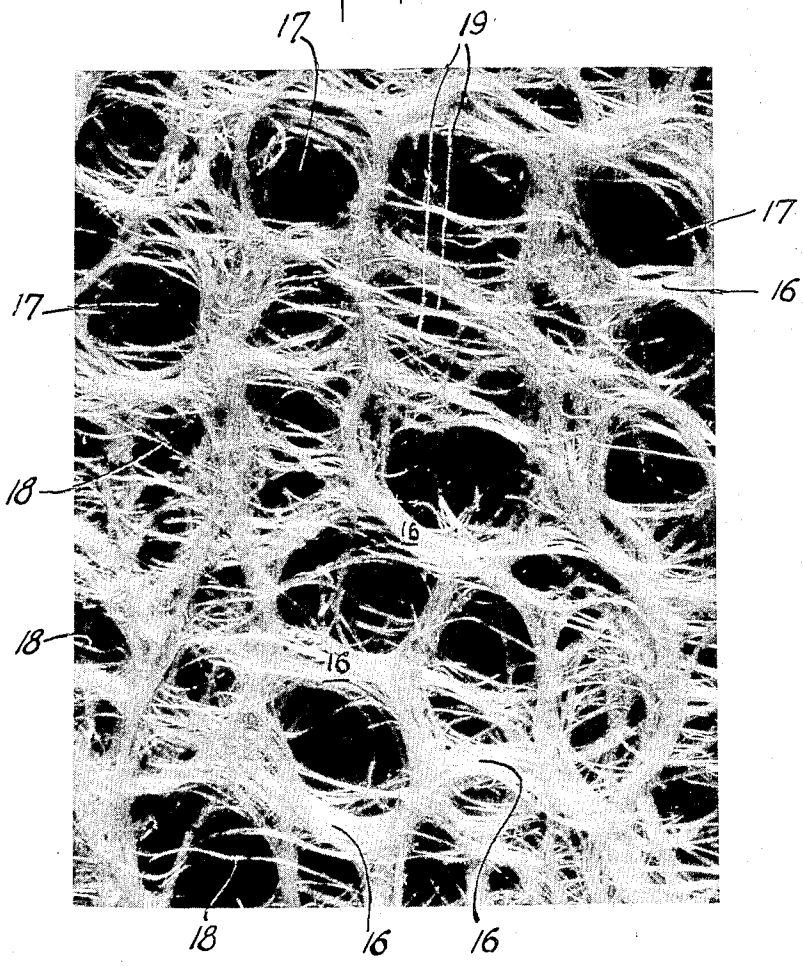
March 19, 1963 H. W. GRISWOLD 3,081,512

METHOD OF PRODUCING APERTURED NONWOVEN FABRIC

Original Filed April 26, 1955 4 Sheets-Sheet 1

Fig. 1.




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Fig. 2.

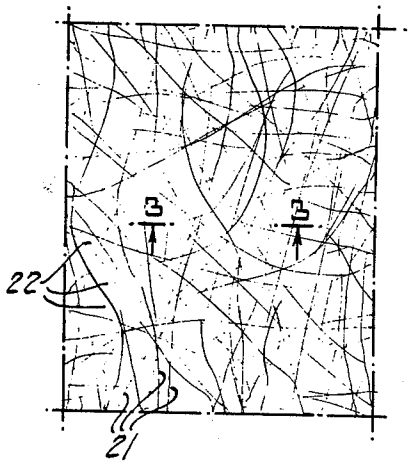



Fig. 4.

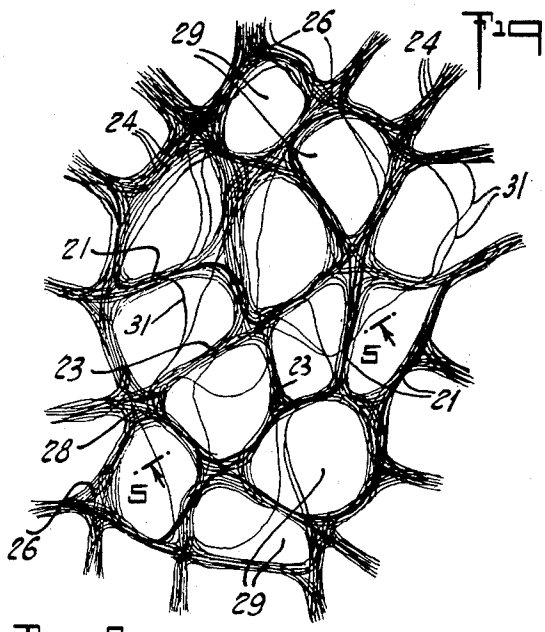



Fig. 3.

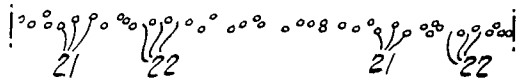



Fig. 5.

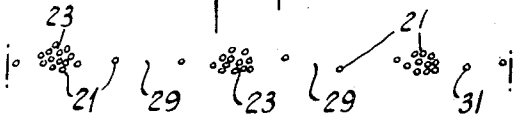



Fig. 6.

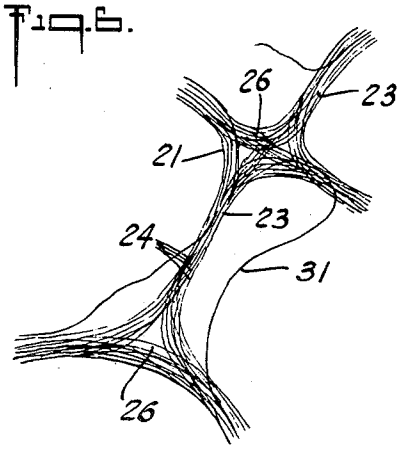
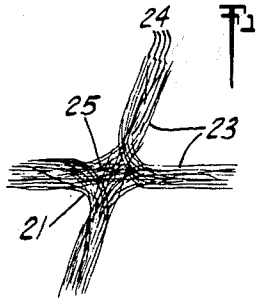



Fig. 7.




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Fig. 8.

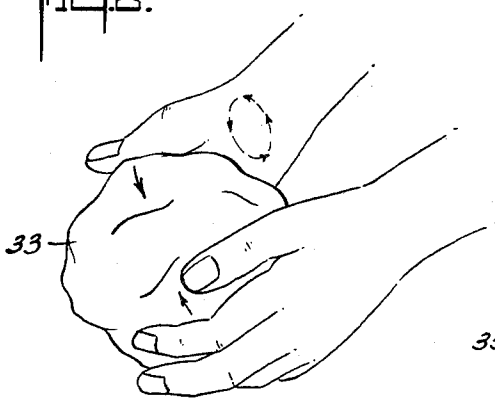



Fig. 9.

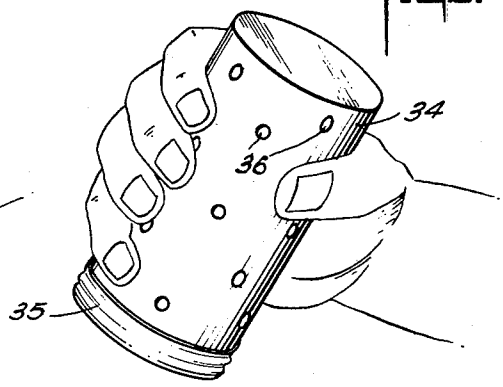



Fig. 10.

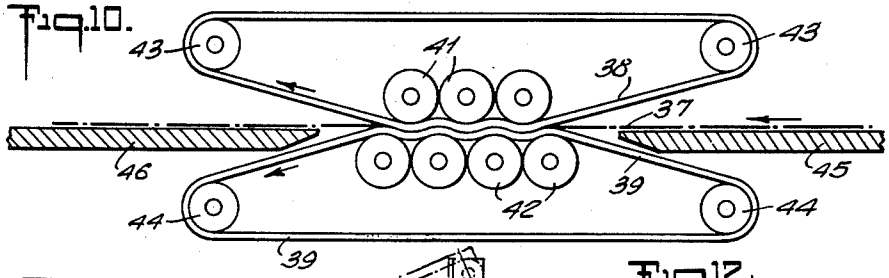



Fig. 11.

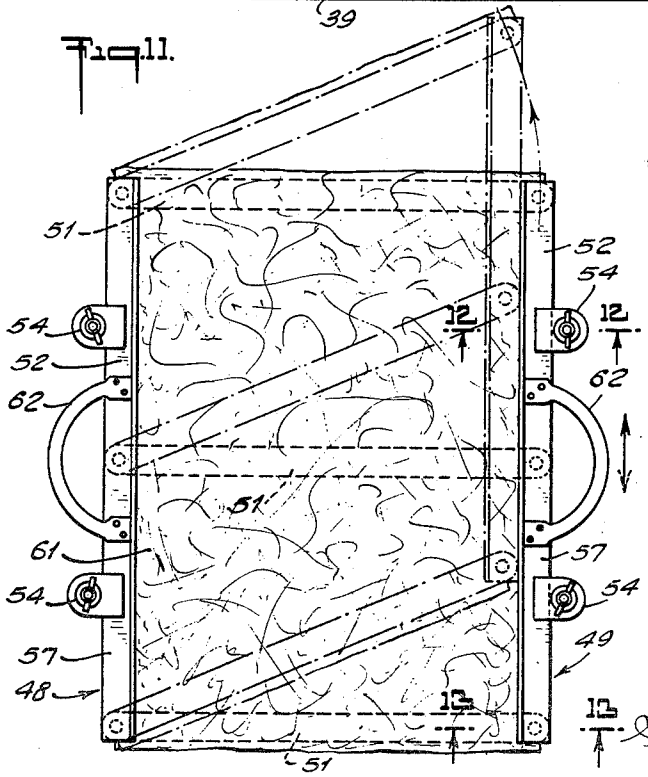



Fig. 12.

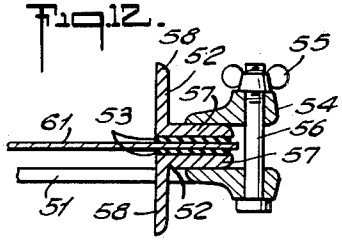
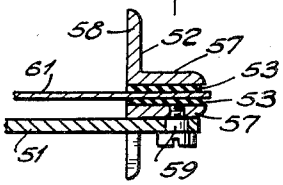



Fig. 13.




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METHOD OF PRODUCING APERTURED NONWOVEN FABRIC

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Fig. 14.

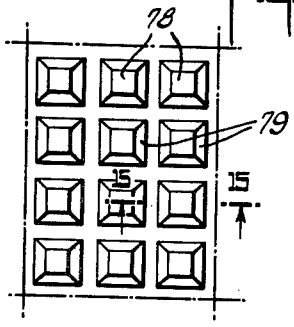



Fig. 15.

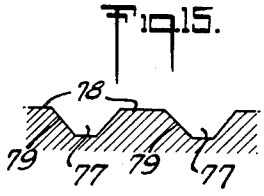



Fig. 16.

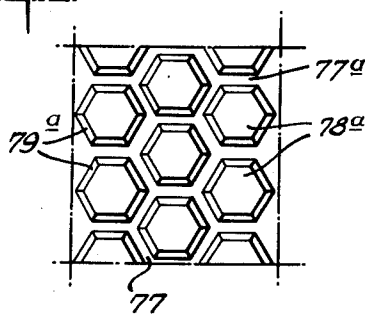



Fig. 17.

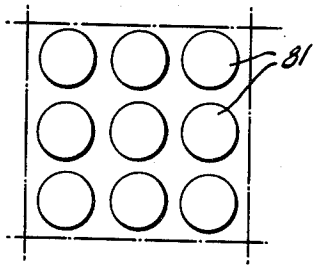



Fig. 18.

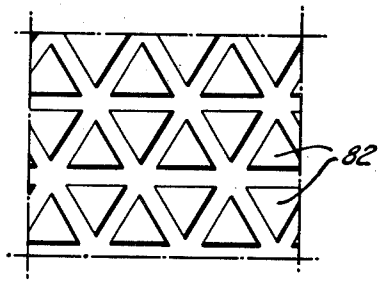



Fig. 19.

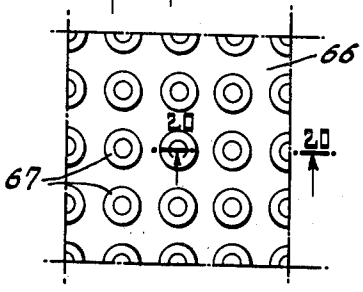



Fig. 22.

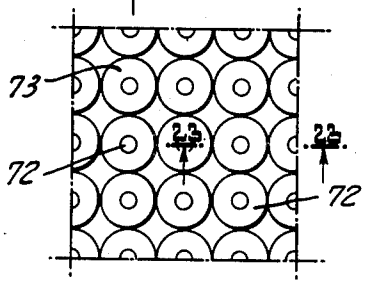



Fig. 20.

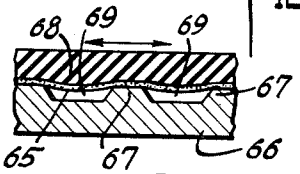



Fig. 23.

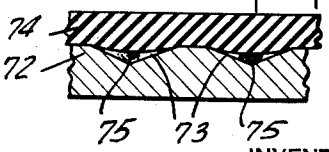
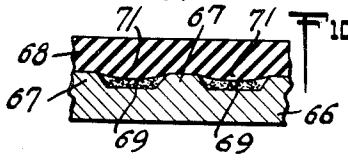



Fig. 21.




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United States Patent Office 3,081,512 Patented Mar. 19, 1963



# 3,081,512
# METHOD OF PRODUCING APERTURED NONWOVEN FABRIC

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Original application Apr. 26, 1955, Ser. No. 503,871. Divided and this application July 27, 1956, Ser. No. 600,510

30 Claims. (Cl. 28—72)

This invention relates to textile fabrics and methods for producing them and is more particularly concerned with so-called "nonwoven" fabrics, i.e., fabrics produced directly from fibers without the use of conventional spinning, weaving, or knitting operations.

The present application is a division of my co-pending application Serial No. 503,871, filed April 26, 1955, which application was in turn a continuation-in-part of my co-pending application Serial No. 437,119, filed June 16, 1954.

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 frictional and interlocking engagement with one another to form yarns which are substantially circular in cross section. It is these yarns, not the fibers acting individually, which serve as the structural members of the resulting woven or knitted fabrics. Generally speaking, these fabrics comprise reticular structures of intersecting, intertwining yarns which define interstices between them.

Nonwoven fabrics have been of two main types, felts and bonded webs. In each of these, the fibers making up the fabric occur individually and act individually as structural members. This is true even though the fibers in many felts are so highly interlocked and compressed together that it is difficult to identify individual fibers. Hat felts, for instance, are extremely dense, relatively "hard" fabrics without apparent interstices, which are quite dissimilar in appearance and qualities to woven or knitted structures. On the other hand, the fibers in bonded webs are usually flatly assembled in layers more or less oriented in one direction as in a card web; or arranged in a "random" manner, as in an air laid isotropic web. Various bonding agents have been used to print a binder pattern on such webs or to impregnate them to hold the individual fibers together. In this type of fabric, the fibers may remain relatively straight and overlapping one another with very little interlocking between them. They are usually arranged in a more or less uniformly spaced condition in the plane of the web, such that only very small 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 oriented to define interconnected groupings of fiber segments and openings or areas of low fiber density between groupings. The groupings or groups are connected by fibers extending from one to another in such a way that they are common to a plurality of groupings. It is preferred that the average length of the fibers be considerably greater than the lengths of the groups containing them with the result that the groups predominately comprise only parts or segments of the fibers passing through them. Preferably the fibers average at least about ¼ inch in length and are textile-like in nature,



i.e., flexible and distinct or unbeaten in the case of woodpulp. 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 one embodiment of a fabric according to this invention, the fiber segments in the groups are closely associated and substantially parallelized along the axes of the groups to the extent that the groups resemble spun yarns. The segments may be so closely arranged in overlapping relationship about the axes of the groups that the groups possess yarn-like thickness and are generally yarn-like in cross section.

In the foraminous structure formed by the interconnected fiber groupings in accordance with the present invention the fibers lie in a state of mechanical equilibrium. The fibers are mechanically engaged, both frictionally and/or by interlocking of the fibers, to the extent that the arrangement of fibers is one of equilibrium.

The nature and appearance of the fibrous structure may be varied with the materials and methods used to prepare a particular fabric according to this invention. For instance, the fiber groupings may appear relatively tight or relatively loose and fluffy and the fabric may resemble a gauze, a fluffy knitted fabric, etc. The groups may act as structural members and as capillary passages for conducting liquids, and the openings which they define may render the fabric permeable to liquids and gases and contribute to absorptive capacity. The three dimensional nature of the interconnected bundles and the arrangement of the fibers contained therein contribute to softness, loft, flexibility, etc. Thus, the resulting nonwoven fabric may be designed to have excellent fabric qualities of handle, drape, loft, permeability, absorptivity, moisture conducting power, as well as other characteristics, and, additionally, the appearance of a woven or knitted fabric.

Generally speaking, the mechanical, i.e., frictional and interlocking engagement between the fibers in the bundles, while contributing strength to the fabric, may be insufficient in itself to provide adequate tensile strength for most applications. Therefore, it usually will be desirable to strengthen the fabric in some way. For instance, an adhesive bonding material or binder may be applied by means such as printing or impregnation. As will be described more fully hereinafter, some binder may be contained in the web during and after its transformation into the fabric of this invention. This binder may not be present in sufficient quantity to provide the desired strength in the fabric. If this is the case, additional binder may be required to provide the desired strength.

Due to their structure and appearance and other qualities described above, fabrics 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 methods for producing the fabric of this invention from a base web consisting of one or more layers of fibers such as may be produced by carding, garnetting, air deposition, papermaking techniques, etc. External forces may be applied to such a base web by members which may oscillate, compress the web, shake it, etc., to cause fibers in the layer to move into new positions in closer proximity with one another and form interconnected fibrous groupings as described hereinbefore. Generally speaking, the fibers are moved to new positions wherein they lie in mechanical equilibrium. During the application of the external forces to the base web, sufficient local support should be provided for the web to assure the maintenance of its

integrity, i.e., to prevent it from being torn or pulled apart, and to prevent the formation of clumps of fibers, large holes, etc. However, the support provided should allow the fibers in the layer to move as described above while the integrity of the web is being maintained. The web may be supported physically by means in local content therewith, both above and below it, or it may be supported by an adhesive binder distributed in the web in such a way that it may be softened to the extent that it will allow the aforementioned movement of fibers while it remains effective to maintain the integrity of the web.

FIG. 1 is a photomicrograph of a typical area of the fabric of Example I of this application at an original enlargement of approximately 30 to 1;

FIG. 2 is an enlarged schematic plan view of a typical base web from which a fabric according to this invention may be produced;

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

FIG. 4 is a schematic plan view of the web of FIG. 2 after it has been rearranged to produce a fabric typical of one embodiment according to this invention;

FIG. 5 is an enlarged sectional view taken along the line **5—5** of FIG. 4;

FIG. 6 is a greatly enlarged plan view of one portion of FIG. 4;

FIG. 7 is a similar plan view of another portion of FIG. 4;

FIG. 8 is an isometric view of the web of FIG. 2 being worked between the hands in accordance with one embodiment of the invention;

FIG. 9 is an isometric view illustrating another method of producing a fabric according to this invention;

FIG. 10 is a schematic view partly in longitudinal section of another device for producing a fabric according to this invention;

FIG. 11 is a plan view of a still different apparatus for this purpose;

FIG. 12 is a view partly in section and partly in elevation along the line **12—12** of FIG. 11;

FIG. 13 is a view partly in section and partly in elevation along the line **13—13** of FIG. 11;

FIG. 14 is a plan view of means presenting projections for producing a patterned fabric according to this invention;

FIG. 15 is a sectional view along the line **15—15** of FIG. 14;

FIG. 16 is a view similar to FIG. 14 of a somewhat different pattern of projections;

FIG. 17 is a similar view showing circular projections arranged in a square pattern;

FIG. 18 is a similar view showing triangular projections;

FIG. 19 is a plan view of a member presenting spaced frusto-conical projections;

FIG. 20 is an enlarged schematic sectional view along the line **20—20** of FIG. 19, showing a layer of starting material positioned between the ends of the projections and a cooperating member also in section;

FIG. 21 is a view similar to FIG. 20 at a later stage in the process;

FIG. 22 is a plan view similar to FIG. 19 showing a somewhat different form of projections; and

FIG. 23 is a sectional view similar to FIG. 20 along the line **23—23** of FIG. 22.

Referring to FIG. 1 of the drawings, there is shown a typical area of the fabric of Example I of this application comprising interconnected yarn-like groups or bundles **16** of fiber segments. The interconnected groups extend more or less uniformly in varying directions in the plane of the web and define relatively large openings **17** between them. There appear to be a large number of fiber segments **18** which lie outside the groups and extend between them. Certain of these segments may combine to form irregularly-located small groups **19** extending between the main groups **16**. Since it is difficult to distinguish the shape and arrangement of the individual fibers in FIG. 1, a more detailed description of the fabric of this invention will be reserved for the somewhat stylized version of FIGS. 4 through 7, described hereinafter.

Referring to FIGS. 2 and 3 of the drawings, a nonwoven fabric according to one embodiment of this invention may be produced from a base web of flexible fibers **21** arranged in substantially nonoriented, overlapping, intersecting relation with one another, such that there is only slight entanglement between them. The fibers in the web are flatly assembled in nongrouped relationship with one another, such that they define only relatively small interstices **22** between them. Preferably, the web contains a small percentage of a uniformly dispersed water-softenable adhesive binder to assist in maintaining the web integrity as it is subjected to forces designed to cause its fibers to form into interconnected groups.

In FIGS. 4 through 7, there is shown one embodiment of a fabric according to this invention produced from the above-described base web. The fabric comprises interconnected yarn-like groups or bundles **23** of individual fiber segments **24**. The fiber segments **24** are substantially parallelized and closely arranged about the longitudinal axes of the groups to the extent that the groups **23** are yarn-like in cross section. As shown in FIG. 5, the groups possess yarnlike thickness in two dimensions, both in the plane of the web and perpendicular thereto, and are more or less oval in cross section. In this figure, an appreciable number of the fibers **21** in the groups appear to be in contact with one another. The groups **23**, in turn, appear to be spaced from one another by distances substantially greater than the widths of the groups themselves.

As shown in FIGS. 4 and 6, the groups **23** are interconnected by fibers which are common to a plurality of groups. In these figures, the individual fibers **21** have an average length which is considerably longer than the groups containing them so that most of the fibers extend through a plurality of interconnected groups, as indicated by the heavy lines representing single fibers in FIG. 4. The groups may be of such a length that a fiber ⅜ inch long may occur in several groups. Thus, generally speaking, each of the groups contains only portions or segments **24** of the fibers **21** passing through it. Due to the relatively random arrangement of fibers in the base web the segments in a given group may be located along entirely different portions of the lengths of their respective fibers. As illustrated in FIGURES 4 and 6 and in FIGURE 7, the fibers connecting individual groups form junctures **26** and **25**, respectively, wherein the fibers extend in a plurality of diverse directions. At the junctures **25** and **26**, the fibers may bend or curve to the left or the right or cross over one another to continue in a more or less straight path. The groups **23** may join almost directly, forming relatively tight junctures **25** between them as shown in FIG. 7, or, as illustrated in FIG. 6, looser junctures **26** may be formed which comprise web-like areas wherein the fibers extend in various directions in overlapping, intersecting relation with one another. When groupings are formed predominantly in one direction of the fabric, as will be described hereinafter, the may appear to be interconnected by a multiplicity of more or less spaced individual fiber segments which do not define definite junctures as described above. Actually, there may be a number of small groups comprising only a few fibers each extending between the main groupings and interconnecting them.

Referring to FIGS. 4, 6, and 7, the relative orientations of interconnected groups may depend upon the lay of the fibers in the base web as well as the conditions and methods used to form the groups. FIG. 6 illustrates a group **23** extending between two areas of interconnection **26** with other groups. At one of these areas four groups join and at the other three come together.

Typically, either three or four groups may join at each juncture. However, more than four may interconnect at one juncture as illustrated in 28 in FIG. 4. Grouping may vary in sharpness in different areas of the web. For instance, grouping in the upper left hand area of FIG. 4 appears less tight than in other areas of this same figure. The fiber segments appear less parallelized and more loosely arranged in the groups in the upper left than elsewhere. This type of difference or irregularity in group formation will appear to be much more extreme as fabrics of this invention are viewed under greater magnification. For instance, the fabric illustrated in FIG. 4, at a magnification of the order of thirty to one, appears much less regular than if viewed by the naked eye.

As shown in FIGS. 4 and 5, interconnected groups 23 may define with adjacent groups openings or areas of low fiber density 29. Generally speaking, the more tightly the groups are formed, the more clearly defined will be the openings 29 between them. The interconnected groups may form a reticular fabric structure having openings which appear similar to the interstices of woven or nitted fabrics and the size of these openings may be controlled to vary the permeability of the fabric to moisture and air. The openings between groups may contain individual fiber segments 31 which lie outside of the groups. The free segments 31 may represent portions of fibers which deviate from the basic structure of interconnected bundles. The extent of fiber deviation or the number of smaller fibrous groupings may vary with the base web and the methods used to produce the fabric and, as mentioned hereinbefore in connection with the group regularity, will be much less apparent when viewed by the naked eye than under a microscope.

As mentioned hereinafter in connection with FIGS. 14 through 23, fabrics according to this invention may be produced in such a way that the fiber groupings extend in a regular reticular pattern defining a regular pattern of openings. Fiber deviation and irregular group formation may be kept to a minimum particularly in fabrics produced by the techniques illustrated in FIGS. 14 through 23. The fiber segments may be closely associated in the groups to the extent that the segments appear to be in appreciable contact with one another along their length when viewed by the naked eye or under a microscope at low magnifications. The segments may follow the shapes and orientations of the groups containing them, with the result that the fibers are bent or shaped to conform to the relative inclinations of the groups. Those fibers in the groups may extend through a more or less symmetrical set of groupings, with the result that they will tend to take a series of fairly regular turns or bends and be sinuous in shape. However, they may wander throughout the groups, turning back on themselves and curling or adopting configurations similar to a question mark or a letter S. The bends in the fibers are usually in the form of curves which may be somewhat sharp or smooth depending upon their arrangement in the bundles. The fibers may comprise relatively straight portions between bends or they may consist of a series of connected curves and curls depending to a large extent upon the shapes of the groups containing them.

In one embodiment of a fabric according to this inchanical engagement with one another in the interconnected groups to the extent that the fabric structure is in mechanical equilibrium. The fibers are in frictional engagement with one another due to their relatively close contact in the groups or bundles and their bent or curled configurations are entangled or interlocked and resist separation. The closeness of the segments tends to constrain the fibers in the groups and the bends in the fibers tend to prevent their movement along the axes of the groups. Obviously, the longer the fibers the more segments there will be in frictional engagement and the more bends or curls will be entangled. Thus, fabric strength is a function of fiber length as well as other variables. If a binder is present in the base web, a certain amount of it may become effective to hold the fibers in their new positions in the groupings. The effective binder may assist in holding the fibers in close contact with one another and may concentrate within the groups themselves, to assist in holding them together.

In one embodiment of a fabric according to this invention the longitudinal axes of the interconnected groups of fiber segments may extend at various angles to one another, either in the plane of the fabric or at an inclination thereto, such that the fibers they contain may be bent or curled in three dimensions. The inclined groups or bundles may connect with other groups which overlap one another with respect to the plane of the web. The overlapping groups and the inclined groups connected to them may contribute body and loft to the fabric and define internal voids between them which add to its absorptive capacity. This structure also is flexible in nature, such that the fabric may be soft and drape or conform well to various shapes. The fabric may vary from a layer of interconnected groups with virtually none overlapping, to a relatively thick fabric with a large number of overlapping groups. FIG. 1 illustrates a typical fabric of this invention falling between these two extremes.

As mentioned hereinbefore, the starting material for the nonwoven fabric of this invention may be a web of fibers 21 arranged in overlapping, intersecting relation with one another, such that there is only slight entanglement between them, as shown in FIGS. 2 and 3. Webs of this type may be formed by carding, by air deposition, by liquid deposition, such as in a papermaking process, etc. They may be formed in a single layer or by laminating a plurality of layers formed by these techniques. The fibers in the base web may be arranged in a random manner or more or less oriented, as in a card web, or a card web laminate. The individual fibers may be relatively straight or slightly bent occurring independently in the web in nongrouped intersecting relation with one another. They may intersect at various angles to one another such that, generally speaking, adjacent fibers only come into contact at the points where they cross. The overlapping, intersecting fibers form interstices 22 between them which vary in size with the fiber density of the web such that for preferred web weights of from 100 to 600 grains per square yard only very small interstices are apparent. Webs ranging in weight from below 100 grains per square yard to about 2,000 grains per square yard may be rearranged into the fabric of this invention. Such webs may be held together by virtue of the mechanical engagement, i. e., the frictional contact and the aforementioned slight entanglement between its fibers, as well as by any binder which may be present. Generally speaking, the fibers lie in mechanical equilibrium in the web or layer.

The base web may be subjected to external forces which cause the fibers 21 to move locally with respect to other fibers they overlap and intersect and into closer proximity with one another until corresponding fiber portions or segments 24 are parallelized in groups 23. As the individual fibers are moved to bring into closer proximity portions of the fibers which are separated in the base web, a large percentage of the original intersections between the fibers in the web will tend to merge into the groups, such that the web structure of overlapping, intersecting fibers, FIG. 2, may be replaced by a fabric structure of interconnected groups, FIG. 4. In the movement of the fibers into closer proximity with one another as shown in FIG. 4, external rearranging forces applied to the fibers will ordinarily include lateral translatory components acting parallel to the plane of the web and other components

of force causing individual fibers to move, with respect to other fibers in the layer with which they overlap and are frictionally engaged into mechanical equilibrium in the most extreme lateral position into which they are moved.

During the application of external forces, sufficient local support must be provided for preventing these forces from destroying the web integrity, i.e., from pulling the web apart or from converting it into mere clumps of fibers, etc. For this purpose, it is preferred that either an adhesive binder be dispersed throughout the base web, or means be provided for physically contacting the web to provide local support therefor. For best results it is preferred that the web both contain a binder and receive local physical support as mentioned above. Means for applying external forces may cooperate with means for supporting the web locally or means may be provided to accomplish both functions. For instance, the web may be supported in an open position between surfaces oscillating slightly with respect to one another to cause its fibers to form into groups. The application of external forces must be controlled with respect to the binder or supporting means employed to prevent the web from being pulled apart and to prevent the formation of undesired holes, clumps, etc.

An adhesive binder may be included in the web during its formation in the case of a wet-formed web, for instance, or it may be added by impregnation, spraying, or other such means. The binder should be uniformly distributed throughout the base web to provide uniformity in strength and arrangement of groups. In order that groups may be formed, the fibers must be free to move to a certain extent locally with respect to one another, as described hereinbefore. This means that the binder should be rendered sufficiently soft or plastic during the application of external forces, to allow this movement. A solvent or softening agent such as water may be added to the web for this purpose when the web contains a binder which may be softened in this way. The amount of softening agent added may be controlled to provide a web strength which will correspond with the nature and intensity of the external forces applied. When local physical support is not provided, a binder is distributed in the web in such a way that it may be softened to the extent necessary to allow the aforesaid local movement of fibers while it remains effective to maintain the integrity of the web during the application of external forces. A relatively low percentage of binder may be dispersed uniformly throughout the web for this purpose by means such as generally mentioned above and as illustrated hereinafter in the examples.

It is preferred that some liquid, such as water, be uniformly distributed in the web to assist in parallelizing fiber segments and bringing them into close association in the groups. The web may be wet to contain a maximum of water, for instance, prior to the application of bundling forces, although in general less water in the order of about 50 to 250 percent moisture is preferred. The term "percent moisture" above, and when used in the following specification and claims, refers to percentage of moisture by weight of the dry web. The preferred moisture content in a given case depends to a large extent upon the methods used and the results desired. A liquid, such as water, tends to assist the above-mentioned external forces in bringing the fibers together and holding them in their new configurations. Its action may include a surface tension effect whereby the surface tension of the liquid present tends to bring fiber segments closer together as the external forces move them into closer proximity with one another. It would seem that the natural tendency of this effect would be to form substantially circular or oval groups of fiber segments appearing similar to the yarns of woven fabrics. The intensity of the surface tension effect will of course depend upon the amount of liquid present in the web. Once the fibers are brought into close alignment, the surface tension of the liquid may tend to hold them there. There may also be an hydraulic effect, wherein droplets of water tend to enlarge the interstices in the web by pushing fibers out of their way as external forces are applied to the web. Most fibers will absorb water and other liquids, swell, and soften to a certain extent while retaining this moisture, such that if moistened fibers are held together, they will tend to conform and fit closely with one another. Fibers in contact may swell together, and softened fibers may be forced into contact with one another to the extent that they are closely interlocked and tend to stick together. The fibers may swell and soften under the influence of moisture to the extent that they may be bent or curled and will retain their new configurations in contact with the other fibers. In general, these fibers become less resilient and more limp and moldable under the influence of moisture.

As shown in FIG. 8, a fibrous web of the type described containing sufficient binder to maintain its integrity may be moistened to soften the binder, bunched into a ball 33 and then rolled between the hands under slight pressure to produce a bundled fabric of this invention. This rolling or compressive action tends to move the fibers in the web into increased contact with one another in the plane of the web. The fibers do not blend or felt into a ball but move about in the web itself such that segments of the fibers come together and form yarn-like groupings. The web may be wet with an excess of moisture and then worked between the hands in such a way that its moisture content is gradually decreased. It has been observed that most of the groupings are formed in the earlier stages of working whether or not the initial moisture content is high or relatively low. It is preferred that the web initially contain well over 100 percent moisture for working by this method. The preferred moisture content for a particular web will depend upon the amount and nature of the binder it contains. Speaking generally, the moist bunched web may be rolled steadily between the hands for a period of less than one half of a minute, for instance, and then opened to exhibit a fibrous structure of interconnected groups. A somewhat more regular structure of groups may be formed if the web is alternately bunched, rolled a few times, opened, and then bunched again, etc., until the desired structure is obtained. The web should be worked with care to avoid abrasion and tearing and to assure uniform bundling.

FIG. 9 illustrates another method of applying forces to a web while it is bunched to move its fibers into increased contact with one another and cause grouping. The web, containing sufficient binder to maintain its integrity, may be moistened, bunched, and placed in a container, such as a can 34 having a removable screw cap 35 on one end. After the moistened web is inserted in the can and the cap is screwed into place, the can may be shaken vigorously for over one half an hour, for instance, in such a way that the bunched web repeatedly strikes the sides and ends of the can. These repeated blows act to move the fibers in the web into further contact with one another such that fiber groupings will be formed under the influence of the moisture present. Holes 36 may be provided in the sides of the can for expelling excess moisture separating from the web during the shaking operation. If mechanical means are provided for shaking the can vigorously and rapidly, the same, or even improved, results may be obtained more quickly.

FIGS. 8 and 9 illustrate methods by which a web containing binder may be rearranged into a fabric according to this invention, wherein the web is bunched and supported loosely while being subjected to general compressive forces applied from varying directions. Since no other local support is provided for the web, the presence of a binder is considered necessary for maintaining its integrity.

FIG. 10 illustrates apparatus for providing local support for a web in an open position while applying external forces in the plane of the web to move its fibers into further contact with one another. Fundamentally, this in-

volves placing the web between surfaces which oscillate slightly in the plane of the web with respect to one another. The movement of the surfaces may push or roll the fibers into further contact with one another such that fiber segments will parallelize and form into groups under the influence of the moisture present. The web 37 may be passed between an upper and a lower resilient belt 38 and 39 which may be superimposed with the web between them and passed between upper or lower rollers 41 and 42 which are designed to oscillate axially, or axially and circumferentially, with respect to one another in a manner such as described in U.S. Patent 2,093,709 or 2,506,-855, both disclosing machines of the continuous felting type. The resilient belts may be continuous with the upper belt 38 passing around the upper rollers 41 and guide rollers 43 at the front and the rear thereof, and with the lower belt 39 passing around the lower rollers 42 and similarly located guide rollers 44. The upper and lower guide rollers 43 and 44 are spaced to cause the upper and lower belts 38 and 39 to converge as they move toward the oscillating rollers and diverge as they leave these rollers.

The web 37 enters between the belts where they converge in front of the upper and lower oscillating rollers and leaves them where they diverge at the rear of these rollers. Suitable tables 45 and 46 may be provided for supporting the web adjacent the points where it enters and leaves the belts. The upper rollers 41 may be urged toward the lower rollers 42, or vice versa, or these rollers may be spaced with respect to one another so as to accommodate the superimposed belts 38 and 39 under pressure between them. The rollers 41 and 42 may oscillate or jiggle circumferentially while they also rotate to feed the superimposed resilient belts between them. As explained in U.S. Patent No. 2,093,709 (page 4, column 2, lines 3–5), the rollers "are subjected to a circumferential vibration which is superposed upon the movement of rotation." Thus a given point on the surface of a roller continues to advance generally because of the roller's rotation even though at any particular moment it may be moving backwards within a narrow angular distance because of the circumferential vibration or oscillatory movement of the roller.

The oscillatory motion of the rollers may be partially transmitted through the belts to the web as the web advances therewith, and partially absorbed by the flexure of the resilient material comprising the belts. The fibers of web 37 may be pushed into further contact with one another, as referred to above, by the relative motion produced in belts 38 and 39 and the resulting lateral translatory components of force acting parallel to the plane of the web. In addition, they may be rolled into closer contact by the rotational components of force applied, through the relative motion of belts 38 and 39 resulting from the oscillation of rollers 41 and 42, to the fibers confined between the belts.

The relative oscillatory movement of the belt surface in contact with the web must be controlled, as mentioned above, to prevent the web from being abraded and pulled apart. This may be accomplished by employing belts which are sufficiently thick and sufficiently resilient to absorb a large percentage of the relative oscillatory movement of the upper and lower tiers of rollers. For instance, a pair of belts each comprising sponge rubber ¼ inch thick has given good results when run between rollers oscillating with respect to one another approximately ⅛ inch at 1,500 cycles per minute, both axially and circumferentially. The amplitudes of axial and circumferential oscillation of the rollers may be decreased considerably below ⅛ inch, thereby allowing the use of thinner belts. In fact, one belt may be eliminated such that the web passes between one of the tiers of rollers and the remaining resilient belt. The amplitudes of the axial and circumferential oscillation of the rollers and the thickness of the remaining belt may be designed such that the belt



absorbs a goodly portion of the oscillatory motion of the rollers and distributes the applied forces throughout the web in a uniform manner. When one belt is eliminated, the thickness of the remaining belt may be increased to a certain extent, assuming the oscillatory motion of the rollers to be the same, to compensate for the lost thickness of the first belt.

The application of bundling forces to the web by this method may occur in more than one step, such that more than one group of rollers of the type shown in FIG. 10 may be employed. Oscillation of the belts with respect to one another in different directions in the plane of the web may facilitate the formation of groups extending in various directions in the web. However, oscillation in only one direction may give good results, particularly when one of the belts comprises projections or other molding portions designed to participate in group formation as will be described hereinafter.

One of the belts may include a multiplicity of regularly spaced projections, such as shown in FIGS. 14 through 23, which are adapted to enter the web and push the fibers into further contact with one another as the belts are oscillated. Rearranging belts employing various sizes and shapes of projections in various arrangements are shown in FIGURES 14 through 23. A method and apparatus employing rearranging devices of this type are shown and described in more detail and claimed in my joint application with George W. Pearce, Serial No. 600,511 filed July 27, 1956 and assigned to a common assignee. As shown in FIG. 20, a web 65 may be interposed between a rearranging belt 66 defining spaced projections 67 and a cooperating belt 68 in such a way that it is held between the surface of the cooperating belt and the ends of the projections. The rearranging belt 66 and the cooperating belt 68 may be urged together and oscillated or moved back and forth with respect to one another in the plane of the web 65 to move fibers in the web away from the ends of the projections 67 and into the spaces 69 between them, as illustrated in FIG. 21. The relative oscillation of the belts may be achieved as described hereinbefore in connection with FIG. 10.

Generally speaking, the size and shape of the holes or openings produced in the web will correspond to the size and shape of the projections. It is preferred that the cooperating belt 68 comprise a resilient material which will protrude into the spaces between the projections 67 as the belts are urged together. The protruding portions 71 of the resilient belt will tend to work the fibers in the spaces 69 between the projections into closer groupings. Group formation may be enhanced by employing projections with inclined sides such as are shown in FIGS. 14 through 16 and 19 through 23. As the belts are oscillated with respect to one another they will first move the fibers off the flat ends of the projections and then, through the protruding portions of the resilient belt, at least part way down the inclined sides of the projections. As shown particularly in FIGS. 22 and 23, projections 72 may be designed with shallow inclined sides 73 to give relatively tight group formation with relatively short projections. The short inclined projections 72 will slowly work their way into the web and the protruding portions of a cooperating resilient belt 74 may be employed to gradually move fibers away from the ends of the projections 72 and down their sides until relatively tight groups 75 of fibers are formed around the bases of the projections.

Belts comprising various sizes and shapes of projections may be employed to give varying results. The projections may be spaced in such a way that the belt might better be described as grooved, in which case the fibers would be moved into the grooves between the projections and the fiber groupings formed would be interconnected in accordance with the pattern of the grooves. FIGS. 14 and 15 illustrate members comprising interconnected

grooves 77 defined by projections 78 having inclined sides 79. Projections 78*a* shown in FIG. 16 have inclined sides 79*a* and are separated by interconnected grooves 77*a*. FIGS 17 and 18 illustrate round and triangular projections, 81 and 82, respectively, defining corresponding interconnected spaces or grooves between them.

The presence of a small amount of binder in the web is advantageous to assist in maintaining the web integrity and to facilitate web handling during the processing period. While the amount of moisture necessary will depend to some extent upon the amount of binder present, it is perferred that the web contain between about 50 and 250 percent moisture. As will appear from the examples, good results have been obtained from working webs containing a small amount of binder by this method with moisture contents between about 100 and 150 percent.

In FIGS. 11, 12, and 13, there is shown a device for applying external forces to a web in the flat by biasing the web. A swinging frame is provided having longitudinal clamping units 48 and 49 spaced from one another by a set of pivot or swinging arms 51 each pivotally connected to the clamping units. Each of the units comprises a pair of small structural angles 52, a corresponding pair of resilient gripping strips 53 and a pair of vise type screw clamps 54 adapted to clamp the angles together with the gripping strips between them. Each of the screw clamps comprises jaws which may be adjusted toward one another by a wing nut 55 which is threaded to a connecting bolt 56 passing through the jaws. The jaws fit over and under opposite horizontal legs 57 of the angles and the inner surfaces of these legs exert clamping pressure on the resilient strips 53. The vertical legs 58 of the angles stiffen the horizontal legs such that the clamping pressure is distributed along the lengths of the angles. Each of the swinging arms 51 is pivotally attached at each end to the horizontal leg 57 of each of the lowermost angles of each of clamping unit by means of a pin 59 which passes through a hole in the arm to screw into the angle.

A moist web 61, preferably containing a binder to maintain its integrity, may be clamped in an open position between the clamping strips 53 of the longitudinal clamping units 48 and 49. The strips 53 should be of a resilient material such as rubber in order to assure that the clamping pressure is distributed uniformly along the clamped portions of the web. The clamping units may then be swung back and forth with respect to one another on the pivot arms 51 to bias the web repeatedly in opposite directions and cause its fibers to come into increased contact with one another and form groupings under the influence of the moisture present. As the clamping units 48 and 49 move from one position to another, they define at all times, parallelogram bounded at each end by a pivot arm 51. For this reason, the distance between corresponding points on clamping units 48 and 49 (for example, opposite ends of a given pivot arm 51), and, by the same token, the distance between corresponding points on the respective web edges clamped by the units, remain constant throughout as the swinging movement proceeds. The pivot arms may be swung back and forth about 30 degrees on either side of their center position, roughly as shown dotted in FIG. 11, at a uniform rate for less than a minute to cause groupings to be formed in the web. Handles 62 may be provided on each of the units for this purpose.

Biasing the web in this manner tends to compress it or bring its fibers closer together in directions perpendicular to angle of swing and transverse to the clamping units. Since the bulk of the fibers in the base web extend at various angles to both its long and cross direction, they will tend to be brought into further contact with one another as the web is compressed as described above. As just described, the web itself may be clamped between the resilient strips 53 and held between the clamping units without support being provided between the units other than by the uniformly dispersed binder it contains. It is also possible to clamp the web between resilient or biasable sheets such as rubber diaphragms or sheets of gauze, etc., not shown, co-extensive with the web such that they will move the web while providing it with local support between the units, thereby minimizing the need for binder support.

Examination of FIGS. 8 through 23 of the drawing discloses that in the various embodiments of the method of this invention there illustrated, the movement involved produces simultaneously both lateral translatory components of force and the other cooperating components of force which are applied in combination in the fiber rearranging steps of the method of this invention.

In the method illustrated in FIG. 8, the various rearranging forces result from the simultaneous bunching and rolling between the hands which are carried out after the initial bunching of the starting web into a ball. The manual working of the compressed material is not a revolving of the entire ball as a unit, but a kneading action against the individual fibers lying in the exposed portions of the ball of material, which actions are in turn transmitted through these fibers as individual kneading actions against the adjacent fibers and thus throughout the mass. It is seen that the opposing forces from the hands will produce lateral translatory components as they rub across the bunched material and as they force one part of the web against another, and will at the same time apply rolling or rotational forces to the individual fibers throughout the material.

In the embodiment of FIG. 9, the fibrous material is rearranged by its impact with the ends of the container and also by any slanting blows of appreciable magnitude to which the bunched material is subjected whenever it strikes the sides of the container at an angle. Both types of blows will produce lateral translatory components of force and vibrational components of force (the frequency of the vibration depending upon the frequency at which the can is shaken).

In the embodiment of FIG. 10, the oscillating and rubbing actions of the belts through which the fibrous web passes apply lateral translatory forces, vibrational forces, and rolling or rotational forces. The same is true when, as mentioned above, one of the belts includes a multiplicity of regularly spaced projections such as those shown in FIGS. 14 through 23.

In the embodiments of FIGS. 11–13, the lateral translatory components, as well as rotational components of force, are produced by the biasing of the web. The biasing of the web results in the rolling of fibers under the effect of forces applied by the other fibers of the biased web.

Two important factors affecting group arrangement are the original orientation of the fibers in the base web and the way in which the web is supported. If the fibers in the base web are predominantly oriented in one direction and the web is supported free of rearranging means, most of the groups will tend to form in that direction in the web with a fairly high percentage of free fiber segments, of the type described hereinbefore, lying between the groups in the opposite direction. When rearranging means or means for producing a fabric in accordance with a definite pattern, such as described in connection with FIGS. 14 through 23, are employed, the groups formed in the direction of orientation of the fibers in the base web will be considerably heavier than those which interconnect them. However, group arrangement will depend upon the rearranging means. If the fibers are distributed in the base web uniformly and are oriented in a substantially random manner, the groups will tend to extend fairly evenly in all directions in the plane of the web.

The following are examples of fabrics and methods according to this invention. It should be understood that they are offered only by way of illustration and are not intended to define the breadth of the invention or limit the scope of the claims.

*Example I*

A fairly uniform fabric of this invention is produced from a very slightly oriented wet-formed base web by working the web between the hands generally as disclosed hereinbefore in connection with FIG. 8. The base web comprises substantially 1.5 denier viscose rayon fibers averaging approximately ⅜ inch in length bonded with approximately 4 percent by weight of a uniformly dispersed highly beaten or hydrated "Mitscherlich" woodpulp binder. Its fibers are arranged to intersect and overlap one another in a substantially nonoriented fashion and the web itself weighs approximately 450 grains per square yard. This web may be formed by dispersing the fibers together with the woodpulp binder in water to create an aqueous slurry which is then passed through a papermaking machine having an inclined Fourdrinier wire which collects the fibers along with the above-mentioned percentage of binder in the form of a fibrous paper-like sheet or web.

After drying, the base web is thoroughly moistened with water and is worked between the hands as described in connection with FIG. 8 at an initial moisture content of approximately 250 percent. The web is bunched, worked, opened, and bunched again, etc., several times for a total working time of about ½ minute. Although the web must be handled with care, the woodpulp binder is adequate to maintain its integrity and hold the web together while fiber groupings are being formed. At the end of this time a fairly uniform grouped structure is achieved with a very marked increase in bulk and a corresponding decrease in area. As a result of the absence of orientation of the fibers in the base web, the groupings interconnect and extend in a more or less random manner in the plane of the fabric. The increase in bulk is due to the bending and curling of the fibers and the corresponding formation of groups at angles to the plane of the web, as might be expected in view of the compressive nature of the means employed. The fibers and the groups containing them appear to be curled and sinuous defining voids between them in a fairly regular manner such that the resulting fabric has a knitted appearance. After having been dried under proper conditions to prevent stiffness, this fabric possesses excellent drape and extensibility and increased permeability to moisture and air. It may be relatively soft and resilient due to its three dimensional grouped structure, and due to this structure and its excellent moisture conducting power, it tends to feel relatively dry when compared with the base web from which it was produced.

*Example II*

A similar fabric is produced by working an "oriented" card web laminate in the same manner. In accordance with this example, a base web whose fibers are oriented about ten to one in the machine direction is formed by laminating several card webs until the laminate weighs about 200 grains per square yard. Approximately 75 percent of 1.5 denier viscose rayon fibers about 2 inches in length and 25 percent bleached cotton comber noils averaging about ½ inch in length are used. The laminate is then impregnated with a polyvinyl acetate dispersion, such as is sold under the well-known tradename Elvacet 81–900, by the E. I. du Pont de Nemours & Co., to deposit approximately 16 percent by weight of resin solids throughout the web. It is preferred that this dispersion be moderately plasticized.

The base web is then wet and worked between the hands as described in connection with Example I, except that complete rearrangement may be achieved in a much



shorter time, such as a quarter of a minute, mainly due to the lighter web being worked. The web then may be dried under proper conditions to prevent stiffness.

The resulting fabric is similar to that of Example I, but is much lighter and exhibits a much less regular structure. As might be expected, in view of the relatively high orientation of the fibers in the base web, most of the groups are arranged in the same direction with a high percentage of free fiber segments extending between them. This fabric is more open than that of Example I and therefore more permeable to moisture and air. This may be due largely to the lighter base web used. The fabric of this Example is net-like and drapes well although it may not be as soft as the fabric of Example I, mainly due to the higher percentage of binder it contains.

*Example III*

A card web laminate similar to that of Example II comprising approximately 1.5 denier viscose rayon fibers averaging around 2 inches in length, also weighing about 200 grains per square yard and having a fiber orientation of about ten to one in the machine direction, may be impregnated with approximately ¼ percent polyvinyl alcohol to form a base web. Said web is thoroughly wet with water, squeezed down to a moisture content of about 200 percent, bunched, and placed in a can having holes in its side and a removable cap, such as shown in FIG. 9. The cap is secured on the can to close its ends and the can is shaken quite violently and with rapidity for an extended period of time in the neighborhood of an hour, during which the bunched web is caused to strike the sides and ends of the can repeatedly to cause its fibers to form into groups in accordance with this invention. The resulting fabric is mesh-like having relatively tight groups of fiber segments predominantly arranged in the direction of orientation of the base web with the largest percentage of free fiber segments appearing at approximately right angles to this direction. After having been properly dried, this fabric is quite porous and permeable to moisture and air with a structure resembling intersecting threads defining voids between them. Its mesh-like structure drapes well and is lace-like in appearance.

*Example IV*

A base web weighing in the neighborhood of 850 grains per square yard and whose fibers are only very slightly oriented may be formed from a dilute aqueous slurry of viscose rayon fibers of approximately 1.5 denier and substantially ½ inch in length and highly beaten "Mitscherlich" sulphite pulp uniformly dispersed therein. The dilute slurry then may be passed rapidly through an inclined Fourdrinier wire such that the above-described web is deposited thereon along with a binder content of about 10 percent by weight.

The moisture content of the base web is adjusted to approximately 200 percent and then worked between the hands, as described in connection with FIG. 8, for a period of approximately two minutes. It then may be dried as mentioned in the foregoing examples. The fabric resulting from this treatment is condensed and considerably thicker than the base web from which it was produced. Its fiber groupings are close together, overlapping and extending at various angles to one another in the plane of the fabric and at an angle thereto, such that many of the voids between groups are hidden and the fabric itself appears quite dense. While this fabric is not as permeable as those described in connection with the preceding examples, it possesses increased body and is flexible and chamois-like in handle.

*Example V*

A lighter base web weighing approximately 350 grains per square yard may be formed by papermaking techniques, as described in connection with Examples I and IV, from ⅜ inch viscose rayon fibers of approximately

1.5 denier and 5 percent by weight of a highly beaten caroa jelly. This web is formed with a fiber orientation of approximately four to one in the machine direction. The moisture content of the web is adjusted to approximately 100 percent and its fibers are formed into groups in accordance with this invention by passing the web between opposed tiers of rollers vibrating with respect to one another as described hereinbefore in connection with FIG. 10. The web is fed between these rollers on a single resilient belt such that the web is in contact with the vibrating surfaces of the upper rollers themselves. The belt comprises a layer of sponge rubber ¼ inch thick supported by a layer of canvas which runs against the lower tier of rollers. The upper rollers are about 4 inches in diameter and present a roughened surface of a phenolic impregnated fabric, similar to the material sold under the trademark, "Micarta," by the Westinghouse Electric Company. The web is fed through the rollers on the resilient belt at a speed of approximately 20 feet per minute while the upper rollers oscillate with respect to the lower rollers. The rollers oscillate axially about 0.15 inch at 1,500 cycles per minute and circumferentially approximately 0.13 inch at the same frequency. The longitudinal orientation of the fibers in the base web causes most of the fiber groups to be formed in this direction with a high percentage of free fiber segments extending between them in the cross direction. After having been dried in such a way as to minimize stiffness, this fabric is quite permeable to moisture and air and by virtue of its open structure is flexible and tends to drape like a woven fabric.

*Example VI*

This example employs a base web weighing approximately 400 grains per square yard formed by air deposition of fibers upon a foraminous collecting member using techniques such as described in United States Patent Nos. 2,676,363 and 2,676,364. A very low fiber orientation may be obtained by these techniques. The web comprises viscose rayon fibers averaging about two inches in length bonded with about 4 percent of a polyvinyl acetate dispersion which may be added by impregnation as in Example II. Water is added until a web moisture content of about 250 percent is attained. The moistened web is then secured in a swinging frame such as shown in FIG. 11 between two layers of 44 x 36 bleached gauze. The frame is then swung at a steady rate, as described in connection with this Figure, for a period of slightly over one minute to cause fiber segments to form into groups by bringing them into further contact with one another while the web, supported by the aforementioned layers of gauze, is repeatedly biased in opposite directions. After drying according to the foregoing examples, the resulting fabric resembles a fluffy gauze and is relatively porous and highly permeable to moisture and air. It is also quite soft and flexible and possesses superior handle and drape.

The base web or layer of starting material may comprise natural fibers, such as fibers of cotton, wood, wool (except to the extent non-feltable fibers are required as indicated below), jute, ramie, or abaca; or artificial fibers of viscose rayon, cuprammonium, cellulose acetate, nylon, Dynel, or other materials, alone or in combination with one another. Normally nonfeltable fibers, i.e., fibers which will not normally felt under ordinary felting conditions, should constitute the predominant proportion of the fibers when the web is worked without external local support, or is otherwise subjected to rearranging forces exerted without any predetermined pattern of application and without any predetermined pattern of restraint of the resulting fiber movement, as by rolliing between the hands, bunching, etc. Viscose rayon is known to give excellent results in producing the fabric of this invention under most conditions, as is evidenced by the examples. While relatively long textile-type fibers above normal papermaking lengths, of close to normal textile length or over, say of about ¼ inch to 2 inches or longer, are preferred for textile applications, shorter fibers, below ¼ inch in length, within the papermaking range, may be used for these and other applications. It is preferred that the shorter papermaking fibers be unbeaten or substantially unhydrated if a textile-like fabric is desired. The choice of fiber length involves practical considerations and is determined to a large extent by the methods which must be used to produce the product desired. In this connection, shorter fibers of woodpulp, for instance, may be mixed with longer fibers with the result that the longer fibers will enhance the strength of the resulting fabric and the shorter fibers will decrease its cost. Fiber length is also an important factor affecting fabric strength, as described hereinbefore, and fiber lengths and materials should be chosen with this and other fabric characteristics in mind.

There are a number of suitable adhesive bonding materials or binders which may be employed to maintain the integrity of the web. For instance, water softenable materials including the following may be used: beaten cellulose jellies of woodpulp, caroa, ramie, etc.; natural gums including karaya, locust bean, gum arabic and others; starches; and synthetics, such as polyvinyl alcohol, carboxymethylcellulose, polyvinyl acetate, etc. Suitable binders, softenable by solvents other than water, are exemplified by polyvinyl chloride and polyvinyl butyral and their copolymers, while nonreversible binders which may be used if rearrangement occurs before they are set, include urea-formaldehyde and melamine-formaldehyde.

Having now described the invention in specific detail and exemplified the manner in which it may be carried into practice, it will be readily apparent to those skilled in the art that innumerable variations, applications, modifications, and extensions of the basic principles involved may be made without departing from its spirit or scope. Thus, the fabrics of the present invention may be laminated with other fabrics, with paper or with other materials, or employed in a host of ways that will be readily apparent to the skilled artisan.

The claims are:

1. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the approximate centers of each immediately adjacent pair of said spaced areas external rearranging forces comprising forces having opposed lateral translatory components of force acting parallel to the plane of the layer and cooperating rotational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

2. The method of producing a nonwoven fabric con-

taining spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of said fibers sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the approximate centers of each immediately adjacent pair of said spaced areas external rearranging forces comprising forces having opposed lateral translatory components of force acting parallel to the plane of the layer and cooperating vibrational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

3. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer locally throughout the area to be effected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the approximate centers of each immediately adjacent pair of said spaced areas external rearranging forces comprising forces having opposed lateral translatory components of force acting parallel to the plane of the layer and cooperating rotational and vibrational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

4. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to the increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the approximate centers of each immediately adjacent pair of said spaced areas mechanical rearranging forces comprising forces having opposed lateral translatory components of force acting parallel to the plane of the layer and other cooperating components of force selected from the group consisting of rotational components, vibrational components, and both rotational and vibrational components; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

5. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer in open position by local physical contact therewith throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism segments of adjacent fibers lying between said spaced areas, by applying to the approximate centers of each immediately adjacent pair of said spaced areas external rearranging forces comprising forces having opposed lateral translatory components of force acting parallel to the plane of the layer and other cooperating components of force selected from the group consisting of rotational components, vibrational components and both rotational and vibrational components; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

6. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer side-ways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers mechanical rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and cooperating rotational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into

mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

7. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltabie, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of said fibers sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers mechanical rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and cooperating vibrational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

8. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers mechanical rearranging forces having lateral translatory components of force acting parallel to the plane of the layer and cooperating rotational and vibrational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

9. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer in open position by local physical contact therewith throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers mechanical rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and other cooperating components of force selected from the group consisting of rotational components, vibrational components and both rotational and vibrational components; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

10. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the wetted layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and cooperating rotational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

11. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the wetted layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of said fibers sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and cooperating vibrational components of force; and at the same time moving individual fiber segments, by application of said translatory and co-

operating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

12. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the wetted layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and cooperating rotational and vibrational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

13. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the wetted layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers mechanical rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and other cooperating components of force selected from the group consisting of rotational components, vibrational components and both rotational and vibrational components; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

14. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and other cooperating components of force selected from the group consisting of rotational components, vibrational components, and both rotational and vibrational components; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

15. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and cooperating rotational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

16. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying be-

tween said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and cooperating rotational and vibrational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconected by fibers lying between the same.

17. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers mechanical rearranging forces having lateral translatory components of force acting parallel to the plane of the layer and other cooperating components of force selected from the group consisting of rotational components, vibrational components, and both rotational and vibrational components; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

18. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer in open position by local physical contact therewith throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and other cooperating components of force selected from the group consisting of rotational components, vibrational components, and both rotational and vibrational components; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

19. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the wetted layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased prallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and other cooperating components of force selected from the group consisting of rotational components, vibrational components, and both rotational and vibrational components; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

20. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises distributing a softenable adhesive binder through the layer to provide local support for the layer; while the binder is in a softened state, moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer an dother cooperating components of force selected from the group consisting of rotational components, vibrational components, and both rotational and vibrational components; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

21. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being

capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises distributing a liquid-softenable adhesive binder through the layer and wetting the layer; moving segments of fibers in said layer sideways from areas of the layer spaced laterally and lonigtudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and other cooperating components of force selected from the group consisting of rotational components, vibrational components, and both rotational and vibrational components; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

22. A continuous method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the wetted layer on a movable support; moving the layer through a rearranging zone upon said support; while said layer is moving through said rearranging zone, moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and cooperating vibrational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, continuing exposure of the layer to said forces in the rearranging zone moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same; and removing the resulting foraminous fabric from said movable support after the latter has passed through the rearranging zone.

23. A continuous method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises feeding the wetted fibrous layer between two endless movable belts; moving said belts through a rearranging zone while pressing said belts together into initial contact with thicker portions of said irregularly arranged layer of normally nonfeltable fibers and into subsequent contact with other portions of said layer; simultaneously causing the belts to oscillate with respect to each other in at least one direction measured in the plane of the fibrous starting layer to cause individual fibers in the layer to move laterally into closer proximity and increased parallelism with adjacent fibers and at the same time to cause individual fiber segments to move with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same; and removing the resulting foraminous fabric from between the endless belts.

24. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted layer of predominantly normally nonfeltable fibers arranged in overlapping, intersecting relation with one another, said layer including a liquid softenable adhesive binder distributed therein to provide local support for the layer, which comprises uniformly wetting the layer to soften the binder, bunching the wet layer and compressing it to distribute compressive forces throughout the area of the layer to be affected to move its fibers laterally with respect to other fibers they intersect and into further parallelism and closer proximity with adjacent fibers and at the same time to cause individual fiber segments to move with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

25. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted layer of predominantly normally nonfeltable fibers irregularly arranged in overlapping, intersecting relation with one another, which comprises supporting the wetted layer between means above and below said layer in initial contact with the upper and lower surfaces of said irregularly arranged layer of normally nonfeltable fibers at thicker portions of the layer and into subsequent contact therewith at other portions of the layer, and simultaneously oscillating said means with respect to one another in the plane of the layer to apply external forces thereto to move its fibers laterally with respect to other fibers they intersect and into further parallelism and closer proximity with adjacent fibers and at the same time to cause individual fiber segments to move with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

26. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted layer of predominantly normally nonfeltable fibers irregularly arranged in overlapping, intersecting relation with one another, which comprises supporting the wetted layer between means above and below said layer in initial contact with the upper and lower surfaces of said irregularly arranged layer of normally nonfeltable fibers at thicker portions of the layer and into subsequent contact therewith at other portions of the layer, at least one of said means presenting a resilient surface in contact with the layer, and oscillating said means with respect to one another in the plane of the layer to apply external forces thereto to move its fibers laterally with respect to other fibers they intersect and into further parallelism and closer proximity with adjacent fibers and at the same time to cause individual fiber segments to move with re-

spect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

27. The method of producing a nonwoven fabric according to claim 25, wherein the said layer includes a liquid softenable adhesive binder distributed throughout the layer and wherein said binder is softened during the application of said external forces.

28. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted base web of predominantly normally nonfeltable fibers irregularly arranged in overlapping, intersecting relation with one another, which comprises gripping opposite edges of said web and moving said edges alternately in opposite directions while keeping the web taut by maintaining substantially constant the distance between corresponding points on said opposite edges of the web, so as to repeatedly bias the web in opposite directions and bring its fibers into further contact with one another and form bundles of fiber segments, the fiber segments in said bundles having been moved laterally into closer proximity and increased parallelism with adjacent fibers of the layer and at the same time having been moved with respect to other fibers in the layer with which they overlap and intersect that any segment of said individual fibers so moved is in mechanical equilibrium in the most extreme lateral position into which it has been moved.

29. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable fibers, which comprises supporting the layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of said fibers sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity and increased parallelism with segments of adjacent fibers lying between said spaced areas by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and cooperating vibrational components of force; and at the same time moving individual fiber segments, by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby defining a plurality of holes surrounded by groups of fiber segments, said groups being interconnected by fibers lying between the same.

30. The method of producing a nonwoven fabric containing spaced holes defined by groups of fiber segments from a wetted layer of irregularly arranged, overlapping fibers in frictional engagement with one another, said fibers being capable of movement in response to applied rearranging forces and the predominant proportion thereof being normally nonfeltable, which comprises supporting the wetted layer locally throughout the area to be affected to maintain its integrity; while the layer is so supported moving segments of fibers in said layer sideways from areas of the layer spaced laterally and longitudinally from each other into closer proximity to and increased parallelism with segments of adjacent fibers lying between said spaced areas, by applying to the fibers external rearranging forces comprising forces having lateral translatory components of force acting parallel to the plane of the layer and cooperating components of force, at least one of said forces being applied repetitively; and at the same time moving individual fiber segments by application of said translatory and cooperating components of force, with respect to other fibers in the layer with which they overlap and are frictionally engaged so as to bring any segment of said individual fibers so moved into mechanical equilibrium in the most extreme lateral position into which it is moved by said fiber rearranging forces, the application of said forces moving segments of individual fibers as aforesaid into closer proximity and increased parallelism with adjacent fibers, thereby arranging groups of fiber segments defining a plurality of holes, the fiber segments in each of said groups being substantially parallelized and consolidated into yarn-like bundles and said groups being interconnected by fibers common to a plurality of groups.

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Du Pont Technical Bulletin X 142, September 1961.

UNITED STATES PATENT OFFICE

# CERTIFICATE OF CORRECTION

Patent No. 3,081,512 March 19, 1963

Hector W. Griswold

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 4, line 21, for "The" read -- This --; line 62, for "the", second occurrence, read -- they --; column 5, line 33, strike out "the"; line 65, for "In one embodiment of a fabric according to this in-" read -- In the fabric of this invention, the fibers are in me- --; column 6, line 41, after "bent" insert a comma; column 11, line 39, strike out "of", second occurrence; line 55, for "times," read -- times a --; same column 11, line 70, after "to", first occurrence, insert -- the --; column 17, line 38, for "effected" read -- affected --; column 18, line 33, after "parallelism" insert -- with --; column 24, line 20, for "prallelism" read -- parallelism --; line 56, for "an dother" read -- and other --; column 25, line 6, for "lonigtudinally" read -- longitudinally --; column 26, lines 32 and 33, for "pluarlity" read -- plurality --.

Signed and sealed this 29th day of October 1963.

(SEAL)
Attest:
ERNEST W. SWIDER
Attesting Officer

EDWIN L. REYNOLDS
Acting Commissioner of Patents