April 5, 1955 I. S. NESS ET AL 2,705,688

NONWOVEN FABRIC AND METHOD OF PRODUCING SAME

Filed April 7, 1952

4 Sheets-Sheet 1

Fig. 1.

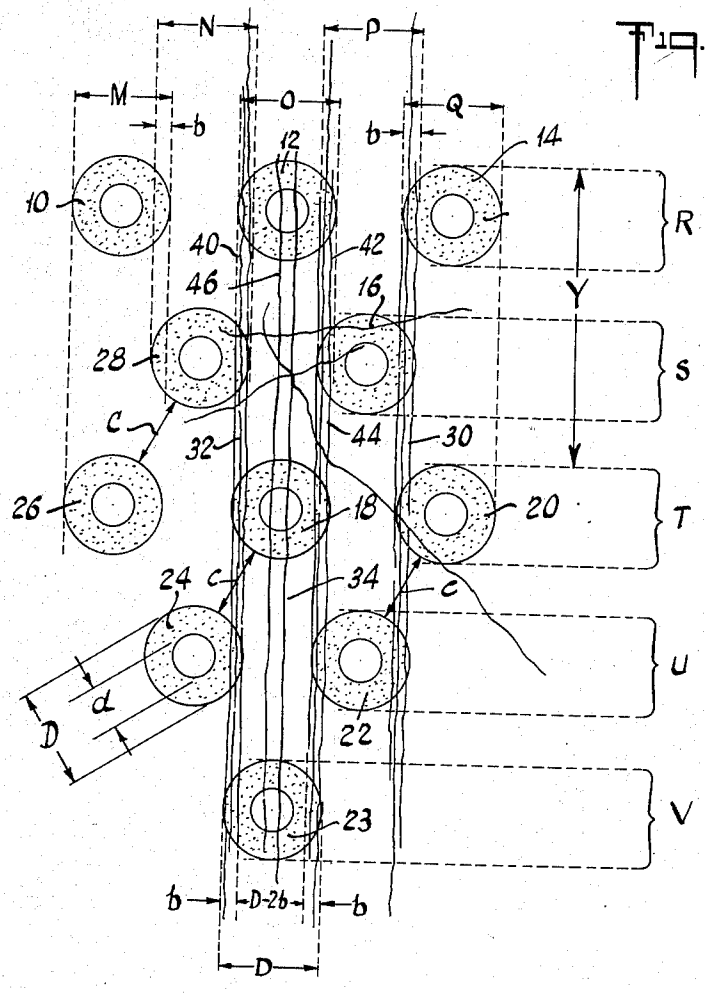
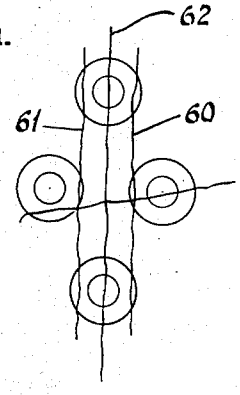


Fig. 1a.



INVENTORS:
IRVING S. NESS.
RONALD V. LINTS
BY DE WITT R. PETTERSON
Benton A. Buell
ATTORNEY:

April 5, 1955 I. S. NESS ET AL 2,705,688

NONWOVEN FABRIC AND METHOD OF PRODUCING SAME

Filed April 7, 1952

4 Sheets-Sheet 2

Fig. 2.

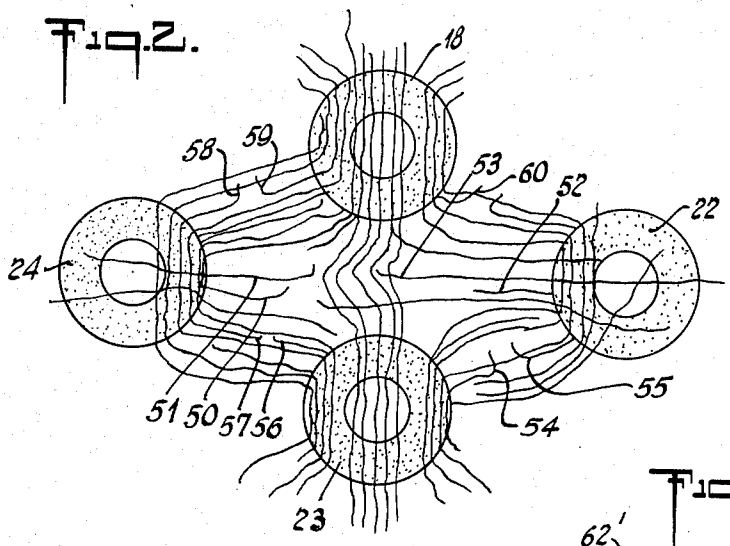


Fig. 2a.

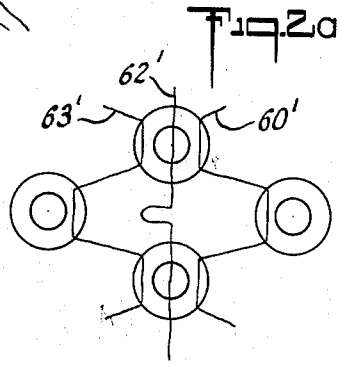


Fig. 3.

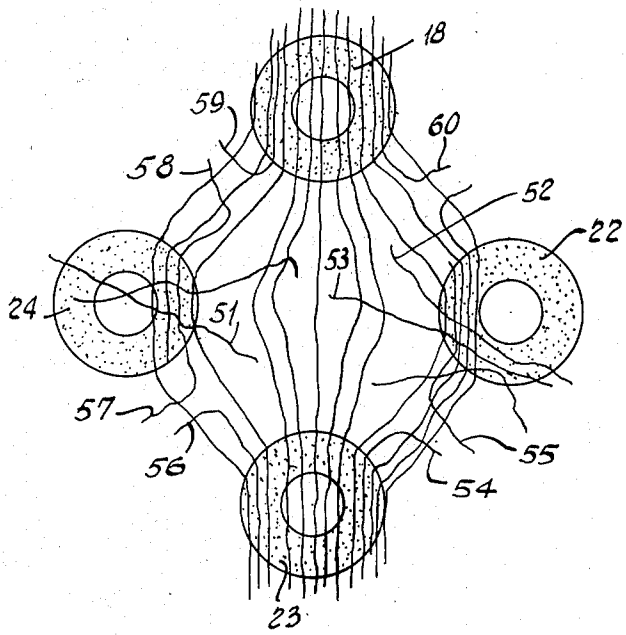
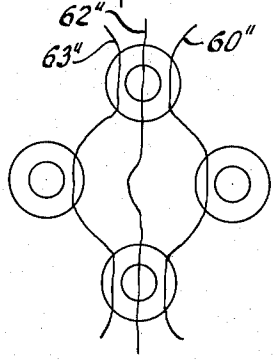


Fig. 3a.



INVENTORS:
IRVING S. NESS
RONALD V. LINTS
BY DEWITT R. PETTERSON
Benton A. Bull
ATTORNEY:

April 5, 1955 I. S. NESS ET AL 2,705,688

NONWOVEN FABRIC AND METHOD OF PRODUCING SAME

Filed April 7, 1952

4 Sheets-Sheet 3

Fig. 4.

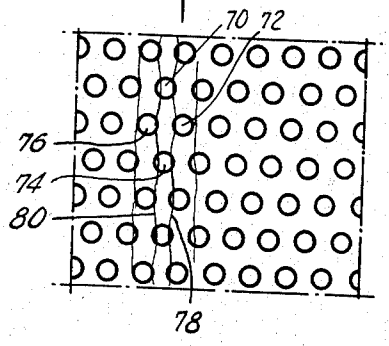


Fig. 5.

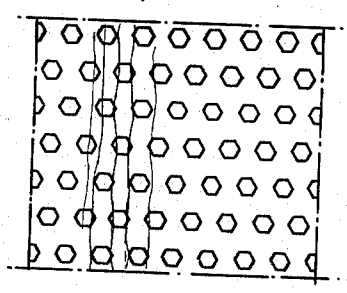
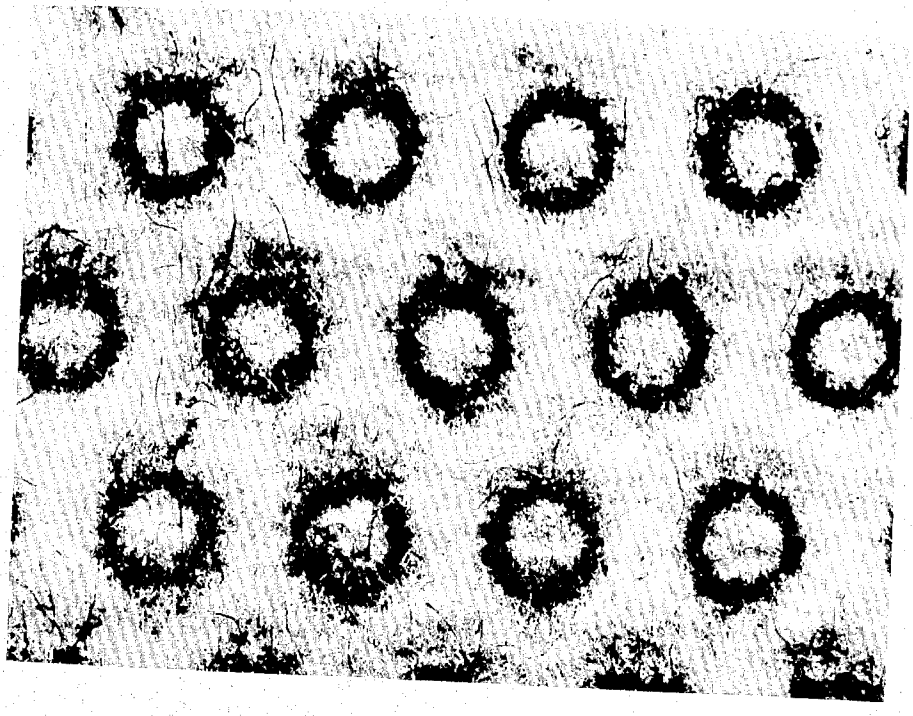


Fig. 6.



INVENTORS:
IRVING S. NESS
RONALD V. LINTS
BY DE WITT R. PETTERSON
Benton A. Bull
ATTORNEY

April 5, 1955 I. S. NESS ET AL 2,705,688

NONWOVEN FABRIC AND METHOD OF PRODUCING SAME

Filed April 7, 1952

4 Sheets-Sheet 4

Fig. 7.

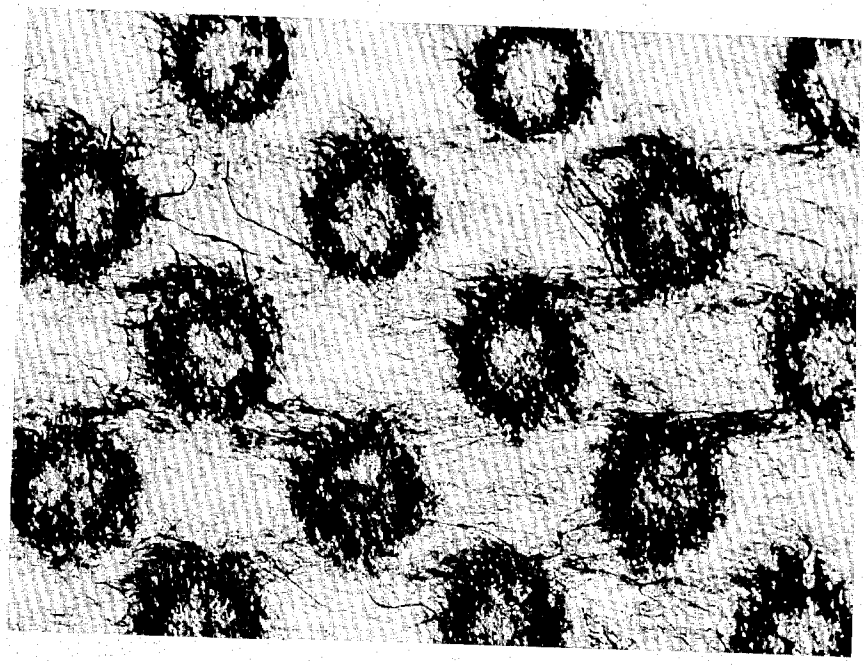
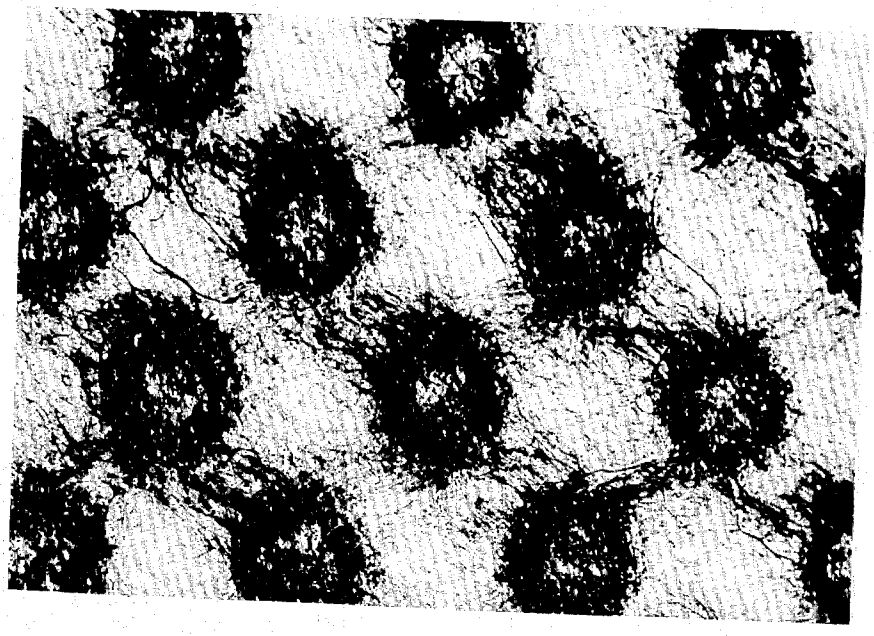


Fig. 8.



INVENTORS:
IRVING S. NESS
RONALD V. LINTS
BY DE WITT R. PETTERSON
Burton Q. Buee
ATTORNEY:

United States Patent Office 2,705,688 Patented Apr. 5, 1955

2,705,688

NONWOVEN FABRIC AND METHOD OF PRODUCING SAME

Irving S. Ness, Princeton, and Ronald V. Lints, Rahway, N. J., and De Witt R. Petterson, West Springfield, Mass., assignors to Chicopee Manufacturing Corporation, a corporation of Massachusetts

Application April 7, 1952, Serial No. 280,963

14 Claims. (Cl. 117—44)

The present invention relates to textile fabrics and their manufacture. More particularly, it is concerned with so-called "nonwoven" fabrics, i. e., fabrics produced from textile fibers without the use of conventional weaving or knitting operations. Although not necessarily limited thereto, the invention is of primary importance in connection with "oriented" nonwoven fabrics composed of unspun textile fibers, the major proportion of which are substantially "parallelized" or oriented predominantly in one direction.

Nonwoven fabrics of various types have become increasingly important in the textile field during the past decade, primarily because of their low cost of manufacture compared to fabrics formed by weaving or knitting spun fibers. Nonwoven fabrics are particularly suitable for applications where launderability is not a prerequisite, or low cost is an important consideration, especially in the case of finished products that are used once and then discarded, as for example in the manufacture of sanitary napkins; surgical dressings; casket liners; or disposable table napkins, hand towels, diapers, drapery fabrics, and the like.

Nonwoven fabrics are conventionally manufactured at the present time by producing a more or less tenuous web of loosely associated textile fibers disposed in sheet form (using any one of a variety of well-known procedures) and then subjecting the web or sheet to a bonding operation to anchor or bond the individual fibers together. The conventional base material for nonwoven fabrics is a web comprising any of the common textile-length fibers, or mixtures thereof, the fibers varying from approximately one-half inch to two inches in staple length. These fibers are customarily processed through any suitable machinery (e. g., the conventional cotton card) to form a web or sheet of loosely associated fibers, weighing from 100 to 4000 grains per square yard. This essentially two-dimensional web or sheet of fibers is produced continuously with the fibers substantially parallelized or oriented in the "machine direction," i. e., the direction in which the product moves continuously from the sheet-forming machine.

The bonding operation is accomplished in several different ways. One method is to impregnate the web over its entire width with various well-known bonding agents such as natural or synthetic resins. Such over-all impregnation produces a product of good longitudinal and cross strength. However, the product tends to be stiff and boardlike, possessing more of the properties of paper or board than of a woven textile fabric: for these reasons, over-all impregnated webs are unsatisfactory for many applications as textile fabrics.

It has also been known to print nonwoven webs with continuous straight or wavy lines or binder extending transversely across the web. The resulting nonwoven

fabric, as exemplified by the product disclosed in the Joshua Goldman Patent 2,039,312 and sold by the present assignee under the trade-mark "Masslinn," is far more satisfactory as a textile fabric in that the softness, drape and hand of the material more nearly approach those of a woven textile fabric. However, the Joshua Goldman type of product in the cross direction is characterized by relatively low elongation properties, low degree of elasticity, and a low energy absorption to break. For these reasons, the product upon stressing in a direction transverse to the direction of fiber orientation, tends to rip, tear or develop irregular holes due to irregular rupture of the continuous binder lines.

More recently discontinuous or "spot bonding" has been proposed. This type of bonding involves the use of tightly spaced, symmetrical solid dots or spots arranged in staggered relationship, as exemplified by the product disclosed in the Esther Goldman Patent 2,545,952. Such "spot bonded" products are flexible when the fabric is folded upon itself. However, flexibility has been attained at the sacrifice of other desirable properties. Thus, the Esther Goldman type of product, although excellent in respect to cross strength, has little if any "give" or elasticity in the cross direction; practically no cross elongation characteristics; low energy absorption to break in the cross direction; and lacks the desired degree of textile properties of hand loft and softness.

Generally speaking, the object of the present invention is to provide a nonwoven fabric that obviates the foregoing disadvantages. Expressed affirmatively, one of the objects of the invention is the provision of a nonwoven fabric characterized by the desirable properties of "spot bonded" fabrics but substantially free of the undesirable properties thereof.

A more specific object is the provision of a nonwoven fabric characterized by the following combination of properties:

1. High cross-elongation;
2. Good cross-strength;
3. Relatively high energy absorption to break in the cross-direction; and
4. Excellent textile-like properties such as softness or "hand," flexibility or "drape," and the three-dimensional appearance or "loft" characteristic of woven fabrics.

A further object is a nonwoven fabric that is additionally characterized by an inherent capacity to develop a more pronounced loft, softness and drape when stretched in the crosswise direction.

Another object is the provision of an oriented nonwoven fabric having a high capacity for fiber reorientation when stressed in the cross direction, with further improvement of its textile-like properties due to the development of a uniform puckering of some of the fibers coupled with a substantially uniform rupturing or pulling out of other fibers from the binder areas and the formation of a uniformly napped or downy-like surface.

Still another object is a nonwoven fabric characterized by a pronounced loft, drape and hand; a uniformly open, net- or lace-like reticular pattern, and a uniform downy-like surface.

Still another object is the provision of a novel binder pattern or design that is capable of imparting the foregoing properties to an unbonded oriented textile web.

An additional object is to provide a simple, commercially feasible, and economical method of manufacturing improved nonwoven fabrics having the properties mentioned above.

Other objects and advantages of the invention will become apparent as the description progresses in connection with the several figures of the drawing wherein:

Figs. 1 and 1-A are plan views, on an enlarged scale, diagrammatically showing relaxed portions of a nonwoven fabric having a binder pattern in accordance with one embodiment of the present invention;

Figs. 2 and 2-A are similar views, also on an enlarged scale, diagrammaticaluly showing portions of the fabric of Figs. 1 and 1-A when uniformly stretched or extended beyond its elastic limit in a direction transverse to the direction of fiber orientation;

Figs. 3 and 3-A are similar views, also on an enlarged scale, diagrammatically showing portions of the fabric of Figs. 1 and 1-A, after the fabric has been uniformly stretched or extended beyond its elastic limit in a direction transverse to the direction of fiber orientation, and then permitted to relax;

Fig. 4 is a plan view, approximately full scale, showing the geometry of the binder pattern in accordance with a preferred embodiment of the present invention;

Fig. 5 is a similar view, also approximately full scale, showing an alternative binder pattern in accordance with the present invention and involving symmetrical hexagons;

Fig. 6 is a photomicrograph of a preferred embodiment, before being stretched;

Fig. 7 is a photomicrograph showing the preferred embodiment in a state of uniform tension in the cross direction; and

Fig. 8 is a photomicrograph showing a portion of the same fabric after it has been uniformly stretched beyond its elastic limit and then permitted to relax.

We have found that the foregoing objects may be attained in accordance with the present invention, one aspect of which involves a web of oriented textile fibers bonded together by a novel binder pattern that may conveniently be characterized as articulated, multiannulate bonding, acting on the "lazy tongs" principle, i. e., composed of a multiplicity of ringlike binder areas that are "hinged," "jointed" or "articulated" with respect to each other and so related as to give the web a high degree of lateral extensibility.

In annulate bonding, according to the present invention, discrete, physically separated binder areas are utilized, each area consisting of an inherently elastic, compressible, closed linear figure or curve. The closed figure may be polyhedral, cyclic, ring- or doughnut-shape in configuration and preferably should have a single point of symmetry. In any event, all such cyclic structures, whether perfectly symmetrical or substantially so, will hereinafter be termed "annular." Each discrete, annular area may be likened to an "atoll" or coral reef island comprising, so to speak, a small "lagoon" of unbonded lengths of parallelized fibers entirely surrounded by binder, the "atoll" itself being an "island" in a "sea" of otherwise unbonded lengths of fibers.

The atoll analogy suggested above is helpful in describing the geometry of the binder area. However, like all analogies, it has its limitations: it is not useful in explaining the "dynamics" or "kinematics" of the system when an annulate bonded, oriented web according to our invention is subject to extensional stress. Accordingly, in the ensuing discussion, the atoll analogy will be used at times in describing the system in a state of rest, while entirely different analogies will be suggested in describing the system in motion. It should be clearly understood, however, that the present invention is in no way dependent upon the aptness or inaptness of any analogies that are herein suggested for the purpose of relating the invention to more familiar concepts.

Referring now particularly to Fig. 1, the over-all binder pattern of the present invention comprises a multiplicity of discrete, physically separated, inherently elastic, annular binder areas **10, 12, 14, 16, 18, 20, 22, 23, 24, 26** and **28**, infused locally into the body of the web. The total lateral surface of the binder areas should not substantially exceed about 35% of the lateral surface of the web, otherwise desirable textilelike properties and cross-extensibility will be substantially sacrificed.

The binder areas or zones are uniformly disposed, preferably in parallel courses or rows R, S, T, U and V extending across the web in a direction preferably transverse to the direction of orientation of the fibers. The binder areas in one course (e. g., T) should be positioned in staggered relationship with respect to corresponding areas in the courses immediately above and below it (e. g., S and U) and so dimensioned and positioned that every imaginary line parallel to the direction of fiber orientation passes through at least two isolated binder areas within a distance equal to the average length of the fibers composing the web and in the area or zone of overlap, through at least three of the binder areas. This is most conveniently accomplished by disposing the binder areas not only in horizontal courses or rows (R, S, T, U and V) extending across the oriented fibers of the web, but also in a series of overlapping columns (M, N, O, P and Q) that are substantially parallel to the direction of fiber orientation. Such columns should have a width (D) equal to the transverse width (i. e., diameter) of each binder area, and should overlap by a distance (*b*) equal to at least two hundredths (0.02) of an inch. Overlap (*b*) in excess of 0.05 has no appreciably beneficial effect on cross strength of the binder design.

By virtue of the foregoing relationship between binder areas, each area is separated from every other area by fiber lengths that are otherwise substantially unbonded. Nevertheless, each annular area (e. g., **18**) is "hinged," "jointed," or "articulated" with respect to the two adjacent-most areas (e. g., **16** and **28**, **22** and **24**) in each of the adjacent courses, (e. g., S and U), i. e., in the courses immediately above and immediately below the area in question. "Articulation" between corresponding areas in adjacent courses is thus effected by bundles of parallelized, otherwise unbonded lengths of fibers interconnecting the binder areas in question. Each bundle has a width approximately equal to the extent of the overlap (*b*) of the overlapping columns and is of the order of about 0.02 to about 0.05 of an inch.

The right hand side of any given binder area (e. g., **18**) will thus be "jointed" or "articulated" with the left hand sides of the closest areas (e. g., **16** and **22**) in the courses (S and U) immediately above and immediately below it. The "joint" or "articulation" consists of a bundle or band of fibers (e. g., **44**) about 0.02 to about 0.05 of an inch in width. On the left hand side of the given binder area (e. g., **18**) the relationship of the fibers to the given area and to the adjacent-most "atolls" immediately above and below it will, in effect, be the mirror image or reflection of the relationship on the right hand side of the same area. In other words, a bundle of fibers (e. g., **32**) having a width equal to the extent of overlap (*b*) will interconnect the left side of the given area (**18**) with the right side of the two areas (**28** and **24**) immediately above and below it and closest to that side. The middle portion of the given binder area will be connected by a bundle of fibers (**46** and **34**) to the closest areas (**12** and **23**) in the second courses (R and V) above and below it. Thus, the third bundle (**46** and **34**) of parallelized fibers hingedly interconnects corresponding areas (**12** and **23**) in alternate courses (R and V), passing through the central portion of each binder area.

In order to understand the dynamics or kinematics of this binder arrangement, a wholly different analogy may be helpful. When an annulate bonded web as described above is stretched in a crosswise direction, its action is suggestive of a "parallel-motion mechanism" or "parallelogram-type device" familiar as "lazy tongs," "collapsible gates" or the "pantograph" device utilized in drafting. Referring to Fig. 1, in the web of the present invention, the bundles of parallel fibers (e. g., **32, 40, 42** and **44**) interconnecting the binder areas (e. g. **12, 16, 18** and **28**) in three adjacent courses (R, S and T) may be likened to the linkages in a pantograph device, while the annular binder areas (**12, 16, 18** and **28**) act, in effect, as the pivotal joints holding the links of the parallel motion mechanism together. The bundle of parallel fibers (**46**) interconnecting corresponding areas (**12** and **18**) in alternate courses (R and T) tends to pucker as the web is stretched in the cross direction. This puckering of fibers (**46**) connecting diagonally opposed points (**12** and **18**) in the parallelogram (**12, 16, 18** and **28**) tends to restrain further extension of the "pantograph" and to restore the extended "pantograph" to its original unextended position.

Changing the metaphor once again, the original unextended web (Fig. 1) may be likened to the "cut blank" from which "expanded metal" is made, while the extended web of Figs. 2 and 3 corresponds to "expanded metal" in

various stages of expansion. From this point of view, the product of Fig. 3 may be characterized as an "expanded nonwoven fabric," expansion being accompanied by a major change in orientation of fibers in the original web.

Regardless of the aptness of any of the analogies suggested above, the individual annular binder areas and the fibers comprising the web are so positioned and interrelated as to interact in a novel manner when the web is stressed in a crosswise direction. By virtue of this mode of interaction, an extraordinary combination of properties is attainable in the bonded web, including among other characteristics, high cross elongation coupled with good cross strength and high energy absorption to break. By virtue of the great proportion of lateral surface that is free of binder area, these properties are attained without sacrifice of textile-like properties such as hand, drape or loft. In addition, when the thus bonded web is stretched in the crosswise direction beyond its elastic limit, the web expands uniformly into an open, lacelike, reticular fabric.

An interesting and profound change in fiber orientation takes place as the web is extended. This change is diagrammatically shown in step-wise fashion in Figs. 1–A, 2–A and 3–A, which correspond to the state of the web in Figs. 1, 2 and 3, respectively. In Fig. 1–A, the bulk of the fibers are substantially parallelized or oriented, as represented by the lines **60**, **61** and **62**. In Fig. 2–A, the fiber **60'** tends to describe a sinuous, serpentine or zig-zag pattern. Fiber **61'** is substantially its mirror image or reflection; and fiber **62'** between the binder areas is buckled up out of the plane of the binder areas. In other words, during extension some of the unbonded lengths of fiber (Figs. 2–A and 2–B; 3–A, **62'** and **62''**) between the discrete binder areas will "pucker" or bend out of the original plane of the fabric, forming a uniformly "puckered" or "quilted" appearance. Nonoriented fibers interconnecting the areas will be ruptured or pulled out of the binder areas during lateral elongation of the fabric. The ends of these broken fibers (Figs. 2 and 3; **51**, **52**, **53**, **54**, **55**, **56**, **57**, **58**, **59** and **60**) tend to move out of the plane of the fabric, forming a uniform nap or down. The puckered fibers plus the downy nap both impart a high degree of loft and softnes to the resultant fabric, rendering it especially attractive in applications where these properties are important.

Referring again to Figs. 1 and 2, the band of fibers in the overlap area B are of a strong, flexible nature, and are held together by the resin areas. Since the fiber band strength can be increased by increasing the extent of overlap *b*, the strength of the material will depend in part upon the degree of overlap (*b*). Within limits any factor tending to increase overlap will tend to increase cross strength. The degree of overlap (*b*, Figs. 1 and 2) should not be less than about 0.02 of an inch and preferably should lie between 0.03 and 0.05 of an inch. The factors effecting cross strength comprise the interrelated variables Y and *b*, and the variable D.

The elongation of the fabric is influenced by the inter-binder area distances D, Y and C. In general, the greater these distances, the greater the elongation. However, it is characteristic of this annular binder area pattern to impart good cross elongation properties regardless of small changes in D, Y and C, provided the overlap *b* is sufficient.

Energy absorption to rupture is indicative of the amount of work necessary to rupture the material and is approximately equal to one-half the breaking load times the elongation. In general, previous fabrics have been characterized by either high strength and low elongation, or low strength and high elongation. Both of these give relatively small and approximately equal work loads of energy absorption capacity. The present invention permits substantial increasing the work load by achieving a proper balance of cross strength and elongation. This property is controlled by the factors effecting the two properties discussed above.

Development of a uniform lace-like or reticular pattern obtained by uniformly streaching a web bonded in accordance with the invention is effected by the same factors mentioned in elongation, i. e., X, Y and C. The uniformity depends upon the symmetry of the applied pattern, while X, Y and C determine the extent of openness, or lace-like structure. The more extendible, the more open the network.

The qualitative textile fabric properties of flexibility, drape, softness, and three-dimensional effect, or loft are enhanced by increasing the inter-resin area distances X, Y and C and by the ratio of the internal diameter (*d*) to the external diameter (D) of the annular binder area. A basic factor in softness is of course the extent to which the lateral surface of the web is covered by binder. Generally speaking, desirable textile properties are attained to a substantial degree only if substantially less than 35% of the lateral surface of the web is bonded. With the present binder pattern the binder may be, and preferably is, used sparingly, with the bonded areas covering 5–25% of the total area of the web or sheet. The three-dimensional effect, or loft, is enhanced by the ability of the fabric to be extended crosswise with development of a uniform lace-like structure. The amount of loft, or three-dimensional effect is controlled by the shape of the reticular fabric structure which is, in turn, controlled by the interannular distances D, Y and C, and overlap (*b*).

Referring now to Figs. 4 and 5, both of these are plan views, roughly full scale, showing a portion of a typical annulate binder pattern in accordance with the invention. In Fig. 4, the annuli are completely symmetrical rings while in Fig. 5 the annuli are substantially symmetrical hexagons. In both figures, the centers of the annuli are substantially free of binder, with the result that the properties of the original web are not detrimentally affected by the binder in respect to softness, drape and hand. Thus the annulate binder pattern imparts cross strength, cross elongation and cross elasticity to a web that originally was devoid of these characteristics, with minimal loss of the textile-like properties of the original web. In addition, during manufacture, the annular binder areas afford a substantial saving of binder and render it much simpler to "doctor" the print roll used to imprint the binder pattern on the web.

Figs. 6, 7 and 8 are photomicrographs of a portion of the same fabric having the preferred binder pattern of the present invention. Fig. 6 shows the fabric in the original unextended state. Fig. 7 shows the same fabric when uniformly stretched beyond its elastic limit and held under tension. Fig. 8 shows the fabric of Fig. 7 after the tension has been relieved and the fabric has been permitted to relax. The sinuous bands of fibers in the extended web are discernible in Figs. 7 and 8. In these photomicrographs, colored binder was employed in order more clearly to show the binder pattern against the white background of unbonded areas of fiber. In many applications, coloring of the binder or the web, or both, may be desirable, while in others it may be preferable to employ a binder of the same color as the web.

In order still more clearly to disclose the manner in which the invention may be carried into practice, specific examples of preferred embodiments will hereinafter be described in detail. It should be understood however that this is done purely by way of example and not for the purpose of delineating the breadth of the invention or limiting the ambit of the appended claims.

In carrying the present invention into practice, any of the conventional web-forming, printing and drying operations, well known in the art, and any of the conventional binder media of the prior art may be used. Typical procedures and binder media applicable in the practice of the present invention include those disclosed in the Joshua Goldman Patent 2,039,312 or the Joseph Goldman Patent 2,407,548, or the Esther Goldman Patent 2,545,952. These operations and media, being well known and conventional, need not be described herein, since reference may readily be made to the prior art, including the patents mentioned.

Assuming the use of an engraved printing roll of the intaglio type (as described, for example, in the Esther Goldman patent) the surface of the print roll is engraved with a pattern such that, when the binder carried in the binder-receiving recesses is transferred to the base fabric, it imprints thereon an annulate binder pattern corresponding to any one of those shown in the several figures of the drawings and having approximately the dimensions given in Table I.

The properties of typical finished webs are summarized in Table I. The binder employed, unless otherwise stated, comprised an aqueous emulsion of polyvinyl acetate. The base web consisted of a card web of rayon fibers of two and one-half inches average staple length, with an average weight per square yard as shown in the table.

The average grain weight after printing is also shown in Table I.

Table I

Code No.	Pattern Geometry—Dimensions					Web Weight in Grains		Properties		
	D (In.)	*d* (In.)	*b* (In.)	Y (In.)	C (In.)	Before Printing (gr./yd.²)	After Printing (gr./yd.²)	Cross Strength [1] (#/in. Width)	Elongation to Break [2] (Percent)	Energy Absorption to Break [3] (In.#)
H-C-1	0.095	.003	0.02	0.31	0.075	660	760	1.3	70	1.3
H-B-4	0.135	.007	0.04	0.38	0.075	660	790	1.3	65	1.3
RV-302	0.16	.003	0.04	0.44	0.06	660	750	1.4	70	1.4

[1] ASTM—D39-49. Section 12.
[2] ASTM—D39-49. Section 14.
[3] Energy Absorption to Break; the area underneath the Load-Elongation curve, and approximated by

$$E.\ A.=\frac{\text{Cross Strength} \times \text{Percent Elongation}}{2}$$

Further defined for fibers as "toughness"; see "Textile Fibers, an Engineering Approach to their Properties and Utilization," by H. De Witt Smith.
ASTM Proceedings 44, 543-592 (1944).

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. We therefore intend to be limited only in accordance with the appended patent claims.

The term "textile fibers" as used herein includes the conventional textile fibers which are capable of being spun into yarn and woven into cloth. Generally speaking this includes fibers whose average length is about one-half inch or longer.

We claim:

1. A web of oriented fibers bonded together by an articulated multi-annulate binder pattern, the individual annuli of which are separated from but hingedly interconnected with each other by substantially unbonded bands of fibers, said binder pattern occupying a minor portion of the surface area of said web, said fibers coacting with said annuli effectively as interconnected parallelograms that are collapsible on the "lazy tongs" principle.

2. A web of fibers oriented predominantly in one direction, the fibers lying in parallelism being bonded together by a uniform binder pattern occupying a minor portion of the lateral surface of said web and comprising a multiplicity of annular areas of binder, uniformly separated from each other by substantially unbonded areas of fiber and arranged uniformly in overlapping columns that are parallel to each other and to the direction of fiber orientation, said binder pattern being such that within the overlap zone every line parallel to the direction of fiber orientation passes through at least three binder areas within a distance along said line equal to the average length of the fibers composing the web.

3. A web of fibers oriented predominantly in one direction, the fibers lying in parallelism being bonded together by a symmetrical pattern occupying not substantially more than about 35% of the lateral surface of said web and comprising a multiplicity of discrete, annular areas of binder, uniformly separated from each other by a substantially unbonded area of fiber and arranged in parallel, uniformly overlapping columns, said symmetrical binder pattern being such that every line drawn parallel to the direction of fiber orientation within a given overlap formed by two overlapping columns, intersects at least one binder area lying predominantly in one column and at least two elongated areas lying predominantly in the other column, within a distance in the direction of fiber orientation equal to the average length of the fibers comprising the weft.

4. A web of carded fibers substantially all of whose fibers lying in parallelism are bonded together by a binder infused into the body of the web to form an annulate binder pattern occupying only a minor proportion of the total lateral surface of the web, said binder pattern comprising a series of parallel, uniformly spaced, broken lines of binder, each line in the series comprising annular areas of binder uniformly separated by spaces that are substantially free of binder, said parallel broken lines being inclined obliquely with respect to the direction of fiber alignment in the web; a second series of parallel, uniformly spaced broken lines of binder, each line in the second series likewise comprising annular areas of binder uniformly separated by spaces that are substantially free of binder, said second series of lines also being inclined obliquely with respect to direction of fiber alignment, but in the opposite sense or direction; said first series of parallel broken lines being so disposed with respect to said second series of parallel broken lines that the annuli of one series lie in the intersegmental spaces of the other series and so that every straight line parallel to the direction of fiber alignment intersects at least two annuli within a distance in the direction of fiber orientation equal to the average length of the fibers composing the web.

5. A web of carded fibers containing substantially parallelized fibers bonded together by a discontinuous but articulated multiannulate binder pattern infused locally into the body of said web and occupying less than 35% of the lateral surface thereof, said web being characterized by substantial capacity for expansion into a uniformly open, lacelike, reticular structure when uniformly stretched in a direction across said parallelized fibers.

6. A web of carded fibers containing substantially parallelized fibers bonded together by a discontinuous but articulated multiannulate binder pattern infused locally into the body of said web and occupying less than 35% of the lateral surface thereof, said pattern comprising a multiplicity of annular binder areas uniformly disposed in staggered relationship in parallel courses extending across said parallelized fibers, said web being characterized by substantial capacity for expansion into a uniformly open, lacelike, reticular structure when stressed in a direction across said parallelized fibers.

7. A laterally extensible web of carded fibers containing substantially parallelized fibers bonded together by a discontinuous but articulated multiannulate binder pattern fused locally into the body of said web and occupying less than 35% of the lateral surface thereof, said pattern comprising a multiplicity of annular binder areas uniformly disposed in staggered relationship in parallel courses extending transversely across said parallelized fibers, each area being separated from every other area by substantially unbonded lengths of fibers but articulated with the adjacent-most areas in adjacent courses by a bundle of parallelized fibers, said web being characterized by substantial capacity for elongation when stressed in a direction across said parallelized fibers and by its capacity to develop a uniformly open, lacelike, reticular structure.

8. The web of claim 7 wherein said bundle of parallelized fibers has a width of at least 0.03 inch.

9. A web of carded fibers containing substantially parallelized fibers bonded together by a discontinuous but articulated multiannulate binder pattern infused locally into the body of said web and occupying less than 35% of the lateral surface thereof, said pattern comprising a multiplicity of annular binder areas uniformly disposed in parallel courses extending transversely across said parallelized fibers, the areas in one course being disposed in staggered relationship with respect to the areas in ad-

jacent courses, each area being separated from every other area by substantially unbonded lengths of fibers but articulated with the adjacent-most areas in adjacent courses by a bundle of otherwise unbonded lengths of parallelized fibers having a width of at least 0.03 inch, said web being characterized by substantial capacity for elongation when stressed in a direction across said parallelized fibers with development of a uniformly open, lacelike, reticular structure.

10. A nonwoven fabric comprising a multiplicity of sinuous bands disposed side by side in opposition to each other and in a common plane, each band being the substantial reflection of the two adjacent bands on either side, with their points of apposition in juxtaposition; each of said bands comprising a multiplicity of unspun textile fibers substantially oriented with the sinuous band in which they are disposed; said bands being bonded together into a self-sustaining reticular structure by annular binder areas infused locally into the fibers of each pair of adjacent bands at their juxtaposed points of apposition.

11. A nonwoven fabric having a substantially open, lacelike, reticular structure, said fabric comprising two series of uniformly spaced substantially symmetrical, sinuous bands of fibers arranged in opposed adjacent pairs that are approximately the mirror image or reflection of each other; each of said bands comprising a multiplicity of unspun textile fibers substantially oriented with the axis of the band in which they are disposed; said bands being bonded together in a self-sustaining web by discrete, annular areas of binder infused locally into said bands, each area bonding a pair of bands at their points of apposition.

12. A nonwoven fabric having a substantially uniform, open, lacelike, reticular structure, said fabric comprising two series of uniformly spaced, substantially symmetrical, sinuous bands of fibers arranged in opposed adjacent pairs that are approximately the mirror image or reflection of each other; a third series of bands of fibers one member of which series is interposed between each of said opposed pairs of sinuous bands of the first two series; each of said bands in the three series comprising a multiplicity of unspun textile fibers substantially oriented with respect to the band in which they are disposed; said bands being bonded together into a self-sustaining web by discrete, annular areas of binder infused locally into said bands, each area bonding a pair of bands at their points of apposition.

13. A nonwoven fabric having a substantially uniform, open, lacelike, reticular structure, said fabric comprising two series of uniformly spaced, substantially symmetrical, sinuous bands of fibers arranged in opposed adjacent

pairs that are approximately the mirror image or reflection of each other; a third series of bands of fibers one member of which series is interposed between each of said opposed pairs of sinuous bands and contiguous thereto at their points of apposition, a portion of the length of each member of said third series of bands, intermediate the points of apposition of said opposed pairs, lying out of the plane thereof; each of said bands of the three series comprising a multiplicity of unspun textile fibers substantially oriented with respect to the band in which it is disposed; said bands being bonded together into a self-sustaining web by discrete, annular areas of binder infused locally into said series of bands and bonding one member of each of said series of bands at their points of apposition.

14. A nonwoven fabric having a substantially uniform, open, lacelike, reticular structure, said fabric comprising two series of uniformly spaced, substantially symmetrical, sinuous bands of fibers arranged in opposed pairs that are approximately the mirror image of each other; a third series of bands of fibers one member of which is interposed between each of said opposed pairs of sinuous bands, a portion of the length of said third band being contiguous with said pair of sinuous bands at their points of apposition while another portion of the length of said third band intermediate said points of apposition lies out of the plane of said opposed pairs; each of said bands comprising a multiplicity of unspun textile fibers substantially oriented with respect to the axis of the band in which it is disposed; said bands being bonded together into a self-sustaining web by discrete, annular areas of binder infused locally into said bands at their points of apposition and embracing a portion of the length of one member of each of said series of bands at each of said points of apposition.

References Cited in the file of this patent

UNITED STATES PATENTS

1,507,949	Angier	Sept. 9, 1924
1,831,403	Woodward	Nov. 10, 1931
2,039,312	Goldman	May 5, 1936
2,207,279	Alderfer	July 9, 1940
2,407,548	Goldman	Sept. 10, 1946
2,498,197	Baxter	Feb. 21, 1950
2,545,952	Goldman	Mar. 20, 1951
2,550,686	Goldman	May 1, 1951

FOREIGN PATENTS

549,254	Great Britain	Nov. 12, 1942
500,020	Belgium	Dec. 30, 1950