Jan. 11, 1966 P. M. STRANG ETAL 3,228,067

METHOD AND APPARATUS FOR CARDING FIBER BY FLUID MEANS

Filed Dec. 20, 1962 2 Sheets-Sheet 1

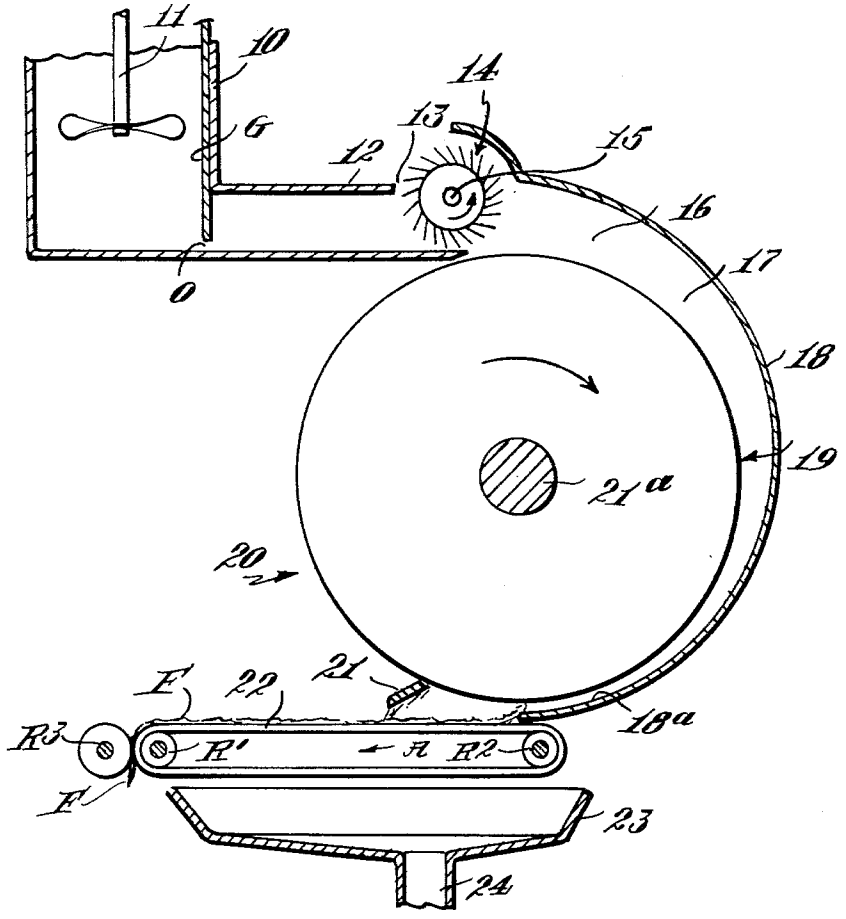


Fig. 1

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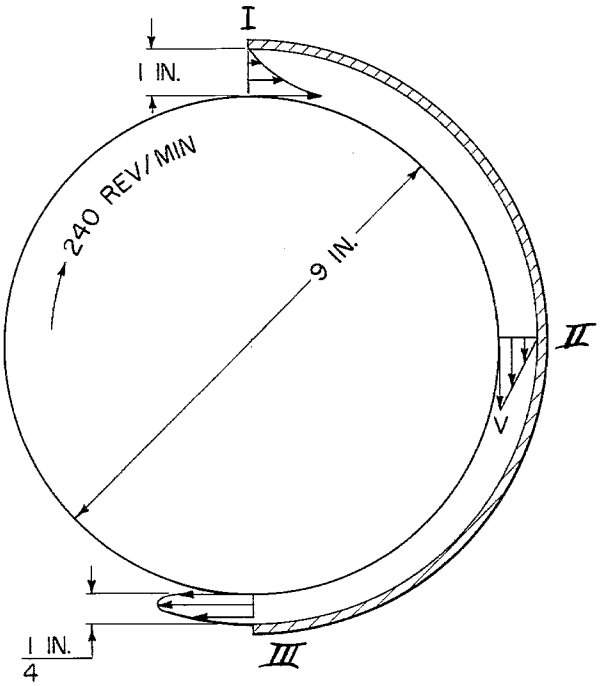


FIG. 2

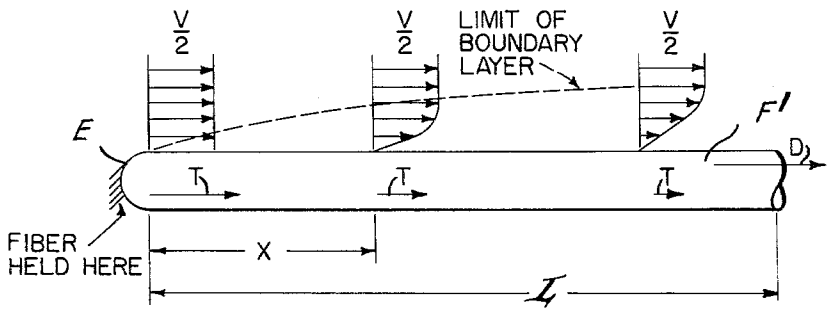


FIG. 3

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METHOD AND APPARATUS FOR CARDING FIBER BY FLUID MEANS

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11 Claims. (Cl. 19—66)

This invention pertains to the preparation of fibrous material for use, for instance, in the manufacture of fabrics, including those generally classified as "textiles," as well as those recognized as "papers," and relates more especially to a method of and apparatus for so treating fibers, for example (but without limitation), cellulosic fibers, either natural or synthetic, as to separate and straighten the fibers by hydraulic forces while arranging them in predominantly parallel relation, and wherein, during the treatment, the fibers are suspended in a liquid medium, usually water.

It is, of course, customary in the textile industry to subject fibrous material to a mechanical "carding" operation, wherein the fibers are subjected to the action of relatively moving toothed elements, with the primary purpose of separating and straightening individual fibers and, as more or less incidental thereto, arranging them in generally parallel relation. In some instances, it has been proposed to supplement the action of such toothed elements by appropriately created and directed air currents. It has also been proposed to spin textile fibers by the use of air currents and, as an incident to such method, to subject the fibers to air jets or currents so directed as to separate the fibers and allegedly to arrange them in parallel relation immediately before twisting them to form a yarn, but so far as is known, it has not heretofore been proposed to separate and straighten individual fibers and dispose them in generally parallel relation so as to form a layer of substantially uniform thickness, solely by the action of flowing fluid, in particular a liquid of a viscosity approximating that of water or air.

In accordance with the present invention, use is made, it is believed for the first time, of certain well-known properties of flowing liquid to separate and straighten fibers and to lay them down to form a uniform layer, if desired, of but a few fibers in thickness and of substantial width, all as a continuous operation thereby providing carded fibers in condition for spinning, and which, if desired, may be delivered directly to spinning apparatus, either of the usual mechanical type or of the hydraulic type. The fibrous layer or film, produced as above suggested, if not of sufficient thickness itself for the intended purpose, as formed, may be assembled with other similar layers to form a multiply material whose constituent fibers are substantially straight and parallel and which are held in assembled relation cohesively, adhesively or otherwise, for the production of certain kinds of unwoven fabrics of the type wherein fibers or strands, according to prior methods, have been disposed in parallel relation by mechanical means.

Generally stated, the present method involves the steps of suspending the selected fibrous material in a body of water, which may contain a dispersing or deflocculating chemical; agitating the liquid so that the fibers are loosened and, to a substantial degree, separated; then delivering the liquid with the suspended fibers into a sluiceway or channel along which it flows into the field of action of means, for example, one or more slowly moving toothed rollers, operative to retard masses of unseparated fiber relatively to the liquid so as to permit such masses to be further disintegrated by the flowing liquid. The liquid, with the suspended, separated fibers then enters

the receiving end of a converging channel between the convex peripheral surface of a rotating imperforate cylindrical drum which defines the inner boundary of a flowing liquid stream, and the concavely curved surface (eccentric with reference to said convex surface) of an imperforate fixed part which defines the outer boundary of said flowing stream of liquid, substantially all of the liquid, with the now generally parallel fibers therein, being discharged at the narrow or delivery end of said converging channel (which is devoid of exit ports between its entrance and delivery ends), for example, onto the upper run of an endless conveyor, of a type which permits the water to pass down through it, leaving the fibers upon the upper surface of the conveyor from which they may be removed in any desired manner as a coherent web, or delivered directly to spinning apparatus of any desired type.

During the flow of fluid through the converging channel, viscosity and varying velocity gradients of the flowing liquid result in separating and drawing the fibers out relatively to one another so that they are individually straightened and have a tendency to become parallel.

An object of the invention, as above noted, is to provide a method of carding fibers hydraulically in accordance with a procedure which may be carried out by very simple and relatively inexpensive means, as compared with usual mechanical carding apparatus, and whereby it becomes possible, at a high rate of speed, to straighten individual fibers and dispose the fibers in generally parallel relation to form if desired a layer or film of any reasonable width. This novel method is applicable, not only to the carding of fibers of textile staple length, but also to much shorter fibers, for example those customarily employed in the manufacture of papers. A further object is to provide novel apparatus for use in the practice of the method.

In the following more detailed description reference will be made to the accompanying drawings wherein:

FIG. 1 is a fragmentary diagrammatic, vertical section, with parts broken away and others omitted—at right angles to the axis of the rotating drum or cylinder which defines one wall of the converging channel—showing one embodiment of apparatus useful in the performance of the novel method;

FIG. 2 is a diagrammatic view wherein the essential elements of the apparatus of FIG. 1 are again shown for convenience in describing graphically the varying velocities of the liquid as it flows throught he convergent channel; and

FIG. 3 is a diagrammatic view, to very large scale, illustrative of the forces which act upon a single fiber as it is advanced by the current of flowing liquid.

Referring to the drawings, the numeral **10** (FIG. 1) diagrammatically indicates a receptacle of any desired kind and size, having arranged therein a stirring element of any appropriate type indicated at **11**, whereby the contents of the receptacle may be agitated. An adjustable gate G governs the size of an orifice O through which liquid may flow into a conduit **12** providing a sluiceway terminating at **13**, where there is arranged a feed roll **14**, desirably a cylinder covered with helical rows of pins or teeth, similar for example, to card clothing, mounted on a rotating shaft **15** which may be turned at slow speed, or merely retarded by a brake or the like and which is operative to obstruct the free movement of small masses of fibers which have not been broken up in the tank **10**, so that, as the liquid flows past the toothed roll, the now turbulent flowing liquid acts to disintegrate the retarded lumps or masses of fiber. The flowing stream of liquid, with the loosened fiber suspended therein, now enters the receiving end **16** of a convergent channel **17** whose outer

wall is the concavely curved, smooth, imperforate surface **18***a* of a fixed part **18**, said smooth surface defining the outer boundary of the flowing fluid stream, the inner wall of the channel being constituted by a portion of the peripheral surface **19** of a smooth, imperforate drum or cylinder **20** mounted on a rotating shaft **21***a*, said smooth, peripheral surface of the drum defining the inner boundary of the flowing liquid stream. Just beyond the delivery end of the channel **17**, a blade-like member **21** is arranged with its edge very close to the periphery of the cylinder so as to remove therefrom any fibrous material which may tend to cling to the cylinder. As here illustrated, by way of example, the liquid, with its entrained, predominantly parallel fibers, which escapes from the narrow end of the channel **17**, is discharged onto the upper surface of an endless conveyor **22** which may, for instance, be similar to a so-called Fourdrinier wire, such as is used in papermaking machines, or it may be of textile material of a weave structure such that it is porous so as to permit the ready downward movement of the water, leaving the parallel fibers as a thin layer or film F on the upper surface of the conveyor—it being understood that the upper run of the conveyor will be moved uninterruptedly in the direction of the arrow A—the conveyor being entrained around parallel drums R^1 and R^2, one of which is driven. Desirably, a receptacle **23** is arranged below the conveyor for collecting the water which is discharged from the conveyor and from this receptacle a suitable conduit **24** leads to any suitable point of discharge. As illustrated, a rotary roll or cylinder R^3 is arranged closely adjacent to the downwardly moving portion of the conveyor **22** as the latter passes around the drum R^1, the roll R^3 being so close to the downwardly moving portion of the conveyor as to press the fibrous film and compact it, and to direct it downwardly as it leaves the conveyor so that it may conveniently be received in any appropriate receptacle or delivered directly by appropriate conveying apparatus (not shown) to spinning mechanism.

Study of FIGS. 2 and 3 above, shows that the forces developed by apparatus such as herein described, whereby fibers may be straightened and arranged in parallel relation, greatly exceed those forces developed by the usual flat card wherein the fibers are exposed to air only. Thus, by the use of apparatus far simpler and less expensive than the usual flat cards and requiring a far lesser expenditure of power, the present invention provides a greatly improved method for preparing fibrous material for textile or papermaking use.

Merely by way of example, but without limitation, the drum or cylinder **20** may be of an external diameter of 9 inches; the diameter of the concave surface **18***a* of the fixed part **18** is desirably between 10¼–10½ inches and of circular curvature; the receiving or larger end of the channel **17** may be of the order of one inch in radial width; and the narrower or delivery end of the channel **17** of a radial width of ¼ inch. The edge of blade **21** may be spaced from the cylinder **20** a distance of the order of 1/32 of an inch, and the cylinder **20** may rotate at 240 r.p.m.

It is desirable, when treating certain types of fiber, for instance, cotton fiber, as an initial step in the process, to suspend the fibers in liquid containing a chemical of the type known in the papermaking industry as a deflocculant.

It will be understood that the drum or cylinder **20** will be housed within a suitable casing (not here shown); that the opposite ends of the channel **17** will be closed, leak-tight; and that suitable means (not shown) will be provided for rotating the cylinder **20** and (if desired) the toothed feed roll **14** at proper relative velocities, as, for example, by the use of an electric motor and conventional speed-reducing and transmitting means. The drawings are only designed to show the essential elements for carrying the method into effect and the relative arrangement of said elements, with exemplary dimensions of these parts suggested in the specification.

Using apparatus such as herein disclosed, wherein the cylinder **20** is 9 inches in diameter and 40 inches in length; the inlet end of the channel is one inch in width and the outlet end is ¼ inch in width, and with the cylinder **20** turning at 240 r.p.m., the output of parallelized and straightened fiber (starting with a slurry consisting of 1% fiber, by weight, and the remainder water), would be approximately 47 pounds per hour of treated fiber, as compared with the present day production of a 40 inch, top-flat mechanical card of about 10 pounds per hour on the average. Apparatus of the present type, being far cheaper than the conventional card and requiring no such complicated and accurate settings as does the conventional card, might, as a practical matter, be arranged in tandem or series if, in dealing with any particular fibrous material, the straightening and parallelizing of fibers resultant from passage through a single apparatus of this type, should not prove sufficient for the intended purpose. It is contemplated that this apparatus may be employed for treating short fibers of customary paperstock length, but, in particular, longer fibers such as are employed in making certain heavy papers such as for insulating purposes, as well as for the manufacture of unwoven textile fabric.

By the use of apparatus such as above described, it is possible to form, on the upper surface of the conveyor **22**, a film or layer of fibrous material wherein the individual fibers are approximately straight and parallel to each other. The layer or film, thus formed, is usually sufficiently coherent to permit it to be separated from the conveyor without destroying it. For example: the layer which is forming upon the conveyor may be removed therefrom by means similar to that employed for removing the fleece from the doffer of a conventional mechanical card, and condensed to form a sliver.

For an understanding of the principle of operation, whereby the above results are attained, and comparison of the forces available for straightening and disposing fibers in parallel relation, as compared with the forces available in a conventional flat card for accomplishing these results, reference may be had to FIGS. 2 and 3 of the drawings and to the following discussion wherein reference is made to a work by Hunsaker and Rightmire entitled "Engineering Applications of Fluid Mechanics," published by McGraw-Hill (1947) and, in particular to chapter 10 of that work which, in the following discussion is, at times, referred to as the "Reference."

Ia. General description

The apparatus consists essentially of a rotating cylinder, half of the circumference of which is covered by a stationary, curved plate forming a convergent channel between itself and the moving cylindrical surface, as shown in FIG. 1. This channel is kept filled with water by means of a suitable inclined trough, and a controlled feed of fibers is maintained by means of a slowly rotating, toothed drum set at the entrance to the channel. As the fibers are carried through the channel the forces exerted on them by the water tend to parallelize and straighten them.

Referring to FIG. 2 of the drawings, the apparatus diagrammatically shown is such that the fluid flow will be turbulent, rather than laminar. Thus, at any point in the channel **17** the velocity will be fluctuating about a mean value. In the following description of the flow, reference will be made only to the mean velocity.

IIa. Characteristics of the flow

Since no liquid enters the channel except at the entrance Section I of FIG. 2 and none leaves except at the exit Section III, the volume rate of flow past Section I equals that past section III or that past any arbitrary intermediate Section II. An equivalent statement is that the areas under the velocity-profile curves shown as I, II and III are all equal.

Since the channel converges in the direction of flow, the shape of the velocity profile changes from section-to-section, as suggested schematically in FIG. 2, the profile at exit Section III being more convex than that at Sections I or II.

The exact shape at any given section depends not only on the convergence of the channel but also on the peripheral velocity of the cylinder and on the difference in elevation between entrance and exit. The higher the entrance above the exit the greater the tendency of the profile to be convex.

The effect of this mean flow is to turn any fiber that is momentarily transverse to the general flow direction and to bring it parallel to this direction. This action is primarily the result of the large radial gradient of velocity. A further straightening effect is produced by the peripheral gradient of velocity, caused by the convergence of the channel.

In the following discussion the order of magnitude of the forces exerted by the liquid on a fiber in several configurations, is compared with the order of magnitude of the forces exerted in a standard flat-top card, in which the operating fluid is air.

IIIa. Forces exerted by the operating fluid on a fiber stationary and transverse to the flow

It may be understood that the fiber length and diameter, cited in the following discussion, are selected arbitrarily and merely by way of example.

This position of a fiber would produce the maximum interaction between it and the fluid. Imagine the fiber to be parallel to the axis of the rotating cylinder and in a region of the channel where the velocity is $V/2$. Typical numerical values for the subject apparatus are as follows:

Half of cylinder velocity, $V/2$ __cm./sec__ 150.
Length of fiber, L _____cm__ 4.
Diameter of fiber, d _____cm__ $(3/2)\times10^{-3}$.
Density of water, p _____g./cm.^{3}__ 1.
Kinematic viscosity of water, v _cm.^{2}/sec__ 1×10^{-2}.

Considering the fiber as a cylinder transverse to a flowing fluid, it may be found, by well-known methods as described in the reference, column 4, that the force on the fiber is on the order of 100 dynes. This estimate is based on the following Reynolds number

$$(V/2)\frac{d}{v}=\frac{150\times(3/2)\times10^{-3}}{1\times10^{-2}}\doteqdot22$$

From FIGURE 10 of reference, the drag coefficient $C_D\simeq2$. From Eq. (10.3) of reference:

$$\text{Force}=D=C_D(p/2)(V/2)^2dL=2\times(1/2)\times2.25\times10^4\times(3/2)\times10^{-3}\times4\doteqdot130 \text{ dynes}$$

For a typical flat-top card operating on the same size of fiber:

Half of cylinder velocity, $V/2$ __cm./sec__ 540.
Length of fiber, L _____cm./sec__ 4.
Diameter of fiber, d _____cm__ $(3/2)\times10^{-3}$.
Density of air, p _____g./cm.^{3}__ 1.2×10^{-3}.
Kinematic viscosity v of air ___cm.^{2}/sec__ 1/7.

The same method yields:

$$(V/2)d/v=\frac{540\times(3/2)\times10^{-3}}{1/7}\doteqdot5.7$$

$$C_D\simeq4$$

$$\text{Force}=D=C_D(p/2)\left(\frac{V}{2}\right)^2Ld=4\times\frac{1.2\times10^{-3}}{2}\times29\times10^4\times4\times(3/2)\times10^{-3}\doteqdot4 \text{ dynes}$$

The ratio of the force in the subject apparatus to that in the flat-top card is thus about thirty to one.

IIb. Fiber stationary and parallel to the flow

This configuration approximates that occurring as a fiber is being introduced into the channel 17 from the slowly rotating, toothed drum or feed roll 14 located just upstream from Section I. The liquid flows past the fiber, which can be thought of as a straight cylinder held fast at its upstream end and parallel to a flow of velocity $V/2$, where V is the linear velocity of the surface of the rotating drum or cylinder 20. See FIGURE 2. The mean velocity at Section II is somewhat less than $V/2$, but $V/2$ is a sufficiently close approximation, since merely the order of magnitude of the force is involved. In accordance with well-established rules of liquid behavior, the liquid immediately in contact with the stationary fiber is at rest. The velocity of the liquid increases rapidly with distance from the fiber surface, reaching essentially that of the free stream a short distance from the surface. This layer of fluid surrounding the fiber, in which the velocity rises from zero essentially to $V/2$ is called a boundary layer. Velocity profiles across the boundary layer at three points along the length of the fiber F[1] are shown schematically in FIG. 3. It is seen that the boundary-layer thickness increases gradually with X, that is, the distance from the front end E of the fiber, reaching a maximum at the downstream end, which is taken at $X=L$. The shearing movement of the liquid in the boundary layer produces a shear stress at every point of the fiber surface, due to the viscosity of the liquid. This stress is indicated by the arrows marked T in FIG. 3. It will be seen that T progressively decreases as the steepness of the velocity profile decreases, with increase in X. The resultant effect of all these parallel shear stresses is a force D tending to move the fiber downstream. As an approximation, D may be computed by methods readily available and designed for application to a flat plate, rather than a cylinder.

The order of magnitude of the result thus obtained will be correct.

From Eq. (10.10) of the reference:

$$\text{Force}=D=\frac{1.33}{\sqrt{V/2L/v}}(p/2)(V/2)^2\pi dL\frac{1.33}{\sqrt{\frac{150\times4}{L\times10^{-2}}}}\times(1/2)\times2.25\times10^4\times\pi\times(3/2)\times10^{-3}\times4\doteqdot1.2 \text{ dyne}$$

For a flat-top card:

$$\text{Force}=D=\frac{1.33}{\sqrt{\frac{540\times4}{1/7}}}\times\frac{1.2\times10^{-3}}{2}\times29\times10^4\times\pi\times(3/2)\times10^{-3}\times4\doteqdot3.6\times10^{-2} \text{ dyne}$$

Again the ratio of the forces is about thirty to one.

IIIb. Fiber moving with the mean velocity of the fluid at its midpoint and oriented parallel to the flow

On account of the convergence of the channel, an observer riding on the midpoint of the fiber F[1] (FIG. 3) would see water flowing away from him toward each end of the fiber. This relative motion sets up a boundary-layer flow from the midpoint toward each end, similar to that described above in paragraph IIb. Calculation shows that opposing drag forces due to these boundary layers will produce a tension in the fiber on the order of 1×10^{-2} dyne. Such a tensile force would have no effect on a straight fiber parallel to the flow, but if the fiber were initially somewhat skewed it would be pulled into line. If furthermore, the fiber were initially bowed into, say, a semicircle, the straightening action of the flow would approximately double the radius of curvature of the fiber.

The above discussion shows that the liquid acts in two distinct ways in performing the carding operation, first, by means of the velocity gradient between the rotating cylindrical surface and the opposed stationary surface; and, secondly, by means of the increase of velocity re-

sultant from the convergence of the opposite walls of the channel. The increasing average velocity of the fluid, caused by the decrease in width of the channel, tends to pull fibers from a mass and straighten them. A straightened fiber will travel at the average velocity of the fluid at the center of length of the fiber. The rear end of the fiber will be held back by the slower moving fluid, while the forward end of the fiber will be pulled forwardly by the faster-moving fluid. The straightening force on a fiber will be approximately proportional to the ½ power of the fiber length and to the 3½ power of the difference between the fluid velocities at the ends of the fiber. Since this velocity difference is essentially proportional to the fiber length, in the converging flow of the apparatus herein described, the straightening force will vary approximately as the square of the fiber length. Furthermore, fibers initially in contact will tend to be pulled apart as they are straightened, and tangled fibers will tend to be pulled out wherever they protrude from a mass.

While for convenience in discussion, the wall **18** of the convergent channel has been considered to have zero velocity in the direction of fluid flow, it will be understood that the invention contemplates the employment of apparatus wherein both of said walls actually move, but at different velocities in a constant predetermined ratio.

It is obvious that by changing the length of the channel **17**, or the speed of the cylinder **20**, the rate of carding may be varied.

While one desirable embodiment has thus been diagrammatically illustrated by way of example, and with an explanation of the principles of operation, it is to be understood that the invention is broadly inclusive of any and all modifications, both of method and apparatus, falling within the scope of the appended claims.

We claim:

1. That method of carding fibrous material thereby to separate and straighten individual fibers and to dispose them in predominantly parallel relation which comprises as steps: suspending the fibrous material in a body of liquid, delivering the liquid with the suspended fibrous material therein into the wide entrance end of a converging channel, defined by opposed spaced walls, one of said walls being fixed and the other wall moving in the direction of the flow of liquid in the channel, thereby separating and straightening the individual fibers and placing them in predominantly parallel relation, and discharging from the narrower delivery end of the channel substantially the same quantity of liquid per unit of time as is received at the entrance end of the channel together with the now predominantly parallel fibers, and thereafter separating the fibers from the liquid.

2. That method of treating fibrous material thereby to separate and straighten individual fibers while disposing them in predominantly parallel relation, said method comprising as steps: suspending the fibrous material in a liquid of low viscosity, delivering the fiber-bearing liquid into the receiving end of a channel to form a flowing stream having opposite, spaced boundaries, one of which is convex and cylindrically curved and the other of which is concavely curved, and wherein at the convex boundary the velocity of the liquid is substantial while at the concave boundary the velocity of the liquid is approximately zero, and, while maintaining a constant volume rate of flow throughout the length of the channel, gradually decreasing the distance between said opposite boundaries thereby progressively increasing the average linear velocity of the stream and so separating and straightening the fibers and disposing them in predominantly parallel relation, discharging liquid, wherein the fibers are separated, substantially straight and predominantly parallel, from the channel at the point at which the boundaries of the stream are at the minimum distance apart, in quantity per unit of time substantially equal to that delivered into the channel, and separating the now substantially straight and separate fibers from the liquid so discharged.

3. That method of treating fibrous material thereby to separate and straighten individual fibers and to dispose the fibers in predominantly parallel relation, said method comprising as steps: suspending the fibrous material in a body of water containing a deflocculating agent, agitating the water thereby to bring the fibrous material into intimate contact with the deflocculating agent, disintegrating masses of coherent fibers, causing the fiber-bearing liquid to flow as a continuous stream having spaced opposite boundaries, at one of which the velocity of the liquid is approximately zero while at the opposite boundary the velocity of the liquid is substantial, maintaining constant the volume rate of flow throughout the length of the stream while gradually decreasing the distance between said boundaries thereby propressively increasing the average linear velocity of the stream with resultant straightening and separating of the individual fibers and disposal of them in predominantly parallel relation, and at the point of minimum separation of said boundaries, at which the flowing liquid carries fibers which have been separated, straightened and disposed in predominantly parallel relation, discharging the fiber-carrying liquid in quantity, per unit of time, equal to that at the stream's source, and thereafter separating the fibrous material from the liquid.

4. That method of treating fibrous material thereby to separate the fibers, to straighten individual fibers, and to dispose the fibers in predominantly parallel relation, said method comprising as steps: suspending the fibrous material in a body of liquid of a viscosity of approximately that of water, causing the fiber-bearing liquid to flow in a stream having spaced boundary surfaces which so converge that the transverse thickness of the stream at its delivery end, where the suspended fibers are substantially parallel, is approximately ¼ its transverse thickness at the entrance end, and wherein one of said boundary surfaces moves in the direction of fluid flow at a linear velocity which exceeds that of the opposite boundary surface by approximately 560 feet per minute, while the volume rate of flow is substantially constant for all transverse sections of the stream, thereby separating and straightening the fiber, and then removing the separated and straightened fiber from the liquid.

5. The method according to claim **1**, wherein the liquid which contacts the movable wall is constrained to follow a path which is cylindrically curved while the liquid which contacts the fixed wall is constrained to follow a path which is arcuate and concave and which is eccentric relatively to said cylindrically curved path, the eccentricity of said concave path being such that the channel progressively decreases in width from a wider end where the liquid enters to a narrower end from which the liquid, containing substantially all of the fibers per unit of volume which it had initially and which are now separated, substantially straight and predominantly parallel, is discharged.

6. That method of carding textile fibers by the action of hydraulic forces thereby to separate and straighten the individual fibers which comprises as steps: suspending the fibrous material in a liquid of low viscosity, causing said liquid to flow as a stream between an initial point and a terminal point while so guiding the liquid that the stream has one boundary which is convex and cylindrically curved and an opposite boundary, spaced from the first boundary, which is concavely curved, the curvature of the concavely curved boundary and its disposition relatively to the cylindrically curved boundary being such that the stream progressively decreases in transverse width from the initial point to the terminal point, causing the cylindrically curved boundary of the stream to move at a linear velocity so much greater than that of the concave boundary that fibers suspended in the flowing liquid are separated and straightened by hydraulic action, and pre-

venting escape of any liquid constituent of the stream between the initial and terminal points whereby all of the liquid and fibrous material which enters the stream at the initial point reaches the terminal point, at which latter point the suspended fibers are separate and substantially straight, and so treating the liquid after leaving the terminal point as to separate the fibrous material from the liquid.

7. Apparatus for so treating fibrous material as to separate and straighten the fibers and to dispose them in predominantly parallel relation, said apparatus comprising means defining opposite, spaced, imperforate, smooth walls of a channel for fluid flow, said channel gradually converging from an entrance end to a discharge end, one of said walls being stationary and the other wall moving at a uniform linear velocity in the direction of fluid flow in the channel thereby causing fibers, suspended in the liquid flowing along said channel, to separate from one another, to be straightened, and to be disposed in predominantly parallel relation, means for delivering fiber-bearing liquid into the wider, receiving end of the channel at a rate such as to fill the space between said walls, restraining means operative to prevent free entrance of masses of coherent fiber into the channel, and means operative to separate fibers from the liquid discharged from the narrower discharge end of the channel.

8. Apparatus for use in so treating fibrous material as to separate and straighten individual fibers, said apparatus comprising a rotary, imperforate, smooth-surfaced cylinder, a portion of whose outer peripheral surface constitutes one wall of a channel for the flow of fluid, fixed means so defining an opposite wall for the channel that the channel converges in width from a receiving end to a discharge end, the opposite wall of the channel being imperforate whereby all of the liquid which enters the receiving end of the channel is delivered from the discharge end of the channel, means for so delivering fiber-bearing liquid into the receiving end of the channel as to form a stream filling the channel, the peripheral surface of the rotating cylinder moving relative to the opposite wall in the direction of fluid flow at a much greater velocity so that fibers suspended in liquid flowing in the channel are separated, straightened and disposed in predominantly parallel relation by hydraulic forces, and means operative to separate the straightened and predominantly parallel fibers from the liquid.

9. Apparatus according to claim 8, having means for turning the rotary cylinder in a direction such that that portion of its smooth, imperforate peripheral surface which constitutes one wall of the channel moves in the direction of fluid flow in the channel while the means which defines the opposite wall of the channel is stationary.

10. Apparatus according to claim 8, wherein the means which defines the fixed wall of the channel, which is opposed to the rotating cylinder, is of a concave, arcuate curvature, whose center of curvature is eccentric with reference to the axis of rotation of the cylinder, its eccentricity being such that the wall of the channel progressively decreases from its receiving end to its discharge end.

11. Apparatus for use in carding textile fiber thereby to separate and straighten individual fibers, said apparatus comprising spaced parts so defining opposite, imperforate walls of a channel that the channel converges from a receiving end to a discharge end, means for so delivering fluid-bearing liquid into the receiving end of the channel as to form a stream which fills the channel, means adjacent to said receiving end of the channel for restraining masses of coherent fibers from freely entering the channel, means for moving at least one of said wall-forming parts in the direction of fluid flow in the channel at a predetermined linear velocity bearing such a constant ratio to that of the other wall-forming part that the fibers suspended in the liquid, in moving along the channel from its receiving end to its discharge end, are separated and straightened by the operation of hydraulic forces, the quantity of liquid delivered from the discharge end of the channel per unit of time equalling that which enters the receiving end of the channel per unit of time and carrying with it the separated and straightened fibers, and means for separating the fibrous material from the liquid delivered from the discharge end of the channel.

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