United States Patent [19]

Lovgren

[11] **3,772,739**

[45] **Nov. 20, 1973**

[54] **WEB FORMING APPARATUS**

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[73] Assignee: **Johnson & Johnson,** New Brunswick, N.J.

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[21] Appl. No.: **108,547**

[52] **U.S. Cl.** **19/156.3**
[51] **Int. Cl.** **D01g 25/00**
[58] **Field of Search** 19/155, 156, 156.4, 19/205, 88, 89, 105

[56] **References Cited**

UNITED STATES PATENTS

1,810,675	6/1931	Nuttall et al.	19/89 X
2,150,040	3/1939	Seigle et al.	19/155 X
2,451,915	10/1948	Buresh	19/105 X
2,911,684	11/1959	Hunter	19/205 X
3,052,928	9/1962	Charlton, Jr. et al.	19/156.3
3,512,218	5/1970	Langdon	19/156.3
3,535,187	10/1970	Wood	19/156.4 UX
3,579,744	5/1971	Menzies, Jr.	19/105

FOREIGN PATENTS OR APPLICATIONS

545,638	6/1942	Great Britain	19/89

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Attorney—Michael Q. Tatlow, Harolw L. Warner and Robert L. Minier

[57] **ABSTRACT**

An apparatus for forming an air-laid non-woven web wherein a pair of parallel lickerins are positioned adjacent one another with the lickerins being rotated in opposite directions, so that when a first supply of fibrous material is fed to one lickerin and a second supply of fibrous material is fed to the other lickerin, separate supplies of individualized fibers are produced that are entrained in separate air streams impelled toward one another and toward a mixing zone between the lickerins. The individualized fibers are doffed from lickerins by the separate air streams and centrifugal force, and the doffed fibers are given an initial trajectory, whereby the inertia of the fibers is sufficient to allow at least a portion of the fibers from each supply to become homogeneously blended as the air streams are impelled against one another. A suction actuated fiber condensing means is positioned in communication with the mixing zone, and the separate air streams are combined into a common air stream that directs the fibers through the mixing zone and toward the condensing means where the fibers are deposited to produce a web comprised of randomly oriented fibers. When the material fed to the first lickerin includes relatively long fibers, such as textile length fibers, and the material fed to the second lickerin contains relatively short fibers, such as papermaking fibers, a web of randomly arranged fibers can be produced having a dispersion of different length fibers in more or less uniform intermixtures, to create a web having desired properties.

8 Claims, 24 Drawing Figures

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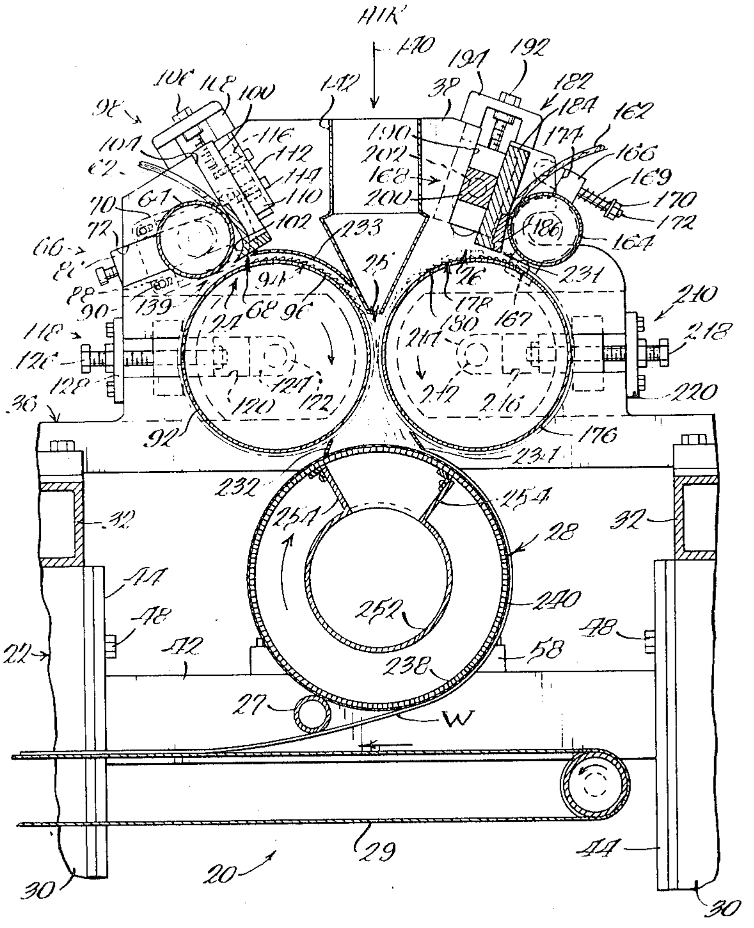
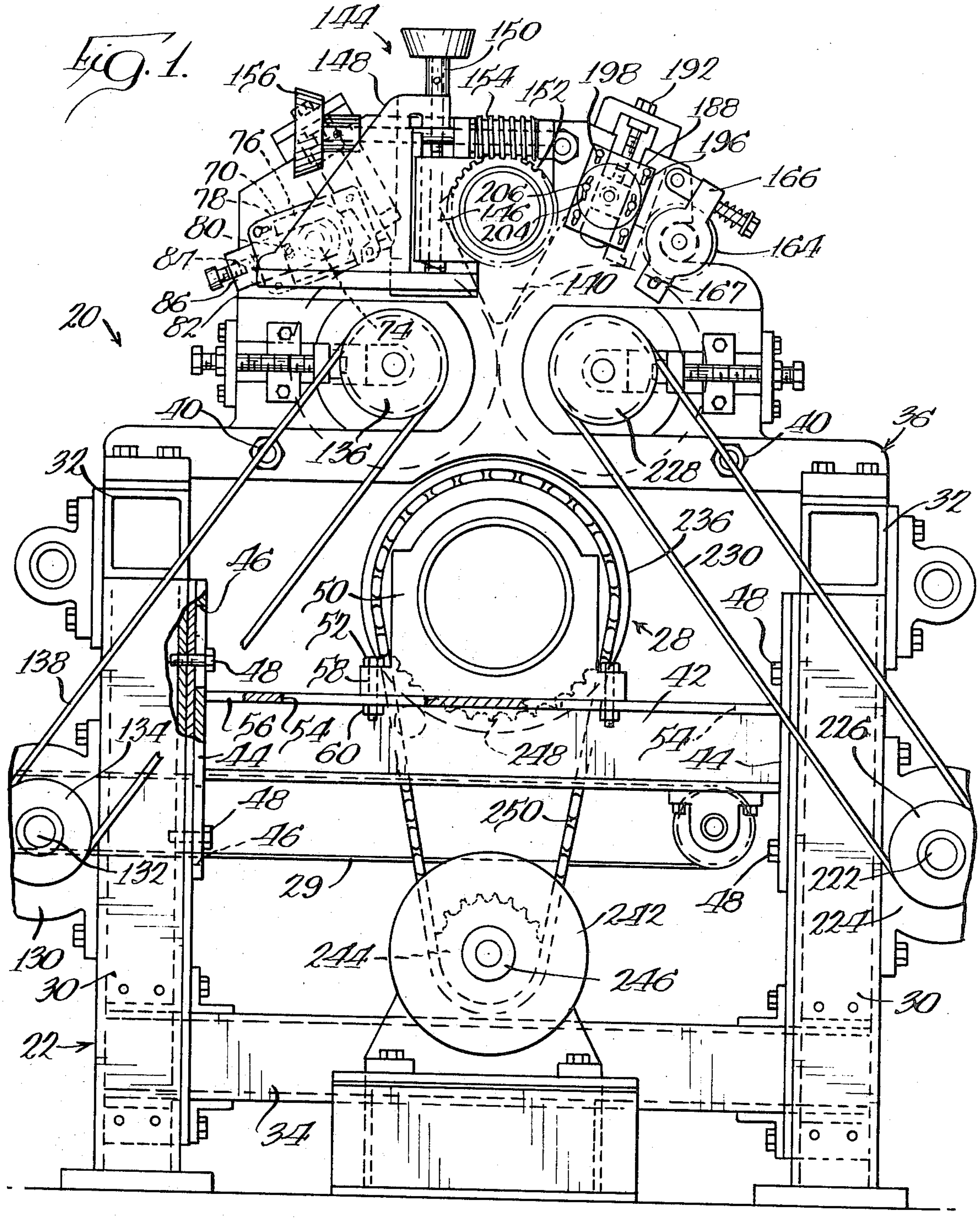


Fig. 1.



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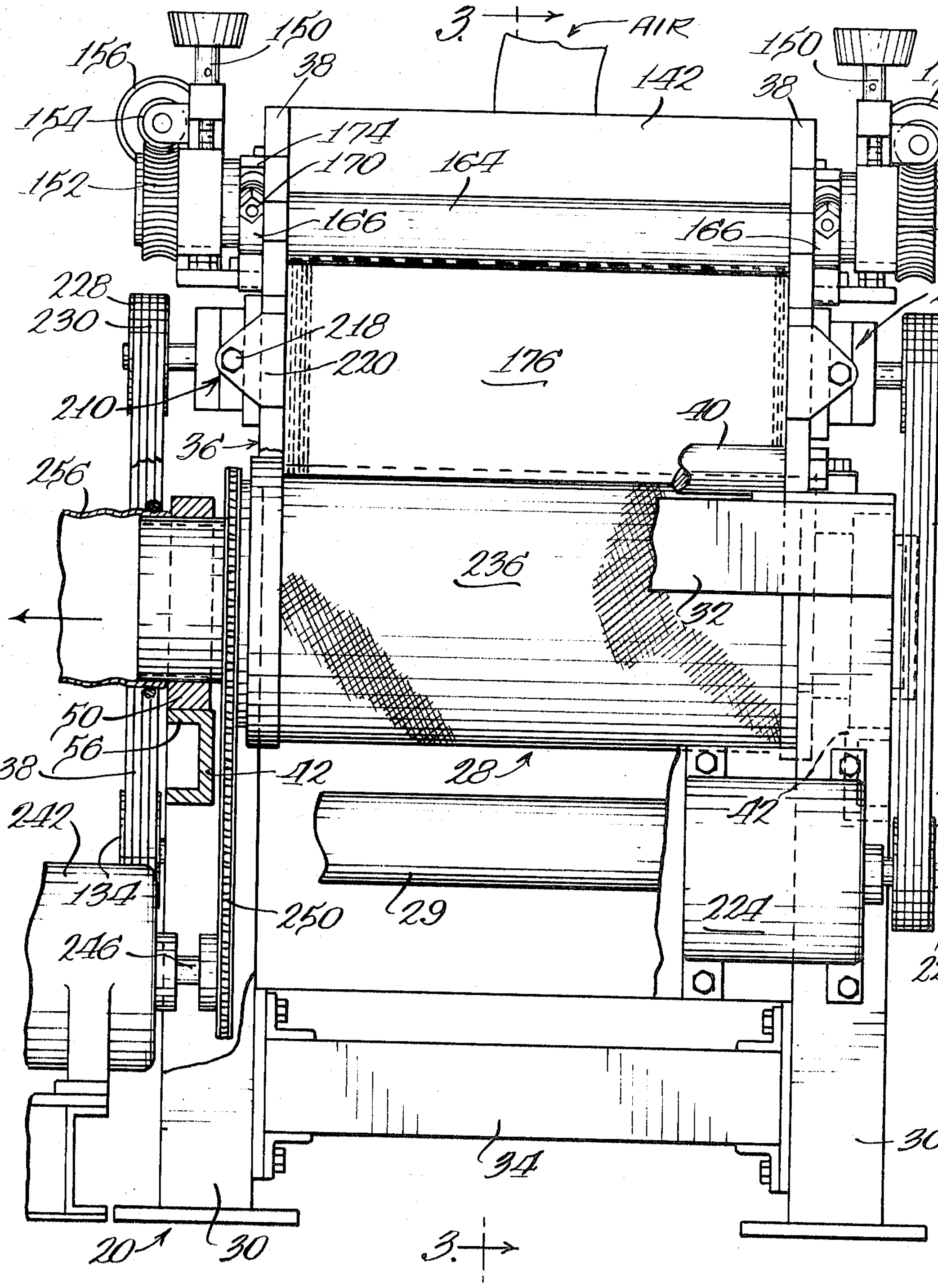

Fig. 2.

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Fig. 3.

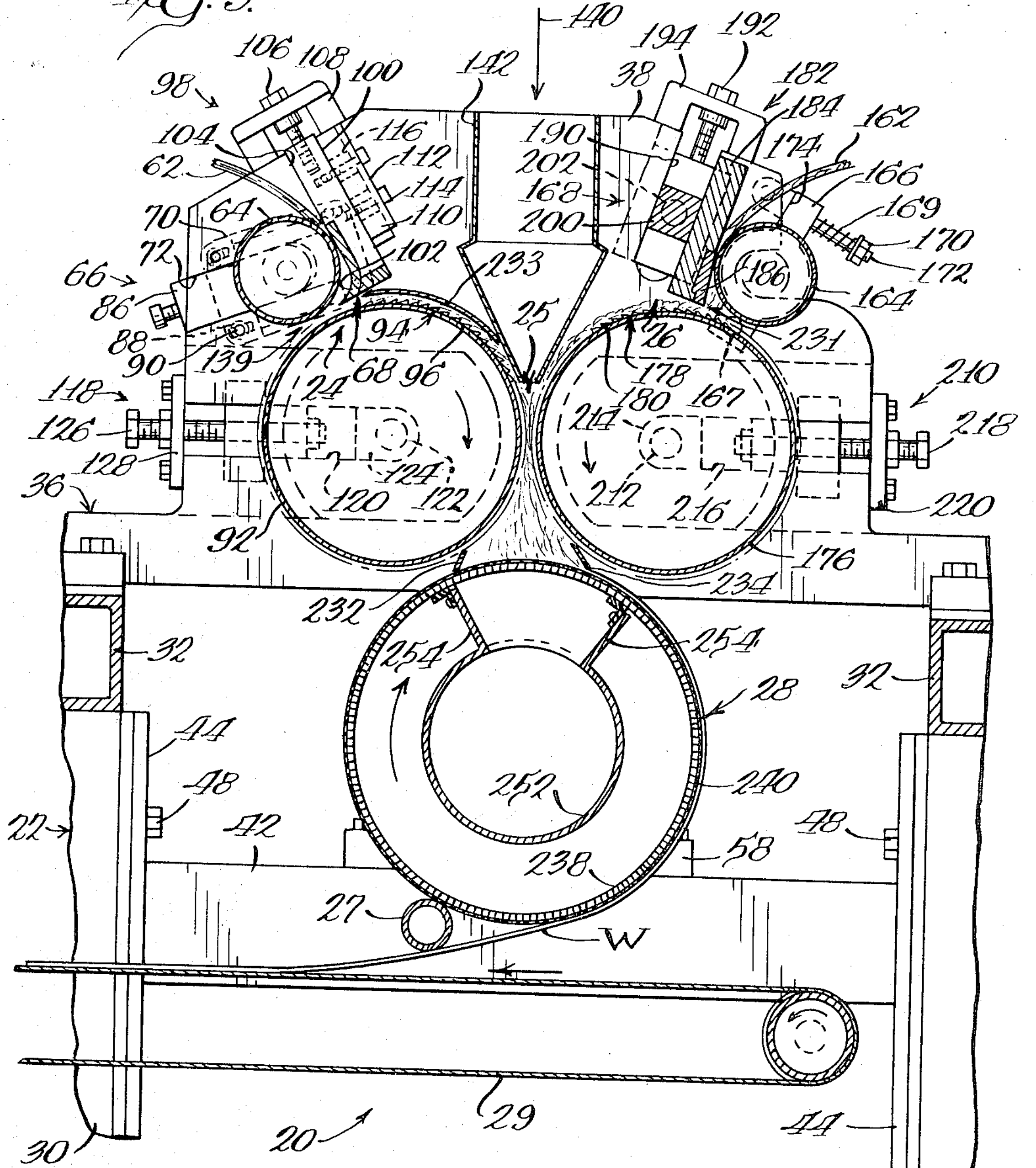

Fig. 24.

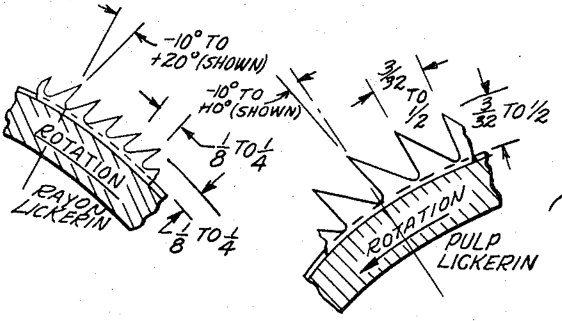

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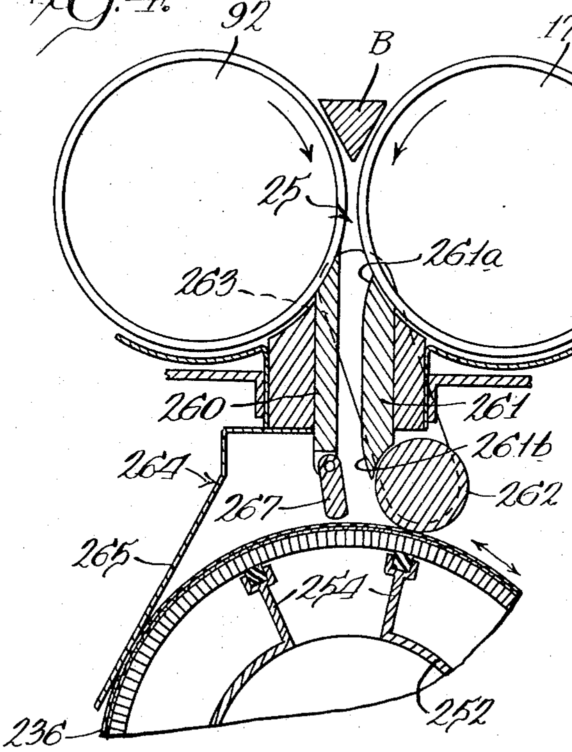
Fig. 4.



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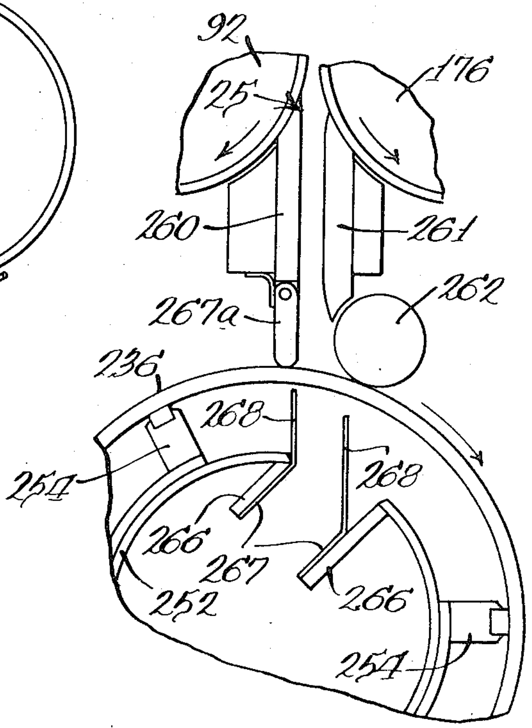

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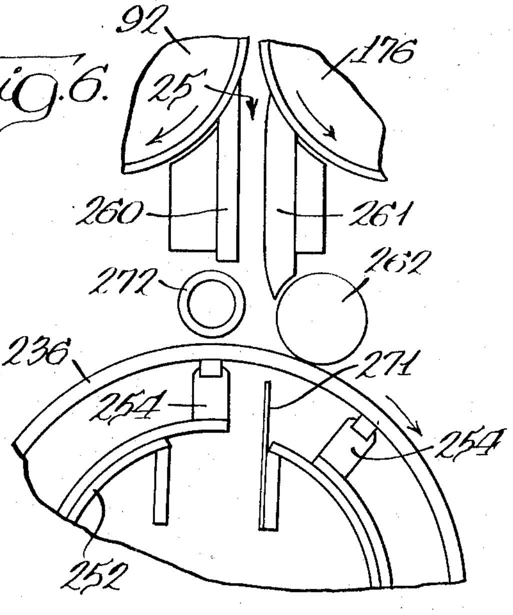

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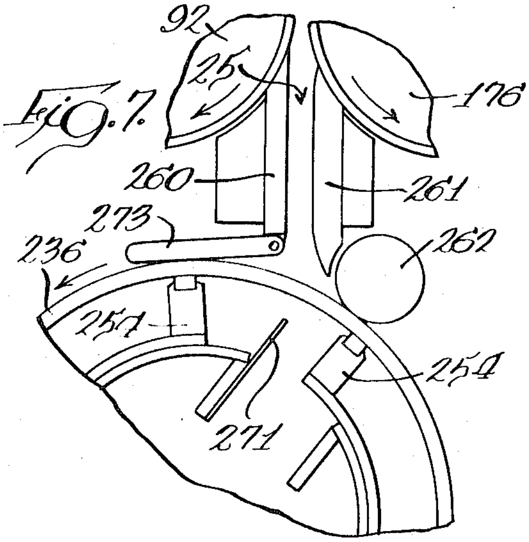

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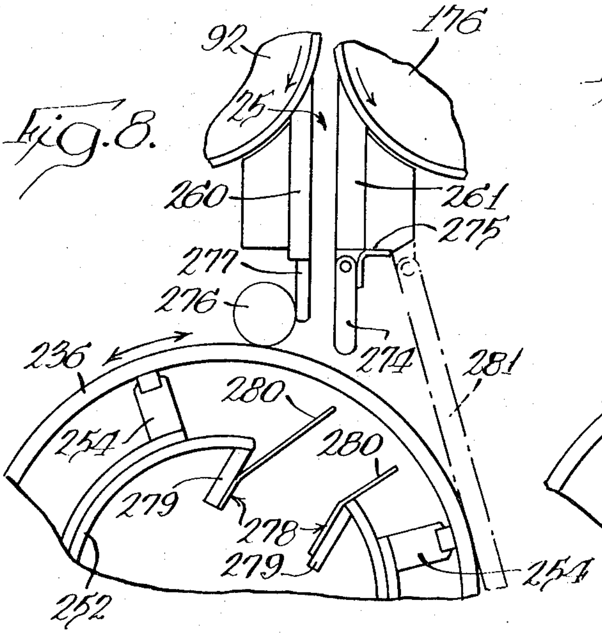
Fig. 8.



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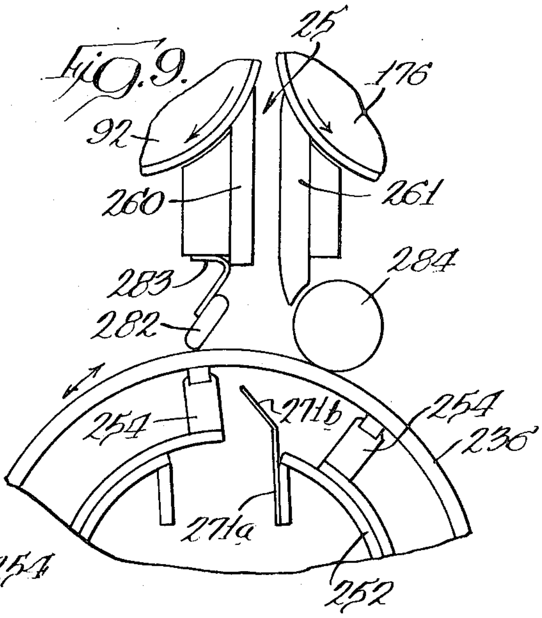

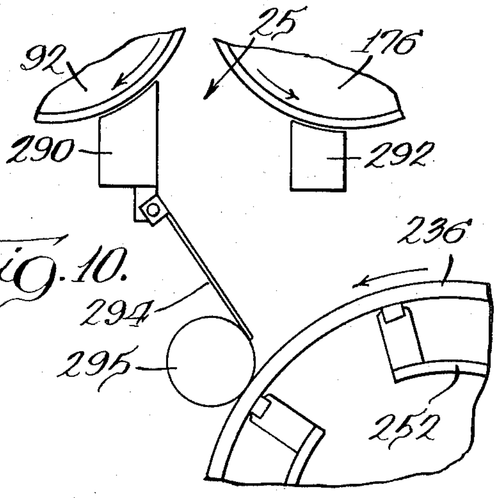

Fig. 10.

Fig. 11.

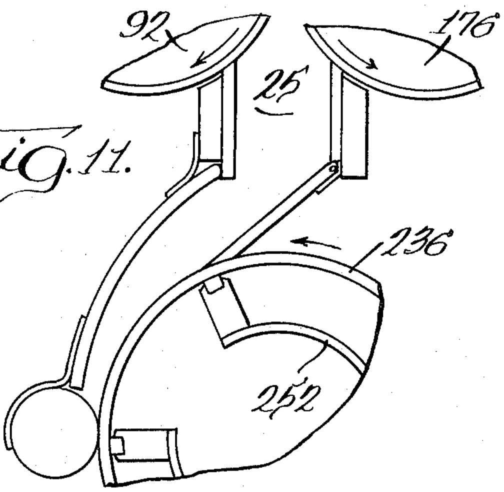

Fig. 12.

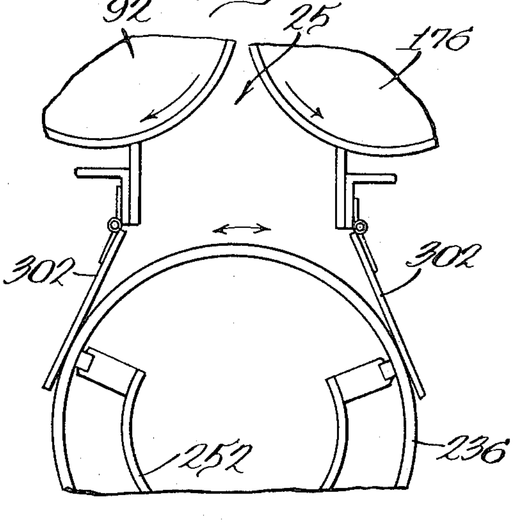

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Fig. 13.

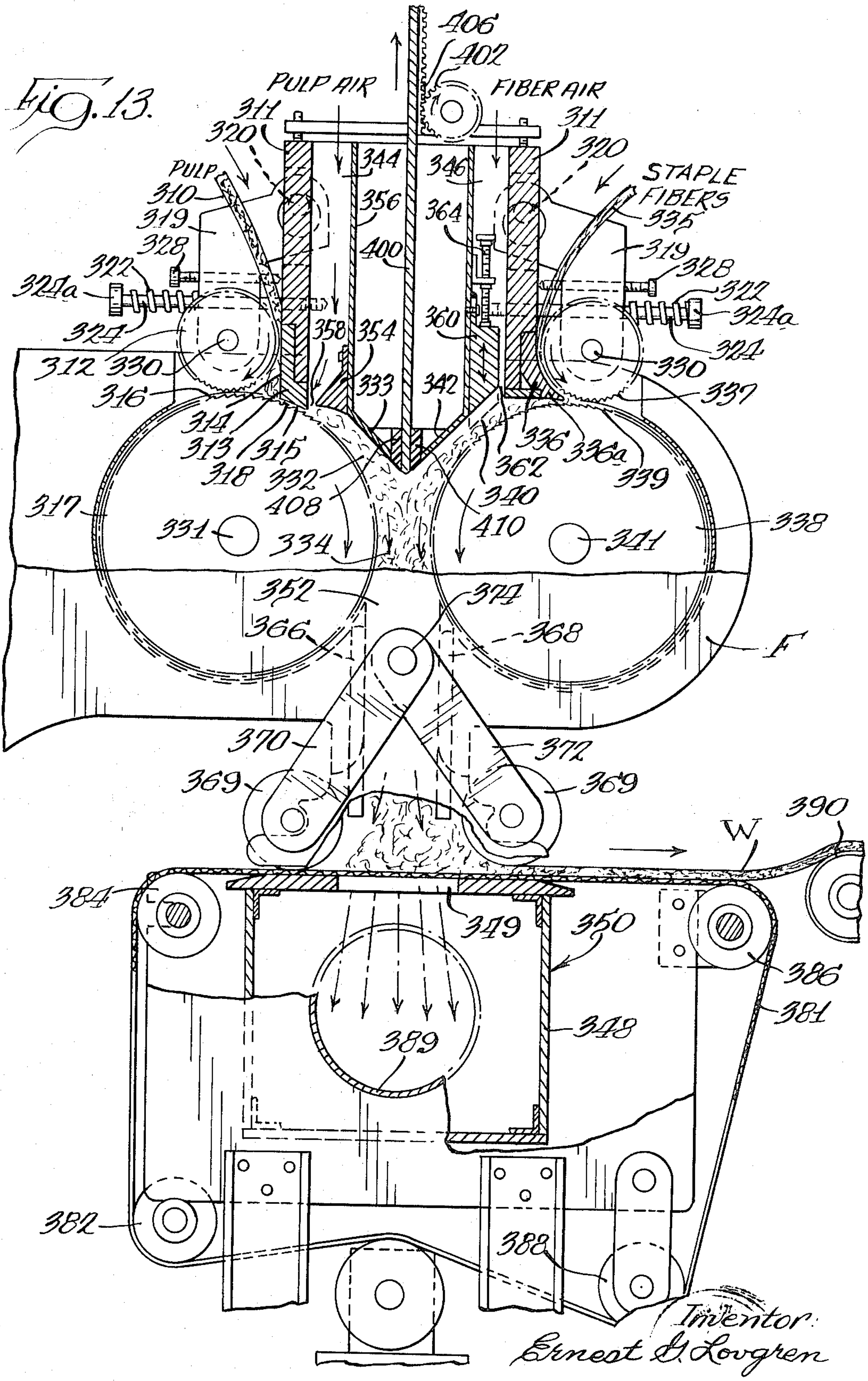

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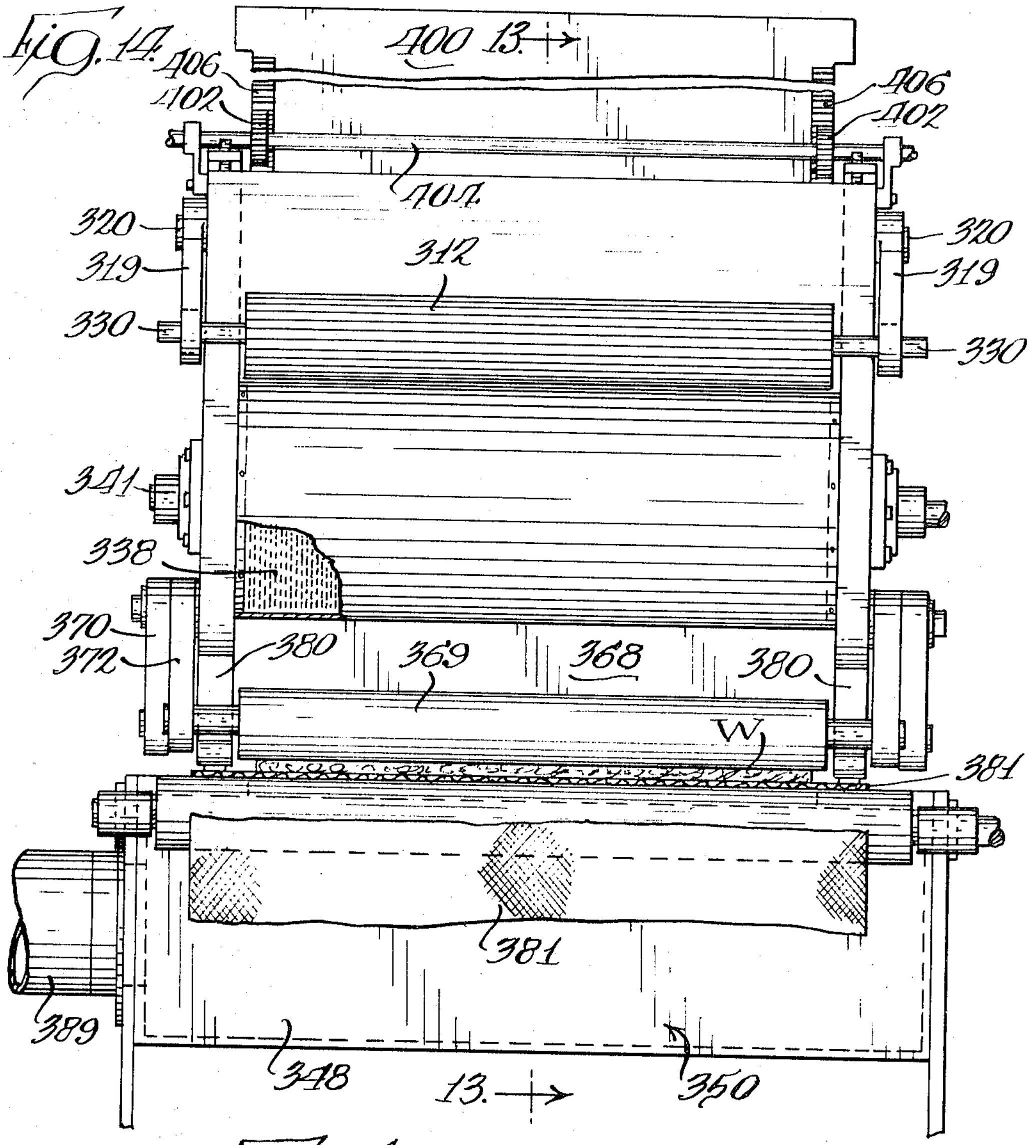
Fig. 14.



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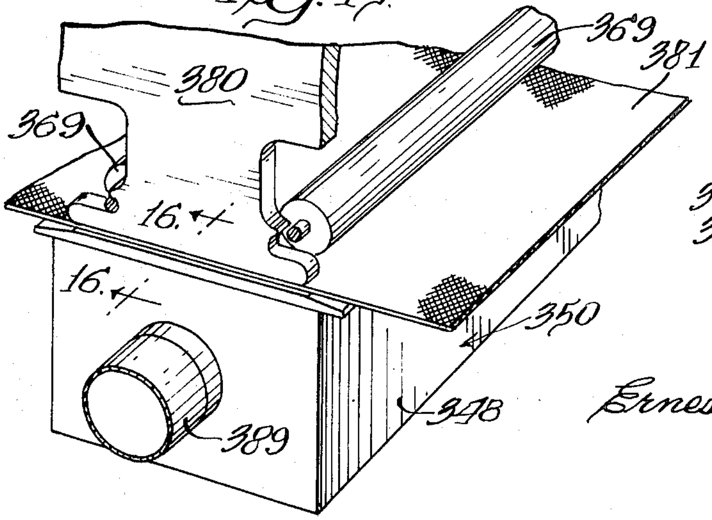

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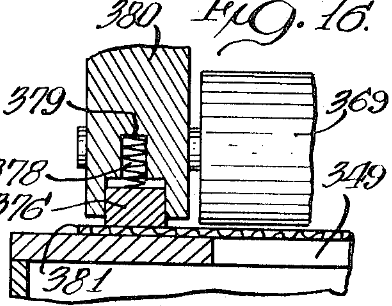

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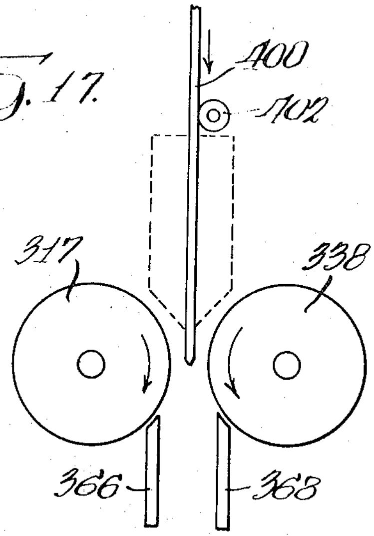
Fig. 17.



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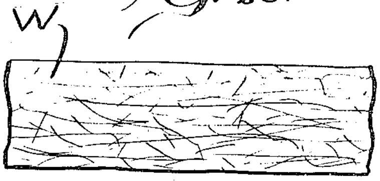
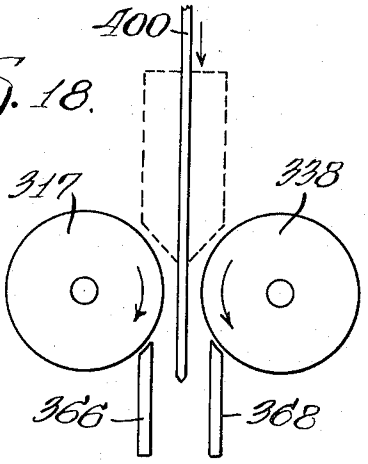


Fig. 21.

Fig. 18.



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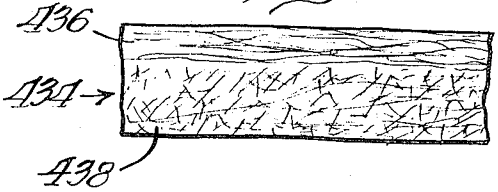

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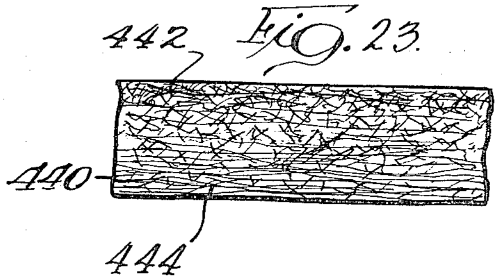
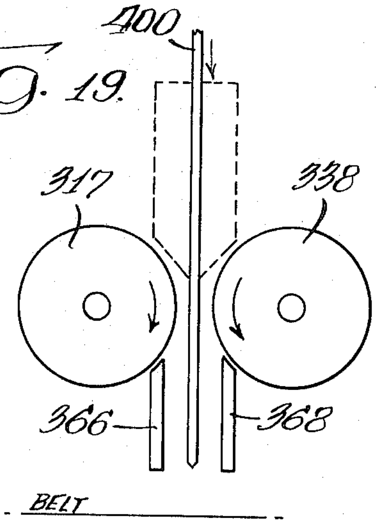


Fig. 19.



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WEB FORMING APPARATUS

This invention relates generally to air-laid nonwoven materials, and more particularly to air-laid monwoven webs consisting of a more or less uniform intermixture of randomly oriented fibers. Preferably, the web comprises a substantially homogeneous blend of long and short fibers; i.e., textile length and papermaking fibers.

Fibers are usually classified according to length, with relatively long or textile length fibers being longer than about one-fourth inch and generally between one-half and two and one-half inches in length. The term "long fibers" as used herein, refers to textile fibers having a length greater than one-fourth inch, and the fibers may be of natural or synthetic origin. The term "short fibers," as used herein, refers to papermaking fibers, such as wood pulp fibers or cotton linters having a length less than about one-fourth inch. While it is recognized that short fibers are usually substantially less costly than long fibers, it is also recognized in many instances that it is desirable to strengthen a short fiber product by including a blend of long fibers therein.

In the recent past, nonwoven fabrics have met with increasing commercial acceptance because such fabrics can be made with physical properties, and appearance, more or less comparable with the more expensive woven fabrics. In general, these fabrics are structures consisting of a random assemblage or web of fibers which are joined together with a binder to provide the desired strength.

It is well known to produce nonwoven webs of textile length fibers by a conventional carding process, and this results in an anisotropic web wherein the fibers are aligned predominantly in the machine direction. It is also known to produce a nonwoven web by a garnetting process, and while webs produced by this technique have less fiber orientation than carded webs, the garnetted webs are generally of unsatisfactory uniformity and also are limited to textile length fibers. Furthermore, the rate at which webs can be produced by either of these techniques is limited, and these techniques do not lend themselves for use in making the very low cost nonwoven fabrics, especially those embodying the use of the relatively low cost wood pulp fibers.

It is also known to eliminate directionality in carded or garnetted webs by replacing the doffing cylinder used in these processes with an air duct leading to an air condenser. In one arrangement, known as the "Duo-Form" technique, a carding lickerin individualizes fibers from pre-opened textile length stock, and an intermediate doffing and transfer cylinder feeds the opened fibers to a second lickerin for further opening. The fibers removed from the second lickerin are carried by an air stream and deposited on a screen cage where the web is formed. The "Duo-Form" process is limited to the production of a web having textile length fibers, and the successful operation of the process requires thorough pre-opening of the fibrous stock.

Another machine that has been proposed for eliminating directionality in carded or garnetted webs consists of two traveling flat cards having doffers which confront one another. Rapidly rotating needle cylinders remove the fibers from the card doffers and transport them in an essentially inverted J-shaped path through the converging upper branches of a generally Y-shaped duct system. The lower branch of the duct system is traversed by a horizontally moving screen upon which the fibers are condensed. This latter apparatus is, of course, limited to textile length materials, and even though the output of two cards is combined, the total production rate is still unsatisfactory.

The velocities of the air streams flowing through the converging branches of the generally Y-shaped duct system of the machine just referred to is, of necessity, quite limited. These low velocities are required to avoid upsetting the web on the doffing cylinders of the cards prior to removal of the fibers by the rotating needle cylinders. Also, while this machine ultimately combines the output of two cards into a single duct, because of the necessity of having low air velocities and thus eliminating the possibility of turbulent flow conditions, in the event that two different textile length fibers were fed into the converging branches of the duct system of the machine, little or no blending of the different fibers would take place, and instead a web of an essentially laminar arrangement of fibers would result with a marked interface between the layers of fibers.

Nonwoven webs have also been produced by feeding filamentary material downwardly between oppositely rotating beater blades which break up or rupture the filaments to form long fibers as the filaments are fed between the beater blades. The thus formed fibers are subsequently deposited on a screen or other condenser to form a web, and while such webs may have the textile length fibers randomly arranged, the process is limited to use with tow or other continuous filament material as the source of the fibers.

A further process for producing a random web of textile length fibers is known as the "Rando-Webber" process, and is practiced upon apparatus available from the Curlator Corporation of East Rochester, New York. In this process, pre-opened textile length fibrous material is fed to a supply device, which further opens and delivers the fibrous material as a loose mat to a web forming unit. The mat is compressed and fed over a nose bar where it is brought into contact with a lickerin, and the teeth of the lickerin remove fibers from the mat and introduce them into a high velocity, low pressure air stream in the reduced cross section throat of a duct. The fibers are subsequently deposited in random fashion on a condensing screen to produce a substantially isotropic web. While this process and apparatus have functioned generally staisfactorily to produce a relatively uniform random web of textile length fibers, it is generally not suitable for use with short fibers nor with blends of short and long fibers. Furthermore, throughputs with this type of apparatus are limited.

It has recently been proposed to produce a random fiber web consisting entirely of short fibers, and one such process is known as the "Texpa" process that is practiced upon apparatus also available from the Curlator Corporation of East Rochester, New York. This apparatus consists essentially of two adjacent, generally vertically disposed foraminous belts that converge downwardly and that are positioned in communication with a duct carrying short fibers. A pair of oppositely rotating opening cylinders are positioned in close adjacency to one another beneath the converging belts, and a suction actuated fiber condensing means is positioned below the opening cylinders. Suction is applied to the foraminous belts to withdraw fibers from the conveying duct thereabove, and the belts convey the fibers downwardly where they are compressed into a single mat at the point of convergence of the two belts. The single mat is fed downwardly to the opening cylinders, one of which is rotating at a faster speed than the other. The cylinders have oppositely disposed teeth, so that as the mat is fed downwardly between the cylinders, the downwardly facing teeth of one cylinder carry the fiber through the nip between the cylinders, while the upward facing teeth of the other cylinder hold the fibers back. This action tears the mat into individual fibers which are then carried by an air stream onto a condenser belt to form a random web. The "Texpa" process is generally not suitable for use with long fibers, or blends of long and short fibers, and the throughputs obtained with this process are limited.

The desirability of, and need for, a web comprised of a mixture of long and short fibers is well understood by those skilled in the art. In general, the desired characteristics of the nonwoven end product as well as its utility dictate the type of fibers and the relative proportions of long and short fibers to be used. Thus, for example, the product may require one or more characteristics such as tear resistance, abrasion resistance, washability and stretchability, burst strength, absorption or nonabsorption to different liquids, heat sealability, ability to resist delamination, etc., all of which will influence the type of fiber or mixture of fibers to be used. Thus, by way of specific example, absorbent products requiring strength characteristics may be a combination of two or more different fibers such as wood pulp fibers and rayon or similar fibers in varying percentages.

Likewise, again depending on the nature of the product desired, the product may have to possess substantially random characteristics as opposed to oriented fiber characteristics in order to provide for balanced properties in both the machine and cross direction for most uses. For example, in the case of products intended for surgical or similar uses requiring absorbency characteristics, such as a sanitary napkin or a portion thereof, absorbent surgical drapes, etc., mixtures of randomly oriented short and long fibers are required to provide improved mechanical characteristics; while in the case of nonwoven materials suitable for use as disposable items in the field of diapers, short fibers are generally employed.

Typical of the short fibers are wood pulp fibers from various types of woods, cotton linters, asbestos fibers, glass fibers and the like; with wood pulp fibers being those which find most frequent use in a large variety of products due to their ready availability and economical attributes. Typical of the long or staple length fibers are synthetic fibers such as cellulose acetate fibers, vinyl chloride-vinyl acetate fibers (e.g. the product marketed under the trademark "VINYON"), polyamide fibers such as NYLON 6, NYLON 66, etc., viscose staple rayon, cupra-ammonium rayon or other regenerated cellulose fibers including saponified ester fibers, cellulose ester fibers such as cellulose acetate and cellulose triacetate, acrylic fibers, polyester fibers, polyvinyl chloride fibers, polyolefin fibers such as polyethylene and polypropylene, fluorocarbon fibers such as "TEFLON" and natural fibers such as cotton, flax, jute, wool, silk, ramie or "rag," or protein fibers such as "VICARA" Combinations of any of the short and staple or long fibers may be employed in this invention. The denier of the fibers used may vary over a wide range and may be from one-half to 100 depending on the type of fiber employed and the requirements of the nonwoven material. Commonly, when using staple fibers such as rayon, the denier will vary from 0.75 to 5 or 6 denier.

Conventionally, the shorter type of fibers such as wood pulp fibers are commerically available for air-laying processes in the form of pulp boards, which are compressed sheets of fibers in intimate contact with each other. The pulp boards come in varying thicknesses and lengths, typical thicknesses being from one-sixteenth of an inch to three-sixteenths of an inch, and sometimes more. If desired, the starting material such as pulp boards may be comprised of a mixture of two or more different fibers, preferably of approximately the same length. Thus, by way of example, in place of utilizing a conventional wood pulp board, a board may be of a mixture of wood pulp fibers and cotton linters, asbestos fibers, glass fibers, etc. Thus, different properties may be imparted to the product by employing various combinations of fibers.

In the case of staple or longer length fibers, such as rayon, for example, they are normally commerically available in bale form in various fiber lengths; and for use in the present invention, they are generally employed in a pre-opened oriented condition, termed a "carded web" or "carded batt" in the art. To this end, baled rayon can be formed into a carded lap according to conventional techniques known to those skilled in the art, which, briefly summarized, first involves formation of a picker lap wherein the fibers are formed into a uniform batt of generally constant weight, whereafter they are carded to orient and open and comb the fibers, and thus form the "carded batt." If desired, in place of using a carded batt of only rayon, a mixture of rayon and other fiber or fibers, or for that matter a mixture of any two or more different long fibers can be employed, thereby providing a product having different fibers and with them the different properties they impart to the ultimate nonwoven fabric. It is not necessary that the staple length fibers be used in the form of a carded batt but these fibers may be presented to the machine of the present invention by other means well known to those skilled in the art, such as chute feeding, CMC even feed, or directly from a card, for example.

Those skilled in the art have recognized the long felt need for providing a process and apparatus for producing a web of homogeneously blended short and long fibers, as described above, with substantially all of the fibers being randomly disposed. Various systems have been proposed in the past, but none have met with wide commercial success because of the failure to either get satisfactory randomnization, satisfactoy homogenization, or a satisfactory production rate.

For example, it has been proposed to individualize short fibers by a milling device, such as a hammer mill or a fitz mill, and to entrain the individualized short fibers in an air stream into which individualized long fibers are fed. In one known technique, the individualized short fibers are transported in a horizontal duct, with a lickerin rotating at a narrowed throat portion of the duct and combing individual fibers from a long fiber web or mat and introducing them into the short fiber air stream traveling therebelow. It has been proposed to form a web by depositing the airborne fibers on a foraminous condenser that intersects the duct, or by allowing the duct to feed fibers into a gravity settling box, where they settle by gravity on a foraminous conveyor. In either technique, because the long fibers are introduced into the air stream above the short fibers, the resulting webs have a tendency toward stratification, with the long fibers predominating at the top of the web, and the short fibers predominating at the bottom of the web. This lack of complete homoginization has made such processes generally unsatisfactory.

Webs of blended short and long fibers that have been produced by such prior art techniques have not only exhibited a marked different in properties from one side to the other, but also have shown a definite tendency to strip or separate at the line of demarcation between the layers. While such webs have been satisfactory for certain products, particularly where the web is an internal layer that is not visible to the consumer, such webs have not been completely satisfactory for other products, particularly where strength is required and, also, where the web is exposed to view by the consumer.

One of the major problems in connection with blended fibrous webs formed by prior art techniques is in the proper opening of the fibrous materials at high speeds to substantially completely individualize the fibers without damaging them. For example, a single lickerin has been used to simultaneously open both long and short fiber materials, and it has been found that lickerin speeds that are suitable to open the short fiber material in a high speed commercial operation have caused excessive damage to the fibers of the long fiber material.

In webs produced by prior art techniques, it is common to find a relatively large percentage of incompletely opened clumps of fibers and it is also common to find a relatively large percentage of "salt" - like hardened particles that are formed by compressing individual fibers during the fiberizing step. Such webs have not been visually acceptable and suitable for use as an exposed layer in an end product, since they are not uniform in appearance. Furthermore, in webs having clumps of fibers, or hardened particles of broken and/or compacted fibers, the functional characteristics of the web are not uniform. For example, the presence of clumps of fibers or compacted fibers causes the web to be of variable weight, strength, cohesiveness, fluid absorbtiveness and uneven in color when dye is used. Webs having a high percentage of salt-like particles, are completely unsatisfactory for many uses, such as surgical towels and dressings, because of the tendency of these particles to flake off the web.

To obviate such problems, it has been necessary to rotate the lickerin at a compromise speed, which is not suitable for commercial production. Other techniques that have been proposed in the past have the same or similar problems.

In accordance with the process and apparatus of the present invention, a nonwoven web of substantially completely open fibers, preferably randomly oriented, is produced wherein at least a portion of the web consists of a homogeneous blend of fibers from two separate and distinct supplies of fibers. The present invention utilizes a pair of parallel lickerins that are rotated in opposite directions to individualize fibers from each supply. When the web is to include a blend of long and short fibers, the lickerin for the short fibers is rotated at a faster speed than the lickerin for the long fibers. A backing member is provided for each fibrous source adjacent its respective lickerin, and different and optimum opening relationships may be established between each lickerin and the nose bar portion of its associated backing member.

The fibers are doffed from the lickerins substantially immediately after individualization by separate gaseous streams flowing adjacent each lickerin, and by centrifugal force, which tends to throw the fibers into their respective gaseous streams. The supplies of indivualized fibers are entrained in the separate gaseous streams, and the streams are impelled toward one another and toward a generally centrally disposed mixing zone, where the fibers intermix.

The supplies of individualized fibers are combined in a common gaseous stream flowing downwardly through the mixing zone, in an exemplary form of the invention. The common air stream may be produced by the cooperative action of a suction actuated fiber condensing means at the terminal end of the mixing zone and by the air generated by the rotary action of the oppositely rotating lickerins.

In the process of the present invention, the fibers entrained in the separate gaseous streams have a trajectory including a component directed toward one another, as well as a component directed toward the mixing zone. Although the fibers are transported by the separate gaseous streams through the mixing zone, the fibers have sufficient kinetic energy by virtue of their mass and velocity that the fibers continue to travel generally in the direction of their initial trajectory because of their inertia. The component of motion of the fibers toward one another causes them to combine in an intimate mixture of fibers as the gaseous streams are impelled against one another and combined into the common stream. The combined stream transport the mixed and blended fibers through the mixing zone to a condensing means where the fibers are deposited to build up a web of the desired thickness.

The blending action may be regulated by controlling certain machine parameters, such as the rate of fiber input, the volume and/or velocity of the air flowing through the machine, the speeds of the lickerins, type of lickerin teeth and the winding of the clothing, and the geometry of the ducting system. For example, at relatively low air volumes, when producing a web comprised of homogeneously blended short and long fibers, since the short fiber lickerin is rotating at a higher speed than the long fiber lickerin, a differential velocity is created in the common gaseous stream, with the portion of the gaseous stream on the short fiber side of the machine having a greater velocity (and hence a lower pressure) than the portion of the gaseous stream on the long fiber side of the machine. Therefore, the individualized long fibers are accelerated and drawn into the faster moving zone of air, and the acceleration of the individualized long fibers keeps them under tension substantially until they are deposited on the fiber condensing means. The suction or drawing action created by the faster rotating short fiber lickerin enhances the intimate admixure of the long fibers with the individualized short fibers.

Also, by having relatively higher gas volumes, with an appropriately shaped ducting system, the gas passing through the machine can be retained in a turbulent condition, which also enhances the degree of blending of the long and short fibers.

In one embodiment of the invention a variable nose bar-lickerin relationship is provided for each supply of fibrous material, so that these realtionships can be individually adjusted and controlled for different materials to produce a lickerin action that will substantially completely open the respective fibrous materials.

The relationship of the fiber condensing means to the fiber mixing zone is also adjustable in an illustrative embodiment of the invention, so that by establishing a desired relationship between the mixing zone and condensing means, the directioning of the individual fibers of the resulting web can be varied and controlled between a completely randomized orientation, and an orientation wherein a majority of the fibers extend either lengthwise or crosswise of the web.

The process and apparatus of the present invention produces a web having at least a portion comprised of a homogeneous admixture of long and short fibers; and in webs where all of the fibers are homogeneously blended, such webs are not only uniform in external appearance, but also have uniform functional characteristics including weight, thickness, etc.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front elevational view, partly in section, of a web forming apparatus constructed in accordance with the present invention;

FIG. **2** is a side elevational view, partly in section and partly broken away, of the apparatus illustrated in FIG. **1**;

FIG. **3** is an enlarged sectional view taken generally along line **3—3** of FIG. **2**;

FIGS. **4—12** are enlarged, fragmentary sectional views of modified configurations for the mixing zone of the apparatus illustrated in FIGS. **1—3**;

FIG. **13** is a central sectional view through a further embodiment of the web forming apparatus, and FIG. **13** is taken generally along line **13—13** of FIG. **14**;

FIG. **14** is a front elevational view of the apparatus illustrated in FIG. **13**;

FIG. **15** is a fragmentary perspective view illustrating details of the condensing screen of the embodiment of FIGS. **13** and **14**;

FIG. **16** is an enlarged sectional view taken generally along line **16—16** of FIG. **15**;

FIGS. **17–19** are schematic representations of the apparatus illustrated in FIGS. **13–16**, and illustrate the baffle in different positions;

FIGS. **20–23** illustrate in cross section various webs that can be produced by the apparatus of FIGS. **13–16** and

FIG. **24** is an enlarged schematic view illustrating the profile of the lickerin teeth used in the apparatus of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

While this invention is susceptible of embodiment in many different forms, there is shown in the drawings and will herein be described in detail only preferred embodiments of the invention and modifications thereof, with the understanding that the present invention is to be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the embodiments illustrated. The scope of the invention will be pointed out in the appended claims.

Referring now to the drawings in detail, and particularly to FIGS. **1–3**, an exemplary embodiment of the apparatus of the present invention is indicated generally at **20**, and the apparatus **20** includes frame means **22** supporting first and second fiberizing means **24** and **26** adjacent the upper end thereof, and supporting a suction actuated fiber receiving means **28** therebelow, as will hereinafter be described in detail. Fiberizing means **24** and **26** are operative on separate sources of fibrous material to substantially completely open the material and create separate supplies of individualized fibers that are entrained and conveyed in separate gaseous streams directed toward each other and toward a common mixing zone **25** therebetween. The individual fibers are doffed from the fiberizing means **24** and **26** by centrifugal force and by the separate gaseous streams moving relative to the fiberizing means. The separate gaseous streams are impelled against one another, and are combined into a common high speed gaseous stream flowing through the mixing zone **25** toward the fiber receiving means **28**. The fibers are given an initial trajectory in the doffing direction, and the kinetic energy imparted to the fibers by virtue of their mass and velocity enables them to have substantial inertia and continue to have a significant component of motion toward the other supply of fibers. This allows at least a portion of the fibers of each supply to become homogeneously blended and further mixing can take place in the mixing zone **25** by adjusting certain machine conditions, as is hereafter explained. The entrained fibers are then directed to, and deposited upon, receiving means **28** by the common air stream to build up a web W. A doffing roll **27** is supported upon frame means **22** adjacent receiving means **28** for removing web W therefrom and transferring it to a conveyor **29** therebelow.

The apparatus of the present invention includes frame means **22** defined in part by upright members **30** that are connected to one another by upper crossrails **32** and lower crossrails **34**. A subframe **36** is mounted upon upper crossrails **32**, and subframe **36** includes a pair of spaced side plates **38** that are stabilized by transversely extending tie rods **40**. Fiberizing means **24** and **26** are supported between side plates **38** at first and second fiberizing stations, respectively.

In order to be able to change the characteristics of web W, as by varying the direction and pattern in which the individualized fibers are deposited on the fiber receiving means **28**, in the embodiment illustrated in FIGS. **1–3**, the position of the fiber receiving means **28** relative to the mixing zone **25** can be varied, and for this purpose, a pair of transversely extending frame members **42** are adjustably connected to uprights **30**. A vertical adjustment means is provided by plates **44** that are fixed to opposite ends of each frame member **42**, with the plates **44** each including spaced, vertical slots **46**. Locking bolts **48** impale slots **46** and are threaded into internally threaded openings in uprights **30**, so that the frame members **42** can be moved vertically when the locking bolts **48** are loosened, and positively retained in the desired position relative to mixing zone **25** when locking bolts **48** are tightened.

Fiber receiving means **28** includes side plates **50** at opposite ends thereof, and horizontally or lateral adjustment of the fiber receiving means **28** is effected by mounting bolts **52** that are slidably mounted in elongate slots **54** in the upper flange **56** of frame member **42**. As can be seen in FIG. **1**, bolts **52** extend through openings in mounting feet **58** that extend laterally from the lower ends of side plates **50**, and nuts **60** are threaded upon bolts **52** to retain the fiber receiving means 28 in the desired position of lateral adjustment relative to mixing zone 25. While the position of the fiber receiving means 28 is variable in the illustrated embodiment of the invention, it should be understood, that the adjustability feature is not critical to the present invention, when, in use, a given type of web is to be continuously produced on the machine.

A mass of long or textile length fibers 62 of the type described above, is fed to fiberizing means 24 by a cylindrical feed roll 64. The opposite ends of feed roll 64 are rotatably supported upon mounting plates 38, and the feed roll 64 is positively rotated by conventional means, not shown, to control the rate and amount of long fiber material that is fed to the fiberizing means 24.

The present invention includes adjustment means 66 for varying the position of the feed roll 64 relative to a nose bar assembly 68 for accommodating different thicknesses of long fiber material. The adjustment means 66 includes a mounting block 70 adjacent each side plate 38, and each block 70 is generally T-shaped in cross section with an offset portion being slidably mounted in an inclined slot 72 in the adjacent mounting plate 38. Each block 70 includes a recess 74 that positions a further mounting block 76 for movement perpendicularly to slots 72. Mounting blocks 76 include a boss 78 having the ends of the feed roll 64 rotatably mounted therein, and elongate slots 80 at each side of blocks 76 are impaled by clamping bolts 82 that are threaded into blocks 70 to allow the blocks 76 to be adjusted at right angles to slots 72. In this manner, the clearance between the feed roll 64 and nose bar assembly 68 can be set at an optimum gap for the particular type and thickness of the fibrous source 62.

Feed roll 64 is retained in a positive material feeding relationship with the nose bar assembly 68, and to this end, feed roll 64 is urged toward the nose bar assembly 68 by springs 84 that act between a recess in one end of each block 70 and an aligned recess in an abutment plate 86 that is secured to each side plate 38. Elongate guide slots 88 are provided in each corner of blocks 70, and clamping bolts 90 impale slots 88 and are threaded into openings in side plates 38. The ends of slots 88 limit the movement of feed roll 64 toward the nose bar assembly 68 and provide a minimum clearance therebetween, it being understood that the bolts 90 can be tightened to positively secure the feed roll 64 in a selected position of adjustment. By virtue of the above-described adjustment means 66, it will be appreciated that feed roll 64 can be located in any of a plurality of locations relative to the nose bar assembly 68. However, in a situation where the fibrous source 62 will always be substantially the same, it should be understood that the adjustment means 66 can be eliminated or greatly simplified.

In order to provide a first supply of individualized fibers, a material opening cylinder 92 is mounted for rotation in a clockwise direction between side plates 38 below feed roll 64, and opening cylinder 92 preferably takes the form of a lickerin having spirally wound toothed clothing 94 thereon. The teeth of the rayon lickerin usually have a lower tooth height and pitch than the pulp lickerin. The pitch and height of the teeth used on the lickerin for the rayon may vary, ggod results being obtained with a tooth pitch of about one-eighth inch to about one-fourth inch and a tooth height of about one-eighth inch to about one-fourth inch. The angle of the teeth of the lickerin for the rayon may also vary, generally within the limits of about −10° to about +20°. The teeth 96 may have only a slight positive rake, or even a slight negative rake, to facilitate doffing of the short fibers from the lickerin 92.

Adjustment means 98 is provided for varying the position of the nose bar assembly 68 relative to the lickerin 92, so as to provide optimum conditions for substantially fully opening the long fiber material 62 without damaging the fibers thereof. The nose bar assembly 68 includes a holder 100 that extends between side plates 38, and holder 100 supports a nose bar 102 thereon that has a curved material supporting surface facing feed roll 64. Holder 100 is mounted for movement toward and away from lickerin 92 in inclined slots 104 in side plates 38, and the position of holder 100 is adjusted by screws 106 that are threaded into holder 100, with screws 106 reacting against saddle members 108 that are secured to side plates 38. A support block 110 is secured to each side plate 38, and clamping plates 112 fixed to holder 100 are tightened against support blocks 110 by screws 114 to positively retain holder 100 in the selected positions of adjustment, it being understood that clearance slots 116 are provided in blocks 110 to allow the holder 100 to move relative thereto. Should it be desired to always include substantially the same type of long fibers in the end product, the aforementioned adjustment means 98 may become unnecessary.

The long fiber material 62 is presented to the teeth of the rapidly rotating lickerin 92 at approximately 11 o'clock position, and the lickerin teeth comb out and individualize the long fibers as the teeth move past the nose bar 102.

In order to be abe to vary and control the mixing characteristics of the long and short fibers as their individual carrier streams are combined, as will hereinafter appear, the width of the throat of the mixing zone 25, i.e., the distance between the fiberizing means 24 and 26, can be varied, and adjustment means 118 is provided for moving lickerin 92 in and out in a horizontal plane. The axle 122 of lickerin 92 is mounted in slide members 124 that ride in horizontal slots 120 in side plates 38, and adjustment means 118 is provided by adjusting screws 126 that are threaded into slide members 124 for varying the position of lickerin 92. Adjusting screws 126 react against plates 128 that are secured to side plates 38.

Lickerin 92 is rotated in a clockwise direction, as shown by the directional arrow in FIG. 3, and to this end, the output shaft 132 (FIG. 1) of a motor 130 is connected to lickerin 92 by a belt drive system including a sheave 134 on shaft 132, a sheave 136 on axle 122, and an endless belt 138 trained over sheaves 134 and 136. Motor 132 can be bolted to an upright 30 of a main frame, as illustrated, or it can be mounted on the floor, and the motor mounting means may be adjustable, so that the position of the motor 130 can be changed when the position of the lickerin 92 is changed. Motor 130 rotates lickerin 92 at a high speed that allows the teeth 96 to comb out and individualize the long fibers from supply 62 at a rapid rate, and for purposes of illustration, a rotational speed of 2,400 rpm has been found to be satisfactory to produce a desired quantity of individualized rayon fibers from picker lap fiber source without damage to the fibers. Lickerin 92 can be rotated at higher speeds for greater throughput, if desired.

The rotation of lickerin **92** generates a stream of gas, e.g., air, as indicated by the directional arrow **139** in FIG. **3**, that flows under the nose bar assembly **68**, to initiate a fiber doffing action, in cooperation with the centrifugal forces acting on the fibers, substantially immediately after the fibers are combed from source **62**. Since doffing is initiated substantially immediately following fiber individualization, i.e. at about the 12 O'clock position, a large number of the fibers are given an initial trajectory having a significant component of motion toward the oncoming fibers from fiberizing means **26**. As the fibers are accelerated and entrained in the stream **139** they possess substantial kinetic energy because of their mass and velocity, and the inertia of the fibers tends to keep them moving along a path generally in the direction of their initial trajectory.

A further gas stresm, represented by the directional arrow **140** in FIG. **3**, flows generally vertically downwardly through the mixing zone **25** toward the fiber collecting means **28** adjacent the periphery of lickerin **92**, and any undoffed fibers are removed from the lickerins by the stream **140**. Stream **140** serves as a common carrier stream for the fibers doffed from both lickerins as will hereinafter appear. The gas stream **140** can be generated in part from a separate source **142**, such as a commercially available air knife, or the gas stream can be generated by the combined action of the separate carrier streams and the suction actuated condenser means **28**, as will hereinafter be explained. In any event, the common stream **140** receives the oncoming fibers and partially, but not completely (as will hereafter appear), overcomes their inertia to change their trajectory and direct them to the condensing means **28**.

In the event that an air knife is used, adjustment means **144** (FIG. **1**) may be provided for positioning the air knife in an optimum position relative to the mixing zone **25** to get the desired type of directionalized air flow. Adjustment means **144** is arranged to move the air knife **142** both vertically and angularly, if desired. To this end, the air knife **42** includes laterally extending support portions **146** at each end thereof having internally threaded vertically extending openings therein. Frame members **148** are secured to side plates **38**, and adjusting screws **150** adjacent each side plate **38** extend through the threaded openings in support portions **146** and through aligned bores in frame members **148** so that the air knife **142** can be vertically adjusted. A worm wheel **152** is provided at each end of air knife **142**, and angular adjustment of the air knife is accomplished by worm gears **154** on adjusting screws **156** that are mounted for horizontal movement in horizontal bores in frame members **148**. By appropriate adjustment of adjusting screws **150** and **156** the direction of the air stream emanating from the orifice at the lower end of the air knife can be varied and controlled.

A mass of short fibers **162**, such as pulpboard or linters board in sheet form, is fed to fiberizing means **26** by a cylindrical feed roll **164**, which is positively rotated by conventional means, not shown, to control the rate and amount of short fiber material that is fed to the fiberizing means **26**. The opposite ends of feed roll **164** are rotatably mounted in support arms **166** that are pivotally connected between side plates **38** by pivot members **167**. Feed roll **164** is biased towards a nose bar assembly **168** by springs **169** that bear against support arms **166**, and springs **169** urge the support arms in a counterclockwise direction about pivots **167**. Springs **169** react between support arms **166** and a nut **170** on spring retention members **172** that are pivotally connected to side plates **138**, it being understood that the members **172** pass through clearance openings in the support arms **166**. Spring holding members **172** include a stop surface **174** for limiting the pivotal movement of the support arms **166**, thereby establishing a minimum clearance between the mass **162** of short fibers and the nose bar assembly **168**.

A material opening cylinder **176** is mounted for rotation in a counterclockwise direction between side plates **38** below feed roll **164**, and opening cylinder **176** preferably takes the form of a lickerin having spirally wound toothed clothing **178** thereon. As is evident from FIGS. **1** and **3**, lickerins **92** and **176** are positioned in parallelism with one another and are preferably of the same diameter. In an exemplary embodiment of the invention, lickerins **92** and **176** have an outer diameter of approximately 9 ½ and a length of approximately 40 inches. The individual teeth **180** of clothing **178** are selected to optimize the opening or grinding conditions for the short fiber material **162**. The pitch and height of the teeth used on the lickerin for the pulpboard may vary, good results being obtained with a tooth pitch or about three thirty-second inch to about one-half inch and a tooth height of about three thirty-second inch to about one-half inch. The rake angle of the individual teeth **180** of clothing **176** is selected to give the optimum opening characteristics for the specific material being fed to the lickerin. The angle of the teeth of the lickerin for the pulpboard may also vary, generally within the limits of about −10° to about +10°. To facilitate doffing the teeth may preferably have a negative rake.

Optimum conditions for substantially completely opening the short fiber material **162** may be further established by virtue of an adjustment means **182** which varies the position of the nose bar assembly **168** relative to the lickerin **176**. The nose bar assembly **168** includes a holder **184** having a nose bar **186** at the lower end thereof that faces feed roll **164**. The nose bar **186** preferably has a straight or flat material engaging surface for supporting the short fiber pulp material **162** in position to have the material combed and the fibers individualized by lickerin **176**. Plates **188** (FIG. **1**) are secured to opposite ends of the holder **184**, and plates **188** are generally T-shaped in cross section, with the offset portion of each plate **188** riding in an inclined slot **190** in one side plate **38**. The adjustment means **182** is provided by adjusting screws **192** that are threaded into openings in plates **188**, with the screws **192** reacting against saddle members **194** that are fixed to the side plates **38**. Plates **188** include a plurlaity of elongate slots **196** (FIG. **1**) therein, and clamping bolts **198** that are threaded into side plates **38** impale slots **196**, it being understood that the bolts **198** are tightened to positively retain the holder **184** in the selected position of adjustment relative to lickerin **176**.

The nose bar holder **184** can also be adjusted angularly relative to the feed roll **164** and the teeth on lickerin **176**, and to this end, a block **200** on one side of the holder **184** is pivotally mounted on a shaft **202** that the extends transversely between plates **188**. Further clamping plates **204** are affixed to the ends of shaft **202**, and arcuate slots **206** in clamping plates **204** are impaled by clamping bolts **198**, that are tightened to positively retain the holder **184** in the selected position of angular adjustment. If should be understood that the adjustment means for either or both of the nose bar assemblies is not critical to the process of the present invention, and fixed lickerin-nose bar relationships may be established for both supplies of fibers, particularly if each lickerin and nose bar is to always open material having substantially the same characteristics, but the adjustability feature adds flexibility to the machine making capable of use with materials having different characteristics.

As is mentioned briefly above in connection with lickerin **92** a preselected spacing between the lickerins **92** and **176** can be established by virtue of an adjustment means **210** for varying the position of lickerin **176** relative to the mixing zone **25** and lickerin **92** acting in combination with the adjustment means **118** for lickerin **92.** To this end, the axle **212** of lickerin **176** is mounted in slide members **214** that ride in horizontal slots **216** in side plates **38.** Lickerin **176** is moved in and out by adjusting screws **218** that are threaded into slide members **214**, with screws **218** reacting against plates **220** that are secured to the side plates **38.** By virtue of the adjustment means **118** and **210**, the width of the throat portion of the mixing zone **25** between the lickerins **92** and **176** can be varied and controlled. The distance between the lickerins will, to a certain extent, be determinative of the volume of fibers that are entrained in gas stream **140** and ultimately deposited upon receiving means **28.** A spacing of approximately .25 inches has been found to give excellent results although smaller gaps, and larger gaps up to 1.5 inches have also given satisfactory results.

Lickerin **176** is rotated in a counterclockwise direction, as shown by the directional arrow in FIG. 3, and to this end, the output shaft **222** (FIG. 1) of a motor **224** is connected to lickerin **176** by a belt drive system including a sheave **226** on shaft **222**, a sheave **228** on axle **212**, and an endless belt **230** trained over sheaves **226** and **228.** Lickerin **176** may be rotated at a speed substantially faster than the rotational speed of lickerin **92** when lickerin **176** is opening short fiber material and lickerin **92** is opening long fiber material. For purposes of example, a rotational speed of 4,000 rpm has been found satisfactory to produce a desired quantity of high quality individualized pulp fibers from a pulpboard. Faster rotational speeds for lickerin **175** can be used if greater throughput is desired. Like motor **130**, motor **224** is illustrated as being secured to an upright **30** of the main frame, although it may be mounted on the floor, and the mounting for motor **224** may also be adjustable.

In order to improve the opening action of lickerins, an arcuate cover plate **233** (shown only for lickerin **92**) may be positioned over the portion of the lickerin between the nose bar and the upper end of the mixing zone. The end of cover plate **233** is spaced from the nose bar **102,** so that the rotation of the lickerin **92** will draw in a stream of gas, e.g. air, between the cover plate **233** and nose bar **102** that will force the fibers against the lickerin **92,** while at the same time force the fibers cooling the cover plate and helping to convey fibers. A gap of one-half inch between the cover plate **233** and nose bar **102** has proven to be effective in providing a stream that forces the upper layer of fibers into the teeth of lickerin **92** for additional working.

Because of the relatively high rotational speeds of lickerins **92** and **176**, each lickerin creates a zone of gas, e.g. air, moving circumferentially therearound. As is mentioned above, lickerin **92** generates gas stream **139** that initiates doffing of the individualized fibers from lickerin **92.** Likewise, lickerin **176** generates a gas stream, represented by directional arrow **231**, that passes under nose bar assembly **168** and in conjunction with centrifugal force and tooth configuration initiates a fiber doffing action substantially immediately after the fibers have been combed from source **162.** As is evident from FIG. 3, the short fiber material is presented to the teeth on lickerin **175** at approximately a 1 o'-clock position. Since a large number of the fibers are doffed from lickerin **176** substantially immediately following individualization, i.e. at about a 12 o'clock position, the fibers are given an initial trajectory having a significant component of motion toward the oncoming fibers from lickerin **92.** As the fibers are accelerated into stream **231**, because of their inertia, they will tend to continue to move in their initial direction.

Since the lickerins **92** and **176** are rotating in opposite directions, the zones of air generated thereby cooperate to produce at least a portion of the common high speed stream **140** that is directed downwardly between the lickerins through the mixing zone **25** toward the fiber receiving means **28.** It is has been found that with rotational speeds of the aforementioned magnitude, i.e., 2,400 rpm for lickerin **92** and 4,000 rpm for lickerin **176**, and with the tooth-to-tooth spacing of the lickerins being in the aforementioned range, the lickerins can produce a substantial portion of the velocity of stream **140**, depending of course on the presence or absence of air knife **142** and the magnitude of the suction drawn by fiber receiving means **28.**

It has been found that at the lickerin rotational speeds mentioned above and with condensing means **28** pulling approximately 400 cfm, the combined air stream **140** has an average volumetric flow rate of approximately 500 cfm. This flow rate gives the individual streams **139** and **231** and the common stream **140** sufficient velocity to effect the desired fiber doffing and blending, so that a separate gas source, such as air knife **142** is not necessary.

As has been mentioned above, the fibers entrained in gaseous streams **139** and **231** posess substantial kinetic energy, and their inertia tends to keep them moving in the initial doffing direction. As the separate gaseous streams **139** and **231** merge into the common gaseous stream **140,** the combined forces of gravity and the suction applied by the fiber receiving means tend to cause the fibers to assume a more downward trajectory, but the momentum of the fibers is such that as the streams **139** and **231** are impelled against one another, a substantial portion of the long and short fibers become intermixed. The position at which the streams **139** and **231** are brought together, and the degree of blending of the long and short fibres can be controlled by varying certain machine parameters such as the volume and/or velocity of gas flowing through the machine, the speed of the lickerins, the rate of fiber input, the geometry of the ducting system, and the position of the fiber receiving means.

In one mode of operation, at relatively low gas volumes, in forming a web of blended long and short fibers, since lickerin **176** is rotating at a substantially greater speed than lickerin **92,** a zone of lower pressure is created in the common high speed stream **140** in mixing zone **25** between and below the lickerins **92** and **176**. The individualized long fibers from the lickerin **92** are accelerated toward the zone of low pressure and retained substantially under tension until the fibers are deposited upon the fiber receiving means **28**. The drawing of the long fibers into the zone of low pressure and the aforementioned inertial impelling of the fibers together, cause the long and short fibres to be homogeneously blended in the mixing zone **25**.

Also, as is explained in detail in the commonly assigned, concurrently filed application Ser. No. 108,545 of A. Farrington, the geometry of the ducting of the machine, may be configured to insure that the gaseous streams will have turbulent flow characteristics from the point of doffing to the point of deposit of the fibers. This, together with the interposition of a baffle between the separate gaseous streams can result in the production of various different webs, including a web comprised of homogeneously blended long and short fibers. Furthermore, as is explained in the commonly assigned, concurrently filed Ruffo et al. application Ser. No. 108,546, at increased gas-to-fiber volume ratios, various high quality webs can be produced at high production rates.

The lower portion of the mixing zone **25**, i.e., the portion between the lickerins **92** and **176** and the fiber receiving means **28** is preferably closed by deflector plates **232** and **234** that are secured between side plates **38**. Because the lower portion of the mixing zone **25** is wider than the throat portion between the lickerins **92** and **176**, the stream **140** having the intimate admixture of long and short fibers therein tends to decelerate as it approaches the fiber receiving means **28**, and hence it is desirable that the fiber receiving means **28** be positioned sufficiently closely to the lickerins **92** and **176** that deceleration of the rayon fibers in the stream is minimized. While the receiving means **28** is illustrated substantially immediately below lickerins **92** and **176** in FIG. **3**, the present invention does not require that the fiber receiving means be positioned this close to the lickerins, and satisfactory webs have been produced withh the distance between the center line to center line spacing between the lickerins and receiving means being as much as 16 inches.

The fiber receiving means **28** is defined by a suction actuated fiber condensing drum **236** having a foraminous fiber supporting surface formed by a radially open honeycomb network **238** (FIG. 3) that has at least one fine mesch screen **240** thereover. In an exemplary embodiment of the invention, drum **236** has an outer diameter of approximately 12 inches. Drum **236** is rotated (clockwise in the illustrated embodiment as indicated by the directional arrow in FIG. 3) by a motor **242** through a chain drive (FIG. 1) including a sprocket **244** fixed to the output shaft **246** of the motor **242**, a sprocket **248** fixed to the drum **236**, and an endless chain **250**. The fiber receiving means **28** further includes a stationary central portion **252** having flanges **254** that extend radially outwardly into sealing engagement with the drum **236**. In the embodiment of FIGS. **1–3**, one flange **254** is positioned in substantial alignment with deflector plate **232**, while the other flange **254** is circumferentially beyond deflector plate **234**. A conduit **256** (FIG. 2) is connected to stationary portion **252** and to a suitable source of negative pressure for applying a suction to drum **236** between the flanges **254**. It will be appreciated that the suction of the fiber receiving means **28** cooperates with the air streams created by the oppositely rotating lickerins **92** and **176** to provide a pressure gradient across the mixing zone **25** which draws the individualized and homogeneously blended long and short fibers onto the drum **236** to build a web. The stream **140** that is produced by the conjoint action of lickerins **92** and **176** and the negative pressure of the fiber receiving means **28** is retained at a large enough velocity that a sufficient means interstitial spacing between the fibers is maintained in the mixing zone which allows the fibers to remain intermixed without agglomeration prior to deposition on the fiber receiving means.

In a typical example of the practice of the invention disclosed herein, lickerins **92** and **176** of the size set forth above were rotated at the above mentioned speeds, and 555 pounds of fibers per hour were fed to the lickerins, with 75 percent of the fibers being pulp fibers, and 25 percent of the fibers being rayon fibers. The tooth-to-tooth spacing between the lickerins was 0.25 inches, and deflector plates **232** and **234** were parallel with one another and spaced by **.625** inches. The air stream **140** had an average volumetric flow rate of 500 cubic feet per minute (2,250 pounds per hour), and there was a feed ratio of about 4.05 pounds of air per pound of fiber. The average volume ratio of air to fiber was approximately 5,000 to 1. Pitot readings were taken at various positions between deflector plates **232** and **234**, and these readings indicated that stream **140** had a high velocity zone adjacent deflector plate **234**. Visual observations confirmed that a large number of fibers were entrained in the high velocity portion stream **140**, and that a majority of the fibers were condensed on the screen adjacent deflector plate **234**. With the conveyor **29** operating at a web take away speed of 200 feet per minute, it was found that an extremely satisfactory web W was produced having an average weight of about 900 grains per square yard.

It will be understood, of course, that conveyor **29** is intended to transport the web W to a further processing zone, such as a bonding zone where a bonding agent may be applied to the web.

The nonwoven webs obtained by the process of the present invention may be post-treated by any suitable conventional technique, to bond the web and provide the required strength and coherency characteristics for a given product. The particular type of bonding technique chosen will depend on various factors well-known to those skilled in the art, e.g., the type of fibers, the particular use of the products, etc. To this end, typical of the conventional techinques are web saturation bonding, suction bonding, foam bonding, print bonding, fiber bonding, fiber interlocking, spring bonding, solvent bonding, scrim bonding, viscose bonding, mercerization, etc.

In the case of web saturation bonding, the nonwoven web is generally soaked with a solution or emulsion binder, and thereafter, the excess fluid is removed usually by mechanical means (e.g. squeeze rollers and/or vacuum), followed by evaporation. In the case of suction bonding, a web is treated with a suitable binder by soaking and the excess removed by means of a vacuum apparatus. In foam bonding, which is a variation of saturation bonding and is particularly useful for products requiring good bulk and through-bonding, a foam binder is employed. In print bonding, generally employed where softness and absorbency is required, a bonding agent will be printed onto the web by, e.g. gravure type rolls. The web can be wet or dry when printed and generally the binder is a water, solvent or plastisol based one.

In fiber bonding techniques, employed where a percentage of the fibers in the web are semi-soluble in certain solvents, e.g. hot water, the web may be bonded by adhesive or by treating the web with a suitable solvent — e.g. polyvinyl alcohol. In a variation of this procedure, if the web includes thermoplastic fibers such as polypropylene, "VINYON" or low melting polyester, hot roll embossing calendars may be employed. Still further, in other case, a low melting spun bonded web may be placed between higher melting fiber webs and hot calendered. Thermoplastic powders may also be used in this technique.

In the case of mechanical interlocking bonding techniques, needle looms are employed in bonding soft fiber webs. Boards of needles with barbs downwardly pointed perforate the web and entangle the layers. A variation of this type of bonding technique is stitch bonding with yarn, as may be accomplished by using an "ARACHNE" apparatus or with the fibers of the web itself.

As the name implies, spray bonding techniques spray a binder onto the web which is subsequently passed into a drying chamber. This type of bonding is particularly useful where high loft is required in products, e.g. which are suitable for use as air filters. Solvent bonding employs a solvent which is applied to the web to soften the fiber surface and render it adhesive. Typical solvent bonding employs the use of chloral hydrate of DMSO (dimethylsulfoxide).

In scrim bonding, a scrim layer or yarn layer act as carriers for a wet or thermoplastic adhesive used to laminate the nonwoven webs to one or more layers of a substrate, e.g. tissue. In viscose bonding, which is a special case of print or saturation bonding, cellulose xanthate is regenerated to pure cellulose on the inner sections of the fibers forming the nonwoven web. In a like manner, acid solutions of nylon may be regenerated in situ.

In mercerization bonding techniques, nonwoven webs are bonded using the uncurling manner of caustic solutions, e.g. caustic soda on all-cotton nonwoven webs. The fibers unwind to entangle each other and, thereafter, the resulting product is thoroughly washed.

The above list of bonding techniques is not intended to be exhaustive as others known to those skilled in the art may be employed, e.g. bonding with the use of high pressure streams of water or other fluids directed onto the nonwoven web to cause the fibers to interlace; or still further, using ultrasonic waves and laser beams.

In any of the above "dry" bonding techniques, the binder areas may be of any suitable shape and size and may be continuous or discontinuous straight, sinuous, curved, or wavy lines; rows of polygons, circles, annuli, or other regular or irregularly shaped geometric figures; all of which normally extend across the width of the nonwoven fabric at various angles to the long direction thereof. Specific examples of such binder areas are noted in U.S. Pats. Nos. 2,705,688, 2,705,687, 2,705,498 and 3,009,822.

The amount of binder employed will depend on the type of bonding technique used and depend on the type and quality of product desired — i.e. the amount of

binder add-on to the nonwoven web may be varied according to the technique employed and will vary within relatively wide ranges, depending to a large extent upon the intended use of the nonwoven fabric, upon its type, weight and thickness, as well as upon the specific binder employed. Typically, the binder areas should not exceed a substantial amount of the total surface of the nonwoven fabric, if a soft hand, drape and other textile-like properties and characteristics are desired or required. In cases where a somewhat different hand and drape is acceptable, increased binder coverages of up to almost any value, say 50 percent or even 75 percent, are useful. For some binders, as low as from about 2 percent to about 20 percent by weight has been found sufficient; for others, as high as from about 40 percent to about 70 percent or more by weight has been found preferable. Within the more commercial aspects of the present invention, however, binder add-ons of from about 3 percent to about 40 percent by weight are known in the art to be satisfactory.

The particular type of binder used may be selected from a large group of binders now known in the industry for such purposes. Non-migratory binders, such as hydroxyethyl cellulose and regenerated cellulose, are preferred inasmuch as they yield sharp and clear boundaries of bonded areas and unbonded areas. Water-insoluble or water-insensitive binders, such as melamine-formal-dehyde, urea formaldehyde, or the acrylic resins, notably the self-cross-linking acrylic ester resin, are also preferred inasmuch as they are capable of completely resisting a subsequent aqueous reararanging treatment. Other binders, however, are also of use and would include polyvinyl acetate, polyvinyl chloride, copolymers thereof, polyvinyl acrylate, acrylate, polyethyl methacrylate, polyvinyl butyral, cellulose acetate, ethyl cellulose, carboxymethyl cellulose, etc.

Following bonding, the nonwoven webs may be treated again according to conventional procedures for any further desired purpose, such as for decorative reasons.

Still further, the nonwoven webs may be treated with various types of resinous coatings according to conventional techniques, or alternatively by bonding the nonwoven web to various substrates to provide laminates.

The products obtained by the process of the present invention, following bonding, find use in various and diverse fields. Moreover, the random nonwoven webs will now have greater utility because of their greater availability, and may be used to replace oriented nonwoven webs where improved machine and cross direction strength ratios are required. Typical of the uses to which the products can be put include limited-wear garments such as dresses, medical and industrial apparel, caps, hospital uses such as for surgical products, e.g. bandages, alcohol preparation, towelling, surgical pad covers, sanitary products such as napkins, absorbent products such as diapers and diaper facings, polishing and buffing cloths, wash cloths, wiping cloths, etc., consumer products such as table cloths and place mats, serviettes, book jackets, labels and tags, mop covers, cosmetic pads, filtration uses such as air filtration media as well as liquid filtration media in the chemical and food industries, etc. This is not exhaustive and many different uses are well known to those skilled in the art.

It should also be understood that while the persons and apparatus of the present invention have been described in terms of producing a web that has at least a portion that consists of homogeneously blended long and short fibers, the present invention comprehends that the web may be formed entirely either of short fibers or long fibers. Furthermore, while adjustment means have been illustrated for varying the positions of the lickerins, the nose bars, the fiber receiving means, and the feed rolls, these mechanisms may also be positioned at fixed locations, on the frame in instances where the apparatus will continuously be operating upon fibrous materials having the same characteristics.

Also, the web formation characteristics and the dry strength of the resulting web can be improved by selecting both machine and fiber materials which produce an appropriate electrostatic attraction and/or repulsion of one fiber to another and their relationship to the machine itself. During transport of the fibers through the mixing zone to the condensing screen, it is desirable to maintain the voltages between the fibers to reduce coalescence. This can be accomplished by selecting fibers and machine components that produce fibers with like charges so as to eletrostatically repel one another when they are transported in the common air stream. In some instances, to optimize the buildup of web W on the condensing screen, fibers can be chosen that will be electrostatically attracted to one another, and this phenomenon can be especially important in retaining the air laid web as a unitary mass during transport from the condensing screen to a further processing station wherein a binder is applied to the web. It is also a factor in how the fibers line up relative to one another.

Instead of merely having outwardly diverging deflector plates, such as **232** and **234**, at the lower end of the mixing zone **25**, many different arrangements can be utilized, and several of these are illustrated in FIGS. **4–12.** It will be understood that with the various arrangements illustrated in FIGS. 4–12, the air flow patterns at the lower end of the mixing zone can be modified to control the manner in which the airborne fibers are accumulated on drum **236.** While several different arragements have been illustrated, these arrangements have been selected for purpose of example only, and in no way should they be construed as limiting the invention as defined in the appended claims.

In the embodiment of FIG. **4**, deflector plates **260** and **261** at the lower end of the mixing zone **25** are arranged so that the intermediate portion of the mixing zone is a narrow channel. Deflector plate **261** may have rounded portions **261**a and **261**b at the upper and lower ends thereof, respectively, to guide the large number of fibers traveling in the high velocity portion of stream **140**, assuming that low gas volumes are flowing through the machine, as described above. A sealing roll **262** is carried upon an arm **263** that is pivotally mounted to the frame of the machine, and sealing roll **262** is driven by conventional means, not shown, with the sealing roll being positioned in alignment with one flange **254** of the internal portion **252** of drum **236.** A baffle **264** is positioned below deflector plate **260**, and includes an inclined portion **265** that extends tangentially with respect to the periphery of drum **236.** An extension plate **267** is pivotally connected to the lower end of deflector plate **260**, and the lower end of plate **267** is spaced from the periphery of drum **236** between the flanges **254.**

With the arrangement of FIG. **4**, the fibers are deposited on drum **236** essentially between roll **262** and plate **267**, with the fibers being guided around the rounded portion **261**b of deflector plate **261.** A generally triangularly shaped blocking element **B** may be positioned above lickerins **96** and **176** to prevent any dense particles that are thrown off the lickerins by centrifugal force from entering the mixing zone. The dense particles collected on blocking element **B** preferably are continuously removed from the machine by means, not shown, such as an air stream, or a screw conveyor or other means.

In many instances it is desired to concentrate the highest portion of the suction from the condensing means over a relatively narrow area in the fiber accumulating zone, and several arrangements for accomplishing this are illustrated in FIGS. **5–9.** In the embodiment of FIG. **5**, the internal portion **252** of the fiber receiving means is angularly adjustable, and the sealing flanges **254** are spaced apart by an angle slightly in excess of 90°. A pair of flanges **266** extend inwardly of the internal portion **252** of drum **236**, and baffles **267** are fixed thereto. Baffles **267** includes parallel portions **268** that extend vertically upwards toward the mixing zone, so that the fibers are deposited on the drum **236** in a relatively narrow area with high velocity as determined by the distance between the baffle portions **268.** The thus laid fibers are retained on the screen by the low velocity and low suction areas outwardly of baffle portions **268** to firmly hold the web on the screen as it moves out of the fiber condensing zone. The lower portion of the mixing zone **25** in the embodiment of FIG. **5** includes deflector plates **260** and **261** similar to those illustrated in FIG. **4**; and a plate **267***a*, similar to plate **267** in FIG. **4**, is pivotally connected to the lower end of deflector plate **260**, with plate **267***a* extending vertically downwardly into engagement with drum **236.** As is evident from FIG. **5**, the internal baffles **268** on drum **236** are positioned in alignment with plate **267***a* and sealing roll **262.** With the arrangement of FIG. **5**, even though the sealing flanges **254** on drum **236** may be positioned more than 90° from one another, the fibers are deposited on the drum in an extremely narrow zone determined by the spacing between baffles **268.**

In the embodiment of FIGS. **6** and **7**, the sealing flanges **254** of the condensing drum **236** are positioned relatively closely to one another, and a narrow area of suction application is obtained by a straight baffle member **271** that is positioned in close proximity to one of the sealing flanges **254.** In the embodiment of FIG. **6**, a stationary tube **272** extends transversely across the frame of the machine below deflector plate **260**, and in alignment with one sealing flange **254.** In the arrangement of FIG **7**, the condensing drum **236** is offset laterally (to the left) relative to lickerins **92** and **176.** A plate **273** is pivotally connected to the lower end of deflector plate **260**, and bears against the periphery of drum **236** in alignment with one flange **254**, while sealing roll **262** is positioned in alignment with the other flange **254.** As is evident from FIG **6**, the internal baffle **271** on drum **236** is substantially parallel to the deflector plates **260** and **261**, while in the embodiment of FIG. **7**, the baffle **271** is positioned at an angle with respect to the deflector plates **260** and **261.**

In the embodiment of FIG. **8**, like the embodiment of FIG. **7**, the condensing drum **236** is offset to the left relative to the vertical center line of the mixing zone. Deflector plates 260 and 261 define a relatively narrow passage at the lower end of the mixing zone 25, as with the embodiments of FIGS. 4–7. The deflector palte 261 in the embodiment of FIG. 8 does not include a rounded lower end, as with the previously described embodiments, and instead, a fiber guiding extension plate 274 is pivotally connected to the lower end of deflector plate 261. A flexible sealing element 275 is connected between the lower end of deflector plate 261 and the upper end of fiber guiding plate 274 to prevent fibers from passing outwardly therebetween. A driven roll 276 is positioned in sealing engagement between drum 236 and an extension 277 of deflector plate 260. In the embodiment of FIG. 8, the highest suction is applied to a relatively narrow zone of drum 236, and to this end, baffles 278 are secured to spaced parallel, inwardly extending flanges 279 on the inner portion 252 of drum 236. Baffles 278 include parallel outer ends 280 that are positioned at an angle with respect to the center line of the mixing zone 25. A sealing plate 281, shown in broken lines in FIG. 8, may be pivotally connected to the lower end of deflector plate 261 and positioned in sealing alignment with flange 254.

The embodiment of FIG. 9 is similar to the embodiments of FIGS. 6 and 7 to the extend that a single baffle member 271*a* is provided on internal drum portion 252, with baffle 271*a* cooperating with one sealing flange 254 of the condensing drum 236 to provide a confined area of high suction on the condensing drum. Baffle member 271*a* includes an inclined outer end 271*b* that extends toward the left hand sealing flange 254 to provide an extremely narrow gap through which the highest suction is applied. A sealing member 282 is positioned in alignment with the left hand sealing flange 254, and is connected to the lower portion of deflector plate 260 by a flexible member 283. A sealing roll 284 is positioned in sealing engagement with drum 236 between baffle portion 271*b* and the right hand sealing flange 254.

The embodiment of FIG. 10 illustrates that fixed deflector plates 290 and 292 may be positioned at different distances from the central line of the mixing zone 25. The embodiment of FIG. 10 also illustrates a pivotally mounted deflector 294 directly below the mixing zone 25 for directing the individualized and blended fibers onto the screen 236.

In the embodiment of FIG. 11, a pivotally mounted deflector plate 296 is provided directly below the mixing zone while a further pivotally mounted arcuate deflector plate 298 extends between fixed deflector plate 300 and sealing roll 292. In the embodiment of FIG. 12, the lower end of the mixing zone 25 diverges in both directions by virtue of pivotally mounted deflector plates 302.

It will be appreciated that all of the webs produced by the structures illustrated in FIGS. 4–12 will have slightly different characteristics, but all of the webs will have at least a portion consisting of homogeneously blended short and long fibers.

Referring now to FIGS. 13–23, which illustrate an embodiment of the invention developed by A. Farrington and which is described and claimed in detail in the above mentioned Farrington application, pulp is introduced into the system in the form of a pulpboard 310, which is directed between a plate 311 and a feed roll 312. Connected to the lower part of plate 311 is a nose bar 313 for providing an anvil against which the pulpboard is directed during the individualizing step. The nose bar 313 has a sidewall 314 that can be made relatively flat, since, due to the integrity of the pulpboard, it is unnecessary that the plate 311 be designed to more accurately direct the pulp into intimate contact with the lickerin 317 that is used to individualize the pulpboard into short fibers. The bottom wall 315 of the nose bar 313 is angularly disposed relative to the sidewall 314 and is spaced a short distance from the teeth 316 of the lickerin 317 to define a passage 318 through which the pulpboard is moved during the individualizing operation. The pulpboard is individualized into fibers by the teeth 316 of the lickerin 317 acting on the pulpboard which is directed and retained thereagainst by the nose bar 313.

Returning to the pulpboard feeding system of FIGS. 13–23, the pulpboard is fed into the system by a feed roll 312 that is journalled in a bracket 319 that is eccentrically mounted at 320 to permit adjustment of the feed roll relative to the pulp lickerin 317 and nose bar 313. The bracket 319 and feed roll 312 are biased to direct the pulpboard toward the nose bar 313 by a spring 322 that is located between bracket 319 and head 324a of bolt 324 which extends through a hole in the bracket 319, and is secured in place in plate 311. The pivotal movement of the bracket 319 is limited by a set screw 328 that is threaded into and through bracket 319 and engages plate 311. The spring 322 insures that feed roll 312 will be maintained in contact with pulpboard 310 to insure that the pulpboard is into contact with lickerin teeth 31 of lickerin 317. This design accommodates varying thicknesses of material that can be used in this system.

The feed roll 312 is secured to a shaft 330 that is suitably supported for rotation by a variable drive means, a portion of which is shown schematically in FIG. 14. The speed at which the feed roll is operated is determined by the rate at which pulp is to be fed into the system. A number of the mechanisms employed for supporting the rollers, lickerins, and so forth, are shown generally in FIG. 14 and they will be referred to when they will aid in understanding the present invention.

During operation, the pulpboard 310 is fed into contact with the lickerin teeth 316 adjacent the nose bar 313. The lickerin 317 is mounted on shaft 331, which is driven at a very high speed (such as 6,000 rpm) by suitable drive means (not shown).

After the fibers are individualized by the lickerin, they are entrained in an air stream and directed through a duct 332 formed between the lickerin teeth 316 and a sidewall 333 into a mixing zone 334. The fibers are then directed onto a condenser 350 where they form a web. The duct 332 and mixing zone 334 form part of a flow duct.

Referring now to the rayon fiberizing system which exists on the right side of FIG. 13, there are shown mechanisms that control the feeding of the rayon 335, a number of which mechanisms are substantially identical to those used on the pulp side of the system. Identical components are given the same numbers as those applied on the pulp side of the apparatus.

The rayon is positively introduced into the clothing of the rayon lickerin 338 to insure that the rayon lickerin teeth 339 will pick the rayon up from the carded lap 335, and to this end, the nose bar 336 is curved at 336A to essentially conform to the adjacent circumference of the rayon feed roll 337. The rayon fibers that are thus picked up from the lap are positively maintained in position relative to the feed roll **337** until the fibers are disposed immediately adjacent the teeth **339** of the rayon lickerin **338**, which teeth will then serve to comb the fibers from the rayon source.

The individualized rayon fibers that are combed from the rayon source are then moved into duct **340** located between sidewall **342** and lickerin **338**. The duct **340** leads into mixing zone **334** where the rayon fibers are blended with the pulp fibers.

The doffing of the fibers from the lickerins **317, 338,** the air entrainment of the previously individualized fibers, and the conveying of the fibers through the ducts **332, 340** and into the mixing zone **334** are accomplished by high velocity air streams that are introduced into the system by being pulled in through parallel passages **344, 346** by a suction fan (not shown) located in the housing **348.** The suction fan is disposed beneath the condenser **350** that is located at the bottom of the air flow duct **352** that interconnects the mixing zone **334** with the condenser **350.** The parallel flow paths **344, 346** lead to lickerins **317, 338,** respectively, to direct high velocity air against their teeth to doff any fibers clinging thereto. The air with entrained particles therein then flows through ducts **332, 340,** respectively, into mixing zone **334** from where it flows through duct **352** and condenser **350.** The fiber particles entrained in the air stream are deposited on the condenser in the form of a web.

The condenser **350** on which the fibers are formed into a web consists of an endless movable mesh screen conveyor **381** directed over four pulleys **382, 384, 386** and **388** which conveyor is driven by suitable drive means (not shown). The conveyor **381** slides over the housing **348,** which contains an aperture **349,** through which the air is sucked into the housing via conduit **389** that leads to the suction fan (not shown). The position of pulley **388** can be adjusted to provide suitable tension on the screen. The speed at which the condenser is moved will determine the thickness of the web being formed. The condenser leads to another conveyor belt **390** on which the web is carried to another station for further processing.

In order to help seal off duct **352** and maximize the efficiency of the suction fan being used, a pair of vertically extending plate members **366, 368** are employed to define two outer wall portions of the duct **352** between the lickerins and the condenser. The lower portion of the duct **352** between the plates **366, 368** and the condenser **350** are essentially sealed off by rollers **360** that are rotatably mounted on pivotally mounted arms **370, 372** that are connected at their upper amrs to a shaft **374.** The weight of the rollers and arms tend to maintain the rollers in a sealing condition to minimize the introduction of air between the rollers **369** and the plates **366, 368** and condenser **350.**

Referring now to FIG. **16,** there is illustrated a sealing mechanism that acts to seal the flow duct **352** along the edges of the web being formed. In each side, there is provided a floating seal **376** that is biased into contact with the web by a spring **378.** The seal **376** is reciprocately mounted in a recess **379** defined in a side plate **380.** This mechanism is duplicated on the opposite side to prevent introduction of air into the suctiion fan other than down through the flow duct **352.**

The condition and direction of the air flowing through the system and the ratio of volume of air to volume of fibers has an effect on the particular webs being formed. For example, it can be appreciated that the quantities of fibers to be conveyed would to a certain extent determine the amounts of air that would be directed against the particular lickerin used for fiberizing a given material. Thus, when forming a web of 90 percent pulp fibers and 10 percent rayon, it may be desirable to have substantially higher quantities of air introduced to convey the pulp than to convey the rayon. In order to control the relative quantities of air directed to the pulp and rayon lickerins while insuring that the air so introduced aids in doffing the fibers from the lickerins, the air passages **344, 346** are appropriately designed and located.

Referring first to air passage **344,** it is seen that this air passage is vertically disposed with the lower end being located immediately adjacent the teeth **316** of the pulp lickerin **317.** In order to insure constant thickness across the width of the web it is desirable that the air flow across the axial length of the lickerin be uniform. Also, the air may improve doffing of the fibers from the lickerin if it is in a generally turbulent condition. To provide for turbulence while insuring that the air is uniformaly distributed across the lickerin there is provided at the lower end of passage **344** a wedge shaped restrictor **354** that is suitably secured to plate **356** that forms a side wall of passage **344.** The restrictor **354** defines a throat **358** through which the air pulled through the passage **344** must pass. This throat portion **358** brings about a low pressure drop flowing therepast and raises the velocity of the air before it contacts the pulp lickerin teeth **316.** The high velocity air aids in doffing the pulp from the lickerin and insures that the air will be turbulent to aid in the mixing of the two fibers in the mixing zone **334.** The wedge shaped restrictor **354** does not substantially effect the quantity of air being sucked through the passage and insures a substantially uniform air distribution across the full width of the orifice to make for a more uniform web.

In a system where there is a web being formed that is made up of 90 percent pulp fibers and 10 percent rayon fibers there will of course be substantially less air needed to process the rayon than the pulp. Assuming that the passage **344, 346** have the same cross-section, then it will be necessary to provide a substantial obstacle to the flow of air through the passage **346** to provide for the desired unbalanced air flow through the system.

In the passage **346** there is a restrictor provided in the form of an adjustable block **360** which has substantial length and fills up a major part of passage **346.** Between the plate **311** and block **360** there is defined a narrow passage **362.** The block **360** results in setting up a turbulent condition for the air flowing into duct **340** and severely limits the quantity of air flowing thereto, as compared to the air flowing through the passage **344** and past restrictor **354.** Suitable positioning of the block **360** can be accomplished by adjusting mechanism **364.** Another way that the air directed to the lickerins can be controlled would be by adjusting the width of the passageways **344, 346** by the insertion of blocks of varying widths therein.

The air that is directed downwardly through the passage **344** and past the restrictor **354** impinges with a high velocity against the teeth **316** of the lickerin **317** just as the lickerin teeth pass the nose bar where the pulp fibers have been individualized. The high velocity air which is moving faster than the lickerin teeth moves through the duct 332 where it acts to doff the fiber from the lickerin teeth in conjunction with the centrifugal force imposed on the fibers due to the high speed of rotation of the lickerin. The air in duct 332 entrains the fibers therein and conveys them as previously mentioned. The duct 332 is directed downwardly at approximately a 45° angle which will lead it into direct communication with the high velocity air flowing past the rayon lickerin.

On the rayon side of the system, the high velocity air passing through passage 362 similarly acts to doff the fibers from the teeth 339 of the rayon lickerin 338 and entrain the fibers therein. The air stream is moving at a high velocity at approximately a 45° angle toward the mixing chamber 334 wherein it comes into impelling relationship with the entrained pulp fibers in the air stream moving downward through duct 332. These air streams are moving at a very high rate of speed and the air is in a turbulent condition with the result that when these two streams intermix the fibers entrained therein will come into blending relationship and form a homogeneous mass in which the fibers are randomly oriented. The blended fibers will then move down through the duct 352 onto the condenser 350 where a randomly oriented fully homogeneous web will be formed.

In the illustrated embodiment it will be observed that the cross-sectional area of the chamber 334 is generally equal to the sum of the cross-sectional areas of the ducts 332 and 340. However, it is not essential to the present invention that these relationships be maintained.

In a particular example, a fully homogeneous web has been formed when the volume of air to fiber ratio in on the order of 5,000 to 1. However, with this apparatus when the volume to air ratio is substantially changed, the type of web capable of being obtained will also change. For example, it has been found that when the volume of air to fiber ratio flowing through the mixing chamber 334 is on the order of 12,000 to 1 or greater (as is explained in the Ruffo et al. application mentioned above) a web having a different construction will be formed. At such a ratio the fibers in the high velocity air streams will tend to cross each other with the result that a web will be formed that has a predominance of wood pulp on one face of the web and a predominance of rayon on the other face of the web with a transition zone in which the predominance of the respective fibers diminishing throughout the thickness of the web.

In addition to being able to provide a completely blended homogeneous web or a web in which there is a predominance of fiber on each of the faces and a transition zone therebetween, the apparatus is desinged so that other types of webs can be formed when the volume of air to fiber ratio is on the order of 5,000 to 1 and alternatively homogenous webs can be formed when the volume of air to fiber ratio is on the order of 12,000 or higher.

The various types of webs listed above, as well as others referred to hereinafter, can be obtained by the introduction of a baffle into the mixing zone which controls the mixing of the two separate air streams moving down ducts 332 and 340. The structure of this baffle will be first described after which the different webs that are formed depending on the position of the baffle will be gone into in detail.

The baffle 400 is constructed to extend down the center of the apparatus into the mixing chamber between the two lickerins and essentially consists of an elongated flat plate that extends the full width of the machine. FIG. 13 illustrates the baffle in the fully withdrawn position, FIG. 17 shows the baffle located generally in alignment with a plane drawn through the axis of the lickerins, FIG. 18 shows the baffle extended downwardly below the lickerins and FIG. 19 shows the baffle disposed immediately adjacent the condenser.

The positioning of the baffle is accomplished by a pair of gears 402 mounted on a shaft 404 (see FIG. 14) that meshes with racks 406 secured to the baffle 400. Leakage of air past the baffle is prevented by sealing and guide members 408, 410.

When the baffle is moved down into one of the positions illustrated in FIGS. 17 or 18, it can be apprecaited that the separate flow streams containing entrained particles in ducts 332 and 340 are prevented from intermixing until they pass below the bottom of the baffle. The particular location of the baffle will determine how much blending will take place between the streams of fibers in ducts 332 and 340. As the baffle is moved downwardly into the duct 352 and with the volume of air to fiber ratio on the order of 5,000, a web will be formed in which the bottom layer will be made up of substantially all wood pulp fibers, the upper layer will be substantially all rayon fibers and the intermediate layer will be a homogeneous blend of the two fibers. The web so formed will of course of made up of fibers that are randomly oriented and thus isotropic. As the baffle is moved further and further down toward the condenser, there will be less of an intermediate homogeneous web portion and the outer sections of the web will be proportionately thicker. With the baffle all the way down as shown in FIG. 22, a two layered web of short and long fibers will be formed with the fibers at the interface being interconnected.

When the volume of air to fiber ratios are increased to something on the order of 12,000 to 1 or greater and with the baffle in the position generally as shown in FIG. 17, a fully homogeneous web will be formed.

As the baffle 400 is moved down to the position shown in FIG. 18 and ratios of 12,000 to 1 or more are maintained, the crossover of fibers will be somewhat reduced and a web will be formed that has a predominance of pulp on the bottom and rayon on the top with a transition zone in between where the quantity of rayon diminishes toward the pulp side and the quantity of pulp diminishes toward the rayon side. The fiber as so formed is separate from that which is formed with these volume to air ratios when the baffle is above the position shown in FIG. 17. The web so formed during this method of operation is one in which the bottom layer of the web will be predominantly rayon and the top layer of the web will be predominantly pulp with the transition zone therebetween wherein the quantity of pulp reduces as it approaches the rayon side and the rayon reduces as it approaches the pulp side.

In the drawings FIGS. 20–23 schematically illustrates some of the various types of webs that can be formed with the apparatus illustrated in FIGS. 13–16. FIG. 20 is intended to be a graphic illustration of a fully homogeneous web W. FIG. 21 shows a cross-section of a web 412 that is made up of a layer 414 that contains essentially all staple fibers, layer 416 of pulp fibers and layer 418 which is a homogeneous blend of staple and pulp fibers. FIG. **22** shows a cross-section of a web **434** made up of separate layers of staple fibers **436**, and pulp fibers **438** which are interlaced at their interfaces. FIG. **23** shows a cross-section of a web **440** in which the upper layer **442** has a predominance of pulp fibers and the bottom layer **444** has a predominance of staple fibers and a transition zone therebetween in which the predominance of staple fibers decreases as it approaches the pulp layer **442** and the predominance of pulp fibers decreases as it approaches the rayon layer **444**.

The following examples apply to the apparatus illustrated in FIGS. **13–16**.

Example 1. A nonwoven web of a homogeneous blend of randomly oriented short pulp fibers and staple rayon fibers was formed in which, by weight, 90 percent of the fibers were pulp and 10 percent of the fibers were rayon.

The short fibers were extracted from pulpboard and the rayon fibers came from a rayon picker lap in which the average fiber length was 1 9/16 inches, with a denier of 1.5.

Lickerins **317** and **338** were approximately 9 ½ inches in diameter and were rotated at about 6,000 and 3,000 rpm, respectively, and the lickerins were spaced from one another by about 1 ½ inches. Lickerins **317** and **338** were spaced from duct walls **333** and **342**, respectively, by about three-fourths inch. Lickerins **317** and **338** were about 18 inches long and a total of 700 pounds per hour of fibers were fed to the lickerins. Deflector plates **366** and **368** were spaced from one another by about 4 ½ inches. The average volume ratio of air to fiber was approximately 5,000 to 1 in the common air stream.

With the web take away mechanism operated at a speed of 125 feet per minute, and with baffle **400** in the withdrawn position, a homogeneous web of randomly oriented fibers was produced having a weight of approximately 4,000 grains per square yard.

Example 2. The basic machine parameters of Example 1 were repeated, with the exception that the fiber feed was controlled to provide a feed rate of 180 pounds of fibers per hour 50:50 (by weight) mixture of pulp and rayon fibers, and the process employed a 70,000:1 volume ratio of total gas to total fiber in the combined stream. Lickerin **317** was rotated at about 5,500 rpm and lickerin **338** was rotated at about 2,800 rpm. The resulting web weighed aproximately 550 grains per square yard, and was removed from the condensation zone at approximately 150 feet per minute.

With the above volume ratio, even though the divider plate **400** remained withdrawn, the resulting product was found to consist of a predominance of rayon fibers at one face of the product and a predominance of pulp fibers at the opposing face of the product, with a decreasing amount of pulp and rayon fibers from the faces at which they predominate, repsectively, to the opposed faces. This "transition" feature was found to be substantially uniform from face to face. The existence of this "cross-over" product was confirmed by high speed movies taken through transparent end plates of the machine which confirmed that a majority of the fibers from the individual streams crossed over at the point where the individual streams were joined to form the common carrier stream.

Example 3. The machine parameters of Example 3 were essentially the same as those in Example 2, except that an 80:20 (by weight) mixture of short pulp fibers and staple rayon fibers were fed to the respective lickerins. In this regard the pulp feed rate was approximately 1,000 pounds per hour and the rayon mately 30,000 to 1. The take away mechanism was adjusted to provide a take away speed of approximately 550 feet per minute, and the resulting web had a weight of approximately 1,400 grains per square yard.

The resulting web was found to be a homogeneously blended nonwoven web of randomly oriented fibers. The cross-over product, such as that obtained in Example 2, was prevented because of the degree of interference of the baffle **400** with the separate gas streams.

What is claimed is:

1. Web forming apparatus for forming a nonwoven web of fibers from at least two sources of fibers, one of said sources being a source of at least partially preopened textile length fibers and the other of said sources being a source of short fibers, said apparatus comprising: a pair of lickerins, one having a different tooth profile than the other; means rotatably mounting said lickerins in spaced parallel relationship, said one lickerin being located adjacent the source of textile length fibers and said other lickerin being located adjacent the source of short fibers, and the converging facing surfaces of said lickerins downstream of said fiber sources defining a first portion of a duct means that is funnel shaped in cross section and which communicates with said sources of fibers, said duct means having a second portion below the center lines of said lickerins, communicating with said first portion for carrying fibers to a fiber deposition zone; means for rotating said one lickerin in a given direction and at a given speed; means for rotating said other lickerin in an opposite direction and at a greater speed than said one lickerin; means for guiding each source of fibers into contact with its respective lickerin at a location thereon at which the tangential velocity of said lickerins has a component toward one another whereby each lickerin individualizes fibers from its respective source; fiber collecting means communicating with the second portion of the duct means and including a movable foraminous member at said depositing zone to collect said fibers and form a web of nonwoven fibers, and means for applying a suction to said foraminous member for providing separate gaseous streams flowing along a path extending about the periphery of said lickerins for a major portion of the distance between said contact location and through the first portion of said duct means to (a) doff at least some of the individualized fibers from each lickerin, (b) entrain the individualized fibers in their respective gaseous streams, and (c) convey said entrained fibers in said separate gaseous streams through said duct means along flow paths at least initially directed toward one another, said duct means guiding said gaseous streams whereby at least a portion of said gaseous streams are combined to intermix at least a portion of the fibers in one gaseous stream with at least a portion of the fibers in the other gaseous stream after which said blended fibers are collected on said foraminous member.

2. Web forming apparatus as set forth in claim **1** in which each fiber source guiding means includes a material supporting surface adjacent each source of fibers, each lickerin-supporting surface relationship being selected to establish optimum conditions for substantially completely opening said textile fiber and short fiber materials.

3. Web forming apparatus as set forth in claim 2 including means for adjusting the relative location of each lickerin and its supporting surface.

4. Web forming apparatus as set forth in claim 1 wherein the second portion of said duct means is defined by a deflector plate mounted beneath each lickerin, each deflector plate having an upper end positioned adjacent one lickerin and a lower end positioned adjacent the fiber collecting means.

5. Web forming apparatus as set forth in claim 1 including means for adjusting the position of said foraminous member relative to said lickerins.

6. Web forming apparatus as set forth in claim 5 wherein said means for adjusting said foraminous member incudes means for varying the position of said suction applying means relative to said fiber receiving station.

7. Web forming apparatus as set forth in claim 1 wherein said lickerins are spaced closely to one another to form a narrow gap therebetween.

8. Web forming apparatus as set forth in claim 1 wherein said foraminous member is positioned generally centrally below said lickerins.

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