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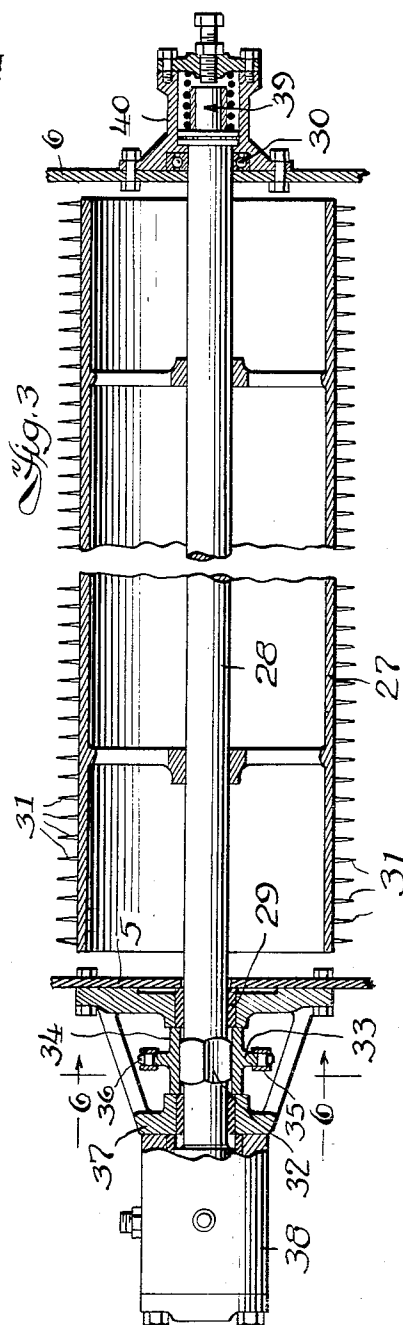
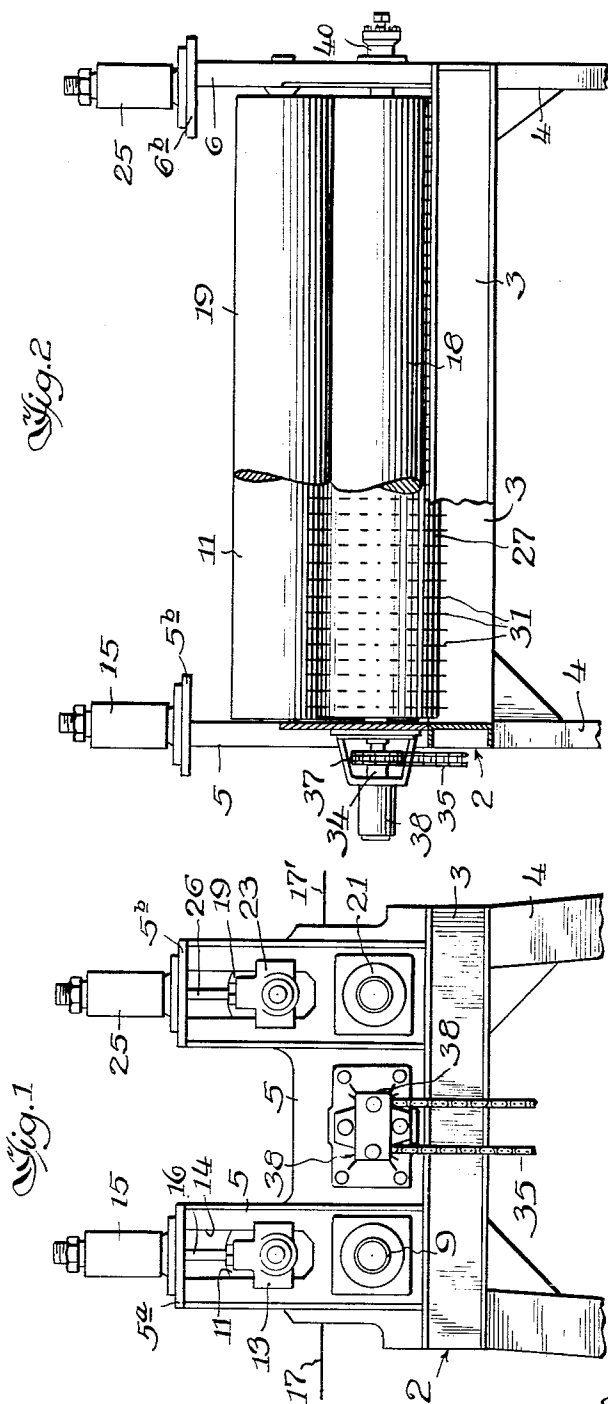
C. HARMON ET AL

3,012,290

APPARATUS FOR PRODUCING NONWOVEN FABRIC AND METHOD

Filed July 5, 1957

3 Sheets-Sheet 1



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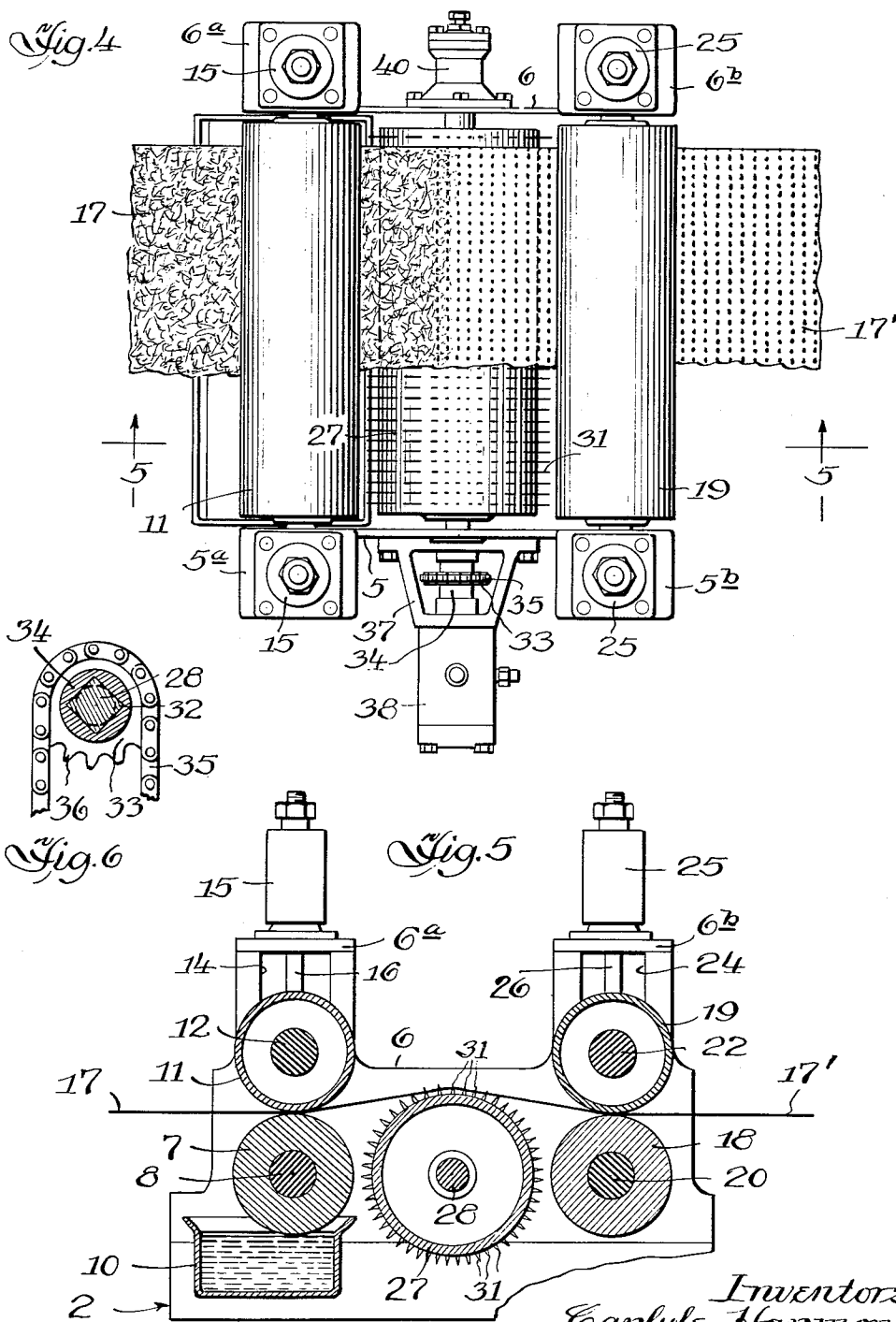
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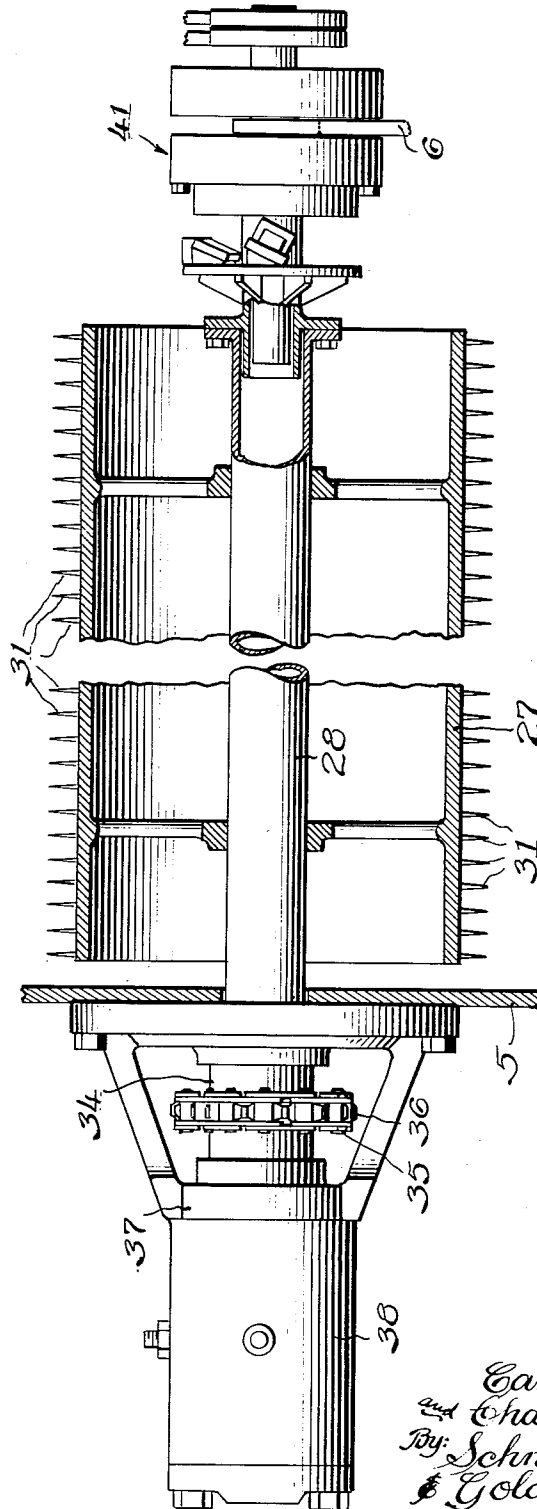


Fig. 7

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1

3,012,290

**APPARATUS FOR PRODUCING NONWOVEN
FABRIC AND METHOD**

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26 Claims. (Cl. 19—161)

This invention relates to a method and apparatus for producing nonwoven fabrics, i.e., fabrics produced 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, either 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 the perimeters of the holes. 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 predominantly comprise only parts or segments passing through them. Preferably the fibers average at least about $\frac{1}{4}$ inch in length and

2

are textile-like in nature, i.e. flexible and distinct or unbeaten in the case of wood pulp. 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 parallelized with respect to one another and more closely assembled than at the junctures.

In the foraminous structure formed by the interconnected fiber groupings, the fibers lie in a state of mechanical equilibrium and in relatively relaxed, tensionless condition. The fibers are mechanically and frictionally engaged to the extent that the arrangement of fibers is one of equilibrium and the fibers themselves have substantially no in-built tendency to depart from their configurations in the structure.

Due to their structure and appearance and other qualities described in the foregoing paragraph, 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 and gauze-like fabrics in general, and a variety of other applications.

The present invention contemplates a method and an apparatus for producing the fabric of this invention 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 an applied mechanical force. In general, any of the starting materials described in the following copending, commonly assigned applications may be used as starting materials in the method of this invention: Griswold S.N. 503,871, filed April 26, 1955; Griswold and Pearce S.N. 503,872, filed April 26, 1955; and Kalwaites S.N. 567,275, filed February 23, 1956, now Patent No. 2,862,251. The preferred starting material is an unbonded fibrous web.

The method of this invention involves the application of external mechanical translatory and vibratory forces to a starting layer of irregularly arranged fibers to move segments of the fibers into groupings in fiber accumulating zones arranged in a predetermined pattern. A group of prongs, which may have rounded ends but are preferably tapered needles or similar sharp, pointed implements defining interconnected spaces between them, are employed for this purpose. The prongs are arranged in positions corresponding to the foraminous portions of the predetermined pattern which is desired for the nonwoven fabric being produced.

The fibrous starting layer is preferably first wet out and then impaled upon the prongs, which are vibrated to cause the fibers of the layer to move into new positions to form a foraminous nonwoven fabric. At the same time that the prongs are caused to penetrate into the fibrous starting layer, they are preferably also vibrated, although if desired, they may first be inserted and then vibrated. The preferred amplitude of vibration of the prongs is large enough that the holes produced in the fibrous layer are larger in area than the cross-sectional area of the respective prongs.

In a preferred embodiment of the apparatus, the needles are carried on a rotatable cylinder against which a moving layer of fibers to be rearranged is positioned. The layer of irregularly arranged fibers is impaled on the needles, and the cylinder is vibrated either longitudinally, or circumferentially or both, to move the individual fibers laterally and in the direction of their respective longitudinal axes with respect to the other fibers in the layer, to bring the individual fibers into relaxed, tensionless positions in the resulting nonwoven fabric.

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:

FIG. 1 is a fragmentary side elevation of a machine embodying the invention, with the feed end of the machine shown on the left and the discharge end on the right side of the figure;

FIG. 2 is an end elevation of the same machine as seen from the right hand side of FIG. 1, with portions of tension rolls at the discharge end of the machine broken away to facilitate illustration of the structure, particularly the needle-bearing cylinder;

FIG. 3 is a longitudinal sectional view through said cylinder showing the means for vibrating it longitudinally of its axis;

FIG. 4 is a top elevation of the machine with a portion of the layer of fibers broken away to show the cylinder;

FIG. 5 is a cross sectional view, taken along the line 5-5 of FIG. 4;

FIG. 6 is a detail sectional view, taken along the line 6-6 of FIG. 3, and showing the means for permitting longitudinal vibration of the drive shaft; and

FIG. 7 is a longitudinal sectional view through the needle-bearing cylinder of another embodiment of the machine of this invention, showing a longitudinal vibrator and a torsional vibrator diagrammatically at opposite ends of the shaft.

In the drawings, the reference numeral 2 indicates a supporting frame comprising a horizontal bed 3 mounted on upright legs 4. Vertical frame plates 5 and 6 extend upwardly from bed 3 at opposite sides of the bed. A wet-out roll 7 is carried by a shaft 8 (see FIG. 5), the opposite ends of which are journaled in bearings 9 mounted in vertical frame plates 5 and 6 at the feed end of the machine. Wet-out roll 7 is partially immersed in a water pan 10. A second wet-out roll 11 is mounted in vertical alignment with roll 7 on a shaft 12, the opposite ends of which are journaled in bearings 13. Bearings 13 are slidably mounted in recesses 14 which extend vertically downward from the upper edge of each vertical frame plate 5 and 6.

The vertical position of wet-out roll 11 is regulated by hydraulic positioning cylinders 15 mounted on brackets 5a and 6a projecting laterally from the top of vertical frame plates 5 and 6 respectively. Each positioning cylinder has a two-way piston (not shown) carrying a piston rod 16 connected at its lower end to the bearing 13. By applying hydraulic pressure through conventional control means to one side or the other of the piston of each positioning cylinder, the pressure at the nip between wet-out rolls 7 and 11 may be varied as desired.

The pair of wet-out rolls 7 and 11 cooperate to control the moisture content of the layer 17 of irregularly arranged fibers, such as a card web of cotton fibers or an air laid web of viscose rayon fibers, which is fed through the nip between the wet-out rolls. The position of roll 11 relative to roll 7 determines the quantity of water that is applied to the layer 17. The fibers of layer 17 are in mechanical and frictional engagement with one another as the layer passes through the wet-out rolls. Preferably the layer of fibers contains in the neighborhood of 150 to 200 percent moisture as it leaves the wet-out rolls. The term "percent moisture," when used in this specification, refers to the percentage of moisture by weight of the dry layer of fibers. If the layer of fibers is not self-sustaining in its initial form, it may be mounted on a suitable carrier adapted to support it until it becomes self-sustaining as a result of the rearrangement of the fibers into a nonwoven fabric in the process of this invention. The carrier may be an endless foraminous belt having one reach passing through the nip of the wet-out rolls and through the nip of a pair of tension rolls 18, 19, hereinafter described.

Tension roll 18 is provided with a shaft 20 journaled

in bearings 21 mounted on vertical frame plates 5 and 6 at the discharge end of the machine. The bearings 21 for tension roll 18 are similar to the bearings 9 for wet-out roll 7, and are mounted in the same horizontal plane at the opposite end of the machine. The tension roll 18 has the same diameter as wet-out roll 7, and the nip between the tension rolls 18 and 19 is in the same horizontal plane as the nip between the wet-out rolls 7 and 11.

The shaft 22 of tension roll 19 is mounted in bearings 23 which are slidably mounted in vertical recesses 24 extending downwardly from the upper edges of vertical frame plates 5 and 6. Each hydraulic positioning cylinder 25 mounted on bracket 5b and 6b projecting laterally from the top of vertical frame plates 5 and 6, respectively, has a piston rod 26 connected to bearing 23 to regulate the vertical position of shaft 22 in the same manner as positioning cylinders 15 regulate the position of shaft 12 for wet-out roll 11. The rearranged fibers in nonwoven fabric 17' pass from the tension rolls 18 and 19 to a suitable drying area (not shown).

Needle-bearing cylinder 27 is carried by a drive shaft 28 journaled in bearings 29 and 30 mounted respectively on vertical frame plates 5 and 6. The cylinder drive shaft 28 is parallel to and in the same horizontal plane as shafts 8 and 20 for wet-out roll 7 and tension roll 18, respectively. The diameter of cylinder 27 is larger than the diameter of rolls 7 and 18, and, therefore, the upper peripheral surface of cylinder 27 is in a horizontal plane higher than the horizontal plane extending from the nip between wet-out rolls 7 and 11 to the nip between tension rolls 18 and 19.

Cylinder 27 is provided with a plurality of tapered needles 31, or other similar sharp, pointed implements, which project radially from the peripheral surface of the cylinder. The needles may be secured to the cylinder in any suitable manner, and are arranged in positions corresponding to the foraminous portions of the predetermined pattern of the fabric to be made from the layer of fibers.

As the layer of fibers extends from the nip between the wet-out rolls to the nip between the tension rolls, it engages the pointed ends of the needles projecting from the uppermost portion of the peripheral surface of the cylinder. This surface is higher than the nip between each pair of rollers on opposite sides of the cylinder, and the layer of fibers is put under a slight longitudinal tension to pull it down against the needles so as to be impaled thereon to an extent sufficient to cause the layer of fibers to move with the cylinder.

The cylinder drive shaft 28 is provided with an integral lateral projection 32 outside the vertical plate 5. Projection 32 is square in cross-section. As shown in FIGS. 3 and 6, a drive sprocket 33 is provided with a hub 34 which fits the square exterior of projection 32 to rotate the cylinder drive shaft 28 as the sprocket is rotated by an endless chain 35 meshed with the teeth 36 of the sprocket and driven by any suitable power source (not shown). As seen in FIG. 3, the longitudinal dimension of sprocket hub 34 is greater than the longitudinal dimension of drive shaft projection 32 so that the shaft projection 32, and the cylinder drive shaft 28 with which it is integral, may slide longitudinally relative to the sprocket hub at the same time that drive shaft 28 is being rotated by the sprocket.

A vibrator supporting bracket 37 is mounted on vertical frame plate 5 and extends outwardly to the end of cylinder drive shaft 28. A vibrator 38 is mounted on the outer end of bracket 37 and is operable to vibrate drive shaft 28 at a rate of at least about forty cycles per second. The vibrator may be operated hydraulically or electrically. The vibrator, which is shown in elevation in FIGS. 1 and 2 and in plan in FIGS. 3 and 4, has a stroke of about $\frac{1}{16}$ of an inch, which is less than the difference between the longitudinal dimensions of the drive shaft projection 32 and the drive sprocket hub 34. At the

5

opposite end of shaft 28 an adjustment device 39 for regulating the amplitude of the vibrator is held adjacent plate 6 by means of a bracket 40 which also holds the cylinder drive shaft bearing 30 in place. The vibrator and adjustment device are both conventional units.

In the operation of the machine of this invention, a layer 17 of irregularly arranged fibers is fed from any suitable source through the nip between the pair of wet-out rollers 7 and 11. Sufficient water is preferably applied to the layer by the wet-out rolls to provide a moisture content of from 150 to 200 percent. The fibers in the layer shown in the drawings are in mechanical and frictional engagement with one another and, therefore, maintain their irregular arrangement.

The layer extends from the nip of the wet-out rolls over the sharp pointed ends of the tapered needles 31 on cylinder 27. The needles penetrate through the layer as the cylinder 27 is rotated by drive shaft 28. Additional driving means, synchronized with the driving means for cylinder 27, may be provided for any of the rolls 7, 11, 13, or 19, if desired, but it has been found that the machine operates satisfactorily with needle-bearing cylinder 27 as the only driven member, so long as means is provided to move the nonwoven fabric 17' away from the discharge end of the machine after its production in accordance with this invention.

As the needle-bearing cylinder 27 of the embodiment shown in FIGS. 1 through 6 rotates, it is vibrated longitudinally of its axis at a predetermined frequency. The predetermined frequency is a single frequency if vibrator 38 has a fixed frequency, or may be one of several frequencies if vibrator 38 has a variable frequency. By regulation of adjustment device 39, the amplitude of vibration of cylinder 27 can be controlled between predetermined limits. The vibration of cylinder 27 produces vibration of needles 31 at a predetermined frequency, in a predetermined direction, and at a predetermined amplitude. The latter depends upon the amplitude of vibration of the cylinder and also upon the length and stiffness of the needles.

If the amplitude of the vibration of the needles is slight, the vibrating itself will produce no substantial lateral movement of the fibers. In such cases, the major fiber rearrangement is produced by penetration of the fibrous layer by the prongs. In this major rearranging step, the fibers are pushed out of the local areas of the layer which are occupied by the advancing prongs. As a result, fibers are pushed into closer proximity and increased parallelism in the areas bordering upon the prongs. If the prongs employed are sharp, tapered implements, the penetration of the fibrous layer by the tapered walls of the implements will apply to fibers adjacent the implements forces having lateral translatable components acting parallel to the plane of the layer which will push segments of the fibers aside into the spaces between the implements.

The rearrangement of the fibers is completed in such cases by the vibratory action of the prongs, which is transmitted to the fibers surrounding the prongs and causes these fibers in effect to "hum" and thereby to be shaken loose to a certain extent from their mechanical and frictional engagement with neighboring fibers in the layer. Since the fibers are already under tension by reason of the lateral translatable forces applied to the fibers by the prongs which have penetrated the layer, loosening their engagement with other fibers causes them to move in the direction of their respective longitudinal axes with respect to the other fibers until the tension has been relieved. Because of this longitudinal movement, the fibers are permitted to lie in mechanical equilibrium and in a relaxed and tensionless condition in the rearranged positions in which they finally come to rest. The water in the layer facilitates the relative movement of the fibers, since it acts as a lubricant and permits the fibers to slide longitudinally relative to one another.

6

In the preferred form of this invention, however, the amplitude of vibration of the prongs is large enough that the vibration contributes to the lateral displacement of the fibers upon penetration of the fibrous layer by the prongs.

In such cases the vibrating prongs repeatedly strike individual fibers adjacent the prongs and move segments of those fibers laterally into successively more extreme positions as the prongs penetrate the fibrous layer. The fiber segments displaced in this incremental fashion are prevented by their inertia from moving back each time to their immediately preceding positions in the layer before they are struck again by their respective vibrating prongs during successive cycles of vibration. The minimum frequency of vibration of the rearranging prongs necessary to achieve the successively greater displacement of fiber segments just described when the prongs oscillate with a maximum amplitude of approximately one-sixteenth inch is about 40 cycles per second for an unbonded fibrous web formed of 2" rayon fibers of 1.5 denier, the web having a basic weight of about 400 grains per square yard and containing water in the amount of about 200 percent of the dry weight of the web.

If desired, the frequency of vibration of the prongs may be increased to the point that a prong returns from the other end of its vibratory cycle so promptly that it "spanks" each fiber in its path before the inertia of the fiber permits the fiber to move back any distance at all toward its original position in the fibrous layer, much less reach its immediately preceding position.

As the succession of blows from the vibrating prongs moves the fibers in its path to positions at successively greater lateral distances, it also causes the fibers to move in the direction of their respective longitudinal axes, with respect to the other fibers in the layer with which they are mechanically and frictionally engaged, so as to permit the segments of the fibers to lie in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are pushed. Again, the water in the layer acts as a lubricant to facilitate this longitudinal movement of the fibers.

In the embodiment shown in FIGS. 1 through 6, the vibration of needles 31 has an amplitude large enough to produce fiber rearrangement by the continuous striking of the fibers just described. The resulting nonwoven fabric 17' has a predetermined foraminous pattern, the foramina of which correspond to the arrangement of needles upon the cylinder, but have an area larger than the cross-sectional area of the respective needles. Individual fibers of the layer have been caused to move into closer proximity and parallelism with one another, and to form interconnected groups of fiber segments in the fiber accumulating zones between the needles. In general, the fiber segments bordering the holes extend in substantial parallelism with portions of the perimeters of the holes.

Nonwoven fabric 17' is moved from the needle-bearing cylinder 27 through the nip between tension rolls 13 and 19, and into a suitable bonding or drying zone (not shown) of a conventional type.

Since the needles shown in the embodiment of FIGS. 1 through 6 are circular in cross-section, the holes in the nonwoven fabric produced by this embodiment are ellipsoid in shape, and are oriented with their major axes transverse to the direction of movement of the fibrous web. The minor axis of each hole is approximately the same length as the thickness of the needle by which it was formed, while the major axis is greater than that by an amount equal to the maximum amplitude of the vibration of the cylinder-bearing drive shaft.

With needles having other cross-sectional shapes and varying amplitudes of vibration, the shape of the resulting foramina will vary correspondingly.

If the amplitude of the shaft vibration is very small with respect to the thickness of individual needles carried by the rotating cylinder, the foramina in the resulting

nonwoven web will each have substantially the same outline as the cross-sectional shape of the respective needle by which the hole in question was produced. In such case, the needle may suitably be a sharp, tapered implement. As already explained, the tapered side walls will then assist in the penetration of the fibrous layer, by providing lateral translatable components of force acting parallel to the plane of the layer as the implements continue their penetration.

In the embodiment of FIGS. 1 to 6 of this invention, the cylinder and the rearranging needles carried by it are vibrated in only one direction, parallel to the longitudinal axis of the cylinder. The cylinder rotates continuously in one direction as the fibrous starting layer is fed into contact with the needles.

In the embodiment of FIG. 7, shaft 28 of cylinder 27 is provided with a torsional vibrator 41, such as that described in Patent No. 2,604,503 issued July 22, 1952, to E. W. Smith, to vibrate the cylinder and the needles carried by it circumferentially or angularly as well as longitudinally of the axis of the cylinder.

If the longitudinal and angular components of vibrating motion applied to the needles in the embodiment of FIG. 7 have the same frequencies, the path traced by each needle with respect to its position of rest will be the same in each cycle. As an example, if such components are 90° out of phase, the resulting path of each needle will be circular in shape.

If the frequencies of the two vibratory components are different, the components will "beat" against each other to form constantly changing resultant paths of vibratory motion.

If desired, the apparatus shown in FIG. 7 may be used to produce vibration of cylinder 27 in a circumferential direction only, with the resulting vibration of needles 31 oriented solely in the direction of travel of the fibrous web being rearranged.

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.

We claim:

1. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: penetrating said layer with a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern and vibrating said prongs, said penetration and vibration cooperating to move the fibers laterally into said predetermined pattern and longitudinally of their respective axes so as to permit them to remain in mechanical equilibrium and in relaxed, tensionless condition in their new positions in said predetermined pattern.

2. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: penetrating said layer with a group of sharp, tapered implements arranged in positions corresponding to the foraminous portions of said predetermined pattern and vibrating said implements, said penetration and vibration cooperating to move the fibers laterally into said predetermined pattern and longitudinally of their respective axes so as to permit them to remain in mechanical equilibrium and in relaxed, tensionless condition in their new positions in said predetermined pattern.

3. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: simultaneously vibrating a group of sharp, tapered implements arranged in a pattern corresponding to the foraminous portions of said predetermined pattern and penetrating said layer with said vibrating implements so as to apply

forces having lateral translatable components acting parallel to the plane of the layer and thereby move individual fibers downward along the tapered sides of the implements, laterally into the spaces between the implements, and in the direction of the spaces between the implements, and in the direction of the respective longitudinal axes of the fibers with respect to the other fibers in the layer with which they are engaged, thereby permitting segments of said individual fibers to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said tapered implements and said vibrating forces.

4. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: positioning said layer of fibers in contact with the pointed ends of a group of sharp, tapered implements arranged in a pattern corresponding to the foraminous portions of said predetermined pattern, applying tension to said layer to impale it on said tapered implements and simultaneously vibrating said implements, so as to apply forces having lateral translatable components acting parallel to the plane of the layer and thereby move individual fibers downward along the tapered sides of the implements, laterally into the spaces between the implements, and in the direction of the respective longitudinal axes of the fibers with respect to the other fibers in the layer with which they are engaged, thereby permitting segments of said individual fibers to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said tapered implements and said vibrating forces.

5. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: wetting out said layer, penetrating said layer with a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern and vibrating said prongs to move the fibers laterally into said predetermined pattern while moving them longitudinally of their respective axes so as to permit them to remain in mechanical equilibrium and in relaxed, tensionless condition in their new positions in said predetermined pattern.

6. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: penetrating said layer with a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern; simultaneously vibrating said prongs to repeatedly strike individual fibers adjacent said vibrating prongs and move segments of said fibers laterally into successively more extreme positions as said prongs penetrate into said fibrous layer, said fiber segments being prevented by their inertia from moving back each time to their immediately preceding positions in said fibrous layer before being struck again by their respective vibrating prongs during successive cycles of vibration of said prongs; and continuing said vibration so as to move said individual fibers not only laterally but also in the direction of their respective longitudinal axes with respect to the other fibers in the layer with which they are engaged, to permit said fiber segments to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said vibrating prongs.

7. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: penetrating said layer with a group of prongs arranged in positions corresponding to the foraminous portions of said predeter-

mined pattern; simultaneously vibrating said prongs to repeatedly strike individual fibers adjacent said vibrating prongs and move segments of said fibers laterally into successively more extreme positions as said prongs penetrate into said fibrous layer, said fiber segments being prevented by their inertia from moving back each time toward their original positions in said fibrous layer before being struck again by their respective vibrating prongs during successive cycles of vibration of said prongs; and continuing said vibration so as to move said individual fibers not only laterally but also in the direction of their respective longitudinal axes with respect to the other fibers in the layer with which they are engaged, to permit said fiber segments to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said vibrating prongs.

8. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: penetrating said layer with a group of sharp, tapered implements arranged in positions corresponding to the foraminous portions of said predetermined pattern; simultaneously vibrating said implements to repeatedly strike individual fibers adjacent said vibrating implements and move segments of said fibers laterally into successively more extreme positions as said implements penetrate into said fibrous layer, said fiber segments being prevented by their inertia from moving back each time to their immediately preceding positions in said fibrous layer before being struck again by their respective vibrating implements during successive cycles of vibration of said implements, and continuing said vibration so as to move said individual fibers not only laterally but also in the direction of their respective longitudinal axes with respect to the other fibers in the layer with which they are engaged, to permit said fiber segments to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said vibrating implements.

9. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: wetting out said layer; penetrating said layer with a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern; simultaneously vibrating said prongs to repeatedly strike individual fibers adjacent said vibrating prongs and move segments of said fibers laterally into successively more extreme positions as said prongs penetrate into said fibrous layer, said fiber segments being prevented by their inertia from moving back each time to their immediately preceding positions in said fibrous layer before being struck again by their respective vibrating prongs during successive cycles of vibration of said prongs; and continuing said vibration so as to move said individual fibers not only laterally but also in the direction of their respective longitudinal axes with respect to the other fibers in the layer with which they are engaged, to permit said fiber segments to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said vibrating prongs.

10. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: penetrating said layer with a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern; simultaneously vibrating said prongs to repeatedly strike individual fibers adjacent said vibrating prongs and move segments of said fibers laterally into successively more extreme positions as said

prongs penetrate into said fibrous layer, said fiber segments being prevented by their inertia from moving back each time to their immediately preceding positions in said fibrous layer before being struck again by their respective vibrating prongs during successive cycles of vibration of said prongs; continuing said vibration so as to move said individual fibers not only laterally but also in the direction of their respective longitudinal axes with respect to the other fibers in the layer with which they are engaged, to permit said fiber segments to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said vibrating prongs; and drying said rearranged fibers to form a nonwoven fabric.

11. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: penetrating said layer with a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern; simultaneously vibrating said prongs to repeatedly strike individual fibers adjacent said vibrating prongs and move segments of said fibers laterally into successively more extreme positions as said prongs penetrate into said fibrous layer, said fiber segments being prevented by their inertia from moving back each time to their immediately preceding positions in said fibrous layer before being struck again by their respective vibrating prongs during successive cycles of vibration of said prongs; continuing said vibration so as to move said individual fibers not only laterally but also in the direction of their respective longitudinal axes with respect to the other fibers in the layer with which they are engaged, to permit said fiber segments to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said vibrating prongs; applying an adhesive binder to said rearranged fibers; and drying said rearranged fibers to form a nonwoven fabric.

12. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: penetrating said layer with a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern; simultaneously vibrating said prongs with a predetermined amplitude to repeatedly strike individual fibers adjacent said vibrating prongs and move segments of said fibers laterally into successively more extreme positions as said prongs penetrate into said fibrous layer, said fiber segments being prevented by their inertia from moving back each time to their immediately preceding positions in said fibrous layer before being struck again by their respective vibrating prongs during successive cycles of vibration of said prongs; and continuing said vibration so as to move said individual fibers not only laterally but also in the direction of their respective longitudinal axes with respect to the other fibers in the layer with which they are engaged, to permit said fiber segments to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said vibrating prongs.

13. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: penetrating said layer with a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern; simultaneously vibrating each of said prongs in two directions, said directions being at right angles to each other, to repeatedly strike individual fibers adjacent said vibrating prongs and move segments of said fibers laterally into successively more extreme positions as said prongs penetrate into said fibrous layer, said fiber segments being prevented by their inertia from

11

moving back each time to their immediately preceding positions in said fibrous layer before being struck again by their respective vibrating prongs during successive cycles of vibration of said prongs; and continuing said vibration so as to move said individual fibers not only laterally but also in the direction of their respective longitudinal axes with respect to the other fibers in the layer with which they are engaged, to permit said fiber segments to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said vibrating prongs.

14. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: penetrating said layer with a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern; simultaneously vibrating each of said prongs in two directions, said directions being at right angles to each other, with the vibrations in said two directions having the same frequency and being 90° out of phase, to repeatedly strike individual fibers adjacent said vibrating prongs and move segments of said fibers laterally into successively more extreme positions as said prongs penetrate into said fibrous layer, said fiber segments being prevented by their inertia from moving back each time to their immediately preceding positions in said fibrous layer before being struck again by their respective vibrating prongs during successive cycles of vibration of said prongs; and continuing said vibration so as to move said individual fibers not only laterally but also in the direction of their respective longitudinal axes with respect to the other fibers in the layer with which they are engaged, to permit said fiber segments to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said vibrating prongs.

15. The method of producing a foraminous, nonwoven fabric having a predetermined pattern from a wetted layer of irregularly arranged fibers in overlapping and frictional engagement with one another which comprises: penetrating said layer with a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern; simultaneously vibrating each of said prongs in two directions, said directions being at right angles to each other, with the vibrations in said two directions having different frequencies, to repeatedly strike individual fibers adjacent said vibrating prongs and move segments of said fibers laterally into successively more extreme positions as said prongs penetrate into said fibrous layer, said fiber segments being prevented by their inertia from moving back each time to their immediately preceding positions in said fibrous layer before being struck again by their respective vibrating prongs during successive cycles of vibration of said prongs; and continuing said vibration so as to move said individual fibers not only laterally but also in the direction of their respective longitudinal axes with respect to the other fibers in the layer with which they are engaged, to permit said fiber segments to remain in mechanical equilibrium and in relaxed, tensionless condition in the most extreme lateral positions into which they are moved by said vibrating prongs.

16. A machine for producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another, said machine comprising a group of sharp, tapered implements arranged in positions corresponding to the foraminous portions of said predetermined pattern, means for moving a layer of irregularly arranged fibers in overlapping and frictional engagement with one another onto said implements, means for impaling said layer upon said implements with the implements penetrating the layer from one side thereof through to the other side, and means for vibrating each of said implements, so as to move individual fibers of said layer

12

laterally and in the direction of their respective longitudinal axes, with respect to the other fibers in said layer with which they are in overlapping and frictional engagement, into relaxed, tensionless positions between said implements.

17. A machine for producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another, said machine comprising a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern, means for moving a layer of irregularly arranged fibers in overlapping and frictional engagement with one another onto said prongs with the prongs penetrating the layer from one side thereof through to the other side, means for impaling said layer upon said prongs, and means for vibrating each of said prongs to move individual fibers of said layer laterally and in the direction of their respective longitudinal axes, with respect to the other fibers in said layer with which they are in overlapping and frictional engagement, into relaxed, tensionless positions between said prongs.

18. A machine for producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another, said machine comprising means for wetting said layer out, a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern, means for moving said wet layer onto said prongs, and means for vibrating each of said prongs to move individual fibers of said layer laterally and in the direction of their respective longitudinal axes, with respect to the other fibers in said layer with which they are in overlapping and frictional engagement, into relaxed, tensionless positions between said prongs.

19. A machine for producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another, said machine comprising a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern, means for moving a layer of irregularly arranged fibers in overlapping and frictional engagement with one another onto said prongs, and means for vibrating each of said prongs in two directions, said directions being at right angles to each other, to move individual fibers of said layer laterally and in the direction of their respective longitudinal axes, with respect to the other fibers in said layer with which they are in overlapping and frictional engagement, into relaxed, tensionless positions between said prongs.

20. A machine for producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another, said machine comprising a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern, means for moving a layer of irregularly arranged fibers in overlapping and frictional engagement with one another onto said prongs, means for vibrating each of said prongs in two directions, said directions being at right angles to each other, and means for selectively controlling the frequency of said vibrations of the prongs, so as to move individual fibers of said layer laterally and in the direction of their respective longitudinal axes, with respect to the other fibers in said layer with which they are in overlapping and frictional engagement, into relaxed, tensionless positions between said prongs.

21. A machine for producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another, said machine comprising a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern, means for moving a layer of irregularly arranged fibers

in overlapping and frictional engagement with one another onto said prongs, means for vibrating each of said prongs in two directions, said directions being at right angles to each other, and means for selectively controlling both the frequency and the phase of said vibrations of the prongs, so as to move individual fibers of said layer laterally and in the direction of their respective longitudinal axes, with respect to the other fibers in said layer with which they are in overlapping and frictional engagement, into relaxed, tensionless positions between said prongs.

22. A machine for producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another, said machine comprising a group of prongs arranged in positions corresponding to the foraminous portions of said predetermined pattern, means for moving a layer of irregularly arranged fibers in overlapping and frictional engagement with one another onto said prongs, means for vibrating each of said prongs in two directions, said directions being at right angles to each other, and means for selectively controlling both the frequency and the amplitude of said vibrations of the prongs, so as to move individual fibers of said layer laterally and in the direction of their respective longitudinal axes, with respect to the other fibers in said layer with which they are in overlapping and frictional engagement, into relaxed, tensionless positions between said prongs.

23. A machine for continuously producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another, said machine comprising a rotatably mounted cylinder, a group of prongs projecting outwardly from the peripheral surface of said cylinder in an arrangement corresponding to the foraminous portions of said pattern, means for rotating said cylinder, means for continuously positioning a layer of irregularly arranged fibers in overlapping and frictional engagement with one another in contact with the outer ends of said prongs, means for applying tension to said layer to impale it on said prongs and to press the prongs through the layer from one side thereof to the other, and means for vibrating said cylinder and prongs, so as to move individual fibers of said layer laterally and in the direction of their respective longitudinal axes, with respect to the other fibers in said layer with which they are in overlapping and frictional engagement, into relaxed, tensionless positions between said prongs.

24. A machine for continuously producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another, said machine comprising a rotatably mounted cylinder, a group of prongs projecting outwardly from the peripheral surface of said cylinder in an arrangement corresponding to the foraminous portions of said pattern, means for rotating said cylinder, means for continuously positioning a layer of irregularly arranged fibers in overlapping and frictional engagement with one another in contact with the outer ends of said prongs, means for applying tension to said layer to impale it on said prongs and to press the prongs through the layer from one side thereof to the other, and means for vibrating said cylinder and prongs in a direction

parallel to the longitudinal axis of the cylinder, so as to move individual fibers of said layer laterally and in the direction of their respective longitudinal axes, with respect to the other fibers in said layer with which they are in overlapping and frictional engagement, into relaxed, tensionless positions between said prongs.

25. A machine for continuously producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another, said machine comprising a rotatably mounted cylinder, a group of prongs projecting outwardly from the peripheral surface of said cylinder in an arrangement corresponding to the foraminous portions of said pattern, means for rotating said cylinder, means for continuously positioning a layer of irregularly arranged fibers in overlapping and frictional engagement with one another in contact with the outer end of said prongs, means for applying tension to said layer to impale it on said prongs and to press the prongs through the layer from one side thereof to the other, and means for vibrating said cylinder and prongs both angularly and in a direction parallel to the longitudinal axis of the cylinder, so as to move individual fibers of said layer laterally and in the direction of their respective longitudinal axes, with respect to the other fibers in said layer with which they are in overlapping and frictional engagement, into relaxed, tensionless positions between said prongs.

26. Apparatus for continuously producing a foraminous, nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers in overlapping and frictional engagement with one another, said apparatus comprising a frame, a pair of wet-out rolls rotatably mounted in said frame at the feed end of the apparatus, a pair of tension rolls rotatably mounted in said frame at the discharge end of the apparatus in laterally spaced parallel relationship to said wet-out rolls, a drive shaft rotatably mounted between said two pairs of rolls, said drive shaft being parallel to said wet-out and tension rolls, and carrying a cylinder having its uppermost surface in a plane above the plane extending from the nip of the wet-out rolls to the nip of the tension rolls, a group of prongs projecting radially from the peripheral surface of said cylinder to penetrate a layer of fibers extending between said wet-out rolls and said tension rolls, said prongs being arranged in positions corresponding to the foraminous portions of said predetermined pattern, means to drive said shaft to rotate said cylinder, means to rotate said wet-out rolls and said tension rolls at substantially the same circumferential speed as said cylinder, and means to vibrate said shaft to oscillate said cylinder with said tapered implements penetrating said layer of fibers and moving individual fibers of said layer laterally, and longitudinally of their respective axes, with respect to other fibers of said layer, to place them in relaxed, tensionless positions in said layer.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,012,290

December 12, 1961

Carlyle Harmon et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 12, lines 14 and 15, after "prongs" strike out "with the prongs penetrating the layer from one side thereof through to the other side" and insert the same after "prongs" in line 16, same column 12.

Signed and sealed this 24th day of April 1962.

(SEAL)

Attest:

ESTON G. JOHNSON

Attesting Officer

DAVID L. LADD

Commissioner of Patents