**March 19, 1963** F. KALWAITES **3,081,501**

APPARATUS FOR PRODUCING NONWOVEN FABRIC

Filed June 12, 1957 4 Sheets-Sheet 1

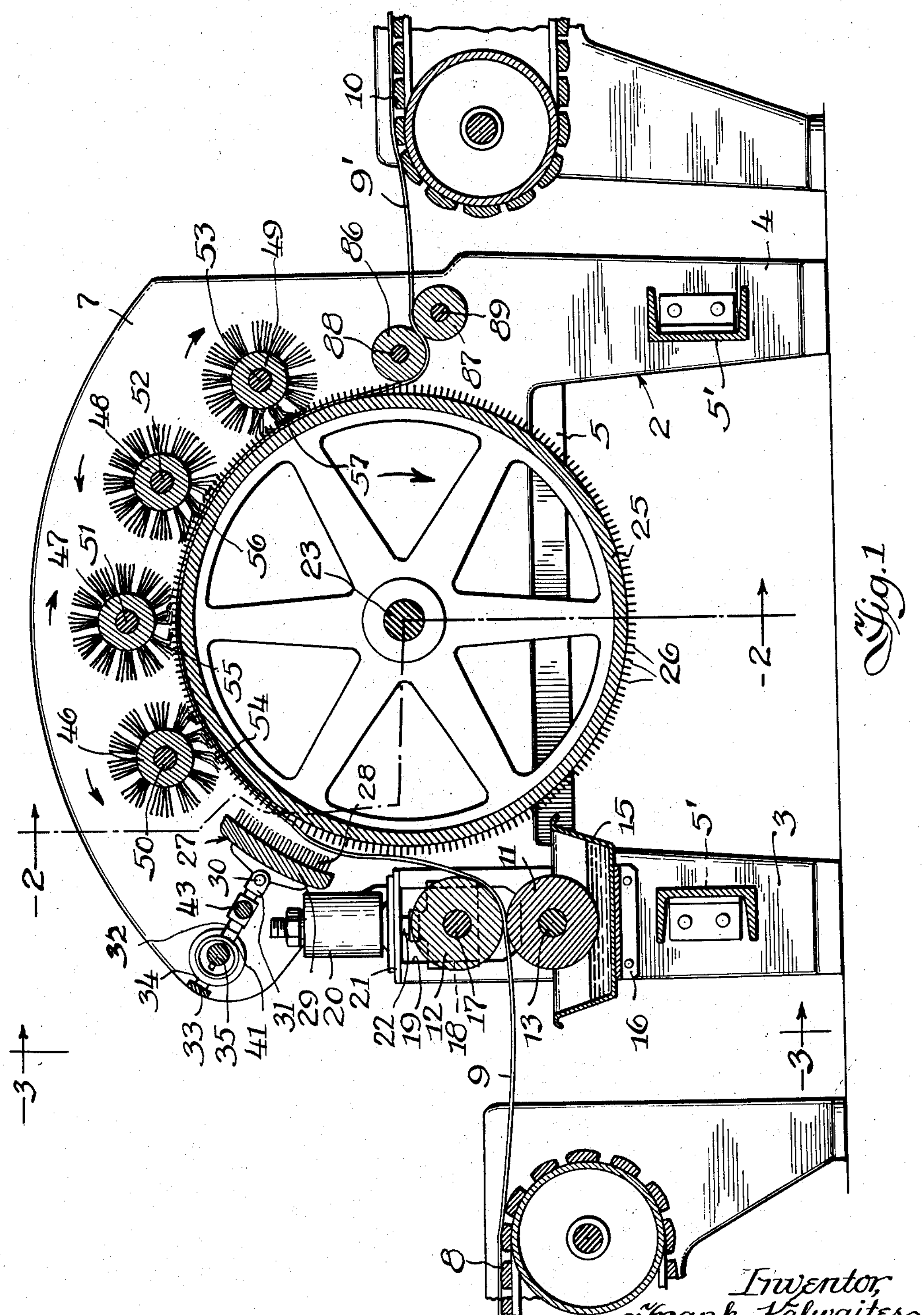


Fig. 1

Inventor,
Frank Kalwaites,
By: Schneider, Dressler & Goldsmith,
Attys.

**March 19, 1963** F. KALWAITES **3,081,501**

APPARATUS FOR PRODUCING NONWOVEN FABRIC

Filed June 12, 1957 4 Sheets-Sheet 2

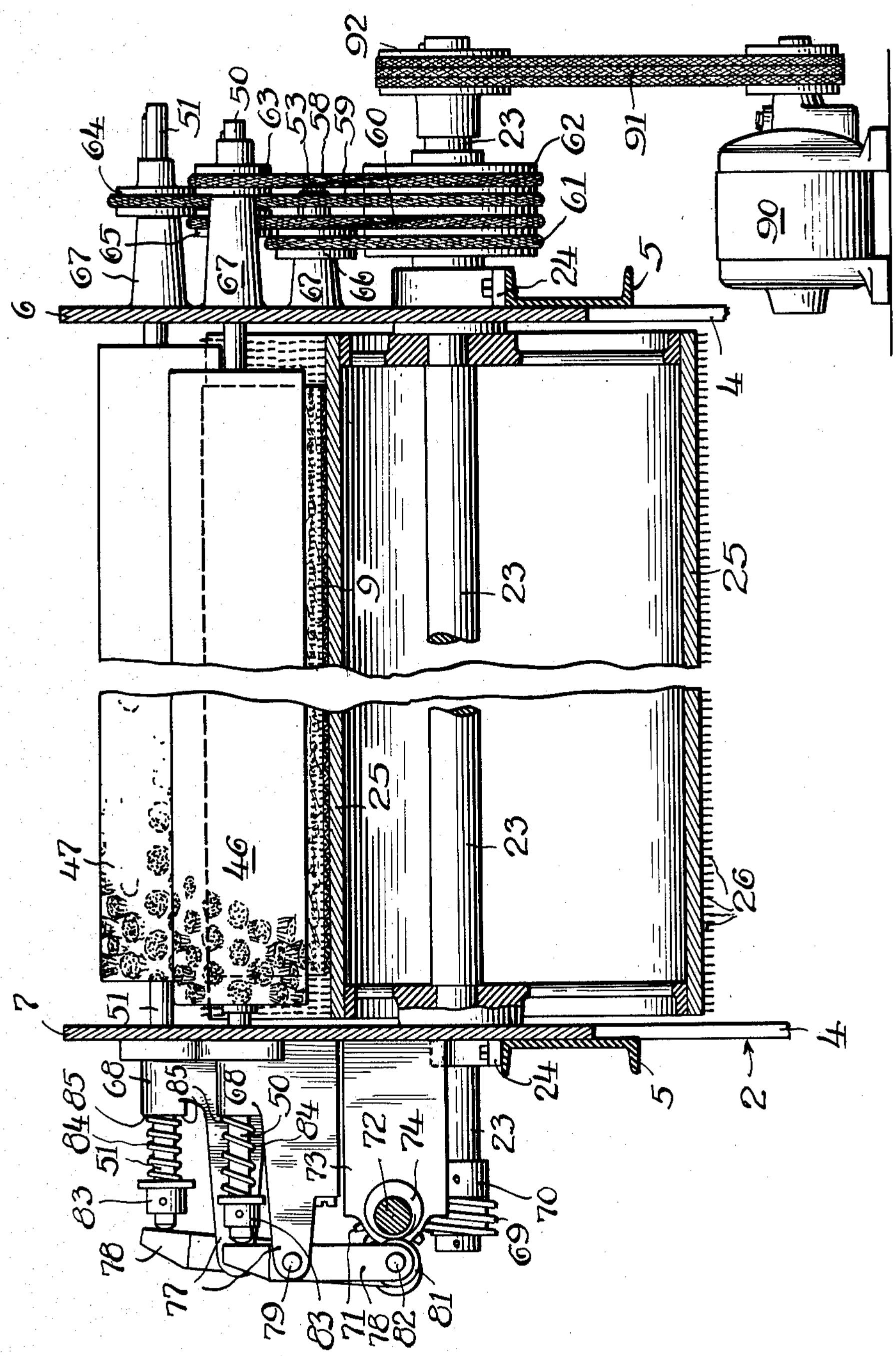


Fig. 2

Inventor,
Frank Kalwaites,
By: Schneider, Dressler & Goldsmith,
Attys.

March 19, 1963 F. KALWAITES 3,081,501

APPARATUS FOR PRODUCING NONWOVEN FABRIC

Filed June 12, 1957 4 Sheets-Sheet 3

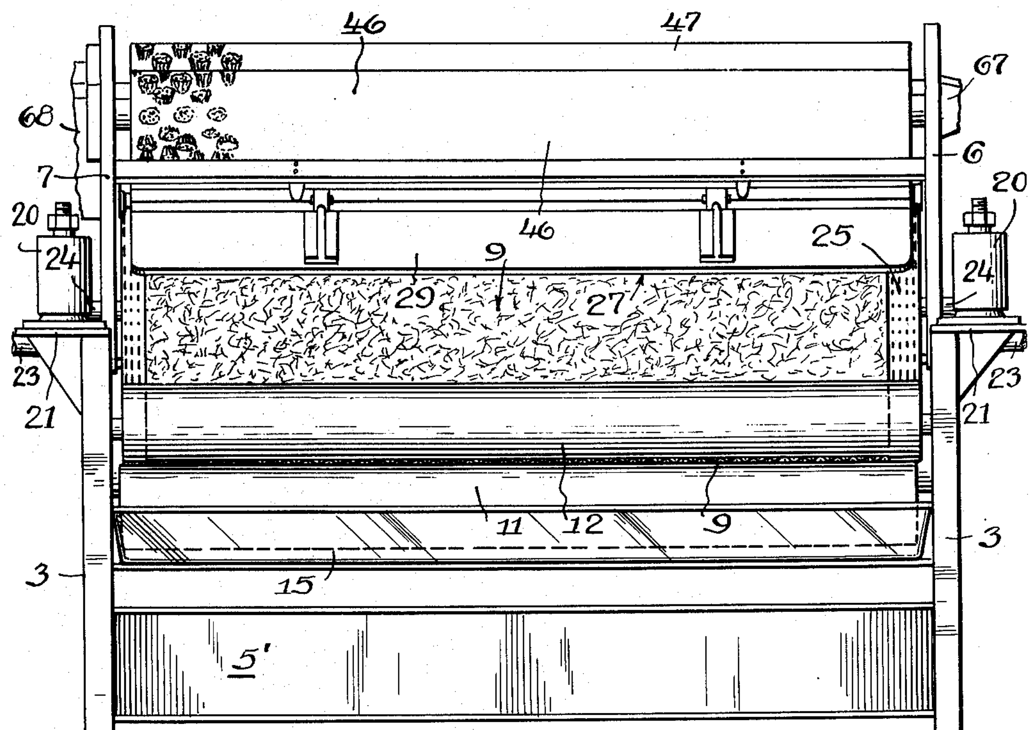



Fig. 3

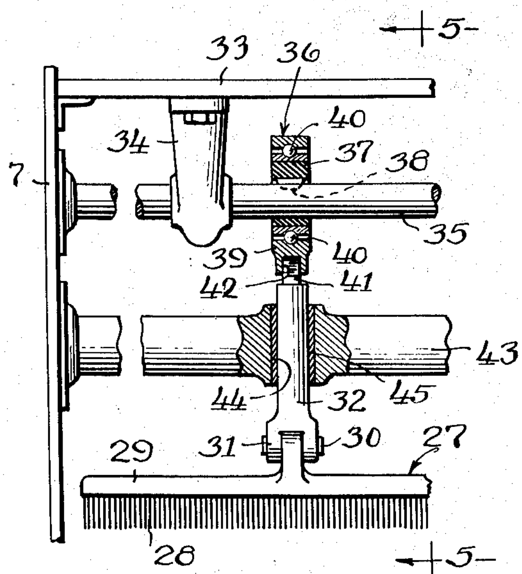



Fig. 4

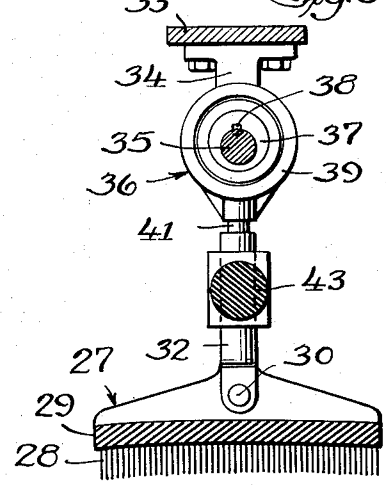



Fig. 5

Inventor,
Frank Kalwaites,
By: Schneider, Dressler & Goldsmith,
Attys.

Fig. 6

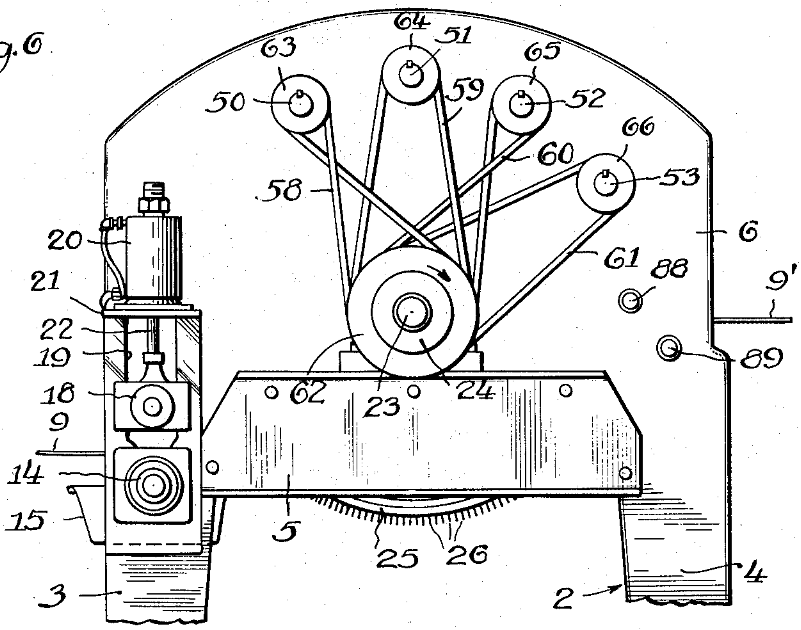
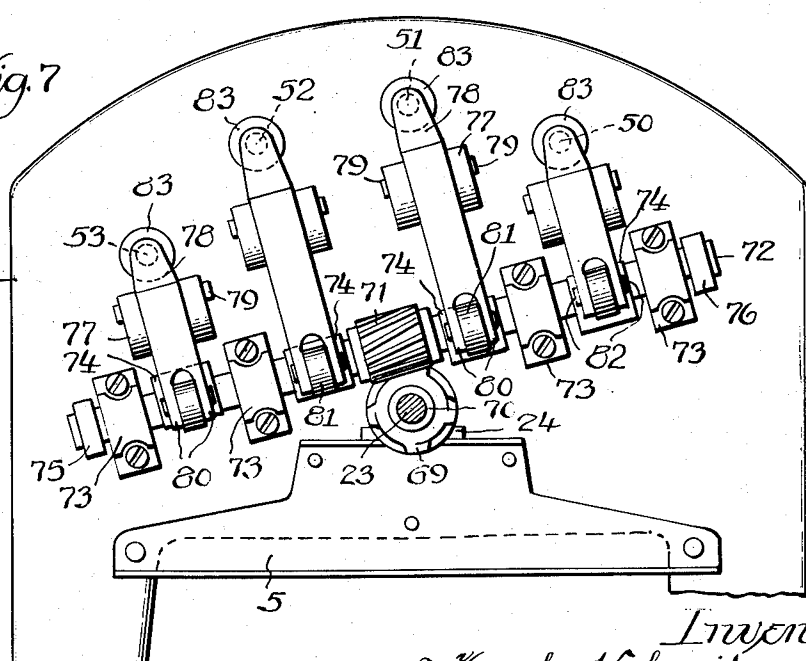



Fig. 7




Inventor,
Frank Kalwaites,
By: Schneider, Dressler & Goldsmith,
Attys.

United States Patent Office

3,081,501

Patented Mar. 19, 1963



3,081,501

# APPARATUS FOR PRODUCING NONWOVEN FABRIC

Frank Kalwaites, Highland Park, N.J., assignor, by mesne assignments, to Johnson & Johnson, New Brunswick, N.J., a corporation of New Jersey

Filed June 12, 1957, Ser. No. 665,229
6 Claims. (Cl. 19—161)

This invention relates to 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 of the fibers passing through them. Preferably, the fibers average at least about ¼ inch in length



and are textile-like in nature. 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 are in a state of mechanical equilibrium. The fibers are mechanically and frictionally engaged to the extent that the arrangement of fibers is one of equilibrium.

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 and gauze-like fabrics in general, and a variety of other applications.

The present invention contemplates a method and an apparatus for producing a nonwoven fabric having a predetermined pattern from a layer of irregularly arranged fibers by first wetting the fibrous layer out, then impaling the layer upon a group of prongs, and finally brushing the fibers into fiber accumulating zones between the prongs.

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, the starting material of the method herein described may be any of the starting materials described in the Kalwaites Patent No. 2,862,251, granted December 2, 1958. The preferred starting material is an unbonded fibrous web.

The preferred method of this invention involves the application of external forces to a continuously moving layer of irregularly arranged fibers impaled upon a group of prongs, by simultaneously brushing the fibers of successive portions of the moving layer longitudinally and transversely of the direction of travel of the layer, thereby moving individual fiber segments into positions within fiber accumulating zones in the interconnected spaces between the prongs.

In a preferred embodiment of the apparatus of this invention, the prongs or needles are carried on a rotatable cylinder against which a moving layer of irregularly arranged fibers is positioned. The layer of fibers is first passed through a pair of wet-out rolls and then into engagement with the pointed ends of the needles. An embedding brush is reciprocated in a direction normal to the peripheral surface of the cylinder, to press successive portions of the advancing layer of fibers downwardly about the needles. The reciprocation of the embedding brush is controlled by an eccentric bearing which permits only an instantaneous contact with the moving layer of fibers, since the embedding brush must be lifted from the fibers immediately because the needle-bearing cylinder is rotated continuously. The embedding brush is pivoted to permit it to move with the cylinder for the very short interval during which it is in contact with the layer of fibers.

The rotation of the cylinder pulls each portion of the layer of fibers progressively past a series of rotary brushes disposed at right angles to the direction of travel of the layer, with their bristles in contact with the layer of fibers embedded about the needles. Alternate brushes are rotated in opposite directions from the direction of rotation of the brushes intermediate the alternate brushes. These rotary brushes press the fibers downwardly about the needles, toward the peripheral surface of the cylinder.

The rotary brushes, which are parallel to the longitudinal axis of the cylinder, are also oscillated longitudinally of the cylinder simultaneously with their rotational movement. The combined rotational and oscillatory movements of the rotary brushes move the individual fibers of the layer along the tapered sides of the needles into contact with the peripheral surface of the cylinder, laterally into the spaces between the needles, and in the direction of their respective longitudinal axes, with respect to the other fibers in the layer, to compact them in fiber accumulating zones between the needles.

The water which is added to the layer of fibers by the wet-out rolls as the layer is moved through the nip between them acts as a lubricant and facilitates the relative movement between the individual fibers in the direction of their respective longitudinal axes. The relative longitudinal movement between individual fibers places the fibers in mechanical equilibrium in their rearranged positions in the resulting nonwoven fabric.

The resulting nonwoven fabric is removed from the needles by passing it through the nip between a pair of doffing rolls positioned beyond the last of the rotary brushes. Either one of the doffing rolls may be driven to insure continuous movement of the nonwoven fabric away from the cylinder, or suitable means may be provided beyond the doffing rolls to carry the nonwoven fabric into a drying area. It is obvious that the driven doffer roll or means for moving the nonwoven fabric from the cylinder to the drying area must be synchronized with the cricumferential speed of the cylinder.

The prongs upon which the fibrous starting layer is impaled before the brushing action is carried out may have rounded, flat, or pointed ends. They are preferably formed with a cylindrical body and long, gradually tapered conical points at their free ends. Conventional card clothing, with the customary burrs removed from the free ends, may also be used. Needles of various sorts are also suitable, including needles having bodies of various cross-sectional shapes, with chisel shaped free ends.

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, partially in section and partly in elevation, of a machine embodying the invention, with a portion of the frame removed to clarify the illustration, the feed end of the machine being shown on the left and the discharge end on the right side of the figure;

FIG. 2 is a fragmentary cross sectional view, taken along the line 2—2 of FIG. 1;

FIG. 3 is a fragmentary elevation of the feed end of the machine, with the structure outside the side frame members generally omitted;

FIG. 4 is a fragmentary detail view, partly in elevation and partly in section, showing the embedding brush and the means for reciprocating it along a line normal to the peripheral surface of the cylinder;

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

FIG. 6 is a fragmentary elevational view of the right side of the machine as seen in FIG. 2, showing the driving mechanism for rotating the rotary brushes; and

FIG. 7 is a fragmentary elevational view of the left side of the machine as seen in FIG. 2, showing the mechanism for oscillating the rotary brushes longitudinally of the cylinder.

In the drawings, the reference numeral **2** indicates a supporting frame comprising a pair of vertical posts **3** on opposite sides of the frame at the feed end of the machine and a pair of vertical posts **4** on opposite sides of the discharge end. Longitudinal beams **5** connect each vertical post **3** to the vertical post **4** on the same side of the machine. A transverse beam **5'** connects the vertical posts **3** at the feed end of the machine, and a similar transverse beam connects the vertical posts **4**. The frame also includes a side frame plate **6** extending vertically upward from the longitudinal beam **5** at the right side of the frame (as seen from the feed end) and a similar side frame plate **7** extending vertically upward from the beam **5** at the left side of the frame.

A conveyor **8** is positioned adjacent the feed end of the machine to carry a layer **9** of irregularly arranged fibers to the feed end of the machine. The layer of fibers may or may not be self-sustaining. If it is not self-sustaining, a permeable carrier web is provided to carry it until such support is no longer required.

A conveyor **10** is positioned adjacent the discharge end of the machine for carrying the nonwoven fabric, in which the fibers of the layer have been rearranged in a predetermined pattern, from the machine to a suitable bonding or drying area (not shown) of a conventional type. The specific structure of the conveyors **8** and **10** is not described, since they do not constitute part of the invention and may be of conventional construction.

Wet-out rolls **11** and **12**, extending transversely of the machine, are rotatably mounted in vertical alignment at the feed end of the machine. A shaft **13**, carrying wet-out roll **11**, is journalled in bearings **14** mounted on each vertical post **3**.

Lower wet-out roll **11** is partially immersed in a water pan **15** supported on brackets **16** mounted on each post **3** below the bearings **14**. Upper wet-out roll **12** is carried by a shaft **17** journalled in bearings **18**. Each bearing **18** is slidably mounted in a recess **19** extending vertically downward from the upper edge of each vertical post **3**. The vertical position of upper wet-out roll **12** is adjustable, and is regulated by hydraulic positioning cylinders **20** mounted on brackets **21** projecting laterally from the top of vertical posts **3**. Each positioning cylinder has a two-way piston (not shown) carrying a piston rod **22** connected at its lower end to the bearing **18**. 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 **11** and **12** may be varied as desired.

The pair of wet-out rolls **11** and **12** cooperate to control the moisture content of the layer **9** of irregularly arranged fibers which is fed from conveyor **8** through the nip between the wet-out rolls. The position of roll **12**, relative to roll **11**, determines the quantity of water that is applied to the layer **9**. The fibers of layer **9** are in mechanical and frictional engagement with one another as the layer passes through the nip between 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.

A main drive shaft **23**, extending transversely between side frame plates **6** and **7**, is journalled in bearings **24** each mounted on one of the longitudinal beams **5**. The drive shaft projects outside each side frame plate for reasons hereinafter disclosed. A cylinder **25** mounted on drive shaft **23** to rotate therewith is provided with a plurality of needles **26** or similar sharp tapered implements projecting radially from its peripheral surface. The needles are secured to the surface of the cylinder in any suitable manner, and are arranged in accordance with the predetermined pattern of the fabric to be made from the layer of irregularly arranged fibers. During the operation of the machine the drive shaft rotates the needle bearing cylinder **25** continuously.

From the nip between the wet-out rolls **11** and **12**, the layer **9** of irregularly arranged fibers is moved into contact with the sharp ends of the needles projecting radially from the peripheral surface of the cylinder. The layer of fibers is pulled into contact with the sharp pointed ends of the needles in an area of the peripheral surface of the cylinder in which pressure means, such as an embedding brush **27**, is adapted to impale the layer of fibers on the needles.

The embedding brush **27** extends longitudinally of the needle bearing cylinder and covers substantially the entire width of the cylinder. The working surface of the embedding brush, formed by the ends of the brush bristles, is substantially flat, but is curved slightly in its transverse direction to allow it to conform to the circumferential curvature of the needle bearing cylinder. The brush **27** comprises a plurality of soft bristles **28** secured to a back **29** which is pivotally secured, as indicated at **30**, to a clevis **31** formed on the lower end of a reciprocating rod **32**. The axis of the pivot pin **30** is parallel to the longitudinal axis of main drive shaft **23** for a reason hereinafter disclosed.

A cross bar **33** extending transversely of the machine has its opposite ends secured adjacent the upper edges of the side frame plates **6** and **7**. A plurality of supporting arms **34** secured to cross bar **33** depend therefrom to rotatably support an embedding brush drive shaft **35** extending parallel to bar **33**, as shown in FIGS. 4 and 5. The arms **34**, and the associated mechanism, are equivalents, and only one will be described. The shaft **35** is driven by any suitable driving means (not shown) and carries a pair of eccentric bearings **36** thereon. Each bearing comprises a disk **37** eccentrically keyed to shaft **35**, as indicated at **38**, and a circular strap **39** fitting around the rim of disk **37**. Roller bearings **40**, mounted in a race between the peripheral surface of disk **37** and the contiguous inner surface of the circular strap **39**, permit the disk **37** to rotate relative to the strap **39**, while the eccentricity of the disk relative to shaft **35** causes the circular strap **39** to reciprocate. One end **41** of rod **32** is threaded to fit into a threaded recess **42** formed in the strap **39**, whereby rod **32** will be reciprocated by the reciprocating movement of strap **39**.

In order to keep reciprocating rod **32** moving back and forth in a fixed path, a guide support cross bar **43**, having its opposite ends secured to side frame plates **6** and **7**, is mounted parallel to embedding brush drive shaft **35**, between that shaft and cylinder **25**. Cross bar **43** has a guide opening **44**, extending normal to the peripheral surface of cylinder **25**, which is provided with a guide bearing sleeve **45**. Reciprocating rod **32** is positioned in the guide bearing sleeve with a sliding fit so that it can move only in a direction normal to the peripheral surface of needle bearing cylinder **25**.

It is seen that rotation of embedding brush drive shaft **35** imparts to the embedding brush **27** a reciprocatory motion having a stroke equal to twice the eccentricity of eccentric bearing **36**. Due to the guide support system just described, the reciprocatory motion is confined to a path normal to the peripheral surface of cylinder **35**.

The reciprocating movement of the embedding brush **27** causes the bristles **28** to engage the layer **9** of fibers and press it downwardly upon the needles **26**. The layer of fibers is constantly moving with the needles of cylinder **25**, and the bristles of the embedding brush remain in engagement with the layer of fibers for only a very short interval of time. The pivotal joint **30** connecting the bottom end of reciprocating rod **32** and brush **27** permits the embedding brush to pivot and move with the needles the slight distance the needle bearing cylinder rotates during the interval the embedding brush is in contact with the needles. When the embedding brush is lifted out of engagement with the needles by the upward stroke of its reciprocatory improvement, gravity will cause the brush to fall back pivotally, again about joint **30**, into its original position shown in FIG. 1. The embedding brush is provided with a stop member (not shown) to prevent pivotal movement of the brush, due to gravity, beyond that position.

Bristles **28** are very soft, so that they will not rupture the layer of fibers when they first move into contact with the layer. The contact of bristles **28** with the layer of fibers produces the major fiber rearrangement as the fibrous layer is impaled upon the needles. In this first rearranging step the fibers are pushed out of the local areas of the layer which are occupied by the advancing needles. As a result, fibers are pushed into closer proximity and increased parallelism in the areas bordering upon the needles. The rearrangement of the fibers is completed by the brushing action of rotary brushes **46**, **47**, **48**, and **49**, now to be described.

As the embedding brush **27** moves upwardly out of engagement with the layer of fibers, the layer, which is now impaled firmly on needles **26**, is moved by the needles past a series of rotary brushes **46**, **47**, **48** and **49** mounted on independent drive shafts **50**, **51**, **52**, and **53**, respectively. In the embodiment shown, the rotary brush drive shafts **50**, **51**, **52**, and **53** are spaced substantially equidistant from main drive shaft **23** and are so positioned relative to the peripheral surface of needle bearing cylinder **25** as to maintain the bristles **54**, **55**, **56**, and **57** of the rotary brushes **46**, **47**, **48**, and **49**, respectively, in engagement with the fibers of a portion of layer **9** as the layer passes between the needle bearing cylinder and the rotary brushes. The bristles of each of the rotary brushes are very soft so that they may rearrange the fibers of layer **9** without destroying the integrity of the layer. As is seen in FIG. 1, some of the bristles are long enough that—except as they are prevented from doing so by the presence of the fibrous web being rearranged—they extend between the spaced needles **26** and below the free side of those needles.

As shown in FIG. 6, independent drive belts **58**, **59**, **60** and **61** extend around a pulley **62** mounted on main drive shaft **23** and pulleys **63**, **64**, **65**, and **66** mounted on rotary brush drive shafts **50**, **51**, **52**, and **53**, respectively. The drive belts **58**, **59**, **60**, and **61** drive the shafts **50**, **51**, **52**, and **53** from main drive shaft **23**. As shown in FIG. 2, the opposite ends of each of the rotary brush shafts **50**, **51**, **52**, and **53** are mounted in bearings (not shown) carried by bearing supports **67** and **68** mounted on the outer surfaces of side frame plates **6** and **7**, respectively.

The drive belts **58** and **60** are each crossed between pulley **62** and their respective pulleys **63** and **65** to drive rotary brushes **46** and **48** in the opposite direction to the direction of rotation of rotary brushes **47** and **49**. From the arrows in FIG. 1 indicating the direction of rotation of the needle bearing cylinder and each of the rotary brushes, it is seen that the rotary brushes **46** and **48** are driven in the opposite direction from that in which the needle bearing cylinder **25** is driven, and that rotary brushes **47** and **49** are driven in the same direction as the cylinder **25**. Since the rotary brush drive shafts **50**, **51**, **52**, and **53** are each outside the periphery of the needle bearing cylinder **25**, bristles **54** and **56** of rotary brushes **46** and **48**, respectively, travel in the same direction as the needles **26** during the portion of their rotational movement while they are in contact with said needles, and bristles **55** and **57** of rotary brushes **47** and **49** travel in the opposite direction from needles **26** while they are in contact with the needles.

The effective fiber rearranging forces exterted by the bristles of each brush as a result of the rotational movement of the brushes depends upon the difference between the linear speed of the bristles and the linear speed of the fibrous layer **9** in the area of contact between them. This difference between the linear speeds of the bristles and the fibers is obtained by subtracting the linear speed of the layer **9** from the linear speed of bristles **54** and **56** which are moving in the same direction, and adding the linear speed of the layer **9** to the linear speed of bristles **55** and **57** which are moving in opposite directions. The rotation of rotary brushes **46** and **48**, upon which bristles **54** and **56** are carried, may be speeded up to obtain equal fiber rearranging forces for each of the rotary brushes.

Additional fiber rearranging forces are applied to the fibers of layer **9** by longitudinal oscillation of the shaft of each of the rotary brushes. The mechanism for oscillating the shafts of the rotary brushes longitudinally of their respective axes is shown in FIGS. 2 and 7. The mechanism is the same for each rotary brush, and the description thereof will generally be limited to a single rotary brush for the sake of brevity.

A worm **69** extending laterally from a sleeve **70** is mounted on the end of drive shaft **23** extending outwardly beyond the side frame plate **7**. The worm is preferably integral with sleeve **70**, but may be formed separately and rigidly secured thereto in any suitable manner. Worm **69** meshes with a worm wheel **71** fixed on oscillator drive shaft **72** which is rotatably mounted in a plurality of bearings **73** extending outwardly from side plate frame **7**. Four oscillator cams **74** are rigidly mounted in eccentric relationship on oscillator drive shaft **72**. The cams **74** are spaced longitudinally of oscillator drive shaft **72** for a purpose hereinafter described. Collars **75** and **76** are fixed to opposite ends of shaft **72** to prevent displacement of the shaft along its axis relative to worm wheel **71** and bearings **73**.

Each bearing support **68** has a pair of fulcrum arms **77** extending outwardly therefrom, and an oscillator lever **78** is pivoted between each pair of fulcrum arms as indicated at **79**. The pivot is positioned between the horizontal planes of shaft **72** and the particular rotary brush drive shaft **50**, **51**, **52**, or **53** which is supported by the bearing in the bearing support **68** from which the fulcrum arms supporting the pivot extend. Each oscillator lever **78** has sufficient length to extend from a point adjacent oscillator drive shaft **72** to a point adjacent the end of the respective rotary brush drive shaft **50**, **51**, **52**, and **53**.

The lower end of each oscillator lever **78** is bifurcated, as indicated at **80**, and a follower roller **81** is mounted to rotate freely on a pin **82** extending across the bifurcated end of the oscillator lever. The cams **74** are spaced in alignment with follower rollers **81**, and each roller **81** is normally held in contact with the periphery of one of the cams **74**. Each rotary brush drive shaft **50**, **51**, **52**, and **53** has a mollar **83** secured adjacent its end and a compression spring **84** coiled around the shaft is biased between the collar and a shoulder **85** on the bearing support **68** to exert a constant force against collar **83** to urge the shaft outwardly into contact with the upper end of the respective oscillator lever **78**.

As the main drive shaft **23** is rotated, it causes oscillator drive shaft **72** to rotate through the gear linkage, already described, and thereby move each of the oscillator cams **74** through its eccentric orbit. As each cam **74** moves outwardly, it presses against its associated follower roller **81**, moving the upper end of the respective oscillator lever **78** and rotary brush drive shaft **50**, **51**, **52**, and **53** inwardly against the action of compression spring **84**. As the cam **74** moves inwardly, the spring **84** pushes the rotary brush drive shaft outwardly to complete the longitudinal oscillation of the shaft. Each rotary brush completes an oscillatory cycle for every revolution of oscillator drive shaft **72**.

If the rearranging forces are applied to an isotropic fibrous web only in a direction parallel to the direction of web travel, they will act most effectively on fibers extending at right angles to the direction of web travel and will have virtually no effect on fibers extending parallel to the direction of web travel. The effectiveness of the rearranging forces will vary for fibers in intermediate positions, with the effectiveness increasing with any increase in the angle of fiber orientation to the direction of web travel.

It is seen that rearrangement of the fibers could not be uniform if the rearranging forces were applied in only one direction, because of the diminished rearrangement of fibers as the angle of orientation of the fibers approaches the angle of direction of the applied forces. Therefore, the best results are obtained by applying the same rearranging forces in all directions. In the apparatus of this invention rearranging force components having the same



effective magnitude are applied to the fibers in all four directions at right angles to each other.

The rearranging force applied by each rotary brush to the fibers of layer **9** is a resultant of forces produced by the above-described oscillation and by the rotation of the shaft on which the rotary brush is mounted. If one plots the *motion* of each brush with respect to layer **9** due to the oscillation of the brush shaft, the graph will be in the form of a sinusoidal curve. A graph of the *motion* of a particular group of bristles on the brush with respect to layer **9** due to rotation of the brush will have the form of a straight line. To determine the resultant fiber rearranging *force* produced by both the rotation and the oscillation of a particular rotary brush **54**, **55**, **56**, or **57**, the force due to the circumferential movement of the brush with respect to the fibers, which is of substantially constant magnitude, must be combined with the varying force due to shaft oscillation.

At a given moment, the force applied to the fibers in any particular direction by the rotating and oscillating brush is proportional to the relative speed of movement of the brush in that direction with respect to the fibers. This is true both of the rearranging force produced by relative movement of the brush bristles and the fibers due to rotation of the brush, and of the rearranging force produced by relative movement of the brush bristles and fibers due to oscillation of the brush shaft.

The linear speed of movement of the bristles with respect to the fibers which is due to brush rotation may be computed for bristles **54** and **56** on the one hand, and bristles **55** and **57** on the other, in the manner already described above. Since the relative speed of bristles and fibers due to rotation of a given brush remains substantially constant, the magnitude of the resulting fiber rearranging force component likewise remains substantially constant during normal operation of the machine of this invention.

The speed of movement of the brush due to oscillation of its shaft varies, however, as the shaft passes through its oscillatory cycle. This *speed* may be represented by a sinusoidal curve 90° out of phase with the curve representing the oscillatory *motion* of the shaft. In the same way, the resulting fiber rearranging *force* may also be represented by a sinusoidal curve 90° out of phase with the curve showing the oscillatory motion of the shaft.

During one half the cycle, the force component produced by the oscillation of the rotary brush drive shaft is applied in one direction transverse to the direction of web travel, and during the next half of the cycle it is applied in the opposite direction. The force component is of continuously varying magnitude, increasing from zero at each outer limit of the cycle of oscillation to a maximum when the shaft passes through its middle position and the sinusoidal curve representing the oscillatory movement of the shaft passes through its node. The component of force then decreases until the shaft reaches the opposite outer limit of its oscillation, when the direction of the force component is reversed.

The brushing force component produced by the oscillation of the rotary brush drive shaft is thus generally sinusoidal. However, the nature of the brushes tends to cause the sine curve representing the brushing force component to be flattened out somewhat at each peak. Since bristles **54**, **55**, **56**, and **57** of the rotary brushes are preferably soft and limber, the bristles will tend to bend and their free ends to lag behind the body of the brush as it moves back and forth. When the brush drive shaft reverses its direction of longitudinal movement at each end of its cycle, the bristle ends exhibit an even greater lag, for they then tend to stop altogether, and to remain stationary until the brush body has moved back in the reverse direction far enough to pick up the slack due to the bending of the bristles. Hence the sine curve representing the force component caused by oscillation of the drive shaft must be drawn with each peak flattened out somewhat rather than rising to the maximum value for a perfect sine curve.

It is seen that the *effective* rearranging force component applied to the fibers in one direction parallel to the axis of each rotary brush may be approximated by determining what may be called a "root mean square" force, by analogy to the computation of the root mean square voltage of an alternating electric current. By "root mean square" is meant a quantity equal to 0.707 of the maximum amplitude of the sinusoidal curve representing that rearranging force.

The effective rearranging force component applied to the fibers in the opposite transverse direction has the same magnitude but opposite sign. It is seen that the "root mean square" or effective transverse rearranging force is applied in each direction parallel to the rotary brush axis during only one half the operation of the machine, and in the opposite direction during the other half of the period of operation. However, the rearranging force in each transverse direction is supplemented, in the embodiment of the machine shown and described, by the force applied by the adjacent rotary brush, which passes through the same cycle of oscillation and produces the same transverse rearranging force first in one direction and then the other.

To produce most nearly uniform rearrangement of the fibers, the rearranging force applied by each rotary brush should have a component parallel to the direction of web travel whose magnitude is substantially equal to the effective magnitude of the force component applied first in one direction parallel to the direction of shaft oscillation and then in the opposite. The force applied to the fibers by the rotary brush at any moment is proportional to the relative speed of movement of the rotary brush with respect to the fibers. Therefore, whenever each rotary brush rotating in one direction (such as brushes **46** and **48** in the embodiment shown and described) is supplemented by another brush (such as brushes **47** and **49**) rotating in the opposite direction, the linear circumferential speed of each brush in relation to the fibers being rearranged is preferably equal to 0.707 of the maximum speed of the oscillating rotary brush drive shaft as it passes through the mid-point in its oscillatory path.

As mentioned above, the initial impaling step produces the major rearrangement of the fibers of the fibrous starting layer into a nonwoven fabric **9'**, having a pattern of openings corresponding to the arrangement of the needles on the needle bearing cylinder. The cumulative effect of brushing the fibers between the needles in different directions, as just described, completes that rearrangement. More specifically, the brushing step supplements the initial lateral movement of the fibers produced by penetration of the prongs or needles, by causing individual fibers to move in the direction of their respective longitudinal axes, with respect to the other fibers in the layer, and thereby to lie in mechanical equilibrium in their final rearranged positions.

After the resulting nonwoven fabric passes the last rotary brush at the discharge end of the machine, it is removed from the cylinder by passing it between the nip of a pair of doffing rolls **86**, **87**. The fabric is moved from the doffing rolls to a conveyor **10** which carries it to a suitable drying or other processing area (not shown). The doffing rolls are rotatably mounted in bearings **88**, **89** carried by the vertical posts and side frame plates at the discharge end of the machine. One of the doffing rolls is preferably driven by a motor **90**. The motor **90** also drives the main drive shaft **23** through a belt **91** extending around a pulley **92** mounted on one end of the drive shaft.

As used in this specification and claims, the term "tapered implements" includes not only an implement which is tapered from its base to its free end but also any implement which has uniform cross-sectional dimensions throughout its body portion and gradually diminishing cross-sectional dimensions at its free end portion.



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.

I claim:

1. A machine for continuously producing a nonwoven fabric having holes arranged in a predetermined pattern from a layer of wet, irregularly arranged fibers, said machine comprising a rotatably mounted cylinder, means to rotate said cylinder, a group of prongs mounted on the peripheral surface of said cylinder, said prongs being arranged in said predetermined pattern, means for impaling successive portions of a layer of wet, irregularly arranged fibers upon said prongs to move certain of said fibers laterally into new positions in the layer, a group of brushes rotatably mounted adjacent said cylinder with their longitudinal axes parallel with the longitudinal axis of the cylinder and having soft-bristles extending therefrom some of whose end portions, upon rotation of the brushes, are adapted to extend between said prongs and below the free ends thereof, and means for rotating various of said brushes in different directions to maintain said impaling and move individual fibers in the direction of their respective longitudinal axes, with respect to the other fibers in the layer, so as to permit the rearranged fiber segments to remain in a condition of mechanical equilibrium in their new positions in the areas between the prongs where they define said predetermined pattern of holes.

2. A machine for continuously producing a nonwoven fabric having holes arranged in a predetermined pattern from a layer of wet, irregularly arranged fibers, said machine comprising a rotatably mounted cylinder, means to rotate said cylinder, a group of prongs mounted on the peripheral surface of said cylinder, said prongs being arranged in said predetermined pattern, means for impaling successive portions of a layer of wet, irregularly arranged fibers upon said prongs to move certain of said fibers laterally into new positions in the layer, a group of brushes rotatably mounted adjacent said cylinder with their longitudinal axes parallel with the longitudinal axis of the cylinder and having soft-bristles extending therefrom some of whose end portions, upon rotation of the brushes, are adapted to extend between said prongs and below the free ends thereof, means for rotating various of said brushes in different directions, and means for simultaneously oscillating said brushes longitudinally of their longitudinal axes, to maintain said impaling and move individual fibers in the direction of their respective longitudinal axes, with respect to the other fibers in the layer, so as to permit the rearranged fiber segments to remain in a condition of mechanical equilibrium in their new positions in the areas between the prongs where they define said predetermined pattern of holes.

3. A machine for producing a nonwoven fabric having holes arranged in a predetermined pattern from a layer of wet, irregularly arranged fibers, said machine comprising a rotatably mounted cylinder, means to rotate said cylinder, a group of prongs mounted on the peripheral surface of said cylinder, said prongs being arranged in said predetermined pattern, means for impaling successive portions of a layer of wet, irregularly arranged fibers upon said prongs to move certain of said fibers laterally into new positions in the layer, a group of brushes rotatably mounted adjacent said cylinder with their longitudinal axes parallel with the longitudinal axis of the cylinder and having soft bristles extending therefrom some of whose end portions, upon rotation of the brushes, are adapted to extend between said prongs and below the free ends thereof, means for rotating alternate ones of said brushes in a different direction from the direction of

rotation of the brushes intermediate said alternate brushes, and means for simultaneously oscillating said brushes longitudinally of their longitudinal axes, to maintain said impaling and move individual fibers in the direction of their respective longitudinal axes, with respect to the other fibers in the layer, so as to permit the rearranged fiber segments to remain in a condition of mechanical equilibrium in their new positions in the areas between the prongs where they define said predetermined pattern of holes.

4. A machine for producing a nonwoven fabric having holes arranged in a predetermined pattern from a layer of wet, irregularly arranged fibers, said machine comprising a rotatably mounted cylinder, means to rotate said cylinder, a group of prongs mounted on the peripheral surface of said cylinder, said prongs being arranged in said predetermined pattern, means for impaling successive portions of a layer of wet, irregularly arranged fibers upon said prongs to move certain of said fibers laterally into new positions in the layer, a group of brushes rotatably mounted adjacent said cylinder with their longitudinal axes parallel with the longitudinal axis of the cylinder and having soft bristles extending therefrom some of whose end portions, upon rotation of the brushes, are adapted to extend between said prongs and below the free ends thereof, means for rotating alternate ones of said brushes in a different direction from the direction of rotation of the brushes intermediate said alternate brushes, the brushes which turn in the same angular direction as the rotating cylinder being rotated less rapidly than the brushes which turn in the opposite direction, and means for simultaneously oscillating said brushes longitudinally of their longitudinal axes, to maintain said impaling and move individual fibers in the direction of their respective longitudinal axes, with respect to the other fibers in the layer, so as to permit the rearranged fiber segments to remain in a condition of mechanical equilibrium in their new positions in the areas between the prongs where they define said predetermined pattern of holes.

5. A machine for producing a nonwoven fabric having holes arranged in a predetermined pattern from a layer of wet, irregularly arranged fibers, said machine comprising a frame, a cylinder rotatably mounted in said frame, means to rotate said cylinder, a group of prongs projecting outwardly from the peripheral surface of said cylinder, said prongs being arranged in said predetermined pattern, means for moving successive portions of a layer of wet, irregularly arranged fibers into contact with the ends of said prongs, an embedding brush mounted in said frame opposite said cylinder, means for reciprocating said brush in a direction normal to the peripheral surface of said cylinder for impaling said successive portions of the layer of fibers on said prongs to move certain of said fibers laterally into new positions in the layer, said embedding brush being pivoted to permit limited movement thereof in the direction of rotation of said cylinder, a group of brushes rotatably mounted adjacent said cylinder and having soft bristles extending therefrom some of whose end portions, upon rotation of the brushes, are adapted to extend between said prongs and below the free ends thereof, and means for simultaneously rotating and oscillating said rotary brushes to maintain said impaling and move individual fibers in the direction of their respective longitudinal axes, with respect to the other fibers in the layer, so as to permit the rearranged fiber segments to remain in a condition of mechanical equilibrium in their new positions in the areas between the prongs where they define said predetermined pattern of holes.



6. A machine for producing a nonwoven fabric having holes arranged in a predetermined pattern from a layer of wet, irregularly arranged fibers, said machine comprising a frame, a cylinder rotatably mounted in said frame, means to rotate said cylinder, a group of implements projecting outwardly from the peripheral surface of said cylinder, said implements having sharp free ends and being arranged in said predetermined pattern, means for moving successive portions of a layer of wet, irregularly arranged fibers into contact with the ends of said implements, an embedding brush mounted in said frame opposite said cylinder, means for reciprocating said brush in a direction normal to the peripheral surface of said cylinder for impaling said successive portions of the layer of fibers on said implements, said embedding brush being pivoted to permit limited movement thereof in the direction of rotation of said cylinder, a group of brushes rotatably mounted adjacent said cylinder and having soft bristles extending therefrom some of whose end portions, upon rotation of the brushes, are adapted to extend between said implements and below the free ends thereof, means for rotating alternate ones of said brushes in a different direction from the direction of rotation of the brushes intermediate said alternate brushes, and means for simultaneously oscillating said brushes longitudinally of their longitudinal axes, to maintain said impaling and move individual fibers in the direction of their respective longitudinal axes, with respect to the other fibers in the layer, so as to permit the rearranged fiber segments to remain in a condition of mechanical equilibrium in their new positions in the areas between the prongs where they define said predetermined pattern of holes.


**References Cited** in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 75,906 | Haythorn et al. | Mar. 24, 1868 |
| 355,296 | Best | Jan. 4, 1887 |
| 493,752 | Clarenbach et al. | Mar. 21, 1893 |
| 1,567,841 | Curtin | Dec. 29, 1925 |
| 1,743,068 | Walsh | Jan. 7, 1930 |
| 1,978,620 | Brewster | Oct. 30, 1934 |
| 2,055,412 | Hurst et al. | Sept. 22, 1936 |
| 2,881,505 | Hoffman | Apr. 14, 1959 |