

[54] **APPARATUS (CLOSED SANDWICH WITH HIGH KNEE BACKING MEANS FORAMINOUS THROUGHOUT ITS AREA)**

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[58] Field of Search **19/161 P**

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Primary Examiner—Dorsey Newton

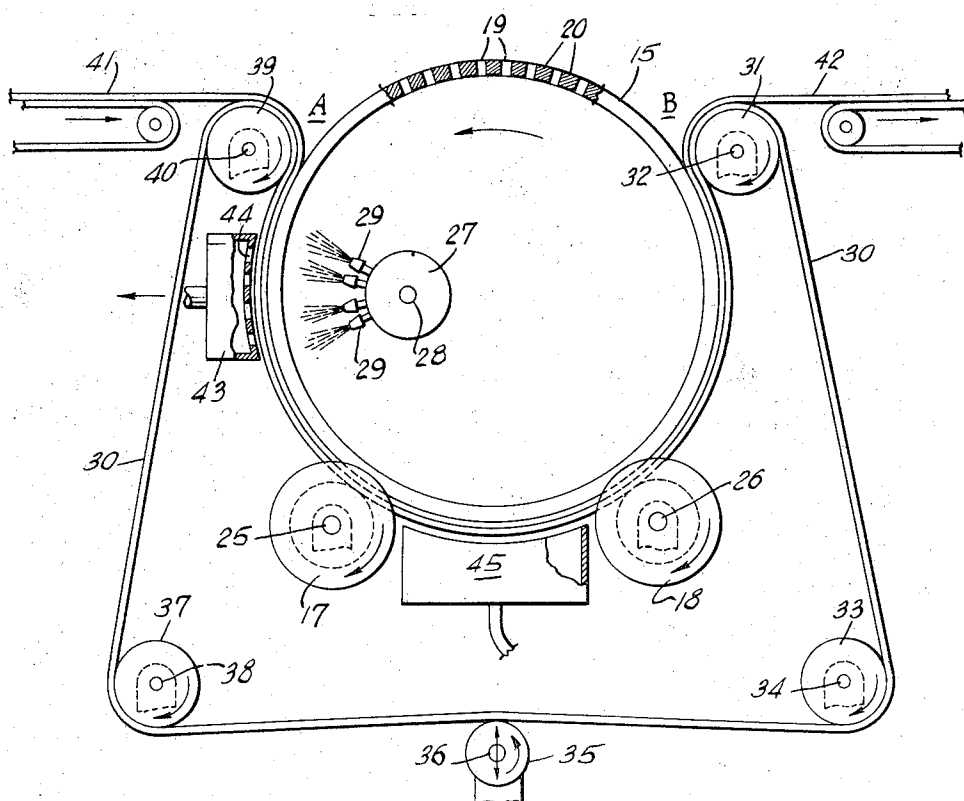
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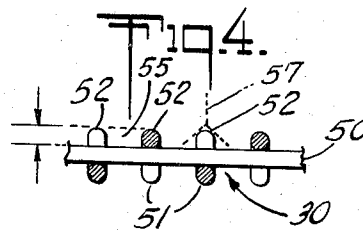
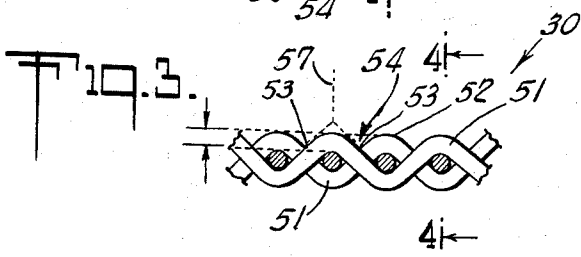
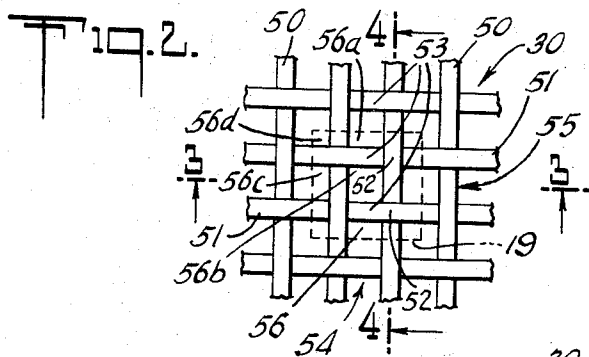
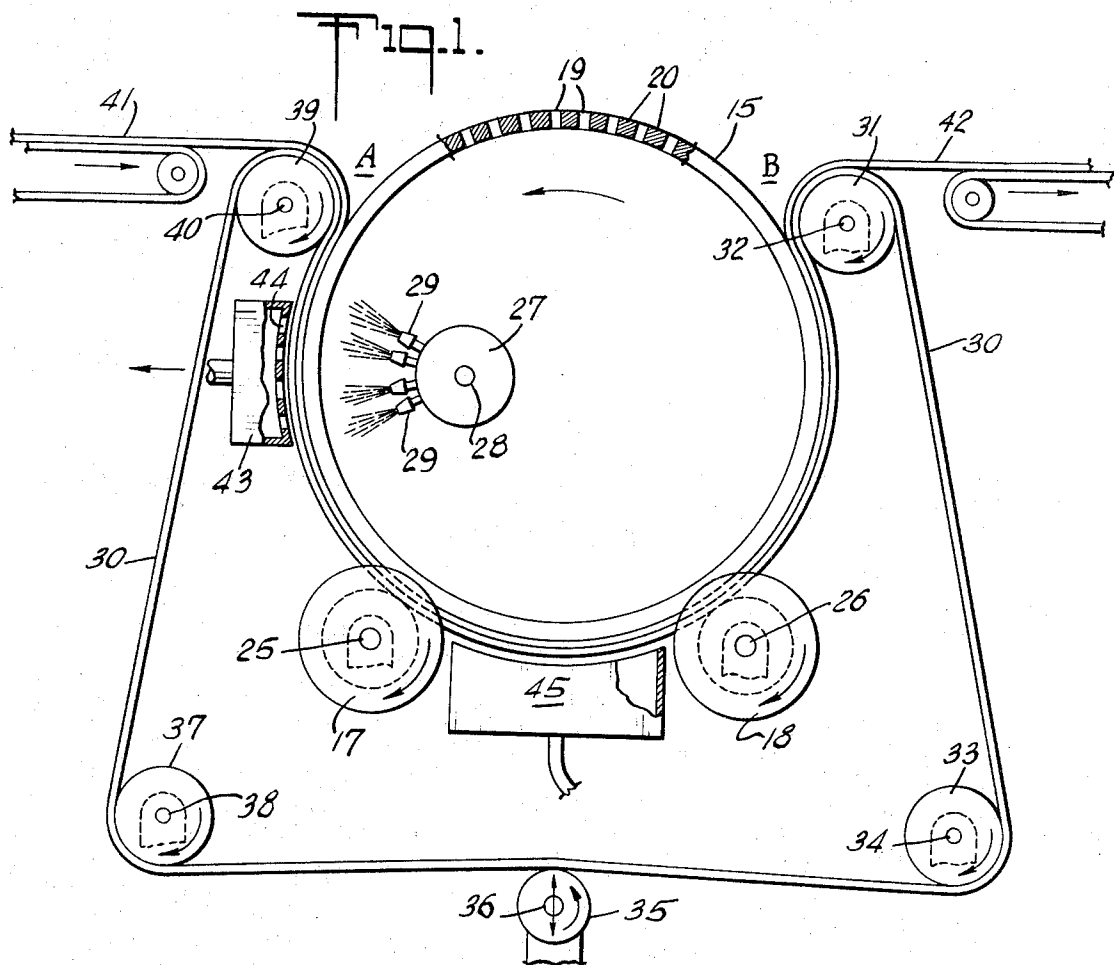
[57] **ABSTRACT**

A method and apparatus for producing, from a layer of fibrous material such as a fibrous web, nonwoven fabrics that contain apertures or holes, or other areas of low fiber density, and have a plurality of patterns of yarn-like bundles of fiber segments that alternate and extend throughout the fabric. One form of the method

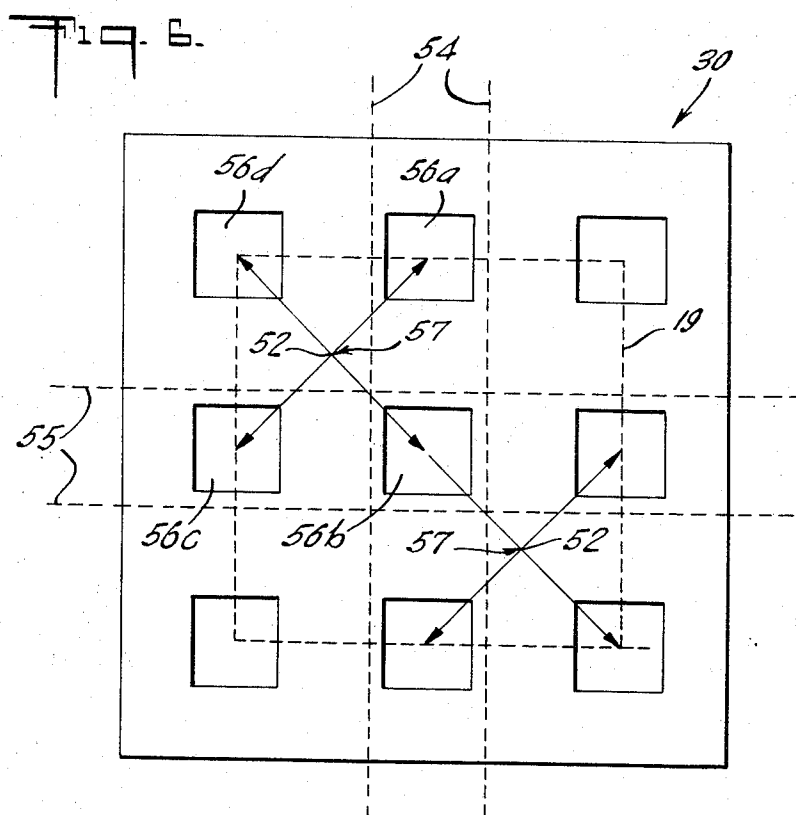
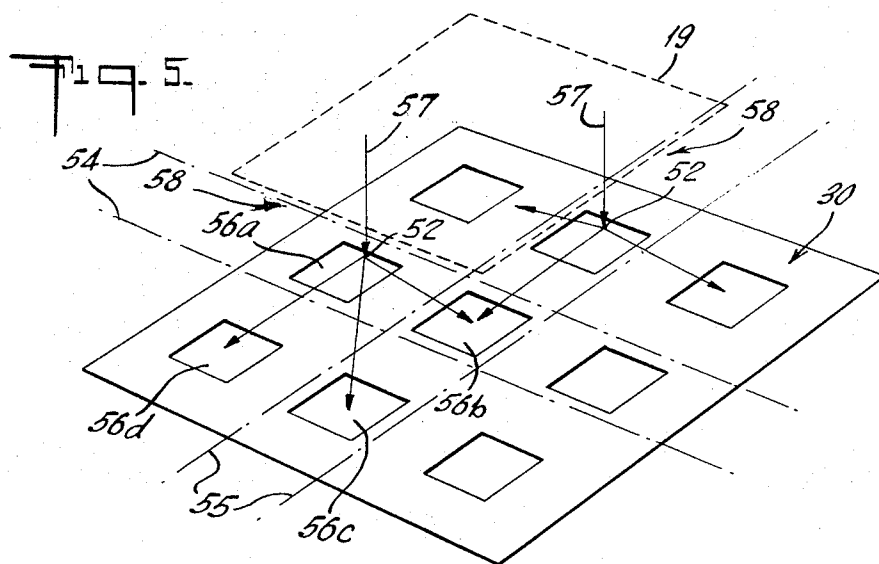
includes the steps of positioning the starting web between apertured forming means and a foraminous backing means having a plurality of protuberances and troughs alternating across its surface, then directing fluid rearranging forces through the apertures of the forming means against the fibers of the starting web, causing some of the fluid streams to strike the protuberances referred to or other solid portions of the backing means and all of the fluid streams ultimately to pass through the backing means. The tops of the protuberances on the backing means rise above the bottoms of immediately adjacent troughs by a vertical distance equal to at least about three times the average diameter of the fibers in the layer of fibrous starting material. Each forming aperture spans a plurality of the protuberances on the backing means. The fluid rearranging forces move some of the fiber segments that are in registry with the forming apertures into surrounding areas in said fibrous layer and position those fiber segments there in yarn-like bundles of closed associated and substantially parallel fiber segments. The rearranging forces also move other fiber segments that are in registry with the forming apertures into the troughs on the backing means to position those fiber segments there in other similar yarn-like bundles of fiber segments. The resulting nonwoven fabric has a first pattern of yarn-like bundles of fiber segments arranged in accordance with the configuration of the land areas of the apertured forming means, and a second pattern of yarn-like bundles of fiber segments arranged according to the configuration of the troughs on the backing means.

5 Claims, 12 Drawing Figures

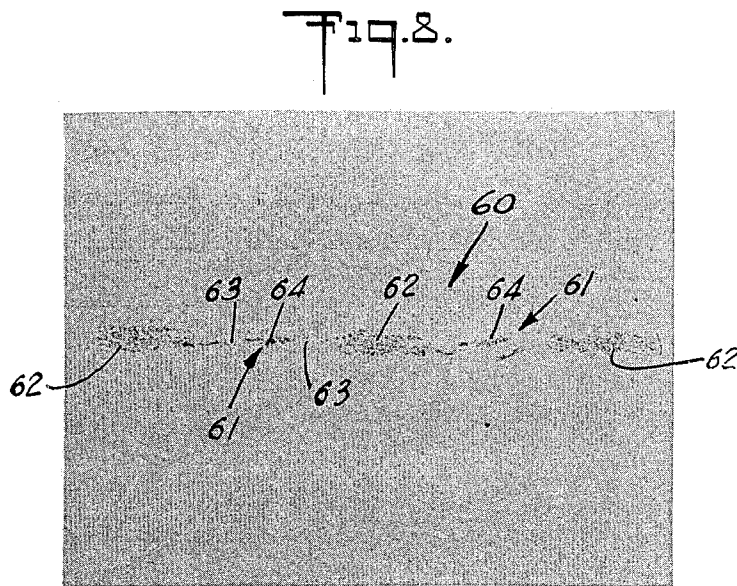
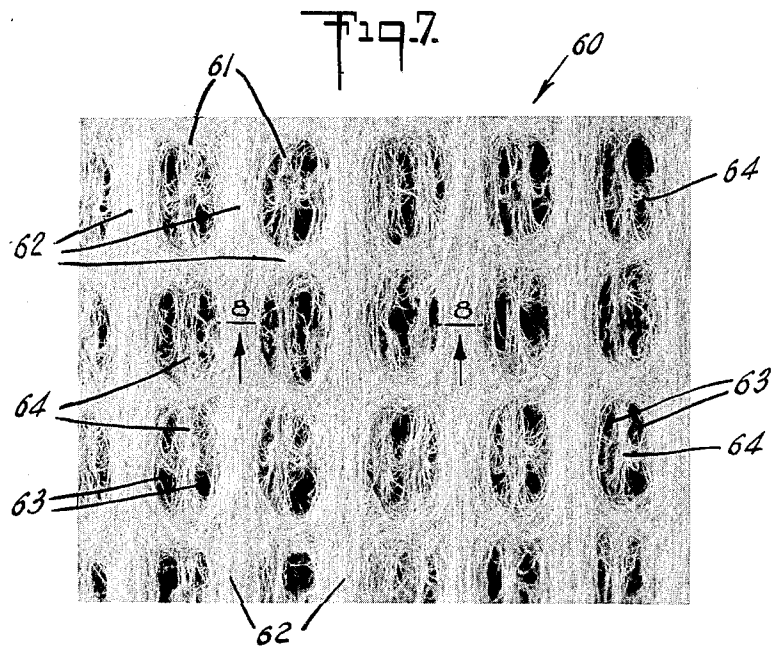




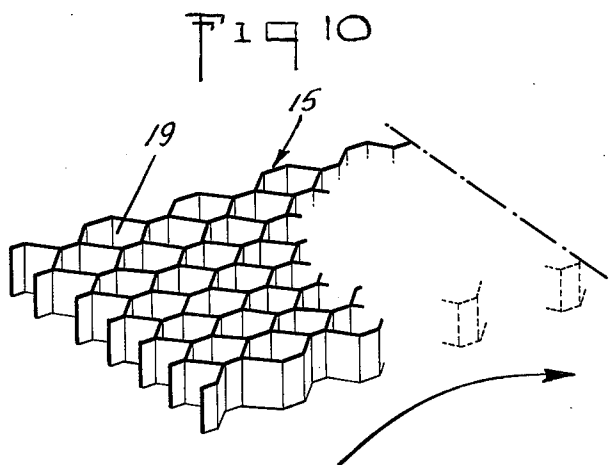
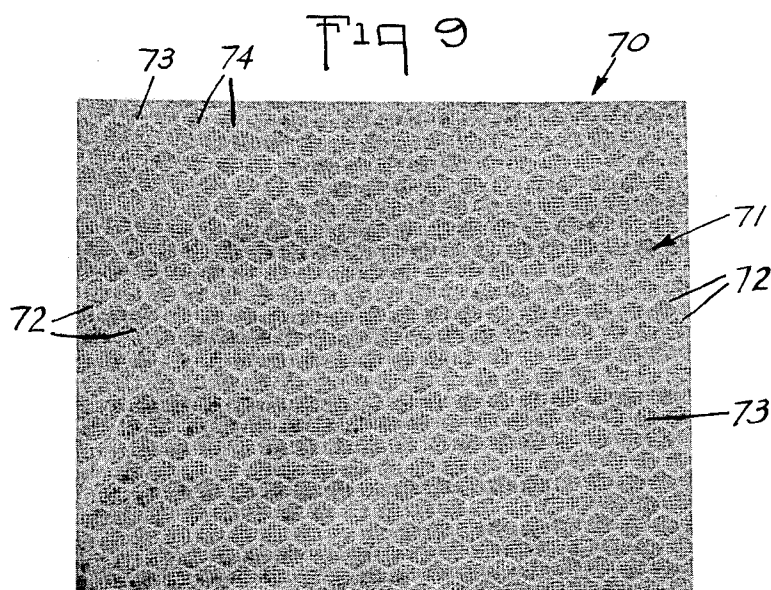
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Fig. 11.

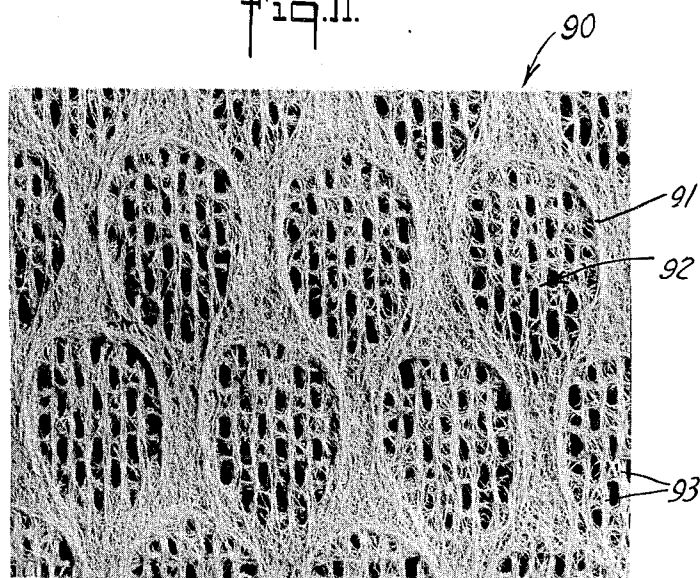
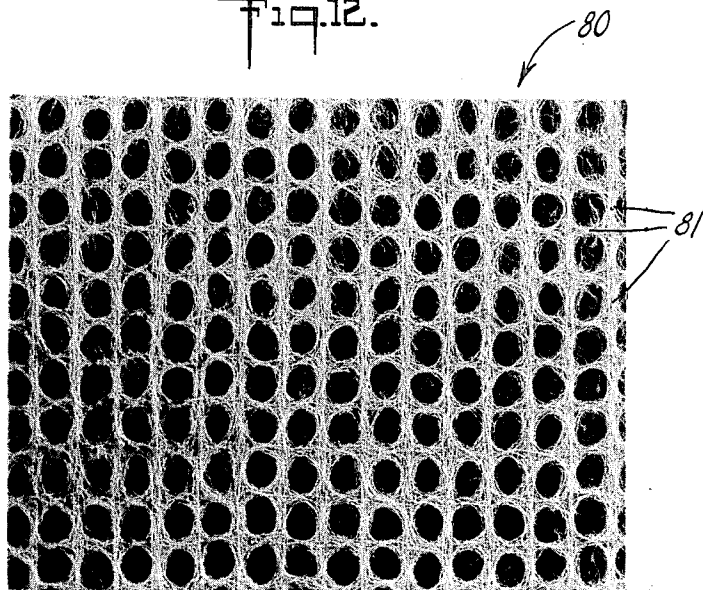


Fig. 12.



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APPARATUS (CLOSED SANDWICH WITH HIGH KNEE BACKING MEANS FORAMINOUS THROUGHOUT ITS AREA)

The present application is a continuation application of my co-pending application Ser. No. 22,322, filed Mar. 24, 1970, now abandoned.

This invention relates to a method and apparatus for the production of nonwoven fabrics, and more particularly to a method and apparatus for the production of nonwoven fabrics from a layer of fibrous material such as a fibrous web in which the individual fiber elements are capable of movement under the influence of applied fluid forces, to form a fabric that has a plurality of patterns of yarn-like bundles of closely associated and substantially parallel fiber segments that alternate and extend throughout the fabric to define apertures or holes, or other areas of low fiber density, in the fabric.

BACKGROUND OF THE INVENTION

Various methods and apparatus for manufacturing apertured nonwoven fabrics involving the rearrangement of fibers in a starting layer of fibrous material have been known for a number of years. Some of the methods and apparatus for the manufacture of such fabrics are shown and described in U.S. Pat. No. 2,862,251, which discloses the basic method and apparatus of which the present invention is a specific form, and in U.S. Pat. Nos. 3,081,500 and 3,025,585.

The nonwoven fabrics made by the methods and apparatus disclosed in those patents contain apertures or holes, or other areas of low fiber density, outlined by interconnected yarn-like bundles of closely associated and substantially parallel fiber segments. (The term "areas of low fiber density" is used in this specification and claims to include both (1) areas in which relatively few fibers are found in comparison to the rest of the fabric, and (2) apertures (holes) that are substantially or entirely free of fibers.) Such fabrics are sometimes referred to as "bundled rearranged" nonwoven fabrics.

One of the specific known methods for producing bundled rearranged nonwoven fabrics is to support a loose fibrous web or layer between an apertured forming member and a permeable backing member, and then direct streams of rearranging fluid through the apertures of the former member in order to apply spaced sets of opposing fluid forces to the layer. The spaced streams of fluid pass through the fibrous layer and over and through the backing member, to pack groups of fiber segments into closer proximity and substantial parallelism in interconnected yarn-like bundles of fiber segments that define holes or other areas of low fiber density corresponding to the pattern of the apertures in the apertured forming means.

Another known method for producing bundled rearranged nonwoven fabrics is to support a loose fibrous web or layer upon a permeable backing member that has protuberances spaced across its surface, with troughs or low areas between the protuberances. Streams of rearranging fluid are applied uniformly over the entire surface of the loose fibrous web or layer, and after the streams pass through the fibrous material some of them strike the protuberances on the backing means and are diverted in sidewise directions. All the streams then pass through the openings in the permeable backing means and leave the rearranging zone. The effect of these fluid rearranging forces is to pack

groups of fiber segments into interconnected yarn-like bundles of closely associated and substantially parallel fiber segments that define holes or other areas of low fiber density that correspond to the protuberances on the permeable backing member.

In the first method just described, the streams of rearranging fluid enter the fiber rearranging zone at spaced locations determined by the position of the apertures in the apertured forming means against which the fluid streams are first directed. Then, when the rearranging fluid leaves the rearranging zone, it does so through foramina uniformly dispersed throughout the permeable backing member.

Exactly the contrary is true with the second method just described. In that method, the streams of rearranging fluid are dispersed uniformly and continuously across the layer of fibrous starting material as they are directed against that layer upon entering the rearranging zone, and leave the rearranging zone at spaced locations lying between the protuberances upon the foraminous backing means.

SUMMARY OF INVENTION

I have now discovered that, unexpectedly, these two different methods of producing bundles rearranged non-woven fabrics can be successfully combined in a single method to produce very satisfactory rearrangement of the fibers of the fibrous starting material into a nonwoven fabric having a plurality of patterns of yarn-like bundles of fiber segments that alternate and extend throughout the fabric.

In the method of this invention, the starting material is a layer of fibrous material whose individual fibers are in mechanical engagement with one another but are capable of movement under applied fluid forces. The layer of fibrous starting material is supported in a fiber rearranging zone in which fiber movement in directions parallel to the plane of said fibrous material is permitted in response to applied fluid forces. Streams of rearranging fluid, preferably water, are then projected into the fibrous layer, in a direction perpendicular to the layer, at entry zones spaced from each other adjacent the entry side of the rearranging zone.

Each stream of rearranging fluid entering an entry zone is passed through the initial part of the rearranging zone, as the fibrous starting material lies in that zone, toward two or more dispersal points lying directly opposite the entry zone and adjacent the exit side of the rearranging zone. In the next step of the method, rearranging fluid is deflected at each such dispersal point diagonally and downwardly, into the area immediately surrounding the dispersal point, away from the perpendicular direction at which the fluid was first projected into the fibrous starting layer.

This deflection of the rearranging fluid moves fiber segments lying opposite an entry zone into the area surrounding a dispersal point opposite that entry zone, and positions some of those fiber segments in yarn-like bundles of closely associated and substantially parallel fiber segments in areas of the fibrous starting material surrounding the entry zone. Other fiber segments moved by the rearranging fluid away from a dispersal point are positioned in similar yarn-like bundles in fiber accumulating zones that lie between adjacent dispersal points and are in registry with an entry zone. The deflected and undeflected portions of the rearranging fluid are then intermingled and passed out of the fiber

rearranging zone through spaced exits at the exit side of the rearranging zone.

In one form of the method and apparatus of this invention, the fibrous starting layer is supported on a foraminous backing means having a plurality of protuberances and troughs alternating across its surface in both the longitudinal and transverse directions, apertured forming means is positioned above the fibrous layer, and streams of rearranging fluid, preferably water, are projected through the apertures of the apertured forming means and against the fibrous starting material. The vertical distance between the tops of the protuberances on the backing means and the bottoms of the immediately adjacent troughs is equal to at least about three times the average diameter of the fibers in the layer of fibrous starting material. Each of the apertures in the apertured forming means is wide enough to span two or more of the protuberances on the backing means.

One would expect that if the protuberances on the backing means in this form of the invention are high enough to have a significant effect on any fibers in the fibrous starting material, they would interfere with the fiber movement necessary to the formation of yarn-like bundles to define holes or other areas of low fiber density that correspond to the apertures in the apertured forming means. Actually, I have found that the effect of the backing means described seems to be not to interfere with, but rather to cooperate with, the formation of yarn-like bundles of fiber segments lying underneath the land areas of the apertured forming means, while at the same time forming independently a second pattern of yarn-like bundles of fiber segments positioned in the troughs or low areas lying between the protuberances on the backing means.

The resulting nonwoven fabric displays a plurality of patterns of yarn-like bundles of fiber segments that alternate and extend throughout the fabric. The first of these is a pattern arranged in accordance with the configuration of the land areas of the apertured forming means, to define a group of holes or other areas of low fiber density that correspond to the apertures of the apertured forming means. The second pattern is a pattern of yarn-like bundles of fiber segments that have been positioned by use of this invention in the troughs on the surface of the foraminous backing means, to define a second group of holes or other areas of low fiber density that are disposed within the first group just mentioned.

FURTHER DESCRIPTION OF INVENTION

The basic method and apparatus of this invention are shown and described fully in my U.S. Pat. No. 2,862,251, issued Dec. 2, 1958. Full particulars of the basic invention as disclosed in that patent are incorporated in this application by reference, although some of those particulars are repeated here. In addition, the specific feature peculiar to the method and apparatus of the present invention — which is the use of a fiber rearranging zone having spaced entry zones (defined, for example, by an apertured forming means) with a plurality of dispersal points (e.g., protuberances on a foraminous backing means) alternating with fiber accumulating zones (e.g., troughs on the backing means) opposite each entry zone — is described in detail in this application.

STARTING MATERIAL

The starting material used with the method or apparatus of this invention may be any of the standard fibrous webs such as oriented card webs, isowebs, air-laid webs, or webs formed by liquid deposition. The webs may be formed in a single layer, or by laminating a plurality of the webs together. The fibers in the web may be arranged in a random manner or may be more or less oriented as in a card web. The individual fibers may be relatively straight or slightly bent. The fibers intersect at various angles to one another such that, generally speaking, the adjacent fibers come into contact only at the points where they cross. The fibers are capable of movement under forces applied by fluids such as water, air, etc.

To produce a fabric having the characteristic hand and drape of a textile fabric, the layer of starting material used with the method or apparatus of this invention may comprise natural fibers such as cotton, flax, etc.; mineral fibers such as glass; artificial fibers such as viscose rayon, cellulose acetate, etc.; or synthetic fibers such as the polyamides, the polyesters, the acrylics, the polyolefins, etc., alone or in combination with one another. The fibers used are those commonly considered textile fibers; that is, generally fibers having a length from about $\frac{1}{4}$ inch to about 2 to $2\frac{1}{2}$ inches. Satisfactory products may be produced in accordance with this invention from starting webs weighing between 80 grains per square yard to 2,000 grains per square yard or higher.

BACKING MEANS

In one form of the method of this invention, and in the apparatus of this invention, the fibrous starting layer is supported on a backing means that is foraminous and is provided with a plurality of protuberances and troughs alternating across its surface in both the longitudinal and transverse directions.

The tops of the protuberances rise above the bottoms of the immediately adjacent troughs by a distance equal to at least about three times, or 0.005 inch, but generally no more than about 30 times, the average diameter of the fibers in the layer of fibrous starting material. Preferably, the distance should be equal to about ten times the average diameter of those fibers. The protuberances should not rise so far above their immediately adjacent troughs as to disrupt formation of the pattern of areas of low fiber density corresponding to the apertures of the apertured forming means.

The fibrous starting material used with the method and apparatus of this invention is comprised of closely intertwined and interentangled fibers arranged (depending upon the degree of fiber orientation in the layer) in a more or less helter-skelter fashion. Some of the fibers of the starting material will by random chance lie generally parallel to the troughs of the backing means over which they lie, but the great majority of the fibers will lie at an angle to the longitudinal axis of the trough, and a substantial number of these will lie at angles of 45° or more to that axis.

Now, as already indicated, the fluid rearranging forces of this invention tend to move some fiber segments that are in registry with an aperture of the apertured forming means sideways until they are no longer in registry with the aperture, to position those segments in yarn-like bundles lying under the land areas of the

apertured forming means. At the same time, streams of rearranging fluid move other fiber segments that are in registry with the aperture into closer association and substantial parallelism with each other in yarn-like bundles in the troughs of the backing means. The latter type of fiber movement is more likely to occur with fiber segments in the starting material that lie only a relatively few degrees away from a position parallel to the longitudinal axis of a trough.

In other words, this type of movement is more difficult the greater the angle between a given fiber segment and the axis of the trough, and when fiber segments lie at too great an angle to the longitudinal axis of a trough, they are pushed altogether out of registry with the forming aperture under which they lie so that they are pushed entirely under the surrounding land areas of the apertured forming means. For the greater the angle between the fiber segment and the trough axis, the shorter is the portion of the fiber that bridges the trough, and the more difficult it is for the rearranging fluid forces to get a "purchase" on the fiber segment to turn it around into a position parallel with the trough axis.

Likewise, the narrower the troughs are on the backing means, the more difficult it is for the rearranging fluid forces to get a "purchase" on the short portion of the fiber segment that bridges the trough, to swing that segment around into a position parallel to the axis of the trough to be consolidated there to form a yarn-like bundle with other similarly positioned fiber segments. For this reason, the distance between immediately adjacent protuberances on the backing means, which determines the width of a trough from the top of one side to the other, is ordinarily at least about 30 times the average diameter of the fibers of the fibrous starting material, or 0.05 inch.

This spacing may be smaller if a vacuum is employed to help rearrange the fibers of the starting material, since the force of the vacuum is then added to the force of the other rearranging fluid employed in this invention. With the use of a vacuum assist, the spacing of immediately adjacent protuberances on the backing means is at least about 15 times the average diameter of the fibers of the fibrous starting material or 0.025 inch.

The minimum spacing of protuberances just mentioned, which affects the width of the troughs lying between immediately adjacent protuberances, also assists in providing good visual resolution between various yarnlike bundles of fiber segments in the fabric resulting from the practice of this invention. For if the protuberances are too closely spaced and the troughs between them are too narrow, yarn-like bundles of fiber segments may be accumulated in the troughs but will not be discernible one from the other, because each one merges into the next adjacent similar bundle of fiber segments.

If the web weight of the fibrous starting material is high the distance between immediately adjacent protuberances on the backing means should be increased, or otherwise the yarn-like bundles of fiber segments will be masked out by the same merging phenomenon just mentioned. Again, satisfactory visual resolution of immediately adjacent yarnlike bundles of fiber segments can be had with somewhat closer spacing of protuberances if the rearrangement of fibers is assisted by the application of vacuum.

APERTURED FORMING MEANS

In one form of this invention, the fluid entry zones into the fiber rearranging zone are defined by an apertured forming means that is solid throughout its area except for the forming apertures disposed longitudinally and transversely across the member. The forming apertures must be substantially larger in area than the openings in the foraminous backing means. The forming apertures may have any desired shape, i.e., round, square, diamond, oblong, free form, etc.

The land areas of the apertured forming means that lie between and interconnect the forming apertures may be either narrow or broad in comparison to the forming apertures, as desired. Generally speaking, the narrower the width of the land areas, the more tightly compacted will be the yarn-like bundles of closely associated and substantially parallel fiber segments that are formed under those land areas in the nonwoven fabric of this invention.

Each of the forming apertures in the apertured forming means with which the backing means described is used is desirably at least about as wide as the horizontal distance between the top of one of the protuberances on the backing means and the top of the protuberance immediately adjacent it on the backing means. However, this requirement needs to be met only very approximately, for holes or other areas of low fiber density can be formed between yarn-like bundles lying in the troughs of the backing means and yarn-like bundles lying underneath the land areas of the apertured forming means even if an aperture is not wide enough to span completely the horizontal distance between the tops of two immediately adjacent protuberances, but is wide enough to extend from a point fairly well up the slope of one side of a trough and near the top of the protuberance that defines that side of the trough, to a similar point fairly well up the slope of the other side of the trough.

For the clearest visual resolution between bundles of fiber segments, each aperture of the apertured forming means should span a plurality of the protuberances on the backing means. For still better results, each aperture in the apertured forming means should span a plurality of protuberances on the backing means measured in both the longitudinal and transverse directions, with the land area defining the forming aperture lying generally above a trough in the foraminous backing means.

During use of the method or apparatus of this invention, the apertured forming means and the foraminous backing means are spaced from each other to provide a fiber rearranging zone in which fiber movement in directions parallel to the backing means is permitted in response to applied fluid forces.

REARRANGING FLUID

The rearranging fluid for use with this invention is preferably water or a similar liquid. It may also be other fluids such as a gas, as described in my U.S. Pat. No. 2,862,251.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully described in connection with the accompanying drawings, in which:

FIG. 1 is a diagrammatic showing in elevation of one type of apparatus that can be employed in the present invention.

FIG. 2 is an enlarged fragmentary diagrammatic plan view of a portion of a backing means that can be used in the apparatus of FIG. 1, an aperture of the apertured forming means being shown in dashed lines.

FIG. 3 is a cross sectional view taken along line 3—3 of FIG. 2.

FIG. 4 is a cross sectional view taken along the line 4—4 of FIGS. 2 and 3.

FIG. 5 is a schematic perspective representation of the paths followed by various streams of rearranging fluid as they pass through the fiber rearranging zone of the present invention.

FIG. 6 is a schematic plan representation of the paths followed by streams of rearranging fluid as they pass through the fiber rearranging zone.

FIG. 7 is a photomicrograph of a nonwoven fabric made in accordance with the present invention, shown at an original enlargement of five times.

FIG. 8 is a photomicrograph of a cross sectional view taken along a line similar to that shown as line 8—8 in FIG. 7, shown at an original enlargement of ten times.

FIG. 9 is a photomicrograph of another fabric made in accordance with the present invention, shown at an original enlargement of five times.

FIG. 10 gives a perspective view of a portion of an apertured forming means that can be used with the method or apparatus of this invention to make the patterned nonwoven fabric of FIG. 9.

FIG. 11 is a photomicrograph of another fabric made in accordance with the present invention, shown at an original enlargement of five times.

FIG. 12 is a photomicrograph of a nonwoven fabric having a single pattern of yarn-like bundles of fiber segments, made in accordance with a method and apparatus different from this invention, shown at an original enlargement of five times.

DETAILED DESCRIPTION OF SPECIFIC FORMS OF THE INVENTION

FIG. 1 shows one form of apparatus that may be used in accordance with the present invention. Full particulars of this apparatus, including methods of mounting, rotation, etc., are more fully described in my U.S. Pat. No. 2,862,251 issued Dec. 2, 1958, and are incorporated in the present application by reference and thus need not be described in complete detail here. In view of this reference, the apparatus of FIG. 1 will be described in general terms insofar as its essential elements are the same as in the patent just mentioned, and the novel feature used to manufacture nonwoven fabrics in accordance with the present invention, i.e., the backing means and its relationship to the apertured forming means, will be described in more detail.

The apparatus of FIG. 1 includes a rotatable apertured drum 15 suitably mounted on flanged guide wheels 17 and 18. The drum has apertures 19 uniformly spaced over its entire surface, with the remaining portions of the drum constituting land areas 20. The guide wheels are mounted for rotation on shafts 25 and 26.

Inside the drum, a stationary manifold 27 to which a fluid is supplied through conduit 28 extends along the full width of the drum. On one side of the manifold is a series of nozzles 29 for directing the fluid against the inside surface of the drum.

About the greater portion of the periphery of the drum there is positioned a novel backing or support

member 30. (The terms backing member and support member are used interchangeably throughout this description.) Support member 30, as shown in FIGS. 2 through 4, is formed of a coarse woven screen, preferably metal.

In the embodiment shown, wires 50 running vertically in FIG. 2 are straight, while wires 51 running horizontally in that figure weave alternately over and under wires 50. Protuberances 52 are present throughout foraminous portion 30 as the topmost part of each "knee" of a given strand 51 of the screen that is formed as the strand weaves over and under the strands 50 that lie perpendicular to it.

As a given strand 51 slants downward to pass under a strand 50 perpendicular to it, it crosses two other strands 51 disposed on either side of it, as those strands slant upward to pass over the same perpendicular strand that the given strand will pass under. Each series of such "crossing points" 53 forms a trough, such as trough 54 in FIGS. 2 and 3, that lies between adjacent protuberances 52. The effective shape of troughs 54, as can be best seen in FIG. 3 (which shows a cross section of element 30 of which a plan view is given in FIG. 2), is substantially an inverted triangle.

A series of slightly deeper troughs 55 is formed between adjacent protuberances 52 but extends at right angles to troughs 54. As best seen in FIG. 4, the bottom of each trough 55 is formed by portions of straight strands 50, with successive protuberances 52 on each side of the trough forming the tops of the trough. As seen in FIG. 4, the effective shape of troughs 55 may be characterized as a shallow U-shape.

As shown in FIG. 2, a plurality of troughs 54 and a plurality of protuberances 52 alternate in one direction across the surface of foraminous backing means 30. FIG. 2 also shows that a plurality of troughs 55 and a plurality of protuberances 52 alternate in a direction perpendicular to troughs 54. Hence a plurality of troughs and a plurality of protuberances alternate in both the longitudinal and transverse directions across the surface of foraminous backing means 30.

To produce satisfactory rearrangement of fibers into yarn-like bundles of closely associated and substantially parallel fiber segments positioned in troughs 54 and in troughs 55, the vertical distance between the tops of protuberances 52 and the bottoms of the immediately adjacent troughs should be at least about three times, generally no more than about 30 times, and preferably about ten times, the average diameter of the fibers in the layer of fibrous starting material. For troughs 54, this distance is the vertical distance indicated in FIG. 3 by the pair of dashed lines that pass, respectively, through the tops of protuberances 52 and the crossing points 53 that define the troughs. The vertical distance from the bottom of each trough 55 to the tops of protuberances 52, on the other hand, is somewhat larger, being shown by FIGS. 3 and 4 to be equal to the diameter of a strand 51.

In the apparatus of FIG. 1, support member 30 passes about drum 15 and separates from the drum at guide roll 31, which rotates on shaft 32. The support member passes downwardly around guide roll 33, rotating on shaft 34, and then rearwardly over a vertically adjustable tensioning and tracking guide roll 35 rotating on shaft 36, and then around guide roll 37 on shaft 38. The member passes upwardly and around guide roll 39 ro-

tating on shaft 40, to be returned about the periphery of the drum.

Apertured forming drum 15 and backing belt 30 provide a rearranging zone between them through which a fibrous starting material may move, to be rearranged under the influence of applied fluid forces into a non-woven fabric having a plurality of patterns of yarn-like bundles of fiber segments that alternate and extend throughout its area.

Tension on the support member is controlled and adjusted by the tensioning and tracking guide roll. The guide rolls are positioned in slideable brackets which are adjustable to assist in the maintenance of the proper tension of the support member. The tension required will depend upon the weight of the fibrous web being treated and the amount of rearrangement and patterning desired in the final product.

Apertured drum 15 rotates in the direction of the arrow shown, and support member 30 moves in the same direction at the same peripheral linear speed and within the indicated guide channels, so that both longitudinal and lateral translatory motion of the backing means, the apertured forming means, and the fibrous layer with respect to each other are avoided. The fibrous material 41 to be treated is fed between the drum and support member at point "A," passes through a fiber rearranging zone where fluid rearranging forces are applied to it, and is removed in its new, rearranged form as nonwoven fabric 42 between the support member and apertured drum at point "B."

As fibrous material 41 passes through the fiber rearranging zone, a liquid such as water is directed against the inner surfaces of rotatable apertured drum 15 by nozzles 29 mounted inside the drum, the liquid passes through apertures 19 into the fibrous web to produce rearrangement of the fibers of the web, and the water thence passes out through the backing means. If desired, vacuum assist box 43 helps remove the water through slots 44, and also helps in the rearrangement of the fibers. Suction box 45 further helps to remove water from the rearranged fabric 42 before it reaches takeoff point "B."

The relative position of a rectilinear forming aperture 19 and protuberances 52 of backing means 30 in one form of the method and apparatus of this invention is shown in dashed lines in FIG. 2. As is seen, aperture 19 spans a plurality of protuberances 52 on foraminous member 30 in both the longitudinal and transverse directions. In the embodiment shown, each of the two protuberances 52 in registry with aperture 19 — having a directional effect in one direction because of its proximity to other similar protuberances on backing means 30, and in the other direction for the same reason and in addition because of the cross-sectional shape of the protuberance — is effective in both the longitudinal and transverse directions.

Protuberance 52 opposite the upper left hand corner of aperture 19 in FIG. 2, through cooperation with protuberance 52 lying just below the lower left hand corner of aperture 19 in that same figure, is effective as a protuberance that defines one wall of trough 54 running vertically down the middle of aperture 19. At the same time, the first named protuberance 52, through cooperation with protuberance 52 lying just outside the upper right hand corner of aperture 19 in FIG. 2, is effective as a protuberance that defines one wall of trough 55 running horizontally across the middle of ap-

erture 19. In addition, the cross-sectional shape of each protuberance 52 (as best seen in FIGS. 2 and 4) exerts a directional effect on the fibers of the fibrous starting material by its sharper definition of the side walls of each trough extending horizontally across FIG. 2) i.e., on the side walls of each trough 55.

The directions the streams of rearranging fluid projected through apertures 19 of apertured forming means 15 take as they move into and through the fibrous web determine the type of forces applied to the fibers and, in turn, the extent of rearrangement of the fibers. Since the directions the streams of rearranging fluid take after they pass through apertures 19 are determined by the pattern of the solid wires that make up back means 30, and in particular the pattern of protuberances and troughs distributed across the surface of means 30, it follows that the pattern of these areas helps determine the patterns of holes or other areas of low fiber density in the resultant fabric.

As is seen from FIG. 2, portions of the streams of rearranging fluid that have passed through forming apertures 19 and the fibrous web can pass directly through openings 56 in foraminous backing means 30. Other portions of the streams of rearranging fluid that have passed through apertures 19 strike the wires of woven screen 30, at protuberances 52 or at other portions of the wire, and are deflected sidewise before they pass out of the rearranging zone through openings 56. The streams of rearranging fluid that strike protuberance 52 opposite the upper left hand portion of aperture 19 in FIG. 2, for example, leave the fiber rearranging zone through openings 56a, 56b, 56c and 56d in the respective sectors or quadrants of the area surrounding the protuberance.

The dotted lines in FIGS. 3 and 4 give a schematic showing of the path followed by a stream of rearranging fluid 57 that is directed through aperture 19 into the layer of fibrous starting material in a direction perpendicular to that layer, to strike protuberance 52 in the upper left hand corner of aperture 19 in FIG. 2. As is seen, the stream of fluid is deflected downwardly and outwardly away from its perpendicular direction of entry into the fiber rearranging zone, and then moves out of the rearranging zone through the openings between wires 50 and 51.

The flow of streams of rearranging fluid through adjacent apertures 19 of apertured forming means 15 produces a set of counteracting components of force which act in the plane of the web until the fluid is able to pass out through the support member. These fluid forces work in conjunction with one another to rearrange fiber segments into interconnected bundles, packing the fiber segments into yarn-like bundles that lie beneath land areas 20 of apertured forming means 15.

The flow of other streams of rearranging fluid after being deflected sidewise upon striking protuberances 52 of backing means 30 produces a second set of counteracting components of force that act in the plane of the web, but frequently in the opposite direction to the first set of counteracting components of force just described. The counteracting fluid forces in this second set work in conjunction with one another to rearrange fiber segments into yarn-like bundles positioned in troughs 54 and 55 of backing means 30.

Surprisingly, these two different sets of counteracting components of force work in cooperation with each

other to produce excellent nonwoven fabrics. When backing means 30 and apertured forming means 15 are employed in the method or apparatus of this invention as shown in FIG. 2, some of the fiber segments in registry with apertures 19 of apertured forming means 15 are moved by streams of rearranging fluid into surrounding areas of the fibrous layer and are there positioned in a first pattern of yarnlike bundles of closely associated and substantially parallel fiber segments that is complementary to apertures 19. At the same time, a second pattern of yarn-like bundles of fiber segments is created within the first pattern, being formed of yarnlike bundles that are positioned in troughs 54 and 55 on backing means 30 when other fiber segments that are in registry with apertures 19 of forming means 15 are moved by the fluid rearranging forces into the troughs.

When the layer of fibrous starting material is first positioned in the fiber rearranging zone between apertured forming means 15 and foraminous backing means 30, before a rearranging fluid has been directed through apertures 19 of forming means 15, the fibrous web of course lies upon the tops of protuberances 52. After fiber rearrangement has proceeded under the impact or rearranging fluid introduced through apertures 19, the fibers are moved down the sloping sides of protuberances 52 into troughs 54 and 55. At this juncture, the layer of rearranged fibers that comprises the nonwoven fabric ordinarily lies largely, if not altogether, below the tops of protuberances 52.

FIGS. 5 and 6 provide schematic representation of the flow of streams of rearranging fluid 57 that has been described in connection with FIGS. 2 through 4. In the practice of this invention, the layer of fibrous starting material is supported in a fiber rearranging zone in which fiber movement in directions parallel to the plane of the fibrous material is permitted in response to applied fluid forces. In FIGS. 5 and 6, the fiber rearranging zone is indicated as being defined on one side by foraminous backing means 30 and on the other by an apertured forming means of which opening 19 is one of the apertures. Streams of rearranging fluid 57 are projected into the fibrous layer as thus supported, in a direction perpendicular to said layer, at apertures or entry zones 19 which are spaced from each other adjacent the entry side of the rearranging zone.

The rearranging fluid entering at each entry zone 19 is passed through the first part 58 of the rearranging zone, as the fibrous layer lies in the zone. The streams of fluid 57 are passed toward dispersal points 52 lying directly opposite entry zone 19 and adjacent the exit side of the rearranging zone.

At each dispersal point 52, streams of rearranging fluid 57 are deflected diagonally and downwardly away from the perpendicular direction of entry of streams 57 into the fibrous starting material, into the area immediately surrounding each dispersal point 52. In FIGS. 5 and 6, fluid stream 57 that is directed toward dispersal point 52 in the upper left hand portion of FIG. 6 is directed upon deflection into sectors or quadrants 56a, 56b, 56c and 56d of the area surrounding dispersal point 52.

A few of the fiber segments of the fibrous starting material that lie opposite entry zone 19 remain, after treatment with streams of rearranging fluid, in substantially the positions they occupied by random chance in the starting layer. Most of the fiber segments lying opposite entry zone 19, however, are moved by the de-

flection of rearranging fluid just described into the area surrounding that dispersal point 52 at which fluid stream 57 was deflected.

Some of the fiber segments moved by the deflected rearranging fluid come to rest in areas of the fibrous starting material surrounding entry zone 19, as for example in the outer portions of areas 56a, 56c and 56d in FIG. 6. These segments as thus located form yarnlike bundles of closely associated and substantially parallel fiber segments that are arranged in a pattern complementary to entry zone 19.

Others of the fiber segments moved by deflected streams of rearranging fluid 57, as for example segments that are moved so that they extend between areas 56a and 56b of FIG. 6, are positioned in fiber accumulating zone 54 which extends vertically in that figure between adjacent dispersal points 52 and in registry with entry zone 19. Likewise, fiber segments that are moved so that they extend between areas 56b and 56c are positioned in fiber accumulating zone 55 which extends horizontally in FIG. 6, and so on. Fiber accumulating zones 54 and 55 correspond to troughs 54 and 55 shown in FIGS. 2 through 4. The yarn-like bundles of fiber segments positioned in the fiber accumulating zones form a second pattern of yarn-like bundles corresponding to the pattern of the fiber accumulating zones, which in turn is determined, among other things, by the position of various dispersal points 52 throughout the fiber rearranging zone.

The deflected portions of rearranging fluid 57 are then passed out of the fiber rearranging zone through spaced exits such as 56a through 56d and similar exit areas in FIGS. 5 and 6. At the same time, other portions of rearranging fluid that were projected into the layer of fibrous starting material at entry zone 19, for example those portions entering the entry zone in direct registry with exit 56b, are moved directly to and through the exits on the exit side of the rearranging zone without being deflected from the perpendicular direction at which they entered the fibrous starting layer.

The two dispersal points in registry with entry zone 19 in FIG. 6 are seen to produce fiber bundles in both the longitudinal and transverse directions in the fiber rearranging zone, and thus effectively act as a plurality of dispersal points measured in both those directions.

In the embodiment shown diagrammatically in FIGS. 2 through 4 and in the schematic representations of FIGS. 5 and 6, the spaced exits on the exit side of the rearranging zone are located in the fiber accumulating zones. Each of the entry zones 19 has the shape of a polygon having an even number of sides, and one pair of parallel, opposite sides of each entry zone lie generally opposite two of fiber accumulating zones or troughs 54 and 55.

In the apparatus of FIG. 1, the relative positioning of backing means 30 and apertured forming means 15 with respect to the fibrous layer 41 being rearranged is maintained through the rearranging zone by guarding against either longitudinal or lateral translatory movement. This maintains the integrity of the rearranged fabric as it is subjected to fluid forces from the rearranging liquid.

The following are illustrative examples of the use of the method and apparatus of this invention to produce patterned nonwoven fabrics:

EXAMPLE 1

In apparatus as illustrated in FIG. 1, a web 41 of loosely assembled fibers, such as may be obtained by carding, is fed between apertured forming means 15 and backing means 30. The web weight is about 450 grains per square yard, and its fiber orientation ratio approximately 7 to 1 in the direction of travel. The web contains viscose rayon fibers approximately $1\frac{9}{16}$ inch long of $1\frac{1}{2}$ denier.

Apertured forming means 15 has about 30 round apertures per square inch, each having a diameter of about one-eighth inch. These apertures 19 are arranged in a rectangular pattern over forming means 30, with each aperture spaced approximately 0.075 inch from adjacent apertures in the longitudinal direction and approximately 0.040 inch from adjacent apertures in the transverse direction.

Backing means 30 comprises a coarse woven wire screen similar to that shown in FIGS. 2 through 4. The screen is approximately 14×18 mesh or substantially 252 openings per square inch. The vertical distance between the tops of protuberances 52 and troughs 54 such as shown in FIGS. 2 and 3 is approximately 0.005 inch, or in other words a little more than three times the 0.0015 inch average diameter of the $1\frac{1}{2}$ denier fibers making up the starting material. Starting same vertical distance for troughs 55 such as those shown in FIG. 4 is slightly larger.

The horizontal distance between the tops of protuberances 52 is about 0.056 inch in one direction and about 0.071 inch in the other. These distances are equal, respectively, to about 37 times and about 47 times the 0.0015 inch average diameter of the fibers of the fibrous starting material.

Each aperture 19 spans a plurality of protuberances 52 on backing screen 30, measured in both the longitudinal and the transverse direction. Apertured forming means 15 and permeable backing means 30 are spaced from each other during use of the apparatus of FIG. 1 to provide a fiber rearranging zone therebetween.

Water is projected from nozzle 29 through apertures 19 in apertured forming means 15, and sent through fibrous web 41 and backing means 30.

After a given portion of fibrous web 41 passes through the rearranging zone, in which streams of water are directed against it as just described, the rotation (in the counterclockwise direction as seen in FIG. 1) of the sandwich comprised of apertured drum 15, the rearranged nonwoven fabric 42, and backing means 30 brings the rearranged fabric over vacuum drying means 45, which helps to remove the water remaining in the fabric. Fabric 42 is then carried forward to take-off zone "B," where it leaves the apparatus.

With the conditions indicated, good fiber rearrangement and bundling are obtained, and an excellent nonwoven fabric such as shown in the photomicrograph of FIG. 7, which has a plurality of patterns of yarn-like bundles of fiber segments each extending throughout the fabric, is produced.

Nonwoven fabric 60 of FIG. 7 contains larger areas of low fiber density 61, each of which has a shape generally similar to apertures 19 and is defined by heavy yarn-like bundles 62 of closely associated and substantially parallel fiber segments. Yarn-like bundles 62 are arranged in accordance with the configuration of land areas 20 of apertured forming means 15, or in other

words in a first pattern complementary to forming apertures 19 of forming means 15.

In addition, nonwoven fabric 60 contains smaller areas of low fiber density 63, arranged in accordance with the pattern of arrangement of protuberances 52 on permeable backing means 30. As indicated, areas of low fiber density 63 are smaller than areas 61, and lie within these areas. Each of the areas 63 is defined by yarn-like bundles 64 of closely associated and substantially parallel fiber segments, which have been positioned by the fluid rearranging forces of this invention in troughs 54 and 55 of backing means 30, and thus form a second pattern corresponding to the pattern of those troughs. Those bundles 64 are lighter in weight than are yarn-like bundles 62, which define larger areas of low fiber density 61.

FIG. 8 gives a cross sectional view of the fabric of FIG. 7 taken along a line similar to that shown as line 8—8 in FIG. 7, and with an original enlargement twice as large as that of FIG. 7. Larger areas of low fiber density 61 and smaller areas of low fiber density 63 may be seen in cross section. The first pattern of yarn-like bundles of fiber segments 62 that define areas 61, and the second pattern of yarn-like bundles of fiber segments 64 that define areas 63, can also be seen.

EXAMPLE 2

FIG. 9 gives a photomicrograph of another nonwoven fabric made in accordance with the present invention.

The starting material is a web similar to the starting material of Example 1, except that it has a web weight of approximately 350 grains per square yard.

Apertured forming means 15 used in this example is a cylinder formed of metal strips arranged in a "honeycomb" pattern of contiguous hexagonal openings 19. The distance between parallel opposite sides of each hexagonal shaped forming aperture 19 is about seven-sixteenths inch. The metal strips comprising the honeycomb structure are approximately 0.040 inch in thickness and about three-fourths inch in depth. A perspective drawing of portion of such a metallic honeycomb structure is provided in FIG. 10.

Backing means 30 comprises a coarse woven wire screen 30 having alternating protuberances 52 and troughs 54 and 55 similar to that used in Example 1. One pair of parallel, opposite sides of each hexagonal shaped forming aperture lie generally above the fiber accumulating troughs on the backing means.

Using the same general mode of operation as in Example 1, an excellent nonwoven fabric of attractive appearance such as is shown in the photomicrograph of FIG. 9 is obtained.

Nonwoven fabric 70 of FIG. 9 contains areas of low fiber density 71, each of which has the general hexagonal shape of forming apertures 19, and is defined by yarn-like bundles 72 of closely associated and substantially parallel fiber segments. These bundles are accumulated, by application of the fluid rearranging forces, under the land areas of the honeycomb apertured forming means 15, and are arranged in a first pattern complementary to the pattern of forming apertures 19.

In addition, nonwoven fabric 70 contains areas of low fiber density 73 that are arranged in accordance with the pattern of arrangement of protuberances on backing means 30. Each of these areas of low fiber density 73 is defined by yarn-like bundles of fiber segments 74,

which are bundled and positioned by the fluid rearranging forces in a second pattern corresponding to the pattern of troughs 54 and 55 of backing means 30. As is seen, areas of low fiber density 73 defined by the second pattern of yarn-like bundles 74 are smaller than and lie within areas of low fiber density 71 defined by the first pattern of yarn-like bundles 72.

EXAMPLE 3

In this example, a web similar to that employed in Example 1 is positioned between apertured forming means and backing means, while water is projected through the apertures of the forming means to pass through the fibrous web and then the backing means. Vacuum is applied to the backing means on the side of that means that is opposite the fiber rearranging zone, to assist in fiber rearrangement.

The apertured forming means employed is a nylon knitted mesh known as a Raschel knit fabric, with oval openings approximately one-sixteenth inch by one-eighth inch. The oval openings are distributed over the area of the apertured forming means in a diamond pattern, with a space of approximately one-sixteenth inch between them measured in the diagonal direction. There are 24 openings per square inch.

The backing means used in this example comprises a woven nylon screen of approximately 28 × 34 mesh, or substantially 952 openings per square inch. The vertical distance between the top of the protuberances formed by the "knees" of the woven screen and the bottom of the troughs lying between the protuberances is about 0.007 inch.

The tops of the protuberances on the backing means are spaced approximately 0.029 inch in one direction and approximately 0.036 inch in the other. This is equivalent, respectively, to about 20 times and about 24 times the average diameter of the fibers of the fibrous starting material.

The use of vacuum assist in this example results in a plurality of discontinuous, oval shaped fiber rearranging zones spaced from each other, with a continuous interconnecting zone between those discontinuous zones in which the apertured forming means and backing means, under the influence of the applied vacuum assist, clamp the fibrous starting material so tightly that the fluid rearranging forces are not capable of effecting fiber rearrangement in that zone. These areas in which fiber rearrangement is prevented underlie the land areas of the apertured forming means. The clamping action described follows from the fact that the apertured forming means employed is a highly flexible knit material readily responsive to the applied vacuum.

Using the method and apparatus indicated, an attractive nonwoven fabric 90 such as is shown in the photomicrograph of FIG. 11 is obtained. As is seen, a first pattern of heavier yarn-like bundles 91 of fiber segments is positioned around the entire perimeter of each of the oval shaped areas of the resulting fabric that corresponds to an aperture of the apertured forming means. Within each such oval area in the fabric, a second pattern or yarn-like bundles 93 of fiber segments having a lighter weight are positioned in both the longitudinal and transverse directions, in accordance with the pattern of the troughs on the backing means.

EXAMPLE 4

This example illustrates that without the use of vac-

uum assist, the tops of the protuberances on the backing means used in the practice of this invention must be spaced from each other by a horizontal distance at least equal to about 30 times the average diameter of the fibers of the fibrous starting material, in order to produce more than a single pattern of yarn-like bundles of fiber segments.

The starting material for this example is the same as that employed in Example 1, and the apparatus is also the same as that used in Example 1 except that the backing means of Example 3 is substituted. That backing means is a woven nylon screen of approximately 28 × 34 mesh, which means that the tops of the protuberances on the backing means are spaced approximately 0.029 inch in one direction and approximately 0.036 inch in the other. This is equivalent, respectively, to about 20 times and about 24 times the average diameter of the fibers of the fibrous starting material.

Because no vacuum assist is employed in this example and the tops of the protuberances on the backing means are not widely enough spaced from each other, the fluid rearranging forces that move fiber segments from positions in registry with the apertures of the apertured forming means into yarn-like bundles of fiber segments underlying the land areas of the apertured forming means are wholly dominant. As already explained above, when the protuberances on the foraminous backing means are not widely enough spaced, and as a result the troughs between the protuberances are not wide enough, the fluid rearranging forces that under other circumstances will bundle fiber segments into yarn-like groups lying at the bottom of the troughs cannot get a sufficient "purchase" on those fibers that happen to lie diagonally to the longitudinal axis of the trough to turn them around into positions parallel with that axis and thus with each other. It follows that the fiber segments lying in registry with the apertures of the apertured forming means are not accumulated in bundles in the troughs lying beneath those apertures, but are all moved sidewise until they lie in positions beneath the land areas surrounding the forming apertures.

For the reasons given, in this example, contrary to the results in Examples 1 through 3 above, the nonwoven fabric produced does not have a plurality of patterns of yarn-like bundles of fiber segments defining areas of low fiber density, but only a single such pattern. This single pattern of yarn-like bundles 81 in nonwoven fabric 80 is arranged in accordance with the pattern of apertures 19 in the apertured forming means 15. As seen in the photomicrograph of FIG. 12, no bundles of closely associated and substantially parallel fiber segments can be distinguished in positions corresponding to the fiber accumulating zones or troughs 54 and 55 of backing means 30 that are in registry with apertures 19 of the apertured forming means.

The above detailed description has been given for clearness of understanding only. No unnecessary limitations are to be understood therefrom, as modifications will be obvious to those skilled in the art.

I claim:

1. Apparatus for producing a patterned nonwoven fabric having a plurality of patterns of yarn-like bundles of fiber segments that alternate and extend throughout said fabric, from a layer of fibrous starting material whose individual fibers are in mechanical engagement with one another but are capable of movement under

applied fluid forces, which comprises: foraminous backing means for said layer of fibrous starting material, said means having a plurality of protuberances and troughs alternating across the surface thereof in both the longitudinal and transverse directions, the tops of said protuberances rising above the bottoms of the immediately adjacent troughs by a vertical distance of more than 0.005 inch, the top of each of said protuberances being spaced from the top of the immediately adjacent protuberance by a horizontal distance of more than 0.05 inch; apertured forming means spaced from said backing means to provide a zone in which fiber movement in directions parallel to said backing means is permitted in response to applied fluid forces, the apertures in said forming means being longitudinally and transversely spaced with land areas therebetween, the width of each of said forming apertures being equal to at least about the horizontal distance between the top of one of said protuberances and the top of an immediately adjacent protuberance; means for moving said backing means and apertured forming means, with a layer of fibrous starting material positioned therebetween, through a rearranging zone without any translatory movement between said two means and the fibrous layer; and means for projecting streams of rearranging fluid through said apertures in the apertured forming means and then against said fibrous layer to pass therethrough, some of said fluid streams striking said protuberances on the backing means and being deflected thereby in sidewise directions, and all of said fluid streams passing through and beyond said foraminous portions of the backing means.

2. The apparatus of claim 1 in which each of said apertures in the apertured forming means has a width sufficient to span a plurality of said protuberances on the backing means.

3. The apparatus of claim 2 in which each of said apertures in the apertured forming means spans a plurality of said protuberances on the backing means measured in both the longitudinal and the transverse directions.

4. Apparatus for producing a patterned nonwoven fabric having a plurality of patterns of yarn-like bundles of fiber segments that alternate and extend throughout said fabric, from a layer of fibrous starting material

whose individual fibers are in mechanical engagement with one another but are capable of movement under applied liquid forces, which comprises: foraminous backing means for said layer of fibrous starting material, said means having a plurality of protuberances and troughs alternating across the surface thereof in both the longitudinal and transverse directions, the tops of said protuberances rising above the bottoms of the immediately adjacent troughs by a vertical distance of more than 0.005 inch, the top of each of said protuberances being spaced from the top of the immediately adjacent protuberance by a horizontal distance of more than 0.025 inch; apertured forming means spaced from said backing means to provide a zone in which fiber movement in directions parallel to said backing means is permitted in response to applied liquid forces, the apertures in said forming means being longitudinally and transversely spaced with land areas therebetween, the width of each of said forming apertures being equal to at least about the horizontal distance between the top of one of said protuberances and the top of an immediately adjacent protuberance; means for moving said backing means and apertured forming means; with a layer of fibrous starting material positioned therebetween, through a rearranging zone without any translatory movement between said two means and the fibrous layer; means for projecting streams of liquid through said apertures in the apertured forming means and then against said fibrous layer to pass therethrough, some of said liquid streams striking said protuberances on the backing means and being deflected thereby in sidewise directions, and all of said liquid streams passing through and beyond said foraminous portions of the backing means; and means for applying a vacuum to said layer of fibrous starting material on the side opposite the points of application of said streams of liquid, to assist in moving said liquid through the fibrous layer and in rearranging the fibers of said layer to form a patterned nonwoven fabric.

5. The apparatus of claim 4 in which each of said apertures in the apertured forming means spans a plurality of said protuberances on the backing means measured in both the longitudinal and transverse directions.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,768,121 Dated October 30, 1973

Inventor(s) Frank Kalwaites

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 52, "aeas" should read --- areas ---.

Column 2, line 16, "unfformly" should read --- uniformly ---.

Column 2, line 25, "bundles" should read --- bundled ---.

Column 4, line 13, "fiers" should read --- fibers ---.

Column 7, line 3, "din" should read --- in ---.

Column 13, line 27, delete "starting" and insert "The".

Column 14, line 42, after the first "of" insert "a".

Column 15, line 51, "froming" should read --- forming ---.

Column 16, line 29, "th" should read --- the ---.

Column 17, line 28, "sai" should read --- said ---.

Column 18, line 33, "saie" should read --- said ---.

Column 18, line 41, "plrual" should read --- plural ---.

Signed and sealed this 4th day of June 1974.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents