United States Patent [19]

Marshall et al.

[11] **3,812,553**

[45] **May 28, 1974**

[54] **REORIENTATION OF FIBERS IN A FLUID STREAM**

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[73] Assignee: **The Kendall Company,** Walpole, Mass.

[22] Filed: **Apr. 27, 1972**

[21] Appl. No.: **248,106**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 196,709, Nov. 8, 1971, abandoned.

[52] **U.S. Cl.** **19/156.3**
[51] **Int. Cl.** **D01g 25/00**
[58] **Field of Search** 19/155, 156–156.4, 19/145, 205, 88, 89; 156/62.4; 425/80; 65/3, 4, 9, 10

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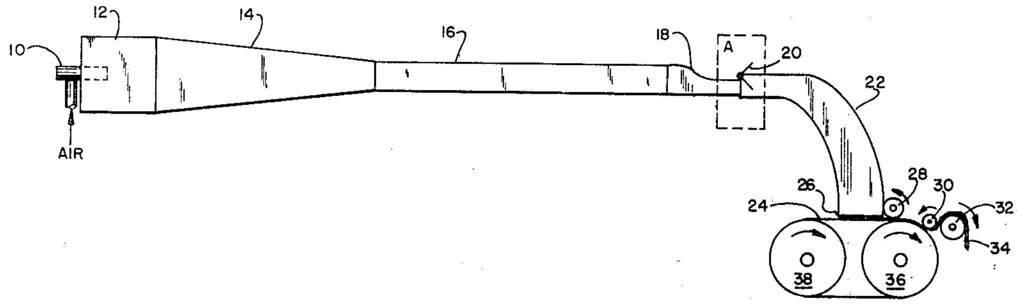
[57] **ABSTRACT**

Fibers in a fluid stream, predominantly oriented in the stream direction, are reoriented by passing the stream into a curved enclosure which subjects the fibers to a centrifugal action which tends to realign the fibers in a direction normal to the fluid flow. By introducing artifical turbulence into the air stream, the orientation of the fibers may be varied from substantially random to substantially normal to the fluid flow. Associated means are provided for converting the fluid stream of fibers into a fibrous web with a controlled fiber orientation.

4 Claims, 9 Drawing Figures



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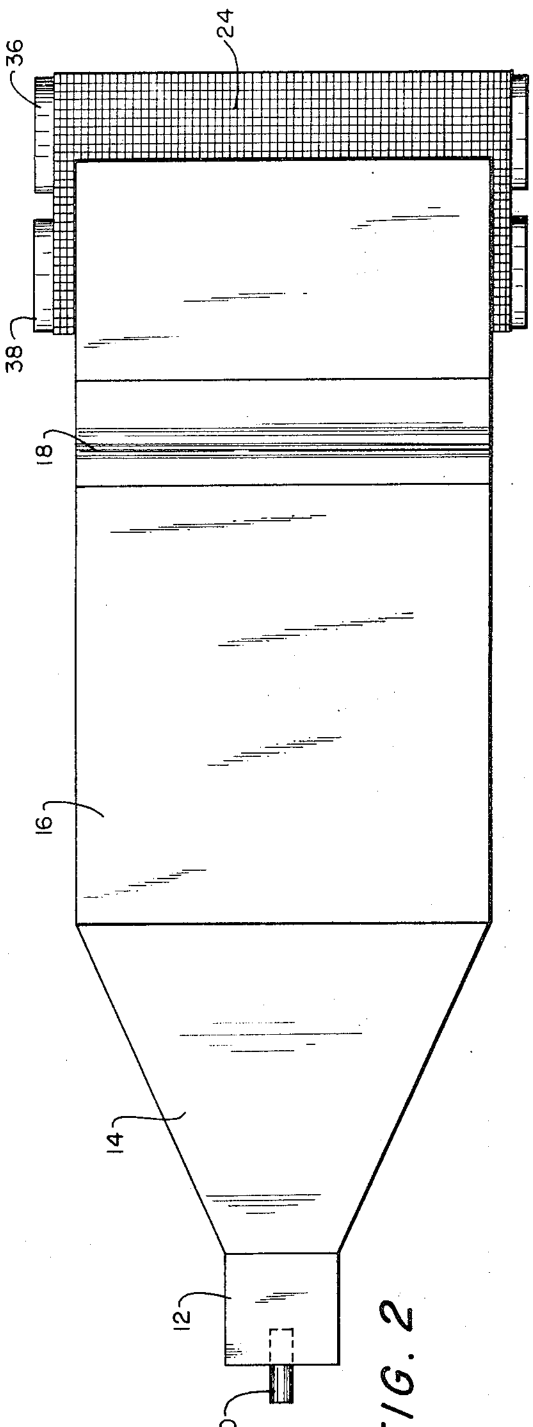

FIG. 2

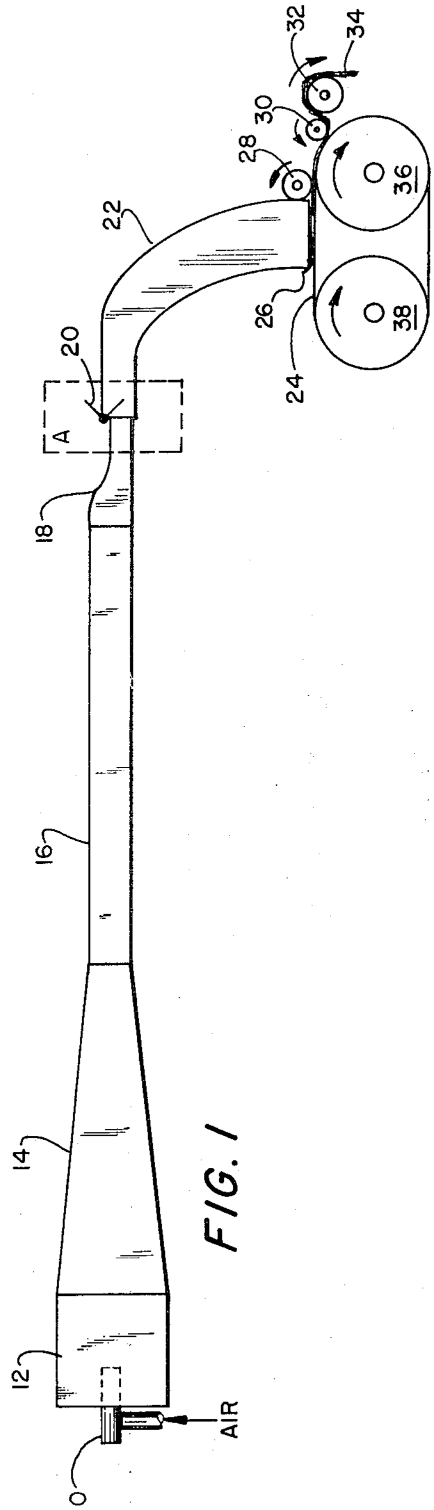

FIG. 1

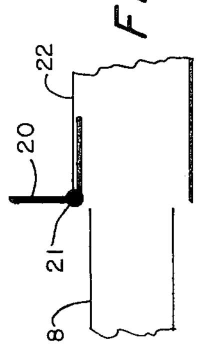

FIG. 3

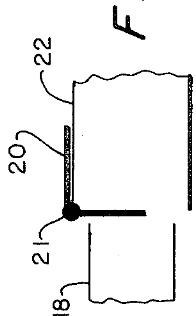

FIG. 4

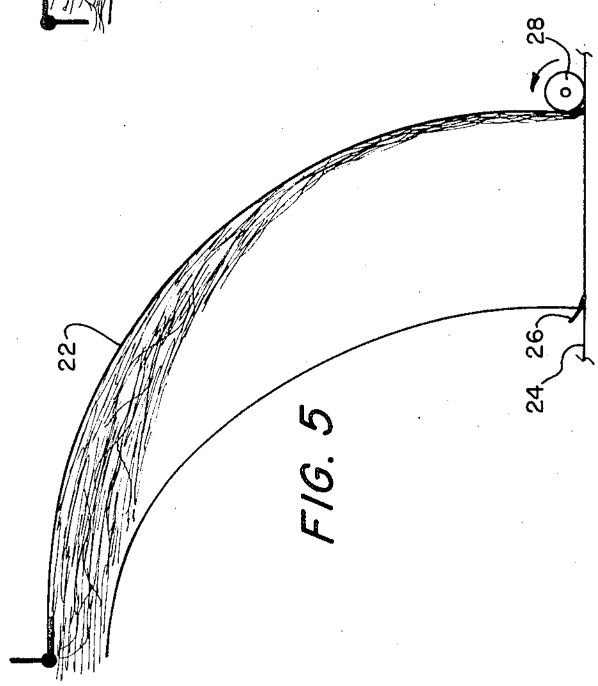

FIG. 5

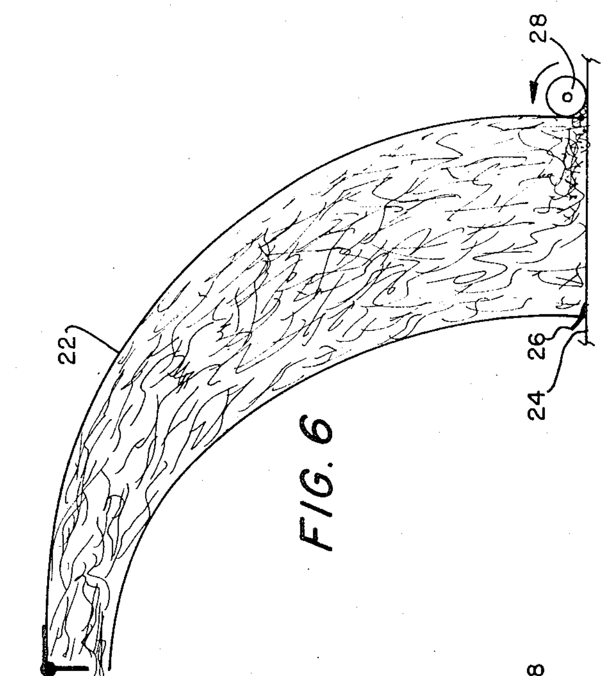

FIG. 6

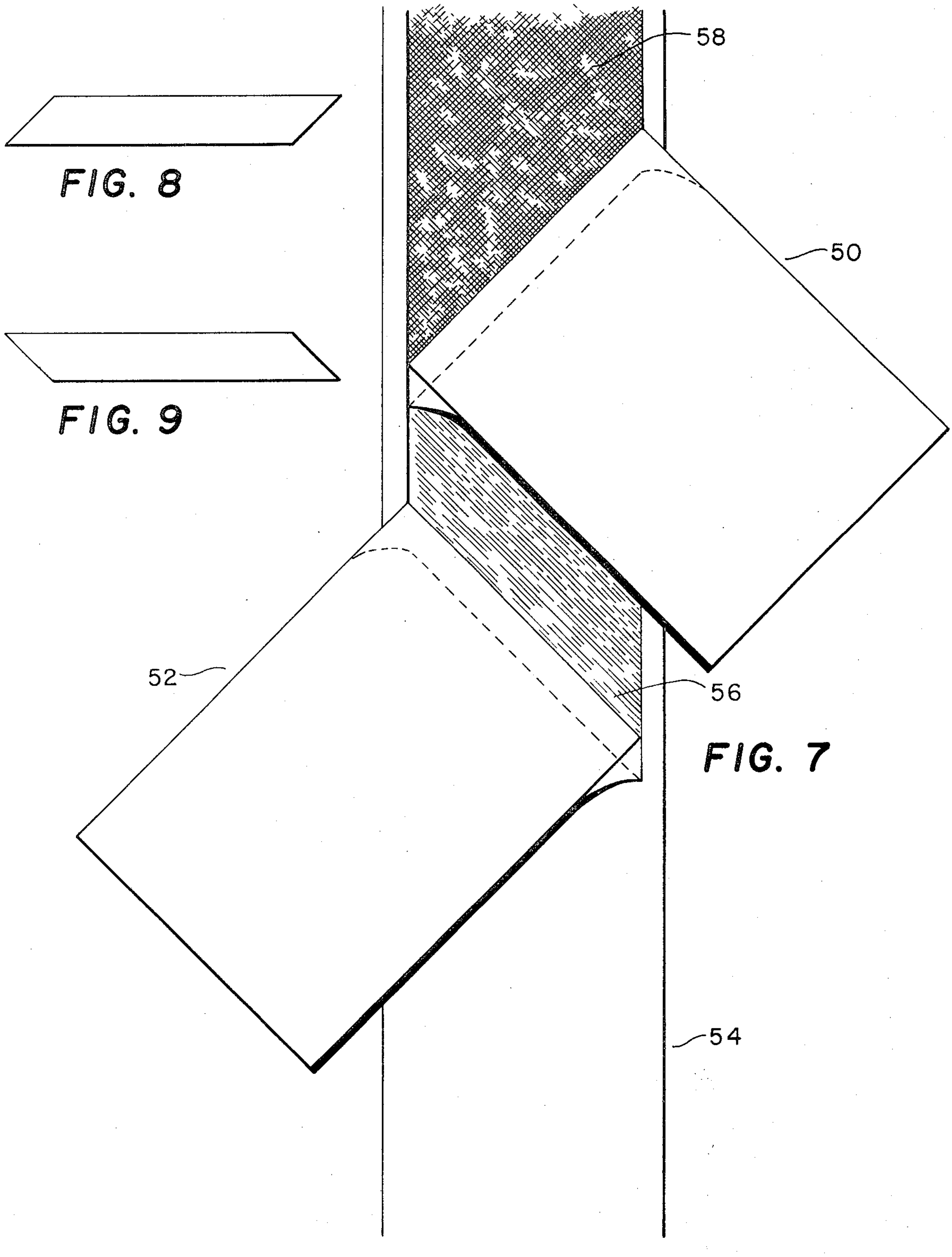

FIG. 8

FIG. 9

FIG. 7

REORIENTATION OF FIBERS IN A FLUID STREAM

This application is a continuation-in-part of our copending application Ser. No. 196,709, filed Nov. 8, 1971, now abandoned.

This invention relates to a process for controlling the direction of orientation of textile-length fibers deposited in the form of a web or fleece. More particularly it relates to a process for applying centrifugal force to a fluid-borne stream of fibers so that they become aligned at a selected angle to the direction of flow of the fluid stream.

One of the chief uses of webs of textile fibers today is to convert them to nonwoven fabrics, by a variety of well-known methods such as saturating, spraying, or impregnating the webs with polymeric binders; by the incorporation in the web of thermoplastic fibers with subsequent exposure to heat and pressure; by adhesive lamination to films or paper; and by other means well-known in the art.

By far the most common web-forming device is the so-called carding machine, which delivers a web or fleece of fibers which are predominantly aligned in the machine direction - that is, parallel to the flow of the web. Since this type of fiber orientation results in nonwoven fabrics in which the machine direction (M.D.) strength is much greater than the cross-direction (C.D.) strength, many classes of nonwoven fabrics are either excluded from certain fields of utility, or else must be made uneconomically heavy in order to meet a cross-direction tensile strength specification.

Various attempts have been made to improve the strength ratio, referring here to the M.D. vs. C.D. tensile strengths. One expedient is to disperse the fibers in more or less random orientation into an air stream, from which they are collected on a perforated drum or screen by suction. Such devices are expensive, and while satisfactory at speeds of around 10 yards per minute, they produce webs of poorer quality at speeds of 30 to 50 yards per minute, due to clumping and poor dispersion of fibers.

Another common method of improving the strength ratio is by means of a cross-laying device, whereby a full-width web of oriented fibers is mechanically pleated back and forth across a conveyor belt to build up a composite batt in which the average angular displacement of the fibers is alternated. Such devices again are slow and cumbersome, and are suitable only for batts of substantial thickness where fold marks and overlap ridges are not objectionable.

Other auxiliary devices have been proposed to randomize carded webs, such as that set forth in U.S. Pat. No. 3,538,552, of common assignee.

Still other devices for creating webs in which the fibers lie in more or less random orientation are described in copending applications Ser. Nos. 159,229, filed July 2, 1971, and 164,255, filed July 20, 1971, to one of the present inventors. In these applications, textile-length fibers are accelerated and drafted through aspirators, diffused and decelerated in a plenum chamber, and eventually collected in the form of randomly-oriented webs.

There is, however, a need for a fiber-handling system which will lay down a web of fibers in which the fibers lie, not in random orientation, but in a direction which can be controlled from being substantially normal to the machine direction of the web, to a direction which lies at a selected angle to the machine direction.

Such cross-oriented webs, possessing low M.D. strength per se, are valuable reinforcements when laminated or combined with card webs which are highly oriented in the M.D., or with papers, fabrics, films, etc. where reinforcement of the crosswise strength is desirable.

Another reason for creating fibrous webs with strength predominantly in the cross direction lies in the nature of the bonding processes used in converting such webs into nonwoven fabrics. While it is possible to convert a web of randomly-oriented fibers into a nonwoven fabric with isotropic strength properties, extreme precautions must be taken to avoid drafting the web, and such practices are so uneconomical as to be commercially not feasible. It is much more practical and economical to produce fibrous webs in which the C.D. strength is greater than the M.D., and then to subject such webs to the normal drafting effected by the tensions of saturating, conveying, drying, and winding up at practical commercial speeds, allowing the drafting operation to reorient the predominantly cross-laid fibers so that the final finished nonwoven fabric has substantially equalized tensile properties in both the machine and in the cross direction.

It should be understood that this does not mean that the fibers are laid down straight and parallel, like a row of matchsticks, since the length of the fibers being dealt with herein is so much greater than their diameter, and the fibers are so flexible, that practically without exception every fiber will lie in a twisted and cursive path, with curves and direction-reversals along its length. Its mean orientation, therefore, is measured by the ratio of its M.D. to C.D. strengths. By cross-oriented webs in this invention is meant webs wherein the C.D. strength is greater than and preferably at least 4 or 5 times the M.D. strength, indicating that the effective lengths of the majority of the fibers lie crosswise of the web, normal to the machine direction.

It is the principal object of this invention to provide a process and an apparatus whereby a fluid-borne stream of fibers is laid down so that the fiber orientation can be controlled from being substantially normal to the machine direction of the web, to being oriented at any selected angle to the machine direction of the web up to and including substantial randomization.

It is an additional object of the invention to provide a process and an apparatus whereby textile length fibers are laid down on a porous conveyor in a narrow line or band which lies at a predetermined angle to the direction of travel of the conveyor.

A further object of the invention is to provide a process and an apparatus whereby textile length fibers are laid down obliquely on a porous conveyor belt in a line or band which is no wider than the average length of the fibers.

Basically, the process comprises the formation of a high-velocity fluid stream of fibers, diffusion and deceleration of the fibrous stream in a chamber that is of substantial width in comparison with its thickness, to form a relatively wide but shallow fibrous stream, and then deflecting the fluid stream of fibers along a downwardly-curved extension of the plenum chamber, in what might be termed a "horn". In this manner the fluid stream of fibers is in a sense centrifuged, in that the stream principally engages the forward curved section of the horn, and fibers which had been traveling parallel to the flow of the fluid stream are reoriented into a direction substantially normal to the flow of the stream.

Immediately adjacent to the downwardly-curved section or horn a collecting means is installed, consisting of a porous moving screen conveyor interposed across the narrow fibrous stream, to collect the fibers into a web.

If no turbulence is created in the air stream, the fibers will be deposited in a narrow band traversing downwardly along the forward section of the horn and onto the screen in the form of a band which may be so narrow as to be less in width than the length of a fiber, thus insuring reorientation. The remaining portion of the screen is seen to be relatively free of fibers.

The invention will be better understood with reference to the following description and drawings, in which

FIG. **1** is a side elevation of an apparatus suitable for carrying out the process of the invention;

FIG. **2** is a top elevation of the apparatus of FIG. **1**, omitting the sealing and doffing devices.

FIGS. **3** and **4** are detailed enlargements of the section A of FIG. **1**, outlined in dotted lines.

FIG. **5** is a side elevation of the centrifugal or horn section of FIG. **1** showing one mode of operation.

FIG. **6** is a similar side elevation of the centrifugal section of FIG. **1** showing fiber distribution in another mode of operation.

FIG. **7** is a top elevation of a mode of operation of the process of this invention where by two separate fibrous webs are laid down on a porous conveyor, the fibers in each web being oriented at 45° to the conveyor, and the fibers in one web being oriented at 90° to the fibers in the other web.

FIGS. **8** and **9** represent the contours of the exit section of the centrifugal or horn sections of the air lay devices of FIG. **7**.

It should be appreciated that the above representations of apparatus suitable for carrying out the process of this invention are illustrative only, and are not restrictive in dimensions or configuration.

Referring to FIG. **1** there is shown a fluid-powered jet or aspirator, **10**, capable of converting a top or sliver of staple-length fibers into a high-velocity fluid stream of substantially individualized fibers. Such jets, their parameters, and their function are described in detail in copending applications Ser. Nos. 159,229 and 164,255 now U.S. Pat. No. 3,727,270, and there are also commercially available aspirators capable of performing a similar function.

The high-velocity fluid stream of fibers is directed into the entry chamber **12**, and thence is diffused into a guiding chamber **14**, which, as seen by comparing FIGS. **1** and **2**, reforms the fibrous stream into a stream which is wider and shallower than the diffuse stream emerging from the aspirator. The wide and shallow fibrous stream flows then through the chamber **16** and preferably to a constricting region **18**, which acts as a Venturi. While not absolutely mandatory, this constriction **18** serves to iron out or minimize local disruptive pressure differences or vortices, thus evening out the flow of fibers.

From the Venturi section **18** the fibrous stream passes past the adjustable baffle or "spoiler" **20**, the function of which will be more fully explained below, and into the curved centrifuge section chamber **22**, where the actual reorientation takes place. The majority of the fibers, for cross-orientation purposes, are thrown against the leading or forward contour of the centrifuge chamber **22**, causing them to become reoriented from their previous orientation parallel to the fluid stream, or long axis of the apparatus, to a position in which they lie predominantly across or normal to the direction of fluid flow. The degree of reorientation can be controlled by the action of the spoiler **20**, and can be more readily understood by reference to FIGS. **3**, **4**, **5**, and **6**. The spoiler, as it is known in aerodynamic parlance, is a device which disrupts or disturbs the smooth flow of an air stream. As seen in the partially broken-away FIGS. **3** and **4**, which are enlargements of the dotted-line Section A of FIG. **1**, one convenient form of spoiler **20** consists of a right-angle bend of sheet metal, extending across the width of the curved centrifugal chamber **22**, and hingedly connected as at **21** to the centrifugal chamber **22** so that it can be adjusted to extend downwardly into the fibrous stream. Other forms of adjustable baffle or spoiler will readily occur to those skilled in the art.

When the spoiler is in the position shown in FIG. **3**, there is minimal interference with the smooth flow of a wide but shallow fluid-borne stream of fibers into the curved centrifugal chamber **22**, and the pattern of fiber flow is as shown in FIG. **5**, where the fibers are reoriented as they tend to gather in a band as narrow as a quarter of an inch wide, as can be observed if the sides of the centrifuge chamber are formed from a transparent material such as an acrylic plastic. Such a mode of operation results in maximum reorientation, yielding fibrous webs in which the C.D. strength is 4 or 5 times the M.D. strength.

When the spoiler is adjusted so that the inner wing extends downwardly across the opening of the centrifugal chamber **22**, however, the smooth fluid flow of fibers is abruptly disrupted. When the spoiler is adjusted as in FIG. **4**, at approximately 90° to the top of the centrifugal chamber **22**, turbulence in the form of innumerable vortices and inequalities of air flow are introduced into the centrifugal chamber, and the chamber will be seen to be more or less uniformly filled with a randomly-dispersed stream of fibers, as shown in FIG. **6**. Such streams of fibers yield webs which are substantially equal in C.D. and M.D. strength.

Intermediate positioning of the spoiler wing between that of FIG. **3** and FIG. **4**, between 0° and 90° will result in intermediate ratios of C.D. to M.D. strength, depending on the degree to which the flow of fibers toward the leading contour of the centrifuge chamber is altered or disturbed by the air turbulence introduced into the chamber.

Whatever the degree of fiber orientation established in the centrifuge chamber, the curving stream of fibers passes downwardly and is collected on the porous screen **24**, driven by rolls **36** and **38** as shown in FIGS. **1** and **2**. In order to prevent leakage in the transfer of the fibrous stream to the belt **24**, a sealing roll **28** rotates on the screen, blocking the egress of fiber-laden air from the front edge of the end of the centrifuge chamber, and a curved plastic strip **26** sealed to the lower rear edge of the centrifuge chamber rides in contact with the moving screen.

The fibrous web **34** may conveniently be doffed from the screen **24** by means of doffing rolls **30** and **32**. It should be appreciated that if the web **34** is predominantly cross-oriented, it cannot be allowed to drop downwardly as shown in FIG. **1**, but must be immediately supported as it leaves roll **32**, due to its lack of machine-direction strength.

The size of the apparatus will naturally vary with the width of web to be produced, the volume of fiber to be processed, and with other factors. A typical set of dimensions might involve an entry chamber **12** in the form of a 10 inch cube. The guiding chamber **14** may taper down to a 4.5 inch depth, while widening out to 40 inches for the purpose of producing a 40 inch-wide web. The chamber **16** may be 40 inches wide and 4.5 inches deep, with a cross-section of 180 square inches, a width-to-depth ratio of at least 5 to 1 being preferred.

The outlet slot of the Venturi section **18** may taper down to a depth of about 1.2 inches, ejecting a fibrous stream into the **2** inch deep opening of the centrifugal section **22**. The guiding surfaces of this centrifugal section **22** are curved in a 15 inch radius through a 90° turn, terminating in an outlet section 6 inches wide, thus giving a **240** square inch screen deposition area.

The above dimensional parameters are illustrative only, and not restrictive. Engineering details for modifications of the apparatus may be made, bearing in mind that the centrifugal force developed is proportional to the square of the velocity of the air stream, and inversely proportional to the radius of curvature.

As might be expected, the degree to which the fibers are reoriented in the process of this invention is a function of fiber length, as well as of the configuration of the centrifuge. With the spoiler in the position shown in FIG. **3** — that is, with centrifuge turbulence minimized — a stream of 6 inch long 5.5 denier rayon fibers produced a web in which the C.D. strength was about five times the M.D. strength. Using a similar feed of 1.5 denier 1.5 inch long rayon fibers, the C.D. strength was about twice the M.D. strength. With fibers as short as 0.25 - 0.50 inches long, isotropic webs are obtained.

In general, employing the above-described apparatus, fibers which are four inches or more in length may be expected to produce webs which have a C.D. strength at least three times the M.D. strength. Fibers of one to two inches in length produce webs in which the C.D. strength is approximately double the M.D. strength, assuming in both cases that no turbulence is artificially introduced into the centrifuge section.

Webs with equalized strength in both directions are also obtained with 6 inch or 1.5 inch fibers, as above, when the spoiler is adjusted to the position shown in FIG. **4**.

The invention will be illustrated by the following example.

EXAMPLE 1.

A 191,317 denier rayon top, consisting of 34,785 fibers in cross-section, each fiber being 5.5 denier and approximately 6 inches long, was prepared from a continuous filament rayon tow cut by a Pacific Converter and then pin-drafted. It was fed to the apparatus of FIG. **1** by passing it through an aspirator jet of Type B as described in copending application Ser. No. 164,255, mentioned above, at a rate 21.6 feet per minute or 18.6 pounds per hour, with the spoiler in the FIG. **3** position. The centrifuged stream of fibers was collected on the conveyor screen as a uniform web, 40 inches wide, weighing 65.3 grams per square yard, at a rate of 5.78 feet per minute.

The C.D. strength was approximately five times the M.D. strength. Adjusting the spoiler to the FIG. **4** position gave a web with approximately equal C.D. and M.D. strengths. Intermediate adjustments of the spoiler between the positions of FIG. **3** and FIG. **4** gave intermediate ratios of C.D. to M.D. strength.

Fibrous webs of novel fiber orientation may be produced by the use of two or more centrifugal devices, as shown in FIG. **7**. Here a pair of fiber centrifuges, **50** and **52**, are disposed at angles of 45° to the porous conveyor belt **54**. The spoiler in each device is in an "Off" position, as shown in FIG. **3**. In this manner, the centrifuge **52** lays down on the conveyor a narrow band of fibers, **56**, oriented northwest-southeast. There is superimposed upon such a web by the centrifuge **50** a narrow band of fibers oriented northeast-southwest, resulting in a fibrous web **58** where the predominant fiber orientations are criss-crossed. The tensile strengths of such a webs, after being bonded to form a nonwoven fabric, will be highest in both bias directions — i.e., at 45° to the M.D. or C.D.

Although FIG. **7** represents webs at 45° to the conveyor and 90° to each other, it will be obvious that these angles are illustrative only, and that various types of angular reorientation are possible. In general, it is preferred that the transverse axis of the horn be inclined at an angle of between 15° and 45° to the transverse axis of the conveyor. Similarly, angularly oriented webs may be plied with randomly oriented webs made by the process of this invention when the spoiler is used to introduce turbulence in the centrifuge chamber, as set forth above.

In practising the process illustrated in FIG. **7**, two modifications of the apparatus shown in FIG. **1** are desirable. In order to produce clean side edges on the web, the shape of the cross section of the exit portion of the centrifuge is changed from a rectangle to a rhomboid, as shown in FIGS. **8** and **9**, the obliqueness of the rhomboid depending on the angle at which it is desired that the fibers be laid down. Also, since it is difficult to maintain the air-seal roll **28** of FIG. **1** in position when the centrifuge chamber is mounted at an angle other than normal to the direction of travel of the conveyor, it is preferred that roll **28** be dispensed with, and that a close sliding fit be provided between the exit section of the centrifuge chamber and the conveyor.

An additional advantage of angular placement of the centrifuge chamber with respect to the conveyor is that it allows heavier webs to be formed with a single centrifuge device. The output of a single centrifuge will be limited by its dimensions. If a centrifuge device chamber 80 inches wide is placed at an angle of 60° to the conveyor, and the spoiler is adjusted as shown in FIG. **4** to create turbulence, a random web 40 inches wide will be deposited on the conveyor. If the angle is increased from 60° to 75°, the centrifuge may be 160 inches in width, and the web thus formed will still be 40 inches wide. Since much bonding and finishing equipment is designed to handle 40 inch wide material, this allows the output of a 160 inch horn, preferably fed by a plurality of jets, to be condensed into a 40 inch wide web.

Having thus described our invention, we claim:

1. The method of making a nonwoven fibrous web with predetermined fiber orientation in which the cross direction strength is greater than the machine direction strength, comprising:

forming a high velocity fluid-borne stream of textile length fibers of at least about one to two inches in length;

passing said fluid-borne stream of fibers through a curved centrifuge chamber having a transversely extending smooth surface therein, said chamber curving down toward a porous conveyor moving past a forward edge of said transversely extended centrifuge chamber;

deflecting said fluid stream principally along the forward portion of said curved centrifuge chamber, aligning said fibers in a transverse direction along said surface and concentrating said fibers thereat in a narrow transversely extended band, substantially each of said fibers lying in a twisted and cursive path with curves and direction-reversals along its length;

controlling the amount of fiber realigning taking place within said chamber by partially disrupting said high velocity stream of fibers in advance of said centrifuge chamber; while still maintaining a cross direction strength that is greater than the machine direction strength; and,

collecting said band of fibers on said porous conveyor moving past the forward edge of said transversely extended centrifuge chamber to produce a fibrous web of indefinite length in which the cross direction strength is greater than the machine direction strength in the direction of movement of said porous conveyor.

2. The method according to claim **1** further including collecting said band of fibers on said conveyor while said conveyor is moving in a direction normal to the transversely extended dimension of said band, thereby producing a fibrous web in which the cross direction strength is at least double the machine direction strength.

3. The method according to claim **1** further including collecting said band of fibers on said conveyor while said conveyor is moving in a direction at an angle to said band.

4. The method according to claim **3** further including collecting on said conveyor a second band of fibers at a second angle to said conveyor, so as to produce a web having fibers in one layer disposed at an angle to the fibers in a second layer.

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