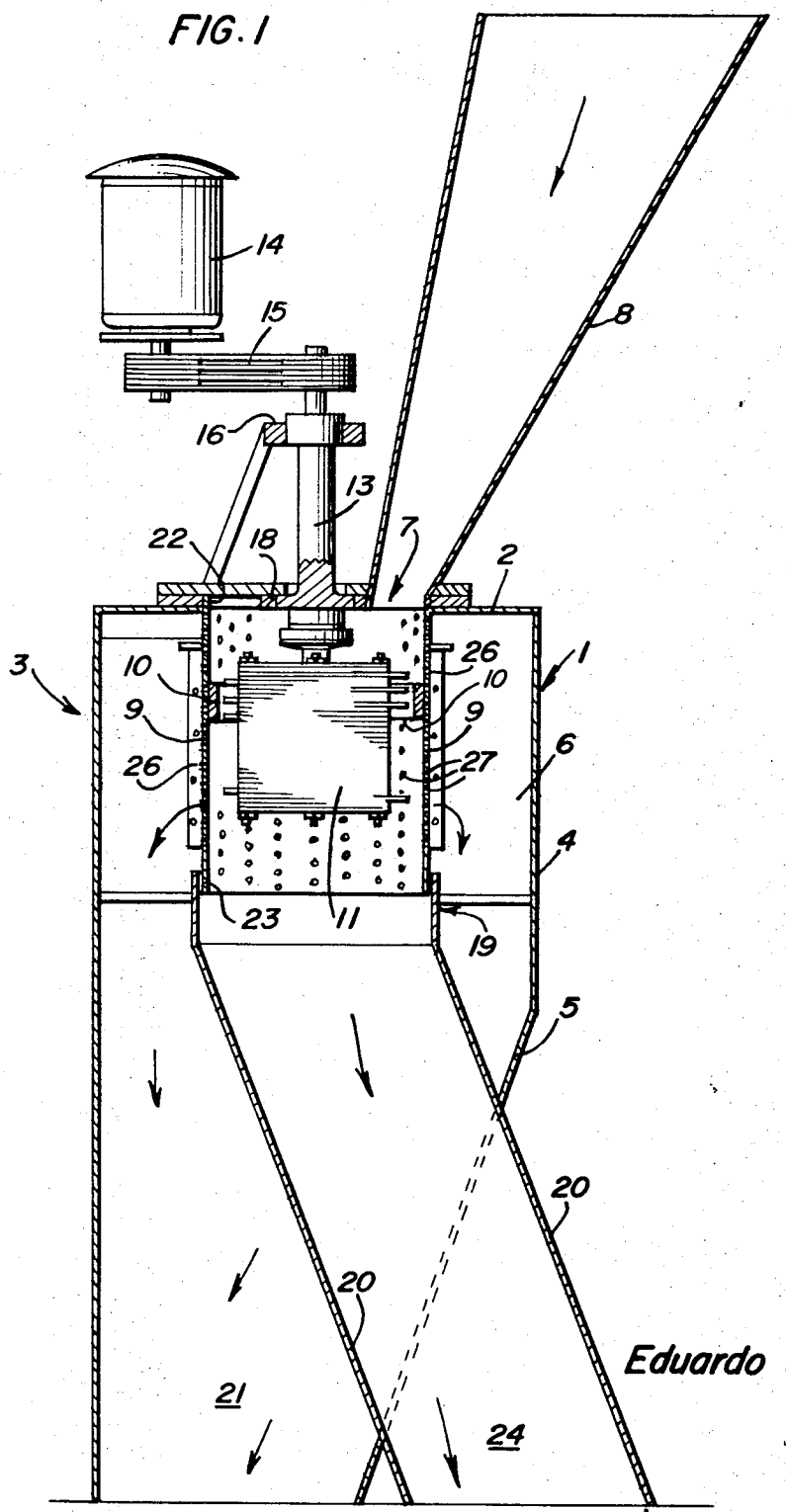
Nov. 3, 1970 E. J. VILLAVICENCIO 3,537,142

APPARATUS AND METHOD FOR PROCESSING FIBROUS STALKS

Filed July 9, 1968 2 Sheets-Sheet 1

FIG. 1



Eduardo J. Villavicencio
INVENTOR

BY William Wheeler Jr.
ATTORNEY

Nov. 3, 1970 E. J. VILLAVICENCIO 3,537,142

APPARATUS AND METHOD FOR PROCESSING FIBROUS STALKS

Filed July 9, 1968 2 Sheets-Sheet 2

FIG. 2

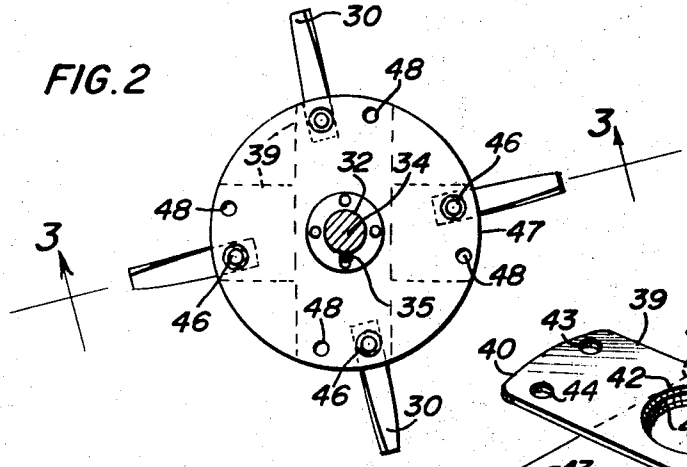


FIG. 4

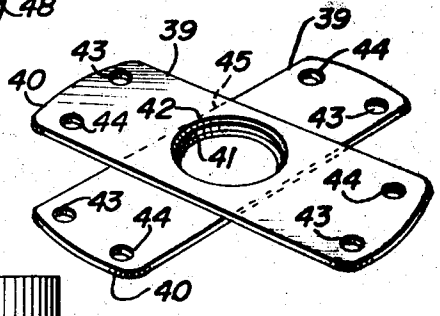
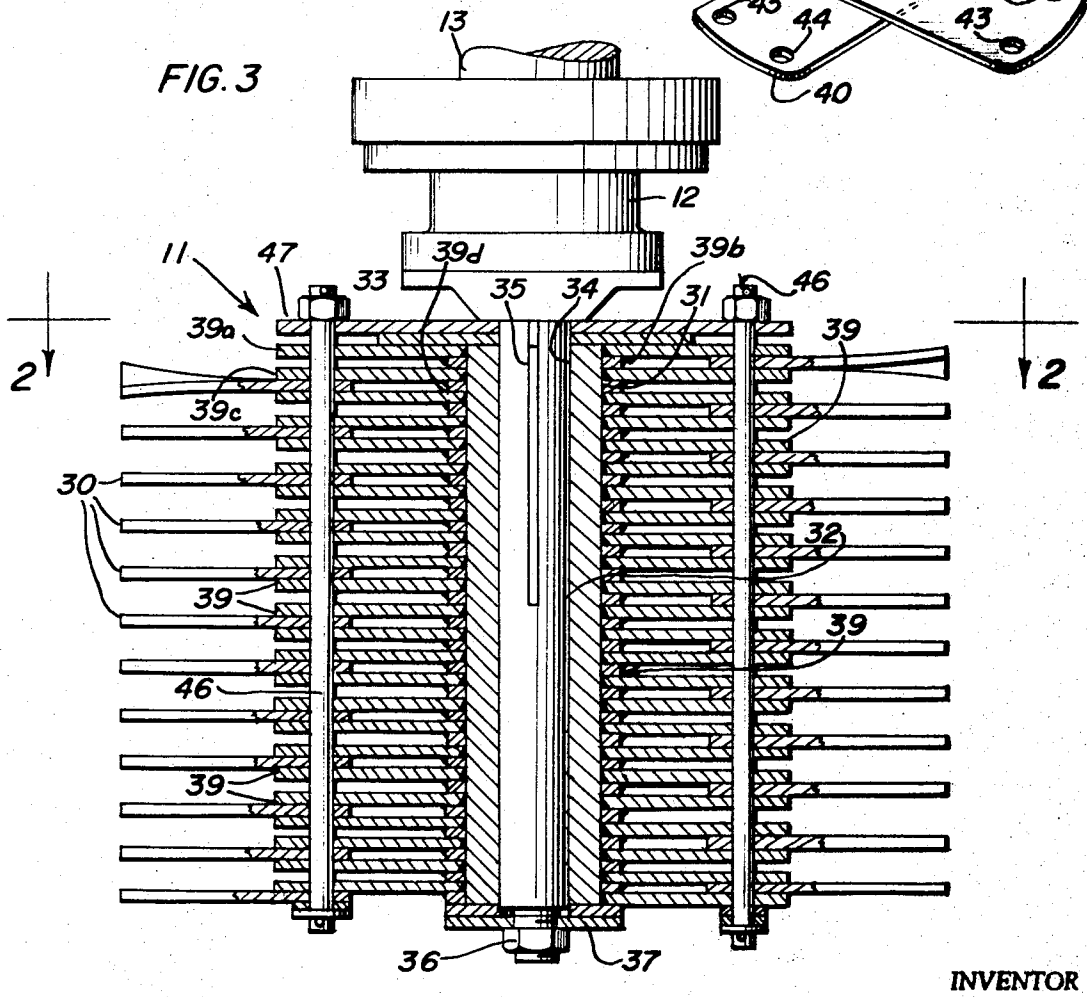


FIG. 3



INVENTOR

Eduardo J. Villavicencio

BY William W. McDonald Jr.

ATTORNEY

United States Patent Office 3,537,142 Patented Nov. 3, 1970

3,537,142

APPARATUS AND METHOD FOR PROCESSING FIBROUS STALKS

Eduardo Joel Villavicencio, Mexico City, Mexico, assignor to W. R. Grace & Co., New York, N.Y., a corporation of Connecticut

Filed July 9, 1968, Ser. No. 743,344
Int. Cl. D01b 1/30
U.S. Cl. 19—26 6 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for processing fragments of crushed fibrous stalks containing pith to separate the pith and the fiber including a vertically disposed casing forming a closed chamber with a feed opening at the top and an outlet at the bottom, a cylindrical screeing element inside said casing and mounted so that the feed opening leads to the interior of the screening element, a rotor assembly coaxially mounted inside the screening element and having a plurality of hammers laterally extending to close proximity with the screening element and arranged to centrifugally and helically propel fragments to be processed through the treating zone defined by the cylindrical screening element and separate the pith fraction from the fiber fraction in the course of the travel through the screening element. According to the method the fragments are centrifugally and helically propelled and gravity fed through the treating zone defined by a vertical cylindrical screening element, in the absence of any extraneous artificially created air pressure differentials, so that a layer of axially aligned oriented fragments is formed on the inner surface of the screening element and the pith is separated by the rolling and rubbing action of the fragments on each other and is forced to the exterior of the screening element by centrifugal forces applied.

This invention relates to an apparatus and method for processing fibrous vegetable materials so as to separate them into two portions, one of which is substantially pith free and the other of which contains a major proportion of the original pith.

The apparatus and method of this invention separates fiber-containing stalk materials into fiber and pith fractions. The separated fractions can be used as desired. For example, the fiber portion can be used for pulp in the paper industry or as a basic raw material for making hardboard of various types. The pith fraction can be used as animal feed, chicken litter, animal bedding, or can be burned as fuel in industrial or heating boilers. The apparatus and method of this invention is especially suitable for obtaining substantially pith-free fiber from sugarcane bagasse for paper-making purposes, but its use is not restricted to sugarcane bagasse alone. The apparatus and method is also suitable for processing other material such as straw, flax, rice hulls, and similar vegetable matter.

The fibers of such materials are suitable for the production of pulp for use in paper or alpha-cellulose production, or other purposes, but their commercial use in such fields has been handicapped by the presence of varying amounts of pith and other non-fibrous material which is intimately admixed with the fibers, and which has little or no value in such pulps. Its separation from the fibers by presently known methods is too costly to be practical.

Bagasse is the name given to the cellular material which forms the remains of sugarcane after the sugar-containing juice has been extracted. In processing raw sugarcane, the cane stalks are first fed into a crushing roller and then into a series of roller type mills which squeeze

the cane and force the sugar-containing juice from the broken cells for further processing and refining treatment. After substantially all of the sugar-containing juice has been expelled from the cane, the remainder, which is then called bagasse, consists of relatively long fibers of substantially pure cellulose together with a large amount of pith, which consists of broken cells and other materials, as well as 2 to 3% by weight of retained sugar. At this stage, the moisture content of the bagasse is relatively high, generally ranging between 48 and 52% by weight. Heretofore, it has been customary to use this bagasse as a fuel for heating and refining the expressed juices, but this is relatively inefficient because of the high percentage of retained moisture in the bagasse. It has been recognized that the long cellulosic fibers retained in bagasse have a high degree of potential utility for such purposes as paper pulp and the like, but the presence of the retained pith has heretofore prevented the effective and economical utilization of the fiber because of the detrimental effect of the retained pith on the finished product. For example, if it is attempted to make paper from a pulp containing a large amount of retained pith, the paper is brittle and of extremely poor quality.

Heretofore, most processes for cleaning and depithing bagasse have been designated as either "wet" or "dry."

Wet processes usually consist of subjecting bagasse, in the form of a suspension or slurry having from about 1 to 9% solids, to screening and refining, and if pulp is desired, to cooking and digesting with chemicals and at high temperatures. Such a wet process requires large amounts of power and a high capital investment per tone of production. Yields usually are low and in the neighborhood of 35 to 55% of usable fiber based on the total starting quantity of bagasse. Thus, while the quality of the finished fiber can be of the best, total cost of production can be prohibitively high.

Dry processes are usually characterized by their relative simplicity and low initial costs, and usually involve the use of some sort of screening to separate fine from coarse particles, and the use of rod or hammer mills or disc refiners to disengage the pith from the fibers. Fibers so formed are usually possessed of low length vs. diameter characteristics, and the final mass of fibers includes a high proportion of fines. The low quality of the fiber is offset only partially, however, by the low production costs.

It is an important object of the present invention, therefore, to provide novel and improved methods of and means for treating and processing bagasse and other vegetable fibrous materials so as to obtain a maximum yield of high quality depithed an decorticated fiber of optimum length and strength characteristics at a minimum cost.

The foregoing and other objects, characteristics, and advantages of the present invention will be more clearly understood from the following detailed description thereof when read in conjunction with the accompanying drawing, in which:

FIG. 1 is a side view, partially in section, schematically illustrating the general arrangement of the improved apparatus for processing bagasse in accordance with the present invention;

FIG. 2 is a top plan view of the new and improved rotor assembly used for processing bagasse in accordance with the present invention;

FIG. 3 is a sectional view taken on line 3—3 of FIG. 2 with some parts shown in full elevation for easier understanding; and

FIG. 4 is a perspective view illustrating the mode of assembling certain elements of the rotor assembly of FIGS. 2 and 3.

It is to be understood that the principles of the present invention, although described herein in connection with the processing of fresh bagasse (i.e., bagasse containing

48–52% moisture), are also applicable to other mature stalk materials of a fibrous nature, such as bamboo, sorghum, corn stalks, broom straw, flax, hemp, sisal stalks, etc.

Referring to FIG. 1 which shows in schematic form the general arrangement of the apparatus of this invention, the reference number **1** denotes an outer casing having sidewalls **3** and **4**, a top wall **2** having a feed opening **7** therein, and an inclined lower wall **5** leading to a pith outlet **21**. The casing **1** forms a closed chamber **6** except for the feed opening **7**, fiber outlet **24** and pith outlet **21**. The horizontal cross section of casing **1** can be of any desired shape, i.e., circular, square, rectangular, or other polygonal arrangement. The only criterion is that there be sufficient space in the closed chamber **6** to accommodate the other elements of the apparatus which are more fully described hereinafter. In one present embodiment of the invention, the horizontal cross section through sidewalls **3** and **4** is approximately a 6 foot square, whereas the cross section through sidewalls **3** and **5** is rectangular, gradually diminishing to a suitable width at the ultimate exit end (not shown) below the exit designated as **21**.

Mounted at any suitable place within the closed chamber **6** is a screening element **9** which is an essentially circular cylinder open at its upper end **22** and lower end **23**. The upper end **22** is snugly fitted within the top wall **2** of the casing **1** and is arranged so that the feed opening **7** in the top wall of the casing leads to the interior portion of the screening element **9** so that material to be processed can be fed through conduit **8** through the opening **7** and into the treating zone defined by the screening element. In typical cases the screen will comprise two semicylindrical halves suitably bolted together at the ribs **26**. In the presently preferred embodiment the screening element **9** is 36 inches high and has an inside diameter at its upper end **22** of about 38⅞ inches gradually tapering to an inside diameter of about 38 inches at its lower end **23** and is perforated throughout with holes or openings **27**. The latter are typically 5/32 inch in diameter or 5/16 inch in diameter, in either case sufficient in number to provide a free area approximately 28 to 33% of the total inside surface area of the cylindrical screening element **9**.

Mounted inside of the screening element is a rotor assembly generally designated as **11** in FIG. 1 and shown in detail in FIGS. 2, 3 and 4. The rotor assembly is driven by connection to a main drive shaft **13** which is in turn powered by the motor **14** and a typical V-belt and pulley system generally designated as **15** in FIG. 1. The rotor assembly is maintained in axial alignment with the axis of the screening element **9** by means of bearing blocks **16** and **18**. The rotor assembly includes a number of laterally extending hammers and other features of construction described in more detail in connection with FIGS. 2, 3 and 4 below. In one presently preferred embodiment of the invention the screening element **9** is tapered slightly from its upper end **22** to its lower end **23** so that the clearance between the hammers at the upper end is slightly greater than the clearance between the hammers and the screen at the lower exit end of the device. This same end result can be accomplished, if desired, by varying the length of the hammers in the device by making the hammers at the lower end slightly longer than the hammers at the upper end of the rotor assembly. In the presently preferred embodiment, the taper is about ¼ inch for each 10 inches of length of the screening element with a final clearance of approximately ¼ inch between the screening element and the lowest hammers of the rotor assembly. This taper assures substantially uniform working of the material being processed as it passes downward through the treating zone defined by the screening element **9**, since the clearance between the screening element and the ends of the hammers gradually decreases as the volume of material being worked decreases as a result of the separation of the pithy element as the material progresses through the treating zone. In one embodiment of the invention the screening element includes a defibrating bar designated as **10** in FIG. 1 which, in conjunction with the hammers of the rotor assembly, will break up and chop into shorter lengths any overly long fibrous fragments passing through the treating zone. The defibrating bar extends all the way around the inner circumference of the screening element **9** and is secured thereto in any suitable manner, e.g., by welding. It is usually located in the upper ⅓ of the overall length of the screening element **9**.

A fiber recovery conduit **19** is connected to the lower end of the screening element **23** and has inclined walls **20** which lead to a suitable fiber recovery means (not shown) below the exit **24** shown in FIG. 1.

Turning now to FIGS. 2, 3 and 4 and especially FIG. 3, it is seen that the rotor hub **31** has a tapered bore **32** and a keyway (see dotted lines in FIG. 2) which mates respectively with the tapered end of the rotor drive shaft **34** and a spline **35**. The hub **31** includes an enlarged head portion **33** which is integral therewith or integrally connected thereto. The rotor drive shaft **34** is connected to the main drive shaft **13** by suitable connecting and bearing means **12**. The rotor drive shaft **34** is secured to the rotor hub by nut **36** and washer **37** at the lower end of the rotor hub. The rotor assembly includes a plurality of support plates **39** which are shown in greater detail in FIG. 4. Each plate is substantially rectangular except for its preferably rounded ends **40**, which are preferably (but not necessarily) obtained by machining after assembly for better dynamic balance. Each plate has a central opening **41** which permits the plate to be slip fitted onto the rotor hub **31**. The opening is partially countersunk with tapered portion **42** which accommodates a welding bead for securing the plate to the rotor hub. Each plate further includes diametrically opposed holes **43—43** and **44—44**. The center-to-center distance between holes **43—43** and holes **44—44** is preferably different in order to give longer hammer knife life. Thus, for example, the distances between holes **43—43** can be 19 inches and between holes **44—44** can be 20 inches. After the device has been in operation for a period of time with the hammers secured in holes **43—43** the ends of the knives will wear substantially uniformly to a point where the device can be shut down and the hammers transferred to the holes **44—44** where they will again extend to close proximity to the screening element and the overall knife life can be extended to approximately double the normal life. The plurality of support plates **39** are assembled onto the rotor hub **31** in alternating right angle directions to each other as schematically illustrated in FIG. 4 and shown in detail in FIGS. 2 and 3. The support plates **39**, which are fabricated from steel, can be of any suitable thickness but are preferably from about ¼ to about 1 inch thick and most especially about ½ inch thick. As the plates are assembled onto the rotor hub **31** they are welded thereto at the tapered countersink **42** as previously explained and are also welded to each other along the mating accessible edges such as edges **45** shown in the schematic illustration of FIG. 4, resulting in a very unitary overall structure.

The rotor assembly also includes a plurality of hammers designated as **30** in FIGS. 2 and 3. In the apparatus of this invention there is one hammer **30** for each support plate **39**. Each hammer is displaced at an angular distance of 90 degrees from each hammer, if any, above and/or below it in the rotor assembly. Thus, as shown in FIG. 3, the hammer associated with the initial plate **39*a*** will be below the first plate and will normally extend to the right hand side of the figure, the hammer for the second plate **39*b*** will be below and will extend normally directly to the rear of the figure, the hammer for the third plate **39*c*** will be below the plate and will extend to the left of the figure, and the hammer for the fourth plate **39*d*** will be

below and will normally extend toward the viewer of FIG. 3. The same sequence follows for the remaining hammers in the assembly. The hammers are held in place by connecting bolts **46** or other equivalent structure which extend through the entire assembly. The hammers may be held in fixed position, if desired, but are preferably freely pivotal about the axis of bolts **46**. The individual hammers are also made of steel and are of the same thickness as the plates **39**. The hammer blade may be of any desired shape but is typically rectangular. The hammers are chosen of suitable length so that the tip will extend in close proximity to the surrounding screening element **9** as described in connection with FIG. 1.

An important feature of the present invention involves twisting the first four hammers closest to the feed opening **7** leading to the rotor assembly so as to impart a positive feeding action and a helical path to the material being processed in the apparatus. The angle of twist is critical. It must be not less than about 10 degrees and not more than about 24 degrees. A preferred range for the angle of twist of the first four hammer tips is from about 12 degrees to about 22 degrees in the intended direction of rotation of the rotor assembly past the feed opening **7**. Twist angles in the lower portion of the range, e.g., 12 degrees, are most especially preferred. If the twist angle is too great, for example 45 degrees, the material to be processed will be fed much too fast and the hammer knives will wear extremely fast. On the other hand, if there is no twist for the initial hammers the machine does not operate at peak efficiency since there is insufficient feeding to utilize its full working capacity.

The rotor assembly also includes a cover plate **47**, the major purpose of which is to prevent material being fed from gravitating toward the axis of the rotating assembly and not receiving the necessary working. The cover plate has four holes denoted **48**, all centered on the circumference of a circle with its center at the axis of the drive shaft **32** and having a diameter equal to the center-to-center distance between holes **43** in the plates **39**, and four holes **49** centered on a circle having a diameter equal to the center-to-center distance between holes **44**. Only four holes are occupied in any one time with the blade holding bolts **46**. As explained previously, when the knives have been used for a period of time to wear down their tips, the assembly is dismounted and the knives are replaced in the holes in the larger diameter circle on which the holes **48** or the holes **49** are located.

In operation of the apparatus of this invention fragments of crushed fibrous stalks to be processed are fed via the chute **8** into feed opening **7** and are processed in the treating zone defined by the rotor assembly **11** and the screening element **9**. The preferred initial twist of the initial four hammers in the rotor assembly imparts a helical flow path to the material being processed as it proceeds vertically downwards through the treating zone. The rotating blades of the rotor assembly centrifugally fling the fragments against the screening element where a layer of axially aligned fibrous fragments will be formed on the inner surface of the element. These fragments are then rolled and rubbed on their axes over and across each other so as to break open the fragments and expose the pith to be removed. Since there are no extraneous artificially created air currents in the device of this invention (in view of the substantially completely closed casing **1**) the fragments are very uniformly oriented so that the fibers tend to lay lengthwise on the inner surface of the screening element with their axes in alignment with the axis of the rotor assembly. The whirling hammer blades which impart the centrifugal and helical forces to the material, in effect push the separated pith portion through the screen in a downward direction for positive rejection without the necessity for any suction or other auxiliary recovery forces. The vertical alignment of the apparatus of this invention further results in reduced power consumption in view of the assistance derived from the forces of gravity which further aid in feeding the material being processed through the treating zone. This vertical gravity assistance feed also eliminates the need for any metering or other means for precluding plugging of the apparatus. The operation of the apparatus of this invention does not require the use of any washing fluids, nor is the use of the same desirable. This makes the apparatus of this invention much simpler and considerably more efficient than known prior art devices.

The apparatus and method of this invention provide very good yields of pith-free fiber at excellent power efficiency not heretofore possible. For example, fresh bagasse processed in the apparatus of this invention has been consistantly treated to yield a fiver fraction containing 95 to 97% fiber (soluble-free basis) in the fiber fraction and a pith fraction containing only about 7 to 8% of fiber (soluble-free basis). Moreover, a prototype of the apparatus of this invention has been found on testing to yield 150 tons of goods, usable, clean fiber per day (24-hour shift) with a power consumption of 100 horsepower on the main shaft, giving an overall efficiency of about 0.67 horsepower per ton. In comparison, in a mill such as that described in U.S. Pat. 3,317,964 (in which the inventor of the present invention is named co-inventor) the yield of good, usable, substantially pith-free fiber is only 100 tons per days in an apparatus which requires 150 horsepower on the main shaft and, in addition, requires 25–30 horsepower for the air fan and several horsepower for the pith discharge screw. This gives an overall efficiency of about 1.8 horsepower per ton. In addition, the apparatus of this prior patent requires metering of the feed into the treatment zone, a requirement which is eliminated in the separating unit of the present invention. Further, a typical bagasse depithing unit such as described in U.S. Pat. 3,299,447 will produce an average of about 60 tons per day of good, usable fiber at an efficiency of approximately 4 horsepower per ton recovered. Moreover, in comparative runs comparing the efficiency of the present device and that of U.S. Pat. 3,299,447, it has been found that the total hammer life in using the apparatus of this invention has been extended from an average of about 3 days in each direction of rotation (i.e., a total of 6 days) in the device of said patent to an average of about 30 to 40 days at one setting and an additional 30 to 40 days (by transferring the slightly worn knives to the outer diameter holes **49** as described above in connection with FIGS. 2 and 3) or an overall total of about 60 to 80 days. In these comparative runs each mill was run 6 days a week, 24 hours a day.

It is seen from the foregoing that the present invention has provided a greatly improved apparatus and method for separating the pith from the fiber of crushed fibrous stalks and in particular for separating pith from crushed fragments of fresh bagasse (i.e., bagasse containing approximately 50% moisture, sometimes known as "green" bagasse).

What is claimed is:

1. Method for processing crushed fibrous stalks containing pith, to separate the pith and the fiber, comprising gravity feeding fragments of the crushed fibrous stalks into the upper end of a vertically disposed cylindrical screening element surrounded by a closed chamber and having a substantially circular cross section tapering inwardly toward the lower end of said screening element; imparting a helical flow path to the said fragments and centrifugally forcing them against the inner surface of the said screening element by means of rotating agitating members, while precluding any extraneous artificially created air pressure differences, to thereby form a layer of the fragments on the interior surface of the screening element, substantially all of which are oriented with their axes coaxial with the screening element axis; continuing to feed the said fragments toward the lower end of the screening element by continuing contact with the rotating agitating members and because of the forces of gravity

acting thereupon while separating the pith therefrom by the rolling and rubbing action of the fragments on each other; gradually increasing the working on said fragments as they progress from the upper inlet end to the lower exit end of the tapered screening element forcing the separated pith particles to the exterior of the screening element by the centrifugal forces on the helically moving mass; and separately recovering substantially pith-free fibers containing less than about 5% pith (soluble-free basis) from the lower exit end of the screening element.

2. Apparatus for processing crushed fibrous stalks containing pith to separate the pith and the fibers, comprising:

(a) a vertically disposed casing forming a closed chamber except for a feed opening in the top portion of the casing and an outlet at the bottom of the chamber,

(b) a screening element having a substantially circular cross section, open at both ends, inside said casing, with its upper end at about the same plane as the top portion of said casing and mounted so that the feed opening in said casing leads to the interior of the screening element,

(c) conduit means at the lower end of the screening element for receiving and separately removing processed material exiting from the said lower end,

(d) a rotor assembly mounted coaxially with and inside of said screening element, said rotor assembly comprising a plurality of rotor plates, one hammer for each of said rotor plates laterally extending to close proximity with the screening element with the distance between the ends of the hammers and the screening element gradually decreasing from the upper end to the lower end of the screening element and the rotor assembly, said hammers being arranged so that each is displaced at an angle of 90 degrees with respect to the hammer on the next succeeding and/or next preceding plate, the first four of said hammers next adjacent the feed opening to the interior of the screening element being twisted at an angle in the range of from about 10 to about 24 degrees in the direction of the intended rotation of the rotor assembly, and

(e) drive means for rotating said rotor assembly.

3. Apparatus as defined in claim 2 wherein the screening element is tapered inwardly towards its lower exit end.

4. Apparatus as defined in claim 3 wherein the twist angle of the first four hammers is about 12 degrees.

5. Apparatus as defined in claim 3 including second separate conduit means for feeding material to be processed into the feed opening of the casing.

6. Method for processing crushed fibrous stalks containing pith, to separate the pith and the fiber, comprising gravity feeding fragments of the crushed fibrous stalks into the upper end of a vertically disposed cylindrical screening element surrounded by a closed chamber and having a substantially circular cross section; imparting a helical flow path to the said fragments and centrifugally forcing them against the inner surface of the said screening element by means of rotating agitating members laterally extending to close proximity with the screening element, while precluding any extraneous artificially created air pressure differences, to thereby form a layer of the fragments on the interior surface of the screening element, substantially all of which are oriented with their axes coaxial with the screening element axis; continuing to feed the said fragments toward the lower end of the screening element by continuing contact with the rotating agitating members and because of the forces of gravity acting thereupon while separating the pith therefrom by the rolling and rubbing action of the fragments on each other; gradually increasing the working on said fragments as they progress from the upper inlet end to the lower exit end of the screening element by providing a gradually decreasing distance between the ends of the rotating agitating members and the screening element from the upper end to the lower end of said element; forcing the separated pith particles to the exterior of the screening element by the centrifugal forces on the helically moving mass; and separately recovering substantially pith-free fibers containing less than about 5% pith (soluble-free basis) from the lower exit end of the screening element.

References Cited

UNITED STATES PATENTS

2,286,545	6/1942	Hoehn	241—188 XR
2,344,611	3/1944	Harris	241—86
2,812,552	11/1957	Horton et al.	19—90
3,299,477	1/1967	Gunkel	19—90

DORSEY NEWTON, Primary Examiner