March 20, 1962 H. W. GRISWOLD 3,025,585

APPARATUS AND METHOD FOR MAKING NONWOVEN FABRICS

Filed Nov. 19, 1959 2 Sheets-Sheet 1

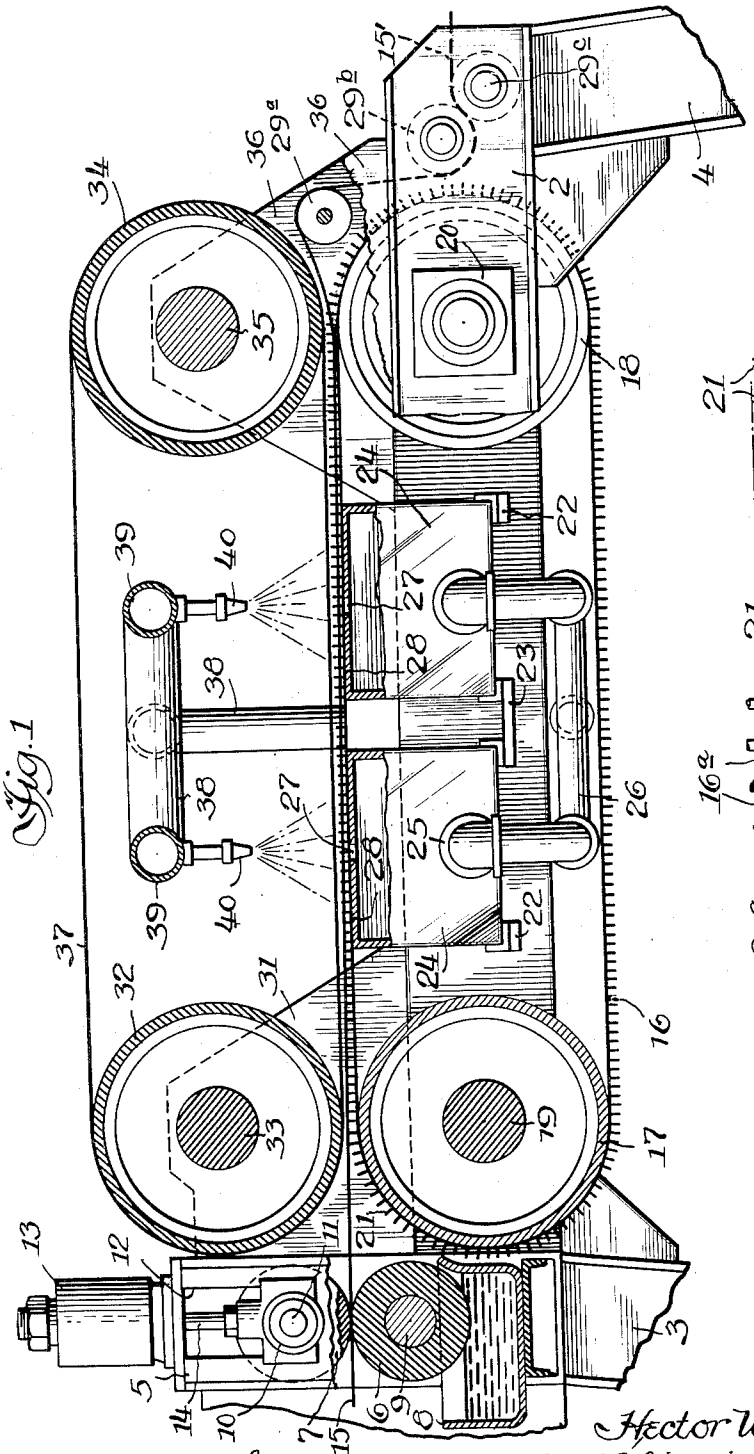

Fig. 1

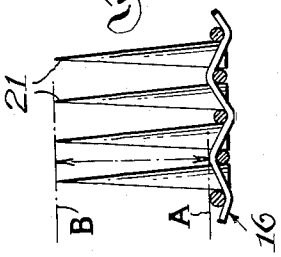

Fig. 2

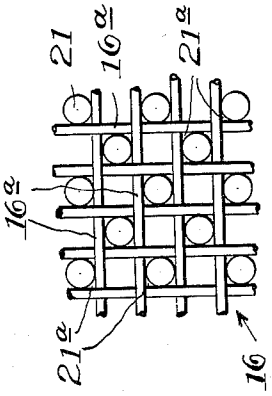

Fig. 3

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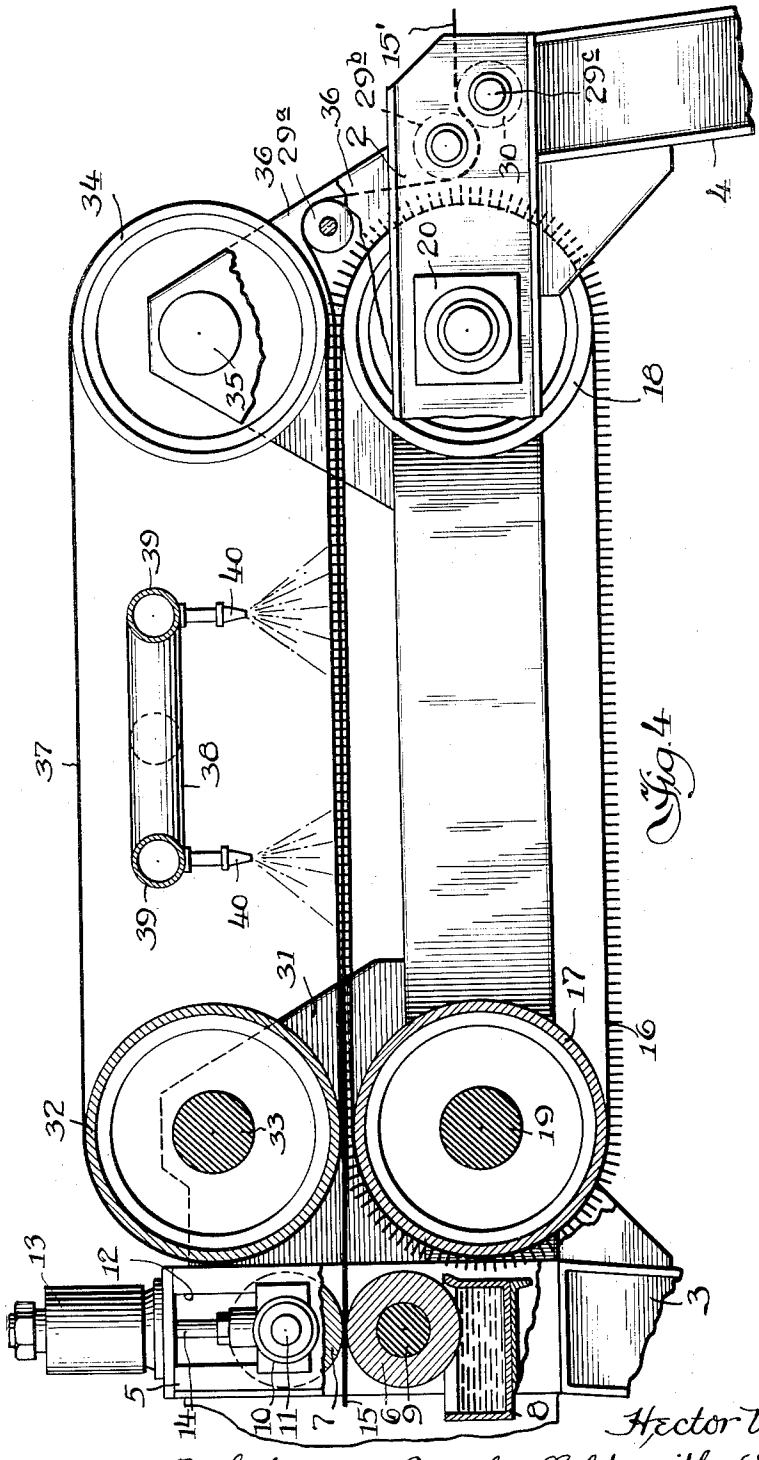

Fig. 4

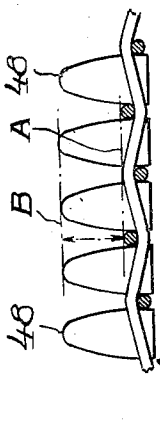

Fig. 6

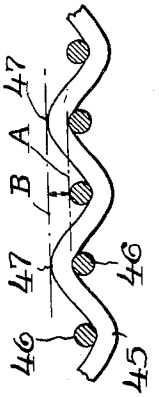

Fig. 5

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United States Patent Office 3,025,585 Patented Mar. 20, 1962

3,025,585
APPARATUS AND METHOD FOR MAKING NONWOVEN FABRIC

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Filed Nov. 19, 1959, Ser. No. 854,148
23 Claims. (Cl. 28—1)

This invention relates to an apparatus and method for producing nonwoven fabrics directly from fibers without the use of conventional spinning, weaving, or knitting operations.

Heretofore, nonwoven fabrics have been essentially different in structure from fabrics which have been woven or knitted. In a woven or knitted fabric, the fibers of the material making up the fabric do not occur individually, but are twisted into yarns or threads which in turn are woven or knitted into the fabric. In the well known spinning operation, fibers are spun or twisted together tightly into mechanical and frictional engagement with one another to form yarns which are substantially circular in cross section. It is these yarns, not the fibers acting individually, which serve as the structural members of the resulting woven or knitted fabrics. Generally speaking, these fabrics comprise reticular structures of intersecting, intertwining yarns which define interstices between them.

Nonwoven fabrics have been of two main types, felts and bonded webs. In each of these, the fibers making up the fabric occur individually and act individually as structural members. This is true even though the fibers in many felts are so highly interlocked and compressed together that it is difficult to identify individual fibers. Hat felts, for instance, are extremely dense, relatively "hard" fabrics without apparent interstices, which are quite dissimilar in appearance and qualities to woven or knitted structures.

On the other hand, the fibers in bonded webs are usually flatly assembled in layers, more or less oriented in one direction as in a card web or arranged in a random manner as in an air laid isotropic web. Various bonding agents have been used to print a binder pattern on such webs or to impregnate them to hold the individual fibers together. In this type of fabric, the fibers may remain relatively straight and overlapping one another with very little interlocking between them. They are usually arranged in a more or less uniformly spaced condition in the plane of the web, in such a way that only very small randomly occurring interstices are apparent between the overlapped fibers and those fibers between interstices remain spaced and more or less flatly arranged, possessing little similarity to the yarns of woven or knitted fabrics.

The present invention contemplates a nonwoven fabric wherein the fibers are arranged to define a predetermined pattern of holes or openings with most of the fiber segments bordering the holes extending in substantial parallelism with portions of their perimeters. In general, the fibers are arranged in interconnected groupings or web areas extending between the holes in a predetermined pattern corresponding to the aforementioned pattern of holes. The resulting fabric may be made to resemble a particular woven or knitted fabric.

The groupings or groups are connected by fibers extending from one to another in such a way that they are common to a plurality of groupings. It is preferred that the average length of the fibers be considerably greater than the lengths of the groups containing them with the result that the groups predominately comprise only parts or segments of the fibers passing through them. Preferably the fibers average at least about ¼ inch in length and are textile-like in nature, i.e., flexible and distinct.

Wood pulp fibers may also be used, in which case they should be unbeaten. In general, the groupings are connected at junctures wherein the fibers extend in a plurality of diverse directions, while the fiber segments in the groups are relatively parallelised with respect to one another and more closely assembled than at the junctures.

Due to their structure and appearance and other qualities, fabrics produced by the method and apparatus of this invention are particularly adapted for use in surgical dressings, absorbent dressings such as sanitary napkins and diapers, most suitably for covering sanitary napkins and diapers, in wiping cloths, toweling, filter materials, lining materials, industrial base fabrics, as a substitute for gauze-like fabrics in general, and a variety of other applications.

The present invention contemplates a method and an apparatus for producing the fabric herein described from a layer of irregularly arranged fibers. The layer may be a nonwoven web of fibers, for example, fibers of rayon or cotton. The individual fibrous elements of the layer are capable of movement under the influence of applied fluid forces. In general, any of the starting materials described in the following commonly assigned patent and copending applications may be used as starting materials in the method of this invention: Kalwaites Patent No. 2,862,251; Griswold application S.N. 503,871, filed April 26, 1955; and Griswold and Pearce application S.N. 503,872, filed April 26, 1955. The preferred starting material is an unbonded nonwoven fibrous web, suitably a card web.

The method of this invention involves the application of fluid streams, preferably water, against the exposed surface of a layer of irregularly arranged fibers of the type referred to above which are supported in overlapping and frictional engagement with one another upon the free ends of a group of tapered projections arranged in a predetermined pattern upon a permeable backing member with interconnected fiber accumulating spaces between them. It is essential that the backing member be permeable to the passage of the fluid from the applied streams, so that the fluid may pass freely through the backing member and away from the layer of fibers rather than having some or all of the fluid reflected back in the same general direction from which it is applied. Any substantial amount of backing up of the fluid would interfere with, and in an extreme case completely prevent, the desired rearrangement of fiber segments to form a nonwoven fabric of a predetermined pattern.

The forces from the spaced fluid streams may or may not be combined with the forces from one or more suction boxes exerting suction against the side of said permeable backing member opposite the side on which the projections are arranged.

Portions of the fluid rearranging forces employed in the method of this invention are deflected, upon striking the projections upon which the starting layer is supported, in directions having components parallel to the layer. These deflected portions combine to form streams of rearranging fluid which also flow in directions having components parallel to the fibrous starting layer and adjacent streams thus formed exert opposed components of force upon groups of fiber segments lying between them. As a result, the fiber segments in each group are moved into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around the bases of the projections supporting the fibrous layer. Since the projections are arranged in a predetermined pattern, the nonwoven fabric resulting from the method of this invention contains spaced holes arranged in the same predetermined pattern, being defined by the groups of consolidated and parallelised fiber segments that have been moved as just described into

the interconnected fiber accumulating zones around the bases of the projections.

The fiber rearranging forces which move segments of the fibers into the spaces between the tapered projections also move individual fiber segments along the paths of their respective center lines, relative to the other fibers in the layer, to move them into positions in which they lie in relaxed and tensionless condition and in mechanical equilibrium. The fiber segments thus rearranged remain in their new positions, with no tendency to return to their original positions, after the layer of fibers has been removed from engagement with the tapered projections.

The individual projections upon which the fibrous starting layer is supported must be shaped so that the transverse cross-sectional area of each projection increases progressively for at least the top portion of the projection as one moves from the free end thereof towards its base. The projections may be, for example, a plurality of prongs, the projections formed by wires of a woven wire screen as they weave over and under successive cross wires, or sharp tapered implements such as needles.

It is important to select the dimensions and spacing of the projections and the size of the holes in the permeable backing member so as to fall within certain general ranges, all with respect to the denier and length of the individual fibers and the density of the fibrous layer as a whole.

The transverse cross-sectional dimensions of each individual projection must obviously be large enough compared to the diameter of each individual fiber that the projection will be able to push the fiber aside from its starting position and thereby exert a significant rearranging effect on the fiber. On the other hand, it is apparent that the cross-sectional dimensions and the spacing of the projections must not be so large compared to the length of the individual fibers that the majority of the mass of the fibers will be caused to lie in helter-skelter fashion in a plastic mass between the projections rather than lying in a plurality of groups of consolidated and parallelized fiber segments. It has been found that projections having cross-sectional dimensions, measured parallel to the fibrous starting layer, of the order of magnitude ranging from about three to five times the diameter of individual fibers as a minimum and about two times the length of the majority of the individual fibers as a maximum, and spaced no farther apart than a distance equal to about half said length, are suitable for use with the method of this invention.

Each projection must have a height great enough to enable the projection to exert a significant rearranging force on the fibers affected. If the projections are too low, the fibers will not follow the predetermined pattern of distribution of the projections, but will be rearranged according to a distribution of forces determined by other factors. It has been found that the projections used with this method must have as a minimum a free height of the order of magnitude of about three times the diameter of the coarsest fibers in the fibrous starting layer. The term "free height" is used to mean the vertical distance between the effective bottom (i.e., where the consolidated fiber segments are accumulated) of the spaces between the rearranging projections and the crests of the adjacent projections.

In order for the projections to exert a rearranging force on all the fibers in the fibrous layer, including those in the top portion of the layer, the projections must be high enough that their free ends will protrude at least a short distance above the top surface of the rearranged fabric which is the product of this method. Or, to put it another way, the projections must have a certain minimum height indirectly related to the density of the fibrous starting layer, which will ordinarily be packed down in its rearranged form into a more dense final product.

The openings in the permeable backing member must obviously not be so large that the individual fibers may be urged through them, thereby destroying the integrity of the nonwoven fabric being produced, as the fluid rearranging streams pass through the fibrous layer and then through the backing member. The openings in a flat foraminous backing member should preferably be no wider than the approximate diameter of the finest fibers in the layer, but wider openings are preferred when a wire screen is used as a backing member. In any case the openings may be wider if the length of the fibers is considerably greater than the distance between the high points on adjacent projections.

Advantages of the invention other than those generally described above will be apparent from the following description and claims taken together with the drawings wherein:

FIGURE 1 is a side view, partly in section and partly in elevation, of a machine embodying the invention, with the feed end of the machine at the left of the figure and the discharge end at the right;

FIG. 2 is a fragmentary detail elevation of a plurality of tapered projections carried by a permeable backing member in the form of a screen having sharply tapered implements welded to the wires of the screen adjacent the base of the tapered implements;

FIG. 3 is a fragmentary top elevation of the same structure on which the fibers are rearranged;

FIG. 4 is a view similar to FIG. 1, showing an embodiment of the machine in which the suction boxes are omitted;

FIG. 5 is a fragmentary detail elevation of a plurality of tapered projections formed by wires of a wire screen as they weave over and under successive cross wires; and

FIG. 6 is a fragmentary detail elevation of a plurality of prongs carried by a permeable backing member as in the case of the embodiment shown in FIGS. 2 and 3.

Referring to the drawings, the machine comprises horizontal frame members **2** supported by upright legs **3** and **4**. At the feed end of the machine, a pair of vertical frame members **5** extend upwardly above the horizontal frame members **2**. A pair of wet-out rolls **6** and **7** are rotatably mounted between the vertical frame members **5**. The wet-out rolls **6** and **7** extend transversely of the machine and are in vertical alignment with each other. The roll **6** is partially immersed in a water pan **8** and its shaft **9** is journalled in bearings (not shown) fixed to the vertical frame member **5**. The bearings **10**, in which the shaft **11** of wet-out roll **7** is journalled, are slidably mounted in recesses **12** extending vertically downward from the upper edge of the vertical frame members **5**.

The vertical position of wet-out roll **7** is adjustable, and is regulated by hydraulic positioning cylinders **13** mounted on the top of each vertical frame member **5**. Each positioning cylinder has a two-way piston (not shown) carrying a piston rod **14** connected at its lower end to the bearing **10**. By applying hydraulic pressure through conventional control means (not shown) to one side or the other of the piston of each positioning cylinder, the pressure at the nip between wet-out rolls **6** and **7** may be varied as desired.

The pair of wet-out rolls **6** and **7** cooperate to control the moisture content of a layer **15** of irregularly arranged fibers, of a type such as mentioned above as being a suitable starting material, which is fed through the nip between the wet-out rolls. The position of roll **7** relative to roll **6** determines the quantity of water that is applied to the layer **15** as it passes through the nip between the wet-out rolls. The fibers of layer **15** are in overlapping and frictional engagement with one another as the layer passes through the nip between the wet-out rolls. Preferably the moisture content of the layer of fibers as it is moved from the wet-out rolls is in the neighborhood of from 150 to 200 percent. The term "percent moisture," when used in this specification, refers to percentage of moisture by weight of the dry web.

The layer of fibers moves from the nip of the wet-out

rolls to the fiber rearranging portion of the apparatus to effect the rearrangement of the fibers in the starting web or layer 15, to produce a rearranged fibrous web or layer 15' having an arrangement of fibers and openings as above described. Thus the starting layer of fibers moves from the wet-out rolls to a foraminous surface in the form of a permeable endless belt **16** which extends around a pair of parallel rolls **17**, **18**, rotatably mounted adjacent opposite ends of the frame. Each of the rolls **17**, **18** is mounted on a shaft **19**, the ends of which are journalled in bearings **20** carried on the horizontal frame members **2**. Conventional driving means (not shown) are connected to either one of the shafts **19**.

The permeable endless belt **16** is shown in FIGS. 1 through 3 in the form of a woven wire screen having the bases of a plurality of tapered implements **21** welded thereto in any desired predetermined arrangement. The wire screen is preferred because it provides adequate support for the tapered implements **21**, sufficient unobstructed space through which the fluid rearranging streams may pass and the applied vacuum may act, and the flexibility required in an endless belt operation. The tapered projections in this embodiment may be needles or other similar sharp, pointed projections. As seen in FIG. 3, spaces **21***a* between the side walls of the bases of tapered implements **21** and wires **16***a* comprising the elements of woven screen belt **16** are preferably filled by some solid material, such as the weld through which the needles are affixed to belt **16**.

It is seen from FIGS. 2 and 3 that the transverse cross-sectional area of each tapered projection **21** increases progressively for at least the top portion of the projection as one moves from the free end thereof to the base of the projection. The tapering walls of the projections assist in the rearrangement of the fibers into a nonwoven fabric in a manner to be described below.

Each projection **21** in the embodiment shown in FIGS. 1 through 3 is well over the minimum free height expressed above of about three times the diameter of the coarsest fiber in the fibrous starting material. The effective bottom of the interconnected fiber accumulating spaces between rearranging projections **21** is the general level at which it is observed from FIG. 2 the groups of consolidated and parallelized fiber segments will lie in the final nonwoven fabric produced by this method. The effective bottom of the fiber accumulating spaces is shown by dashed and dotted line A in FIG. 2 and the crests of the adjacent tapered projections **21** are shown by dashed and dotted line B. The vertical distance between these lines, indicated by the dashed and dotted arrow, is the "free height" of projections **21**.

A plurality of brackets **22**, **23**, mounted on horizontal frame members **2**, support a pair of suction boxes **24** which extend transversely of frame members **2** between rolls **17** and **18** which carry the permeable endless belt **16**. It will be obvious that the number of suction boxes may be varied. Each suction box is closed on all sides except for an opening **25** to which a vacuum line **26** is connected, and a slot or group of perforations **27** which extend longitudinally of the top wall **28** of the suction box. The top wall of each suction box is positioned adjacent the underside of the upper reach of permeable endless belt **16**.

The fabric **15'**, after rearrangement but before reaching the position where permeable endless belt **16** starts to track around the roll **18**, is lifted off the belt by causing it to pass upwardly and over a horizontal cylindrical doffing member **29***a* which extends transversely of the machine and is supported at its ends in the side frames. The fabric then passes downwardly and around through the nip between guide rolls **29***b* and **29***c* on its way to a suitable drying area not shown. Guide rolls **29***b* and **29***c* are parallel to doffing member **29***a*, and like it are supported at their ends in the side frame members of the machine.

While not necessary to the formation of a rearranged fabric in accordance with the invention as herein described, it may be desirable in some instances, in order to obtain greater diffusion of liquid in the fabric rearranging area, to interpose a permeable spray diffusion belt in the path of the liquid discharged from the nozzles. While such a diffusing member could be stationary, its preferred form, shown in the embodiment disclosed in the drawing, is a permeable endless belt **37** arranged to track around a pair of rollers **32** and **34** arranged parallel with rollers **17** and **18** and which may be mounted on shafts **33** and **35** journaled for rotation in side frame members **31** and **36** of the machine. Rollers **32** and **34** are arranged so that the lower reach of belt **37** is adjacent to and just above the upper ends of the tapered projections extending upwardly from the upper reach of permeable endless belt **16**.

Rollers **17**, **18**, **32** and **34** are preferably operated so that permeable endless belt **16** has the same linear speed as spray diffusing belt **37**. This may be desirable to prevent any longitudinal displacement of diffusing belt **37** relative to the layer **15** of fibers which moves longitudinally through the machine in engagement with the tapered projections **21** on endless belt **16** while the fibers are being rearranged to form the nonwoven fabric. The machine is designed to utilize fluid rearranging forces, and any mechanical forces introduced into the operation by a difference in speed between permeable backing belt **16** and spray diffusing belt may only interfere with the desired rearrangement. Specifically, longitudinal displacement of spray diffusing belt **37** relative to the layer of fibers may to some degree prevent the desired movement of the fibers by exerting a frictional pull on the individual fibers.

A water pipe **38**, mounted in any suitable manner, supports a pair of headers **39** above the lower reach of spray diffusing belt **37**. The number of headers may be varied, but whenever suction boxes **24** are provided, as in the embodiment being described, it is preferred to have a header positioned over each suction box. Each header extends transversely of belt **37** and has a row of jet nozzles **40** to provide water sprays across the width of diffusing belt **37**. The water sprays strike the upper surface of the lower reach of belt **37** and the water is diffused by the permeable belt as it passes through the belt and into contact with the fibers.

The water sprays cooperate with the suction boxes to move fiber segments into consolidated and parallelized groups between the tapered projections, and downwardly to the surface of belt **16**. The water present from the sprays and from the wet-out device also acts as a lubricant to facilitate movement of individual fibers longitudinally of their respective center lines with respect to other fibers of the layer **15** and to help rearrange them in relaxed, tensionless condition in the interconnected fiber accumulating spaces around the bases of projections **21**.

The layer **15** of irregularly arranged fibers is fed from any suitable source to the machine where it is positioned on top of the sharp, tapered projections **21** projecting upwardly from the belt **16**. If it is desired to wet out the web before it enters the rearranging zone this may be done by initially passing the layer through the nip between wet-out rolls **6** and **7** arranged adjacent the entering end of the machine in the embodiment shown in the drawings, although it should be understood that the use of such rolls is not essential to the proper operation of the machine.

The engagement of the pointed ends of the tapered projections **21** is sufficient to move the layer **15** with the permeable endless belt **16** across the tops of the suction boxes **24**. It is seen from FIG. 1 that as the layer of fibers **15** passes the first row of nozzles **40** and the first slot **27**, the force of the water and the force of the vacuum cooperate to move the fibers downwardly along the tapered sides of the needles **21** toward the permeable

end less belt 16, and the force of the water from the second row of nozzles 40 cooperates with the force of the vacuum at the second slot 27 to complete the downward movement of the fibers to form nonwoven fabric 15'. It is preferable to carry out the fiber rearrangement in a plurality of stages to enhance the uniformity of the product and to increase its speed of formation.

The fiber rearranging forces applied by the water sprays from nozzles 40 and by the suction from slots 27 are of various types. Among these are the forces resulting from the deflection, in directions having components parallel to the fibrous starting layer, of portions of the laterally and longitudinally spaced streams of water of which the water sprays are comprised, as those streams strike tapered projections 21 and then pass on through the fibrous layer and permeable backing belt 16. Portions of adjacent streams thus deflected exert opposed components of force upon groups of fibers lying between the projections, moving segments in each group into closer proximity to and increased parallelism with each other, and the fiber groups are at the same time moved down into the fiber accumulating spaces around the bases of projections 21.

Another type of rearranging force is exerted by the water sprays and suction in cooperation with the tapered sides of needles 21. The sprays and suction press the fibers downward around the tapered sides of the projections, and thereby produce translatory forces acting parallel to the plane of fibrous layer 15, to help push the fibers laterally into the fiber accumulating spaces around projections 21.

As the water particles and air streams bounce off projections 21 and are sucked down between the individual fibers into the screen belt openings and from there into suction boxes 24, they will tend to agitate the fibers somewhat, resulting in a certain amount of vibration in the individual fibers which also helps produce fiber rearrangement. Additional vibration will be produced by the impact of any water particles that pass directly through the openings in spray diffusing belt 37 and impinge upon the fibers of web 15 without having the force due to their ejection from spray nozzles 40 reduced by intervention of the land areas of the diffusing belt. The vibration of the fibers caused in these two ways will assist in producing the sliding movement of fibers along their respective longitudinal center lines which is essential to bring the fibers into the positions in which they lie in mechanical equilibrium and relaxed, tensionless condition in the rearranged nonwoven fabric.

From this discussion of the various types of rearranging forces exerted by the streams of water and by the applied suction, it is seen that it is essential that backing belt 16 be sufficiently permeable that the water and air can pass freely through it. The rearranging forces depend upon the efficient movement of the two fluids not only through the fibrous layer but also away from it on the side opposite the entry of the fluids. There must be no "flooding" or other backing up or turbulence of either fluid of proportions great enough to destroy the integrity of the fibrous starting layer or rearranged web, or even to oppose to any serious extent the effect of the forces tending to rearrange the fibers into the pattern desired for the resulting nonwoven fabric.

The individual fibers are of such length compared to the dimensions of the openings in permeable belt 16 between projections 21 that they will not be washed through the belt by the water streams from the sprays nor will they be pulled through the belt by the force of the applied vacuum, but will simply be held against the screen wire of belt 16 by the water flow and the air suction.

With the embodiment of permeable endless belt 16 and tapered projections 21 shown in FIG. 3, there will be no forces tending to move the fibers in web 15 into the small spaces 21*a* defined by the base walls of each projection 21 and the wires 16*a* surrounding it, for these spaces are filled with solid material. Thus the fibers will tend to be packed in uniform bundles extending from one open space bounded by a set of four elements 16*a* to the next adjacent similar open space.

The embodiment of the invention shown in FIG. 4 is the same as that of FIG. 1 except that the suction boxes are omitted. Otherwise the structure shown in FIG. 4 is identical with the corresponding structure in FIG. 1 and therefore the specific description will not be repeated. The same reference numerals are used in both figures to identify the structure. With the structure shown in FIG. 4, the rearrangement of the fibers is effected by the water from sprays 40 without the application of any suction against the underside of the layer of fibers 15.

Omission of spray diffusing belt 37 is preferred when nozzles 40 are of a quality good enough to produce a uniform fine spray. In such case, the velocity at which the water spray leaves nozzles 40 should be reduced below that normally employed when the diffusing belt is present.

FIG. 5 illustrates another embodiment of tapered projections that may be employed with this invention. A single wire 45 of a woven wire screen is shown in FIG. 5 as it passes over and under successive cross wires 46 to form tapered projections 47. Since both the longitudinal and transverse dimensions of each projection 47 increase progressively for at least the top portion of the projection as one moves from the free end thereof toward the cross-sectional center of the screen, it follows that the transverse cross-sectional area of each projection increases progressively at the same time.

The effective bottom of the fiber accumulating spaces between tapered projections 47 is indicated by dashed and dotted line A in FIG. 5, and the level of the adjacent crests is shown by dashed and dotted line B. The arrow showing the vertical distance between lines A and B represents the "free height" of projections 47 formed by the protruding wires of the woven screen.

FIG. 6 illustrates another embodiment of tapered projections usable with this invention. In this embodiment prongs 48 are welded to wire screen 49 in the same manner as needles 21 are welded to screen 16 of FIGS. 2 and 3. The effective bottom of the fiber accumulating spaces between the prongs is shown by line A, the crests of the adjacent prongs by line B, and the "free height" of the prongs by the arrow between lines A and B.

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

What is claimed is:

1. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: supporting the layer upon the free ends of a plurality of tapered projections arranged in said predetermined pattern upon a permeable backing member with interconnected fiber accumulating spaces between them, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, applying fluid streams to the fibrous starting layer so as to cause the fluid to pass first through said layer supported on the tapered top portions of said projections, then through the interconnected spaces between said projections and thereafter through the permeable backing member, deflecting portions of said fluid, after it has struck said projections, into streams flowing in directions having components

parallel to the fibrous starting layer as it is supported upon the free ends of said projections, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments laying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said projections.

2. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied liquid forces, which comprises: supporting the layer upon the free ends of a plurality of tapered projections arranged in said predetermined pattern upon a permeable backing member with interconnected fiber accumulating spaces between them, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, applying streams of liquid to the fibrous starting layer so as to cause the liquid to pass first through said layer supported on the tapered top portions of said projections, then through the interconnected spaces between said projections and thereafter through the permeable backing member, deflecting portions of said liquid, after it has struck said projections, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon the free ends of said projections, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said projections.

3. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: supporting the layer upon the free ends of a plurality of tapered projections arranged in said predetermined pattern upon a permeable backing member with interconnected fiber accumulating spaces between them, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, while creating a reduced pressure on the side of the permeable backing member opposite the side on which the projections are arranged simultaneously applying fluid streams to the fibrous starting layer so as to cause the fluid to pass first through said layer supported on the tapered top portions of said projections, then through the interconnected spaces between said projections and thereafter through the permeable backing member, deflecting portions of said fluid, after it has struck said projections, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon the free ends of said projections, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said projections.

4. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied liquid forces, which comprises: supporting the layer upon the free ends of a plurality of tapered projections arranged in said predetermined pattern upon a permeable backing member with interconnected fiber accumulating spaces between them, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, while creating a reduced pressure on the side of the permeable backing member opposite the side on which the projections are arranged simultaneously applying streams of water to the fibrous starting layer so as to cause the water to pass first through said layer supported on the tapered top portions of said projections, then through the interconnected spaces between said projections and thereafter through the permeable backing member, deflecting portions of said water, after it has struck said projections, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon the free ends of said projections, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said projections.

5. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: supporting the layer upon the free ends of a plurality of tapered prongs arranged in said predetermined pattern upon a permeable backing member with interconnected fiber accumulating spaces between the prongs, the transverse cross-sectional area of each of said prongs increasing progressively from its top downwardly for at least a portion of the prong, the free height of each prong being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, applying fluid streams to the fibrous starting layer so as to cause the fluid to pass first through said layer supported on the tapered top portions of said prongs, then through the interconnected spaces between said prongs and thereafter through the permeable backing member, deflecting portions of said fluid, after it has struck said prongs, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon the free ends of the prongs, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said prongs.

6. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied liquid forces, which comprises: supporting the layer upon the free ends of a plurality of tapered prongs arranged in said predetermined pattern upon a permeable backing member with interconnected fiber accumulating spaces between the prongs, the transverse cross-sectional area of each of said prongs increasing progressively from its top downwardly for at least a portion of the prong, the free height of each prong being greater than the thick-

ness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, applying streams of liquid to the fibrous starting layer so as to cause the liquid to pass first through said layer supported on the tapered top portions of said prongs, then through the interconnected spaces between said prongs and thereafter through the permeable backing member, deflecting portions of said liquid, after it has struck said prongs, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon the free ends of the prongs, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said prongs.

7. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied liquid forces, which comprises: supporting the layer upon the free ends of a plurality of tapered prongs arranged in said predetermined pattern upon a permeable backing member with interconnected fiber accumulating spaces between the prongs, the transverse cross-sectional area of each of said prongs increasing progressively from its top downwardly for at least a portion of the prong, the free height of each prong being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, while creating a reduced pressure on the side of the permeable backing member opposite the side on which the prongs are arranged simultaneously applying streams of water to the fibrous starting layer so as to cause the water to pass first through said layer supported on the tapered top portions of said prongs, then through the inter-connected spaces between said prongs and thereafter through the permeable backing member, deflecting portions of said water, after it has struck said prongs, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon the free ends of the prongs, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the inter-connected fiber accumulating spaces around said prongs.

8. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: supporting the layer upon a woven wire screen having projections formed by wires thereof as they weave over and under successive cross wires, said projections having interconnected fiber accumulating spaces therebetween, the free height of each projection being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, applying fluid streams to the fibrous starting layer so as to cause the fluid to pass first through said layer supported on said projections, then through the interconnected spaces between said projections and thereafter through said screen, deflecting portions of said fluid, after it has struck said projections, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon said projections, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said projections.

9. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied liquid forces, which comprises: supporting the layer upon a woven wire screen having projections formed by wires thereof as they weave over and under successive cross wires, said projections having interconnected fiber accumulating spaces therebetween, the free height of each projection being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, applying streams of liquid to the fibrous starting layer so as to cause the liquid to pass first through said layer supported on said projections, then through the interconnected spaces between said projections and thereafter through said screen, deflecting portions of said liquid, after it has struck said projections, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon said projections, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said projections.

10. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied liquid forces, which comprises: supporting the layer upon a woven wire screen having projections formed by wires thereof as they weave over and under successive cross wires, said projections having interconnected fiber accumulating spaces therebetween, the free height of each projection being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, while creating a reduced pressure on the side of the screen opposite the side on which the layer is supported simultaneously applying streams of water to the fibrous starting layer so as to cause the water to pass first through said layer supported on said projections, then through the interconnected spaces between said projections and thereafter through said screen, deflecting portions of said water, after it has struck said projections, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon said projections, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said projections.

11. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: supporting the layer upon a plurality of sharp, tapered projections arranged in said predetermined pattern upon a permeable backing member with interconnected fiber accumulating spaces between the projections, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each tapered projection being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, applying fluid streams to the fibrous starting layer so as to cause the fluid to pass first through

said layer supported on the sharp, tapered top portions of said projections, then through the interconnected spaces between the projections and thereafter through said permeable backing member, deflecting portions of said fluid, after it has struck said projections, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon the free ends of said projections, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said projections.

12. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied liquid forces, which comprises: supporting the layer upon a plurality of sharp, tapered projections arranged in said predetermined pattern upon a permeable backing member with interconnected fiber accumulating spaces between the projections, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each tapered projection being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, applying streams of liquid to the fibrous starting layer so as to cause the liquid to pass first through said layer supported on the sharp, tapered top portions of said projections, then through the interconnected spaces between the projections and thereafter through said permeable backing member, deflecting portions of said liquid, after it has struck said projections, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon the free ends of said projections, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said projections.

13. A method of producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied liquid forces, which comprises: supporting the layer upon a plurality of sharp, tapered projections arranged in said predetermined pattern upon a permeable backing member with interconnected fiber accumulating spaces between the projections, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each tapered projection being greater than the thickness of the fibrous starting layer and at least about three times the diameter of the coarsest fibers in said layer, while creating a reduced pressure on the side of the permeable backing member opposite the side on which the projections are arranged simultaneously applying streams of water to the fibrous starting layer so as to cause the water to pass first through said layer supported on the sharp, tapered top portions of said projections, then through the interconnected spaces between the projections and thereafter through said permeable backing member, deflecting portions of said water, after it has struck said projections, into streams flowing in directions having components parallel to the fibrous starting layer as it is supported upon the free ends of said projections, and directing portions of adjacent streams thus formed in opposed directions against groups of fiber segments lying between said adjacent streams, so as to move the fiber segments of said groups into closer proximity to and increased parallelism with each other and into the interconnected fiber accumulating spaces around said projections.

14. A machine for producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: a permeable endless belt carrying a plurality of tapered projections arranged thereon in said predetermined pattern, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous layer to be rearranged and at least about three times the diameter of the coarsest fibers in said layer, and means for projecting fluid streams against the outer surface of said starting layer as it is supported on the tapered top portions of said projections.

15. A machine for producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: a permeable endless belt carrying a plurality of tapered projections arranged thereon in said predetermined pattern, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous layer to be rearranged and at least about three times the diameter of the coarsest fibers in said layer, and means for projecting liquid streams against the outer surface of said starting layer as it is supported on the tapered top portions of said projections.

16. A machine for producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: a permeable endless belt carrying a plurality of tapered projections arranged thereon in said predetermined pattern, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous layer to be rearranged and at least about three times the diameter of the coarsest fibers in said layer, spray means for projecting liquid streams toward said starting layer as it is supported on the tapered top portions of said projections, permeable spray diffuser means interposed between said spray means and said projections so that streams of liquid from the spray means pass through said spray diffuser means before striking the fibrous starting layer, and means for moving said endless belt and said spray diffuser means in the same direction and at substantially the same rate.

17. A machine for producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: a permeable endless belt carrying a plurality of tapered projections arranged thereon in said predetermined pattern, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous layer to be rearranged and at least about three times the diameter of the coarsest fibers in said layer, means for

creating a reduced pressure on the side of said permeable belt opposite the side on which said projections are carried, and means for projecting fluid streams against the outer surface of said starting layer as it is supported on the tapered top portions of said projections.

18. A machine for producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: a permeable endless belt carrying a plurality of tapered projections arranged thereon in said predetermined pattern, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous layer to be rearranged and at least about three times the diameter of the coarsest fibers in said layer, means to wet out the fibrous starting layer, and means for projecting fluid streams against the outer surface of said wet starting layer as it is supported on the tapered top portions of said projections.

19. A machine for continuously producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: a pair of rotatably mounted parallel rollers, an endless foraminous belt mounted on said rollers for movement therewith, tapered projections extending outwardly from said belt in said predetermined pattern, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous layer to be rearranged and at least about three times the diameter of the coarsest fibers in said layer, means for positioning a layer of irregularly arranged fibers in engagement with the free ends of said tapered projections, means to wet out said fibrous layer, spray means directing streams of water towards said wet layer of fibers, and means to move said foraminous belt carrying said wet fibrous starting layer through the zone beneath said spray means, the streams of water from said spray means moving individual fibers into fiber accumulating spaces around the bases of adjacent tapered projections as the belt and wet fibrous layer move beneath said spray means.

20. A machine for continuously producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: a pair of rotatably mounted parallel rollers, an endless foraminous belt mounted on said rollers for movement therewith, tapered projections extending outwardly from said belt in said predetermined pattern, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous layer to be rearranged and at least about three times the diameter of the coarsest fibers in said layer, means for positioning a layer of irregularly arranged fibers in engagement with the free ends of said tapered projections, means to wet out said fibrous layer, spray means directing streams of water towards said wet layer of fibers, a second pair of parallel rollers rotatably mounted in vertical alignment with said first mentioned pair of rollers, a permeable spray diffuser belt mounted on said second pair of rollers, a suction box adapted to exert suction through its top wall, the top wall of said suction box being positioned adjacent the under surface of the upper reach of said projection-carrying foraminous belt, and means for moving said endless projection-carrying belt and said spray diffuser belt in the same direction and at substantially the same rate between said spray means and said suction box, said spray means and suction box cooperating to move individual fibers into fiber accumulating spaces around the bases of adjacent tapered projections as the belts and wet fibrous layer move between them.

21. A machine for producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: a permeable endless belt carrying a plurality of tapered prongs arranged thereon in said predetermined pattern, the transverse cross-sectional area of each of said prongs increasing progressively from its top downwardly for at least a portion of said prong, the free height of each prong being greater than the thickness of the fibrous layer to be rearranged and at least about three times the diameter of the coarsest fibers in said layer, and means for projecting fluid streams against the outer surface of said starting layer as it is supported on the tapered top portions of said prongs.

22. A machine for producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: a permeable endless belt comprising a woven wire screen having projections formed by wires thereof as they weave over and under successive cross wires, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous layer to be rearranged and at least about three times the diameter of the coarsest fibers in said layer and means for projecting fluid streams against the outer surface of said starting layer as it is supported on the tapered top portions of said projections.

23. A machine for producing a nonwoven fabric having spaced holes arranged in a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another and which are capable of individual movement under the influence of applied fluid forces, which comprises: a permeable endless belt carrying a plurality of sharp, tapered projections arranged thereon in said predetermined pattern, the transverse cross-sectional area of each of said projections increasing progressively from its top downwardly for at least a portion of said projection, the free height of each projection being greater than the thickness of the fibrous layer to be rearranged and at least about three times the diameter of the coarsest fibers in said layer, and means for projecting fluid streams against the outer surface of said starting layer as it is supported on the tapered top portions of said projections.

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