June 6, 1939. A. FORMHALS 2,160,962

METHOD AND APPARATUS FOR SPINNING

Filed July 1, 1936 2 Sheets-Sheet 1

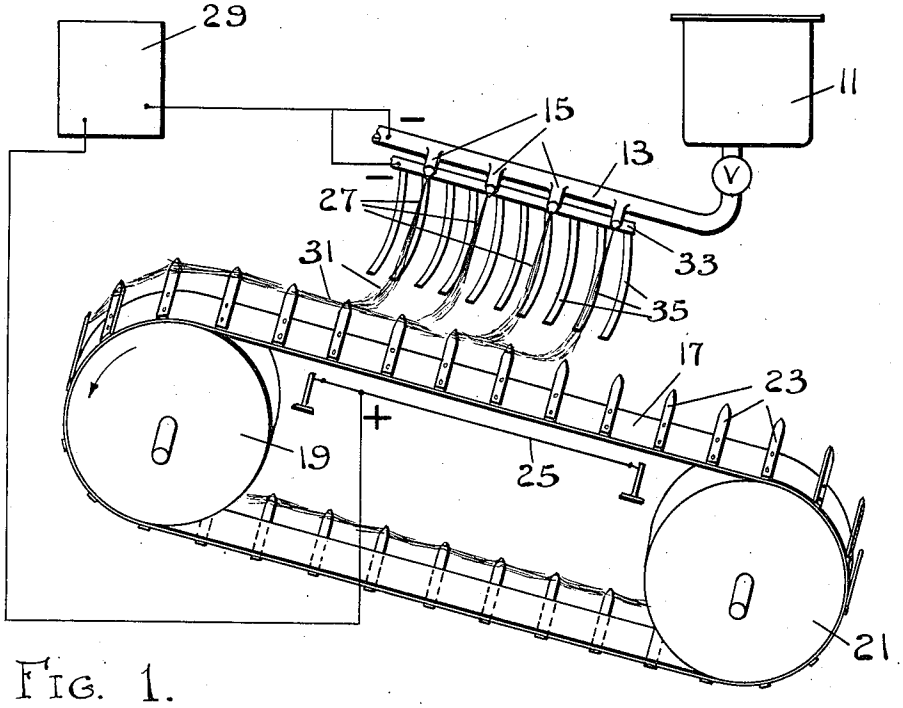

FIG. 1.

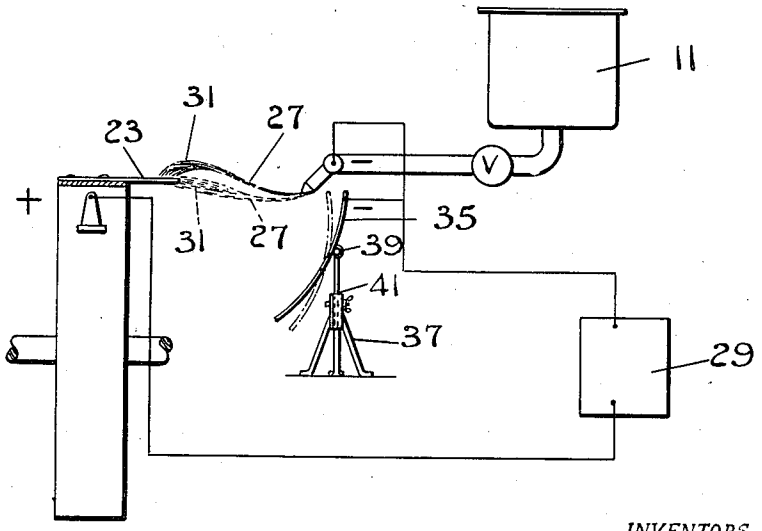

FIG. 2.

INVENTORS.
Richard Schreiber Gastell and
BY Anton Formhals
Louis A. Wiesa
ATTORNEY.

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METHOD AND APPARATUS FOR SPINNING

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FIG. 3

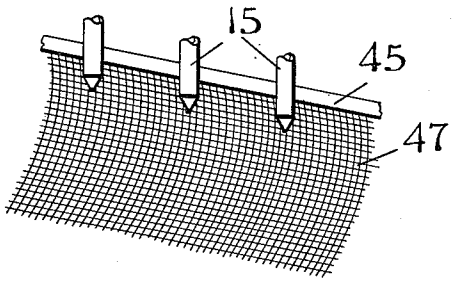
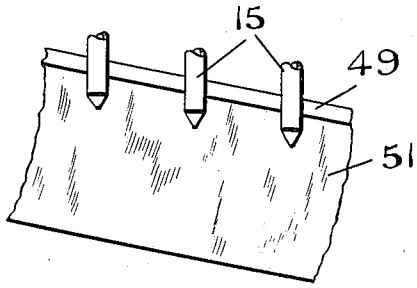


FIG 4



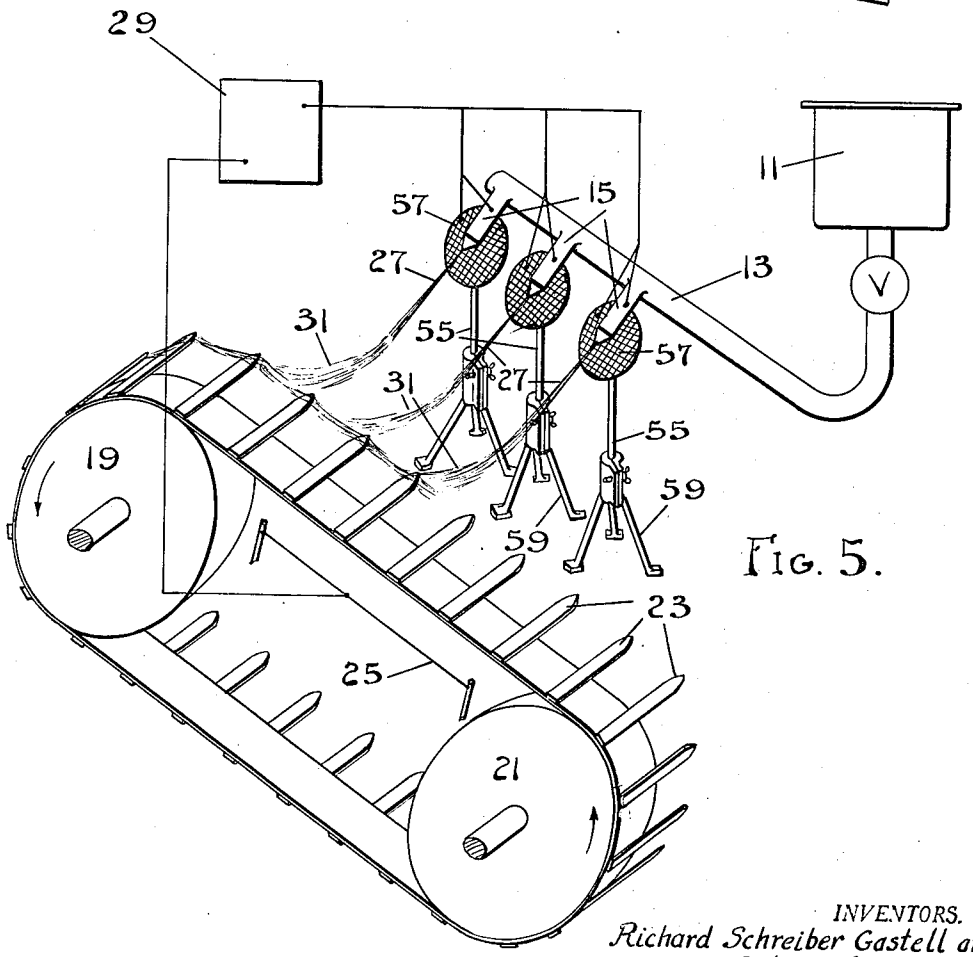


FIG. 5.

INVENTORS.
Richard Schreiber Gastell and
BY Anton Formhals
Louis A. Wiebe
ATTORNEY.

Patented June 6, 1939

2,160,962

UNITED STATES PATENT OFFICE

2,160,962

METHOD AND APPARATUS FOR SPINNING

Anton Formhals, Mainz, Germany, assignor of forty-five one hundredths to Richard Schreiber-Gastell, Mainz, Germany

Application July 1, 1936, Serial No. 88,430

5 Claims. (Cl. 18—8)

This invention relates to the production of artificial fibers and more particularly it relates to the dispersion or shattering of streams of spinning solution into comparatively fine fibers by means of a high potential electrical field, moving and directing said streams and fibers along a predetermined and fixed path towards a moving collecting device which constitutes one pole of the electrical field and collecting said fibers substantially parallel to each other in the form of a continuous fiber band on said moving collecting device. The dispersion of a stream of spinning solution into fibers by a high electrical potential shall hereinafter, for convenience, be referred to as the "electrical spinning" of fibers.

Reference is made to the applicant's copending application, Serial No. 88,428, filed July 1, 1936, relating to a new article of manufacture.

In accordance with previously known apparatus and methods for the electrical spinning of fibers, for example, the apparatus and method disclosed in U. S. Patent 1,975,504 to Formhals, a number of difficulties have been experienced. Due to the comparatively short distance intervening between the solution feeding devices and the fiber collecting devices it was exceedingly difficult to sufficiently completely dry out the formed fibers, and as a result the said fibers would tend to stick not only to the collecting devices but also to each other. Furthermore, in the previous methods the formed fibers would not tend to collect in a compact closely aggregated form. While this was due partly to the fact that the collecting electrodes presented continuous plane or curved surfaces for receiving the fibers and to the use of serrated devices for feeding discontinuous quantities of spinning solution into the high potential electrical field, the apparatus would still not collect the fibers in a compact concentrated fashion even though continuous streams of spinning solution were fed into the electrical field. Particularly when a plurality of spinning nozzles was used it was found that the streams, and the fibers formed from said streams, would take different courses and paths to the collecting device, thus preventing the formation of a closely packed or aggregated fiber band on the collecting device. In other words, while the paths which the streams and fibers might take between the feeding and the collecting devices were determined to an approximate degree by the relative position of these devices to each other, it was not possible to predetermine this path precisely and constantly, nor was it possible to predetermine the paths of all of the streams and fibers therefrom in a perfect manner from the different nozzles.

A further difficulty of previous apparatus and methods was experienced by the bothersome tendency of certain stray fibers to become electrically charged in the proximity of the collecting device, thereby tending to fly back into the field toward the solution feeding device. The occurrence of this phenomenon may be quite troublesome and will seriously interfere with the continuity of operation of the process. Stray fibers which thus fail to attach themselves permanently to the collecting device and tend to fly back into the proximity of the feeding device tend to become attracted and attach themselves to various parts of the solution feeding mechanism, for instance, the spinning nozzles. As the fibers accumulate on and around the spinning nozzle they may amass to a sufficient extent so as to cause serious interference to the free and uninterrupted delivery of spinning solution. In extreme cases they may amass themselves around a spinning nozzle and completely interfere with its satisfactory delivery, thereby necessitating stopping and cleaning of the apparatus.

The above and other difficulties have contributed to the failure to heretofore obtain on a smooth continuous manufacturing basis a continuous, compact, coherent fiber band composed of heterogeneous artificial filaments arranged substantially parallel to each other and being capable, without additional textile operation, of being drawn and twisted into threads or yarns of good quality and strength on standard textile machinery.

It is therefore an object of this invention to provide a method for the electrical spinning of fibers in which the distance between the solution feeding device or nozzle and the moving fiber collecting electrode may be increased in order to obtain greater and more complete drying out of the electrically spun fibers than has heretofore been possible.

It is another object of this invention to provide a method for the electrical spinning of fibers whereby the streams of spinning solution and the fibers therefrom are directed along a fixed, predetermined and constant path towards the collecting electrode.

It is another object of this invention to provide means when a plurality of nozzles is used, whereby all streams of spinning solution and fibers therefrom may be directed along fixed, predetermined and constant paths thereby

avoiding irregularities in paths of the solutions as spun from one nozzle as compared to that spun from another nozzle or nozzles.

It is a still further object of this invention to provide means for directing streams and fibers along predetermined paths so as to cause the collection of said fibers in a predetermined position on the collecting device as, for instance, at or near the points of said electrodes as described below, in a compact, closely organized, parallel manner so as to produce a coherent fiber band.

It is still another object of this invention to provide means whereby the shape, position and size of the electrical field in the vicinity of the spinning solution can be regulated at will.

It is a further object of the invention to provide means whereby fibers from the shattering or dispersing zone which might otherwise tend to fly back into areas of the solution feeding device, or to fly off at random away from the collecting device, may be substantially prevented from this behavior.

Another object is to provide means for regulating the distance from the nozzle at which said stream of spinning solution will begin to shatter or disperse.

Other objects of the invention will appear hereinafter. The objects of the invention may be accomplished by introducing streams of a spinning solution into a high potential electrical field between solution feeding devices such as nozzles and a moving fiber collecting device whereby said streams are caused to shatter or disperse into a multitude of fibers which are collected in a continuous fiber band on the moving collecting device, and at the same time so regulating or controlling the shape of the electrical field surrounding said streams of liquid and fibers by means of conducting strips, wires, plates, screens and the like placed in close proximity to said streams that said streams and fibers are impelled or caused to follow along a fixed predetermined and constant path to a predetermined position on said collecting device.

In order to more clearly set forth the present invention reference is made to the following detailed description taken in connection with the accompanying illustration, in which:

Figure 1 is a diagrammatic perspective view of an electrical spinning apparatus constructed in accordance with the present invention.

Figure 2 is a diagrammatic and elevational view of the electrical spinning apparatus of Figure 1.

Figure 3 is a fragmentary perspective view of a modified form of fiber directing means.

Figure 4 is a fragmentary perspective view of a still further modified form of fiber directing means.

Figure 5 is a diagrammatic perspective view of a modified form of spinning apparatus comprising a plurality of individually adjustable fiber directing means.

Referring to the drawings reference numeral 11 designates a supply reservoir containing a spinning liquid. A conduit 13 is connected to the supply reservoir 11 for passing spinning liquid to a plurality of spinning nozzles 15. Positioned parallel to the series of nozzles 15 is a moving collecting device comprising a belt 17, pulleys 19 and 21, individual electrodes 23, and a high potential electrical conductor 25. A plurality of streams of spinning solution 27 is extruded from the nozzles 15. A high tension electrical charge is imparted to the streams of spinning solution 27 in any desired manner, for example by connecting the nozzles or conduit 13 to a source of high electrical potential 29. The source of high electrical potential may be a transformer and rotary converter for changing ordinary line current such as 110 volt, 60 cycle alternating electric current into a high voltage pulsating direct current; however, any other source of high electrical potential for imparting an electrical charge of high potential to the stream of spinning solution will be suitable for use in the present invention. The conductor 25 is connected to the source of high electrical potential 29 so as to impart thereto a high potential electrical charge of opposite polarity to that imparted to the streams of spinning solution. A portion of the high potential electrical charge on the conductor 25 will pass across the air gap therebetween and the electrodes 23 to charge the latter with a potential somewhat lower than the potential imparted to the streams of spinning solution. The streams of spinning solution 27 will be shattered or dispersed into a plurality of comparatively fine fibers 31 which will collect in the form of a continuous coherent compact fiber band supported on or near the projecting ends of the individual electrodes 23 as they move past the streams 27. The fiber directing means comprising strip 33 and prongs 35 is positioned back of the nozzles 15, as shown in Figures 1 and 2, and is connected to any source of high electrical potential, for instance, 29. The polarity of the high potential charge imparted to the directing means 33 and 35 must be the same as the polarity of the charge imparted to the streams of spinning solution 27. The prongs 35 are preferably and individually adjustable and are suspended from strip 33 and constitute an electrical shield which when charged with the high electrical potential of the same polarity as the charge on the streams of spinning solution functions to repel and direct the streams and the resulting dispersed fibers along a definite predetermined and constant path depending on the size, shape and position of said directing means. The fiber directing means 35 is preferably adjustably positioned on a supporting means 37, as shown in Figure 2. The shield 35 is to be connected to the supporting means at 39 and slideably positioned therein at 41. The position and/or shape of the shield 35 can thus be adjusted to change the shape and direction of the field, thereby changing the path along which the streams of spinning solution and the fibers will be directed towards the supporting prongs 23. The path of the stream of spinning solution 27 and the fibers 31 into which the latter is dispersed are shown in solid lines in Figure 2. The dotted lines in this figure indicate the manner in which the path of the stream 27 and fibers can be changed by changing the angle of the directing means 35.

Referring to Figure 3 of the drawings reference numeral 45 designates a modified form of directing means which is adaptable for directing the streams of spinning solution and fibers in accordance with the present invention. The fiber directing means 45 comprises a woven screen 47 of a desirable curvature instead of a plurality of prongs 35 such as shown in Figure 1 of the drawings. In Figure 4 of the drawings is shown a fiber directing means 49 comprised of a solid sheet 51 of metal having a slight curvature for providing a somewhat curved electrical field.

Referring to Figure 5 of the drawings each nozzle 15 is provided with an individual, separately adjustable fiber directing means 55. The

individual fiber directing means **55** comprises shields **57** which are vertically adjustable in supports **59**. The individual shields **57** are also preferably pivotally adjustably connected to the supporting means in the manner set forth in Figure 2 of the drawings. The individual adjustable directing means **55** have the advantage of permitting the separate adjusting of each stream of spinning solution **27** and fiber bundle **31** without substantially interfering with the adjacent stream of spinning solution or fiber band. Furthermore, the intensity of the electric field created by the shield **57** may be adjusted individually.

The source of high potential used to charge the fiber directing means may be the same or different than that which is used to charge the stream of spinning solution. Furthermore, the magnitude of the potential to which the directing means may be charged may be the same or different than the magnitude of the potential on the streams. It is, however, necessary that the polarity of the high potential charge which is imparted to the fiber directing device and the stream of spinning solution be the same.

In the electrical spinning of fibers in accordance with the previously known processes, the streams of spinning solution and the fibers into which the streams are dispersed travelled toward the collecting electrode solely by the repelling and attracting forces imparted thereto by the high potential charges on the streams and solution feeding devices and the collector respectively. In other words, heretofore little or no control has been exercised over the shape of the electrical field. In the absence of positive means for suitably shaping the electrical field surrounding the streams and fibers so as to definitely and constantly direct them along predetermined paths, little or no control could be exercised over the spinning and collecting process to permit the direct formation of a compact coherent bundle of fibers in the form of a commercial sliver suitable for drawing and twisting into threads and yarns. By means of my invention I am now able to so control the path of the streams and fibers as to cause the latter to collect in a technically useful sliver suitable for direct processing. Furthermore, my invention permits me to work with a greater distance between the nozzles or other feeding devices and the collecting device than has heretofore been achieved, thus affording a longer travel for the fibers prior to being collected, during which travel the fibers become more thoroughly dried out. Furthermore, since I prefer a plurality of field directing elements corresponding preferably to the number of spinning streams employed, I am able to individually adjust the path of each stream, thereby correcting for any irregularities that might otherwise exist in the paths of the various streams. This feature is particularly important in assisting the formation of a compact fiber band since otherwise different streams in taking different paths would tend to deposit their fibers in quite different zones, areas or parts of the collecting device. A further advantage arises from the fact that with a large number of spinning nozzles operating simultaneously an operator is supplied with means for exercising close control over the operation which control can be used to correct for slight differences in delivery of spinning solution of different nozzles, differences in size of orifice and other irregularities which are incident to commercial scale manufacture.

A further unexpected advantage of my charged field shaping or directing means comes about in connection with a troublesome phenomenon which often occurs in the course of continued spinning of large quantities of fibers. It may happen that an occasional stray fiber will fail to reach the collecting device or, in certain cases, having reached the collecting device may become only momentarily attached thereto. These stray fibers thus fly off at random into space. When this phenomenon occurs, my field shaping and directing means, when taken in conjunction with the proper electrical potential between the nozzles and collecting device for good spinning, will repel most of said stray fibers back again to the collecting device where they become associated with the fiber band thereon. The small residue of stray fibers which are still not thus repelled to the collecting device will attach themselves to the prongs or other parts of the field shaping means in preference to flying to the nozzles where they would attach themselves and interfere with the continuity of the spinning operation. The continuity of my operation is thus greatly enhanced and such stray fibers as occur from time to time are either properly collected as part of the sliver, or are without effect on the continuity of the spinning process.

Another advantage of my directing means herein described lies in the fact that it may be used to regulate the length of the unbroken stream between the spinning nozzle and the point where the stream begins to shatter into fibers which, in turn, affects the rate of drying out of the fibers. For instance, if the directing means is disposed in close proximity to the streams, a longer unbroken travel of spinning solution is obtained than in the case where the directing means are removed at some little distance from said streams. The proper position for the directing means will be determined obviously by a number of different factors in the particular spinning apparatus and process employed, and will be quickly realized by one skilled in the art when taught by my disclosure.

In accordance with the preferred form of the invention the potential of the electric charge on the collecting electrode is maintained lower than the potential of the electric charge on the stream of spinning liquid as described in my copending application, Serial No. 88,431, filed of even date herewith, now Patent No. 2,123,992. In this preferred form, the attracting force of the collecting device is comparatively low with reference to the impelling force on the spinning nozzles.

The electrically charged directing means may consist of a number of pointed conducting rods or wires, of plates, strips, or tubes of various sizes and bent into various shapes or may even consist of spheres placed in various positions relative to the solution delivery devices or nozzles so as to control the electric field adjacent to the solution delivery devices.

Obviously many changes and modifications may be made in the processes and apparatus above described without departing from the nature and spirit of the invention. It is therefore to be understood that the invention is not to be limited thereto except as set forth in the appended claims.

I claim:

1. A process for the electrical spinning of fibers which comprises dispersing a stream of spinning solution into fibers by means of a high electrical potential created between two electrodes constituting a spinning solution feeding device and

a moving fiber collecting device horizontally spaced from said feeding device, said high electrical potential exerting a directing force on said stream and fibers, and augmenting said directing force by means of an electrically charged element of the same polarity as that of the feeding device positioned below and adjacent the feeding device, said element having at least a portion thereof positioned in a vertical plane passing through the space between the feeding and collecting devices, and being of a shape as to direct the fibers onto the collecting device, thereby forcing stray fibers onto the collecting device and preventing said fibers from leaving said collecting device and flying back to the feeding device.

2. In an apparatus for the electrical spinning of fibers, a solution feeding device for forming a stream of spinning solution, a moving fiber collecting device horizontally spaced from said feeding device, means for creating a high electrical potential between said devices whereby to electrically disperse the stream into fibers and direct the same towards said collecting device, and an electrically charged fiber influencing means of the same polarity as that of the feeding device positioned below and adjacent the feeding device, said means having at least a portion thereof positioned in a vertical plane passing through the space between the feeding and collecting devices and being of a shape as to direct the fibers onto the collecting device, thereby forcing stray fibers onto the collecting device and preventing said fibers from leaving said collecting device and flying back to the feeding device.

3. In an apparatus for the electrical spinning of fibers, a solution feeding device for forming a stream of spinning solution, a moving fiber collecting device horizontally spaced from said feeding device, means for creating a high electrical potential between said devices whereby to electrically disperse the stream into fibers and direct the same towards said collecting device, and an electrically charged fiber influencing plate of the same polarity as that of the feeding device positioned below and adjacent the feeding device, said plate having at least a portion thereof positioned in a vertical plane passing through the space between the feeding and collecting devices and being of a shape as to direct the fibers onto the collecting device, thereby forcing stray fibers onto the collecting device and preventing said fibers from leaving said collecting device and flying back to the feeding device.

4. In an apparatus for the electrical spinning of fibers, a solution feeding device for forming a stream of spinning solution, a moving fiber collecting device horizontally spaced from said feeding device, means for creating a high electrical potential between said devices whereby to electrically disperse the stream into fibers and direct the same towards said collecting device and an electrically charged fiber influencing screen of the same polarity as that of the feeding device positioned below and adjacent the feeding device, said screen having at least a portion thereof positioned in a vertical plane passing through the space between the feeding and collecting devices and being of a shape as to direct the fibers onto the collecting device, thereby forcing stray fibers onto the collecting device and preventing said fibers from leaving said collecting device and flying back to the feeding device.

5. In an apparatus for the electrical spinning of fibers, a solution feeding device for forming a stream of spinning solution, a moving fiber collecting device horizontally spaced from said feeding device, means for creating a high electrical potential between said devices whereby to electrically disperse the stream into fibers and direct the same towards said collecting device and an electrically charged fiber influencing rod of the same polarity as that of the feeding device positioned below and adjacent the feeding device, said rod having at least a portion thereof positioned in a vertical plane passing through the space between the feeding and collecting devices and being of a shape as to direct the fibers onto the collecting device, thereby forcing stray fibers onto the collecting device and preventing said fibers from leaving said collecting device and flying back to the feeding device.

ANTON FORMHALS.