0.004 times the inner diameter of said screen means, the surface of said flight being smoother than the inner surface of said screen means, the helical flights being so con-

structed and arranged to prevent bridging of fibrous material between adjacent flights, means for rotating said scroll member at a predetermined angular velocity differential relative to the angular velocity of the rotation of said screen means, the relationship between the length of said screen means, the amount of angular velocity differential, the angle of inclination of said helical flights and the smoothness of the flight surfaces relative to the inner surface of the screen means being maintained such that during operation of the apparatus the fibrous material is retained upon the inner surface of said screen means at least approximately 1½ seconds, feed inlet means, liquid receiving means, and fibrous material receiving means.

Another object of this invention is to provide an apparatus as aforedescribed in which the size of openings formed in the inner surface of said screen means varies within a range of approximately 0.5 millimeters to approximately 2 millimeters, and preferably within a range of approximately 1 millimeter to approximately 1.68 millimeters.

Another object of this invention is to provide a centrifugal apparatus as aforedescribed in which the size of openings formed in the inner surface of said screen means varies within a range of approximately 10 to 50 times the diameter of the fibers contained within the mixture.

Another object of this invention is to provide an apparatus as aforedescribed in which said scroll member has more helical flights formed adjacent the first end thereof than adjacent the second end thereof.

Another object of this invention is to provide an apparatus as aforedescribed in which the edges of said flight are composed of an elastomeric material such as polyurethane, polyethylene, nylon, rubber, silicone rubber, and polyvinyl chloride.

Another object of this invention is to provide a centrifugal apparatus as aforedescribed including a second screen means mounted generally concentrically of the rotatably mounted screen means.

Another object of this invention is to provide a centrifugal apparatus as aforedescribed in which the minimum dimension of the openings of said second screen means, taken in a direction generally normal to the longitudinal axis thereof, is less than the corresponding minimum dimension of the openings of said rotatably mounted screen means.

Another object of this invention is to provide a centrifugal apparatus as aforesaid in which the construction and arrangement to prevent bridging of fibrous material between adjacent flights includes perpendicularly spacing each flight from an adjacent flight adjacent at least the second end of said scroll member by an amount equalling at least approximately 0.03 and preferably 0.04 times the inner circumference of said screen means and said flights form an included angle with a plane disposed perpendicular to the longitudinal axis of said scroll member of not more than approximately 55° and preferably not more than approximately 45°.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention embodies other novel features, details of which are hereinafter set forth in the specification and claims and illustrated in the accompanying drawings, wherein:

FIG. 1 is an elevational view, partially cut away and in partial cross-section, showing an apparatus constructed in accordance with the subject invention;

FIG. 2 is an enlarged cross-sectional view of the screen means shown in FIG. 1;

FIG. 3 is a schematic view, in cross-section, taken perpendicular to the longitudinal axis of the screen means adjacent the end receiving material to be processed therethrough and showing a layer of lightly compacted, relatively porous, fibrous material deposited upon the inner surface of said screen means and the mass of densely compacted, relatively impervious fibrous material formed adjacent one surface of the helical flight of said scroll member and between the edge of said flights and the inner surface of said screen means;

FIG. 4 is a view taken similar to that of FIG. 3 showing the recess formed on the inner surface of the basket of said screen means and the overlapping ends of the inner screen member disposed within said recess;

FIG. 5 is a schematic view showing the angle of impingement upon the inner surface of a second screen means of the material passing through the inner or first screen means;

FIGS. 6–9 are cross-sectional views of a helical flight and a portion of the scroll member to which same is attached;

FIGS. 10 and 11 are views in partial cross-section of conically shaped scroll members and screen means;

FIG. 12 is a view, in partial cross-section, of a scroll member and screen means wherein the first end of the screen means has a conically shaped inner surface the diameter of which decreases in a direction proceeding toward the second end, and the second end has a conically shaped surface the diameter of which decreases in a direction proceeding toward said first end;

FIG. 13 is a view similar to that shown in FIG. 12 except that the first end has an axially extending inner surface of substantially constant radius;

FIG. 14 is a graph showing the relationship between the quantity of pulp processed through an apparatus constructed in accordance with the subject invention to the consistency of the discharged product;

FIG. 15 is another graph showing the optimum accelerative forces at which the pulp is to be centrifuged and related power requirements for maximum product dryness at a given rate of feed;

FIG. 16 is another graph showing clarification of the centrifuged effluent obtained by use of a second screen means; and

FIG. 17 is another graph showing the results obtained by adding long fibered material to low consistency short fibered pulp in dilute form.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, in FIGS. 1 and 2 is shown a centrifugal apparatus 20 constructed in accordance with the subject invention. The centrifugal apparatus 20 comprises a hollow, rotatably mounted screen means 22 of predetermined length, a second screen means 23 preferably stationarily mounted, a rotatably mounted scroll member 24, feed inlet means 26, means 28 located exteriorly of said screen means 22 for receiving the liquid to be removed from the mixture, and fibrous material receiving means 30. The centrifugal apparatus 20 has an upper casing member 32 and a

lower casing member **34**. The scroll member **24** is cylindrically shaped and is concentrically mounted upon a shaft **36** for rotation therewith. The screen means **22** is securely attached to a hollow shaft **40**. The shaft **36** is concentrically mounted within the hollow shaft **40** for relative rotation with respect to hollow shaft **40**. The shaft **40** passes through a pair of spaced apart bearings (not shown). The shaft **40** is driven by V-belts **41** and has a gear **42** securely attached thereto for rotation therewith. The gear **42** attached to shaft **40** drives a mating gear **42A** which is mounted on a shaft **43**. A second gear **44** is mounted on shaft **43** for rotation therewith and is disposed in driving engagement with a gear **45** securely attached to the shaft **36**. By suitable selection of the gears, one of the shafts **40** may be operated at a predetermined angular velocity differential relative to the angular velocity of the other shaft **36**. The gear **42** that is securely attached to the shaft **40** is driven by the motor **46**. The gears referred to above are mounted within the gear box **47**. The lower casing member **34** has an opening **48** which, if desired, may be connected to a vacuum source (not shown).

The hollow, rotatably mounted screen means **22** preferably comprises an inner screen member **49**, an outer encompassing perforated basket **50** and a layer of woven backup wire **51** sandwiched therebetween, see FIG. **2**. The inner screen member **49** has a plurality of openings **52** formed therethrough. The minimum dimension of said openings, taken in a direction generally normal to the longitudinal axis of the opening, varies within a range of not less than approximately 0.3 millimeters nor more than approximately 3 millimeters. Good results have been obtained where the minimum dimension of said openings varies within a range of not less than approximately 0.5 millimeters nor more than approximately 2 millimeters and excellent results have been obtained where the minimum dimension varies within a range of not less than approximately 1 millimeter nor more than approximately 1.68 millimeters. Understandably, the size of opening is related to the diameter of the fiber within the mixture being processed through the apparatus. Consequently, it is preferred that the minimum dimension of said openings vary within a range of not less than approximately 10 nor more than approximately 50 times the diameter of the fibers contained within the mixture. The effective open area of the inner screen member **49** should be as large as possible and should be at least 10 percent or greater. Additionally, in order to obtain a long operating life it is desired that the inner screen member **49** be able to resist the abrasive action of the fibrous material moving along the inner surface of the screen means. Such abrasive action becomes pronounced following removal of sufficient liquid to increase the consistency to approximately 8 percent or more. Consequently, long life for a screen member **49** is obtained by making same as thick as possible. It has been found that these objectives are attained by utilizing an inner screen member having openings **52** formed as aforedescribed and wherein the thickness of said inner screen member **49** approximately equals said minimum dimension of said openings. It will be understood that the backup woven wire **51** provides support to the inner screen member **49** and the perforated basket **50** provides good support to both the backup wire **51** and the inner screen member **49**.

As previously indicated, the rotatably mounted scroll member **24** is generally cylindrical in shape. The scroll member **24** is axially mounted within the screen means **22**. The scroll member **24** has first and second ends **54** and **56**. These ends **54** and **56** are disposed, respectively, adjacent first and second ends **58** and **60** of the screen means **22**. The scroll member **24** has a plurality of helical flights **62** formed thereon at a predetermined angle of inclination and extending from one end to the other. The scroll member **24** may also have additional flights **64** formed on the surface thereof adjacent the first end **54**. The flights on the scroll member **24** are constructed and arranged to prevent bridging of fibrous material between adjacent flights, said construction and arrangement comprising perpendicularly spacing, adjacent the second end of said scroll member or that portion of the scroll member in contact with a fibrous material mixture no longer in liquid form such as normally is the case where the consistency equals approximately 8 percent or more, each flight from an adjacent flight by an amount equalling at least approximately 0.03 and preferably 0.04 times the inner circumference of said screen means and said flights forming an included angle with a plane disposed perpendicular to the longitudinal axis of the scroll member of not more than approximately 55° (for a cylindrically shaped scroll member and screen means) and preferably not more than approximately 45°. At the present time, it is preferred that said included angle vary within a range of approximately 10 to 15°.

For certain applications it has been found desirable to form the flights or at least coat the edges thereof with a material which has a relatively low coefficient of friction and is relatively rigid but ablative in character. As shown in FIG. **6**, the helical flight **66** may be formed from a suitable elastomeric material, such as polyurethane, polyethylene, nylon, rubber, silicone rubber and polyvinyl chloride, and secured to the scroll member **24** in any suitable manner such as with threaded bolts **68** (only one of which is shown). In FIG. **7** is shown a helical flight **70** comprising a member **72** integrally formed to the scroll **24** and a layer of material **74** securely attached to a substantial surface portion of the member **72**. The edge **76** of the helical flight **70** is arcuately formed as contrasted to the planar edge **78** shown in FIG. **6**. In FIGS. **8** and **9** are shown helical flights **80** and **82** each of which comprise a member **72** integrally formed with the scroll **24** and a layer of elastomeric material. The layer **84** of elastomeric material shown in FIG. **8** is attached to one surface of the member **72** and projects beyond the radial end thereof by a predetermined, relatively short distance. The layer **86** of the material shown in FIG. **9** is, in cross-section, generally U-shaped in configuration. The use of a layer of material as aforedescribed greatly facilitates the forming of a helical flight which, during rotation, circumscribes a configuration substantially similar to the inner surface of said screen means. For example, it is necessary that the clearance between the edges of the helical flights and the inner screen surface be maintained within close predetermined limits. Where conical configurations are involved this is effected merely by moving the screen means axially and, thus, toward or away from the scroll member. However, this technique cannot be used for cylindrical configurations. In order to overcome this problem and to reduce manufacturing costs, the edges of the helical flights are coated with an

elastomeric material as aforesaid until the overall diameter thereof approximately equals the inner diameter of the screen means. The scroll member is then assembled within the centrifugal apparatus and rotated until the elastomeric material has been worn away sufficiently such that the surface thereof has the desired clearance with the inner screen surface during operation. The rigidity of the material insures that the inner screen surface will be efficiently cleaned while the coefficient of friction and ablative properties contribute to lower power consumption and reduced malfunctioning of the apparatus. Additionally, in the event the edges of the helical flight experience excessive wear, it is a relatively simple matter to remedy same by removing the remaining portion of the layer of material and replacing same with a new layer of material.

Each flight includes a fibrous material engaging surface such as surface **67** of helical flight **66** shown in FIG. **6** or surface **75** of helical flight **70** shown in FIG. **7.** The fibrous material engaging surfaces are smoother than the inner surface of the screen means. More specifically, the coefficient of friction of the fibrous material to the fibrous material engaging surface of the flight is less than the coefficient of friction existing between the fibrous material and the inner surface of the screen means. Due to the fact that a plurality of openings are formed on the inner surface of the screen means, it will be understood that the coefficient of friction existing between fibrous material and the inner surface of the screen means will normally be higher than the coefficient of friction existing between fibrous material and the fibrous material engaging surface which is formed relatively smooth. A predetermined relationship must be maintained between the length of the screen means, the amount of angular velocity differential between the screen means and the scroll member, the angle of inclination of the helical flights and the smoothness of the fibrous material engaging surfaces of the flights relative to the inner surface of the screen means such that, during operation of the apparatus, the fibrous material is retained upon the inner surface of the screen means at least approximately 1½ seconds. The ability of an apparatus constructed in accordance with the subject invention to remove liquid from a fibrous material in an efficient manner will be adversely effected where the retention time is materially less than that as aforespecified.

In FIG. **4** is shown a modified screen means **88** comprising an inner screen member **90** and an outer encompassing perforated basket **92.** The basket **92** has a generally longitudinally extending recess **94** formed on the inner surface thereof. The inner screen member **90** is formed from a layer of material which has the opposite ends **96** and **98** thereof secured together in overlapping relation. The overlapping ends **96** and **98** are disposed within said recess **94** whereby the inner surface of said screen member is substantially smooth throughout the peripheral extent thereof. Additionally, this particular construction of the screen means **88** facilitates the formation of a screen means which is easily balanced for dynamic operation.

As previously indicated, under certain applications it has been found desirable to utilize a second screen means located exteriorly of screen means **22.** The reason for using a second screen means is to recover a substantial portion of the fibrous material which passes with the liquid through the screen means **22.** In FIG. **5** is schematically shown a second screen means **100** which is mounted generally concentrically to the screen means **22** and exteriorly thereof. In order to maximize the amount of fiber being recovered on the inner surface of the second screen means **100** it is required that the material passing through the screen means **22** impinge upon the inner surface of the second screen means **100** in a direction non-perpendicularly disposed with respect to the inner surface of said second screen means and preferably at an oblique angle with respect to the surface of said second screen means such as an angle varying between approximately 20 to 30°. Since the screen means **22** is rotated at a relatively rapid angular velocity in the direction indicated by the arrow **102** it is possible to effect the foregoing merely by mounting the second screen means **100** stationarily within the apparatus **20.** The arrows **104** indicate the trajectory or path of travel of the material following exiting of same from the screen means **22.**

Although it is preferred that the scroll member-screen means assembly used in an apparatus of this invention preferably be cylindrical in configuration, the results of previous work show that satisfactory results can be obtained where the screen means is formed with an inner surface which, in cross-section, forms with a line disposed normal to the longitudinal axis of the screen means an included angle varying between approximately 75 and 105°. The included angle of the screen means **106** shown in FIG. **10** is approximately 83°. The mixture to be processed through the machine is fed between the screen means **106** and the scroll member **108** at the upper end thereof in the direction indicated by the arrow **110.** The fibrous material exits from said assembly in the direction indicated by arrows **112.** In FIG. **11** is shown an assembled screen means **114** and scroll member **116.** The inner surface of the screen means **114** forms with a line disposed normal to the longitudinal axis of said screen means an included angle of approximately 97°. In FIG. **11,** the material to be processed through the apparatus is fed between the screen means and the scroll member in the direction indicated by the arrow **118** while the fibrous material exits from said assembly in the direction indicated by the arrows **119.** With respect to the assemblies shown in FIGS. **10** and **11,** it will be understood that in both instances the screen means must rotate at a slightly faster angular velocity in a counter clockwise direction (or a slightly slower angular velocity when rotated in a clockwise direction), taken with respect to a plan view thereof, than the scroll member in order for the material to be processed through said assembly in the manner as aforedescribed. Although the longitudinal axis of the assembly shown in FIGS. **10** and **11** is disposed in the preferred vertical position, it is to be understood that beneficial results may be obtained when the longitudinal axis of an apparatus constructed in accordance with the subject invention is disposed vertically or horizontally or in any other position.

The results of work which has been done to date show that the screen means and scroll member may be formed with a hybrid configuration such as that shown in FIGS. **12** and **13.** For example, FIG. **12** shows a screen and scroll member assembly wherein the first end of the screen means has an inner surface which, in cross section, forms with a line disposed normal to the longitudinal axis of the screen means an included angle varying between approximately 90 and 105° while the

second end has an inner surface which, in cross-section, forms with a line disposed normal to the longitudinal axis of the screen means an included angle varying between 75 and 90°. As shown, the down stream portion of the first end, taken in the direction of flow of fibrous material mixture therethrough, is contiguous with the upstream portion of the second end. In FIG. **13,** is shown a screen means and scroll member assembly wherein the first end of the screen means has an axially extending inner surface of substantially constant radius while the second end has an inner surface which, in cross-section, forms with a line disposed normal to the longitudinal axis of the screen means an included angle varying between approximately 75 and 90°. It is preferred that the longitudinal length of the first end of the screen means shown in either FIGS. **12** or **13** should be of a sufficient length to produce a fibrous material thereon having a consistency of at least approximately 8 percent. The screen means and scroll member assemblies shown in FIGS. **12** and **13** are mounted, respectively, within second screen means **120** and **121.**

FIG. **3** is a schematic view, in cross-section, taken perpendicular to the longitudinal axis of the screen means **122** adjacent the end thereof receiving material to be processed therethrough. In FIG. **3** is shown a layer **124** of lightly compacted, relatively porous fibrous material deposited upon the inner surface of said screen means and extending a substantial distance between adjacent flights **126** which are integrally formed on the scroll member **128.** Additionally, in FIG. **3** is shown a mass **130** of densely compacted, relatively impervious fibrous material formed adjacent the leading surface or fibrous material engaging surface **132** of each helical flight **126** and between the edge **134** of each flight and a corresponding portion of the inner surface of said screen means **122.** A portion of the mixture being processed through the apparatus is represented generally by the numeral **136.** The arrows **138** represent, quantitatively, the relative amount of liquid exiting from the outer surface of the screen means **122.** For all practical purposes, no liquid exits through the screen means **122** which is in contact with the mass **130** of densely compacted, relatively impervious fibrous material. As viewed in FIG. **3,** the amount of liquid passing through the layer **124** of lightly compacted, relatively porous fibrous material decreases as the thickness of said layer increases and is a maximum where the fibrous material has been cleaned from the screen surface by one of the masses **130.** It is important that the degree of compaction of the layer **124** upon the inner surface of the screen means **122** be controlled sufficiently to permit liquid to pass therethrough if sufficient removal of liquid, particularly for high feed rates, is to be obtained. It will be understood that since the screen means **122** is moving in a counterclockwise direction slightly faster than the angular velocity of the scroll member **128,** the leading surfaces **132** of the flights **126** will contact the fibrous material deposited upon the inner surface of the screen means **122** as shown in FIG. **3.** Thus, each flight **126** upon initially coming into contact with the fibrous material deposited upon the inner surface of the screen means **122** further compacts the fibrous material at the point of contact or impact, removes same from the inner surface of the screen means, and operates to effect a rolling and wringing action thereof which further decreases the amount of liquid contained therein before the fibrous material is redeposited upon the inner surface of the screen means following which the foregoing action is repeated until the fibrous material exits from between the scroll member and the screen means. The portion **124A** of layer **124** represents that fibrous material from which additional liquid has been removed as a result of the rolling and wringing action as aforedescribed. Consequently, it will be appreciated that as the fibrous material moves along the inner surface of the screen means, liquid will continue to be removed from the fibrous material although the amount being removed will decrease as the action continues.

It is important that control of the fibrous material deposited upon the inner surface of the screen means be maintained at all times if optimum results are to be realized. For example, with prior art methods and apparatuses in which centrifuging was involved, it was found that under certain conditions the fibrous material would become tightly wedged between adjacent flights and could no longer be moved longitudinally of the screen means. This problem normally occurred after a predetermined amount of liquid had been removed from the fibrous material, normally when the consistency of the material exceeded approximately 8 percent. The occurrence of this bridging condition would stop up the apparatus thereby necessitating a complete shut down in order to remove the fibrous material from between the flights. It has been found, however, that means may be incorporated within an apparatus of this invention to preclude this condition. For a cylindrically shaped screen means and scroll member such means includes forming the helical flights in a manner whereby same form an included angle with a plane disposed perpendicular to the longitudinal axis of the scroll member of not more than approximately 55° and preferably not more than approximately 45°. At the present time, the most desired angle to be used is one varying between approximately 10 and 15°. The tendency of fibrous material to bridge between adjacent flights is further minimized by maintaining, at least adjacent the second end of the scroll member, the perpendicular distance between successive flights adjacent equal to at least approximately 0.03 and preferably 0.04 times the inner circumference of the screen means.

The included angle formed between the helical flights and a plane disposed perpendicular to the longitudinal axis of the scroll member varies somewhat from the above criteria where conically shaped screen means and scroll members are involved. For example, where a conically shaped screen means and scroll member similar to that shown in FIG. **10** are involved, the included angle may be increased up to a maximum of approximately 65° as the configuration of the inner surface of the screen means changes from an axially extending surface of substantially constant radius to a 75° conically shaped member. Where a conically shaped screen means and scroll member similar to that shown in FIG. **11** are involved, the maximum included angle is decreased from 55° down to approximately 45°. More specifically, as the configuration of the inner surface of the screen means changes from an axially extending surface of substantially constant radius to a 105° conically shaped member, the aforesaid included angle will decrease proportionally. In connection with the foregoing, it will be understood that effecting and maintaining control of the fibrous material deposited upon the inner surface of the screen means increases in difficulty when the configuration of the inner surface of the screen means departs from an axially extending surface of substantially constant radius to a conical shape

the angle of which varies between 75 and 90°. However, the problem of effecting control is decreased where a configuration of the inner surface of the screen means changes from an axially extending surface of substantially constant radius to a conical shape the angle of which varies from 90 to 105°. It will be understood that with the latter type of configuration more power is required to operate such an apparatus and, thus, the efficiency thereof is less. In view of the foregoing, it will be appreciated that the screen means and scroll assembly shown in FIG. **13** not only permits good control of the fibrous material along the screen means but also enables operation of same with reduced power consumption.

As previously indicated, the clearance maintained between the edges of the helical flights and the opposed inner surface of the main screen means, at least adjacent the end into which the fibrous material mixture is supplied to the main screen means and scroll member, equals approximately not more than 0.004 times the inner diameter of the screen means. Where the centrifugal force at which the fibrous material mixture is centrifuged is increased, it will be understood that the clearance factor becomes increasingly more important and, further, the amount of clearance should preferably be correspondingly decreased. Moreover, the importance of the amount of clearance involved decreases as the material proceeds toward the outlet end of the screen means. By this it is meant that the amount of clearance may increase from the inlet end toward the outlet end without unduly affecting the results obtained from an apparatus constructed in accordance with this invention. It will also be understood that the amount of clearance is also dependent, to some extent, upon the length of fibers contained within the fibrous material mixture. In this connection, the amount of clearance is somewhat proportional to the length of the fibers involved, i.e., a larger clearance may be used for a longer fiber length.

FIG. **14** is a graph showing the relationship between quantity of pulp processed through an apparatus constructed in accordance with the subject invention to the consistency of the product discharged from said apparatus. The apparatus used in obtaining the data shown in FIG. **14** was constructed generally in accordance with the apparatus shown in FIG. **1** except that the relatively short flights **64** were omitted and the opening **48** either was omitted or was not connected to a source of vacuum. The screen means **22** was 48 inches high and had an inner diameter of 36 inches. The scroll member **24** and 16 flights each of which formed an included angle with a plane disposed perpendicular to the longitudinal axis of the scroll member of approximately 40°. The following is a tabulation of test data obtained with respect to various kinds of pulp which were processed through the aforementioned apparatus:

Feed rate, g.p.m.	Feed consistency, percent (by wgt.)	Feed freeness, C.S.F.	Feed temp., °F.	Centrifugal force factor	Scroll-screen r.p.m. differential	Product O.D. solids percent (by wgt.)
Bleached Hardwood Kraft						
700	3.08	595	50	187	8	25.6
320	3.08	595	50	187	8	27.1
160	3.08	595	50	187	8	29.1
0	30.8	595	50	187	8	37.5
700	4.12	587	50	247	9	27.6
365	4.12	587	50	247	9	28.4
196	4.12	587	50	247	9	27.7
0	4.12	587	50	247	9	37.0
Unbleached Softwood Kraft						
700	2.39	686	120	247	9	25.4
330	2.39	686	120	247	9	28.6
165	2.39	686	120	247	9	31.5
0	2.39	686	120	247	9	37.6
Bleached Softwood Sulfite						
700	3.02	693	120	308	10	28.7
390	3.02	693	120	308	10	28.8
0	3.02	693	120	308	10	37.6
700	2.84	695	50	187	8	25.8
255	2.84	695	50	187	8	26.9
136	2.84	695	50	187	8	28.7
0	2.84	695	50	187	8	38.0
Bleached Softwood Kraft						
700	3.66	677	50	247	9	24.5
295	3.66	677	50	247	9	25.9
180	3.66	677	50	247	9	28.4
0	3.66	677	50	247	9	41.9
Bleached Redwood Kraft						
700	3.10	617	50	247	9	26.2
335	3.10	617	50	247	9	26.4
196	3.10	617	50	247	9	26.8
0	3.10	617	50	247	9	41.9
Bleached Softwood Pandia Kraft						
700	3.19	597	120	308	10	28.9
295	3.19	597	120	308	10	29.6
700	3.36	513	50	247	9	25.5
310	3.36	513	50	247	9	26.3
158	3.36	513	50	347	9	27.2
0	3.36	513	50	247	9	34.8
Corrugated Boxboard Broke						
700	3.85	503	160	308	10	30.5
285	3.85	503	160	308	10	31.1
0	3.85	503	160	308	10	42.5
Unbleached Softwood Kraft at 12.5 pH						
700	1.83	698	160	308	10	31.7
350	1.83	698	160	308	10	33.9
0	1.83	698	160	308	10	39.1

In FIG. **14**, the data obtained above for the bleached hardwood kraft that was processed through the apparatus of this invention at 187 times the force of gravity is shown in curve **138** while that which was processed at 247 times the force of gravity is represented in curve **140**. The data obtained above for unbleached softwood kraft which was processed at 247 times the force of gravity is shown in curve **142**. The data obtained above in connection with bleached softwood sulfite which was processed at 308 times the force of gravity is shown in curve **144** while that which was processed at 187 times the force of gravity is shown in curve **146**. The data obtained above with respect to the bleached softwood kraft which was processed at 247 times the force of gravity is shown in curve **148**. The data obtained above with respect to bleached redwood kraft which was processed at 247 times the force of gravity is shown in curve **150**. The data obtained above with respect to the bleached softwood pandia kraft which was processed at 308 times the force of gravity is shown in curve **152** while that which was processed at 247 times the force of gravity is shown in curve **154**. The data obtained above with respect to corrugated boxboard broke which was processed at 308 times the force of gravity is shown in curve **156**. Finally, the data obtained above with respect to unbleached softwood kraft at 12.5 Ph which was processed at 308 times the force of gravity is shown in curve **158**. From the foregoing, it will be readily apparent that a high consistency product was obtained from a low consistency pulp even at high feed rates of approximately 700 gallons per minute. It will be noted that although FIG. **14** shows feed rates only from 100 gallons per minute to 700 gallons per minute the data listed above was also obtained at zero feed rate, i.e., the consistency of the fibrous material contained within the apparatus following a complete shut-

down thereof. In this connection there nearly always remains within the apparatus a small amount of fibrous material following shut down thereof.

FIG. **15** shows the optimum centrifuge gravity forces and related power requirements for maximum product dryness at given feed rates. The information reflected in the graph shown in FIG. **15** was obtained by processing bleached hardwood kraft pulp through an apparatus constructed in accordance with the subject invention. The feed consistency of the bleached hardwood kraft varied between approximately 3.1 and 4.1 per cent. The Canadian Standard Freeness (C.S.F.) varied between 573 and 595. The Canadian Standard Freeness is a value, expressed in millimeters, indicating the ease with which a pulp will drain. The larger the C.S.F. number for a pulp means the easier it will drain. The temperature of the bleached hardwood kraft was 50°F. In this connection, it is to be noted that the product consistency increased with an increase in the centrifugal force at which same was being centrifuged up to a certain point and thereafter even though the centrifugal force at which same was being centrifuged was increased, the product consistency decreased.

One of the difficulties encountered in attempting to remove liquid from a fibrous material through the use of a centrifuge was that of experiencing relatively large losses of fiber in the effluent. In an attempt to reduce the amount of fiber being lost in the effluent, the size of the screen openings was reduced. Unfortunately, when the size of the screen openings was reduced sufficiently to reduce to an acceptable minimum the amount of fiber being lost in the effluent, it was found that the production capacity of the centrifuge was reduced so drastically that, from an economic viewpoint, same could not be considered for use in pulp mills for removing liquid from a fibrous material. It has been found, however, that the amount of fiber being lost to the effluent may be substantially reduced through the use of a second screen means disposed in encompassing relationship about the first screen means and generally spaced apart therefrom. For example, in FIG. **16** the line **160** shows the amount of fiber material passing with the liquid through the screen opening. The points indicated on line **160** represents the data obtained for various kinds of pulps. Thus, the line **160** represents the amount of fiber contained in the primary effluent, i.e., the effluent passing through the first or main screen means. The points shown between lines **162** and **164** represent the amount of fiber contained in the secondary effluent, i.e., the effluent passing through the second screen means. More specifically, the fiber content of a primary effluent having a consistency of approximately 0.21 per cent (approximately 17 lbs. of fibrous stock per 1,000 gallons of primary effluent) will, upon passing through the second screen means, be reduced to approximately 0.05 per cent consistency (approximately 4 lbs. of fibrous stock per 1,000 gallons of secondary effluent). Thus, the data shown between lines **162** and **164** represent the amount of fibrous stock contained in the secondary effluent. The second screen means used to obtain the data shown in FIG. **14** had conically shaped openings formed therein, the diameter of said openings increasing in a direction proceeding from the inner surface of said screen means to the outer surface thereof. The minimum diameter of said openings and the thickness of said screen means equalled approximately 0.125 millimeters. Although the use of a woven wire screen or a cloth screen as a part of the main screen means is normally to be avoided, it has been determined that same may be advantageously used in the second screen means.

Heretofore, the results obtained by processing a short fibered pulp (characterized as being produced by a two or three pass stone or refiner groundwood process) through the use of a continuous centrifuge were even more discouraging than those obtained with respect to the relatively long fibered pulps. For example, the consistency of short fibered pulp processed through a centrifuge remained essentially unchanged, i.e., where a feed consistency of approximately 3.5 per cent was involved the product consistency might increase only by an amount of 1 or 2 percent. It has been found, however, that liquid may be easily removed from a short fibered material by adding to said material a predetermined quantity of fibers which are relatively long in length, then impinging said mixture upon a rotating screen until substantially all of the fibrous material contained therein forms a layer on said surface while passing a portion of the liquid through said screen, followed by effecting a further removal of liquids from the mixture by cleaning the screen surface by moving the surface of a transporting member adjacent said screen surface while simultaneously producing and maintaining a mass of densely compacted, relatively impervious fibrous material adjacent one side of said member and between said surfaces and passing additional portions of the liquid through the screen. The quantity of relatively long fibers added to the short fibered material must be sufficient to effect the producing and maintaining of the mass of densely compacted, relatively impervious fibrous material while at the same time reducing the amount of fiber lost in the effluent. It has been found that where an insufficient amount of long fibers is involved, it is impossible to form the mass of relatively impervious fibrous material, unless the flight edges were located prohibitively close to the inner surface of the screen means, due to very low cohesiveness of the short fibered material. However, by adding even a small quantity of long fibered material, said mass is easily formed and maintained. Additionally, where short fibered material is involved, the amount of fiber lost in the effluent increases with a decrease in the length of the fibers. However, this condition is overcome by adding a small quantity of long fiber material since the long fibers assist in forming the layer of material while substantially reducing the amount of fiber passing through the screen openings. Good results are obtained when the amount of relatively long fibers equals at least approximately one-half of 1 percent, by weight, of all the fibrous material contained in the mixture. In FIG. **17** is shown the results of processing short fibered material in accordance with the method and apparatus of this invention by the addition of predetermined amounts of long fibered material therein. For example, curve **166** shows the results of processing an unbleached hardwood stone groundwood in accordance with the method and apparatus of this invention, said fibrous material including two per cent, by weight, of bleached softwood kraft. The fibrous material was centrifuged at 247 times the force of gravity. Curve **168** shows the results obtained by processing the same fibrous material at 187 times the force of gravity. The feed consistency of the fibrous material was approximately 3.62 percent and the temperature thereof was approximately 50°F. The ease with which the fibrous material could be drained was very poor, the Canadian Standard Freeness being only 82. It will be understood that different types of fibers have different lengths.

However, as used herein a short fibered material refers to a fiber produced by a two or three pass stone or refiner groundwood. Such fibers are short enough to pass through a 16 mesh screen. The size of the openings in a 16 mesh screen is approximately 1 millimeter or less. As used herein, a long fibered material refers to a fiber having a length of at least approximately 1.25 millimeters or longer.

The amount of liquid removed from a fibrous material is dependent, in part, upon the amount of time that the fibrous material is retained upon the inner surface of the rotating screen means. The amount of time required for fibrous material to pass through an apparatus constructed in accordance with the subject invention is dependent upon a number of factors. For example, the retention time is directly proportional to the length of the screen means. The retention time is also dependent upon the angle formed between the helical flights and a plane disposed perpendicular to the longitudinal axis of the scroll member and the difference in angular speeds between the scroll member and the screen means. In this connection, it will be noted that normally the angular velocity differential will by necessity be mechanically increased with a decrease in the flight angle as aforesaid if the retention time is to remain unchanged. Another factor affecting the retention time is the coefficient of friction of the screen and the coefficient of friction of the helical flight surfaces. In this connection, the retention time is increased with an increase in the coefficient of friction of the inner surface of the screen and decreased with a decrease in the coefficient of friction of the helical flight surfaces. Since the efficiency of the method and apparatus of this invention is dependent upon the retention period, in order to obtain good operating results the retention period should neither be too long or too short. Accordingly, the retention time upon the main screen means should be maintained between approximately 1½ seconds and 12 seconds and preferably between approximately 1½ seconds and 6 seconds. Excellent results are obtained where the retention time is between approximately 1½ seconds and 3 and 6/10 seconds. For many applications, it has been found that a retention period of approximately 3 seconds provides optimum results. In connection with references made herein with respect to the period of time that the fibrous material must be centrifuged or retained upon the main screen means, it is to be understood that such periods are based upon the amount of time calculated for the fibrous material to move along the inner surface of the main screen means from one end thereof to the other in which consideration is given only to the angular velocity differential existing between the screen means and the scroll member, the angle of inclination that the helical flights are formed upon the scroll member, and the length of said screen means. More specifically, the retention time periods referred to herein are based upon calculations which are made without regard to the effect of the force of friction.

Referring now to FIG. **1,** a fibrous material mixture is fed to the apparatus **20** through the feed inlet **26.** The fibrous material mixture falls upon the upper surface of the scroll member **24** and is immediately centrifuged radially outwardly to the inner surface of the screen means **22.** The fibrous material contained within the mixture is retained upon the inner surface of the screen means **22** while some of the liquid passes through the openings **52** formed therein. Since the scroll member and its associated helical flights are rotated in a counter clockwise direction as viewed from the first end at a slightly slower angular velocity than the counter clockwise rotating screen means, it will be understood that relative movement between the edges of the helical flights and the inner surface of the screen means is effected. Movement of the helical flight relative to the inner surface of the screen means functions to remove the layer of fibrous material retained on the inner surface of the screen means. The fibrous material is centrifuged at a force to permit a layer of fibrous material to be formed upon the inner surface of the screen means which will be sufficiently porous to permit the passing of a portion of the liquid through said layer of material and through the screen. This condition is met for most pulps where the centrifugal force varies within a range between approximately 70 to 650 times the force of gravity. As the helical flights move relative to the inner surface of the screen means, a mass of densely compacted, relatively impervious fibrous material is formed and maintained adjacent one side of the edge of the helical flight and between opposed surfaces of the helical flights and the inner surface of the screen means. This mass of relatively impervious material is used to remove continuously the layer of fibrous material disposed on the inner surface of the screen means. As the fibrous material is removed from the inner surface of the screen means, it moves along the adjacent surface of the helical flight or, following formation of said mass of relatively impervious material, along the mass of relatively impervious material following which same undergoes a rolling and wringing action due to the continued application of the centrifugal force all of which results in effecting a further removal of liquid from the mixture. The liquid removed from the material being fed into the apparatus **20** passes through the screen means **22** and into the liquid receiving means **28** from which same is continuously being removed. The fibrous material deposited upon the inner surface of the screen means passes along the inner surface of the screen means generally longitudinally and circumferentially thereof into the fibrous material receiving means area **30.** In the event it is desirable or necessary to wash or treat with a liquid the fibrous material following removal of a portion of the liquid therefrom, said washing or treatment is effected by feeding a liquid through the conduit **170** which is disposed in communication with the interior of the scroll member **24.** The liquid passes through the interior of the scroll means **24,** through an opening **172** formed in the radially extending plate **174** into the lower portion **176** of the scroll member **24.** The liquid then flows radially outwardly through a plurality of openings **178** formed in the outer surface of the scroll member **24.** The liquid passing through the opening **178** comes into contact with the fibrous material disposed on the inner surface of the lower portion of the screen means **22** and thence into the liquid receiving means **28.** The liquid collected within the liquid receiving means **28** is continuously removed through the opening **180.**

It will be understood that the fibrous material may be washed or treated with a liquid or treated with a gas by passing the liquid or gas through conduit **170** into the interior of the scroll member **24.** In certain instances, it is highly desirable that the gas used to treat a mixture does not become dissolved within the liquid being collected within the liquid receiving means **28.** This is effected by connecting the opening **48** to a source of reduced pressure (not shown) for the purpose of insuring

that all of the gas is moved along with the fibrous material.

It will be understood that where a second screen means **23** is used in conjunction with the screen means **22** as shown in FIG. **1**, suitable means **182** will be provided for collecting the liquid passing through said second screen means. The fibrous material deposited upon the inner surface of the second screen means **23** will pass into and be collected in the means **28.** Although the fibrous material so collected on the inner surface of the second screen means **23** need not be processed again through the apparatus **20,** it has been found desirable to do so in many circumstances for the purpose of increasing the consistency of the material collected on the inner surface of the second screen means.

Referring again to FIG. **10,** it will be noted that the assembled scroll member and screen means is concentrically mounted within a second screen means **170** which has a conically shaped inner surface. Additionally, it will be noted that the diameter of said second screen means **170** decreases in the direction of flow of the fibrous material through the apparatus. The purpose of forming the second screen means **170** in this manner is to increase the retention period that the fibrous material passing through the openings formed in the first screen means **106** is retained upon the inner surface of the second screen means **170.** By increasing the amount of time that the fibrous material is retained upon the inner surface of the second screen means **170,** it is possible to remove an increased amount of liquid thereby increasing the consistency of the fibrous material collected from the inner surface of the second screen means **170.**

In view of all of the foregoing, it will now be readily appreciated that a method and apparatus for continuously removing liquid from a mixture by centrifuging same has been described. Further, the method and apparatus of this invention permits the continuous removal of large quantities of liquid from a fibrous material mixture in a most efficient manner with equipment which is relatively inexpensive to manufacture. Additionally, a single centrifuge constructed in accordance with the subject invention may be used to handle large volumes of fibrous material mixture. The life of a centrifuge constructed in accordance with the subject invention has been considerably increased due to the reduced speeds at which same may be operated, the use of a relatively thick screen means which permits the efficient removal of liquid from a fibrous material mixture and, if desired, the coating of the flight edges with elastomeric material as specified herein. The method and apparatus of this invention is additionally enhanced through the use of a second screen means for substantially reducing the overall amount of fiber which would otherwise be lost in the effluent. Construction of the screen means is simplified through the use of an outer, encompassing perforated basket having a longitudinally extending recess formed therein and in which is disposed overlapping ends of an inner screen member. The method and apparatus of this invention is further enhanced by recognizing and controlling the amount of time that the fibrous material is centrifuged. Moreover, the method and apparatus of this invention may be beneficially used to remove liquid from a very low consistency fibrous material mixture and, by adding a small quantity of long fibered material, the method and apparatus may be used to remove liquid from a short fibered fibrous material.

It is to be understood that this invention is not limited to the exact methods and embodiments shown and described, which are merely by way of illustration and not limitation, as various other methods, forms and modifications will be apparent to those skilled in the art. For example, it will be understood that an apparatus of this invention may be used in combination with gravity or vacuum filters as well as with presses. Therefore, it is intended that the appended claims cover all such changes and modifications.

We claim:

1. A method of continuously removing liquid from an organic cellulose fiber-liquid mixture such as paper pulp comprising the steps of:

a. continuously feeding said mixture into one end of an annular first screen having openings formed therethrough, the minor dimension of each opening being between 0.3 and 3.0 mm;

b. rotating said first screen at a rate sufficient to develop a centrifugal force varying between 70 and 650 times the force of gravity;

c. impinging said mixture against the inner surface of said first screen thereby removing liquid from said mixture and passing said liquid so removed through the openings of said first screen while collecting fibers on the inner surface of said first screen;

d. continuously scraping the collected fibers from the inner surface of said first screen, rolling and wringing the scraped fibers, and redepositing same on the inner surface of said first screen while simultaneously urging the fibers toward the other end of said first screen and removing additional liquid from said mixture and passing said additional liquid through the openings of said first screen; and

e. continuously removing the fibers from the other end of said first screen.

2. A method as described in claim **1** including the step of impinging said mixture against the inner surface of said first screen and scraping fibers from said inner surface of said first screen, rolling and wringing the scraped fibers, and redepositing the rolled and wrung fibers on the inner surface of said first screen for a time period between 1½ to 12 seconds.

3. A method as described in claim **1** further comprising the step of entrapping and collecting those fibers passing through the openings of said first screen upon the inner surface of a second screen mounted concentrically about the outer surface of said first screen.

4. A method as described in claim **3** in which the step of entrapping and collecting fibers includes impinging said fibers and liquid passing through the openings of said first screen upon the inner surface of said second screen at an angle obliquely disposed with respect to the surface of said second screen.

5. A method as described in claim **1** in which the step of rotating said first screen includes rotating said first screen at a rate sufficient to develop a centrifugal force between 100 and 550 times the force of gravity.

6. A method as described in claim **1** in which the step of rotating said first screen includes rotating said first screen at a rate sufficient to develop a centrifugal force between 140 and 450 times the force of gravity.

7. A method of continuously removing liquid from an organic cellulose fiber-liquid mixture, such as paper pulp, in which a substantial portion of said fibers are minus 16 mesh in length, said method comprising the steps of:

a. adding to said mixture a quantity of fibers to form

a mixture in which at least approximately one-half of 1 percent of the fibers have a length of at least 1¼ millimeters;

b. continuously feeding said mixture into one end of an annular first screen having openings formed therethrough, the minor dimension of each opening being between 0.3 and 3.0 mm;

c. rotating said first screen at a rate sufficient to develop a centrifugal force varying between 70 and 650 times the force of gravity;

d. impinging said mixture against the inner surface of said first screen thereby removing liquid from said mixture and passing said liquid so removed through the openings of said first screen while collecting fibers on the inner surface of said first screen;

e. continuously scraping the collected fibers from the inner surface of said first screen, rolling and wringing the scraped fibers, and redepositing said rolled and wrung fibers on the inner surface of said first screen while simultaneously urging the fibers toward the other end of said first screen; and

f. continuously removing the fibers from the other end of said first screen;

8. A method as described in claim **7** including the step of impinging said mixture against the inner surface of said first screen and scraping fibers from said inner surface of said first screen, rolling and wringing the scraped fibers, and redepositing the rolled and wrung fibers on the inner surface of said first screen for a time period between 1½ to 12 seconds.

9. A method as described in claim **7** further comprising the step of entrapping and collecting those fibers passing through the openings of said first screen upon the inner surface of a second screen mounted concentrically about the outer surface of said first screen.

10. A method of continuously removing liquid from a low consistency organic cellulose fiber-liquid mixture such as paper pulp comprising the steps of:

a. centrifuging said mixture having a consistency, by weight, between one-half and twelve per cent at a centrifugal force between 70 and 650 times the force of gravity;

b. impinging the centrifuged mixture against the inner surface of an annular, rotating screen having openings formed therethrough, the minor dimension of said openings being between 0.3 and 3.0 mm, while simultaneously removing from said mixture a portion of the liquid and passing the liquid so removed through the openings of said screen;

c. continuing the centrifuging and impinging steps and simultaneously removing an additional part of said liquid and passing the additional part of liquid so removed through the openings of said screen by continuously scraping the fibers from the inner surface of said screen, rolling and wringing said scraped fibers, and redepositing same on the inner surface of said screen while simultaneously urging the fibers spirally along the inner surface of said screen; and

d. continuously removing the fibers from the inner surface of said screen.

11. A method as described in claim **10** further comprising the step of entrapping and collecting those fibers passing through the openings of said first screen upon the inner surface of a second screen mounted concentrically about the outer surface of said first screen.

12. A method as described in claim **10** in which the impinging step includes impinging the centrifugal mixture against the inner surface of an annular, rotating screen having an effective open area of at least 10 percent.

13. A method of continuously removing liquid from an organic cellulose fiber-liquid mixture such as paper pulp comprising the steps of:

a. continuously feeding said mixture into one end of an annular rotatably mounted screen having openings formed therethrough, the minor dimension of each opening being between 10 and 50 times the diameter of the fibers of said mixture;

b. rotating said screen;

c. impinging said mixture against the inner surface of said screen thereby removing liquid from said mixture and passing said liquid so removed through the openings of said screen while collecting fibers on the inner surface of said screen;

d. continuously scraping the collected fibers from the inner surface of said screen, rolling and wringing the scraped fibers, and redepositing same on the inner surface of said screen while simultaneously urging the fibers toward the other end of said screen and removing additional liquid from said mixture and passing said liquid through the openings of said screen; and

e. continuously removing the fibers from the other end of said screen.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,814,246 Dated June 4, 1974

Inventor(s) Peter C. Wilson et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 15, Line 66, under the heading "Feed consistency, percent (by wgt.)", change "30.8" to --3.08--.

Column 16, Line 23, under the heading "Centrifugal force factor", change "347" to --247--.

Signed and sealed this 17th day of December 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents