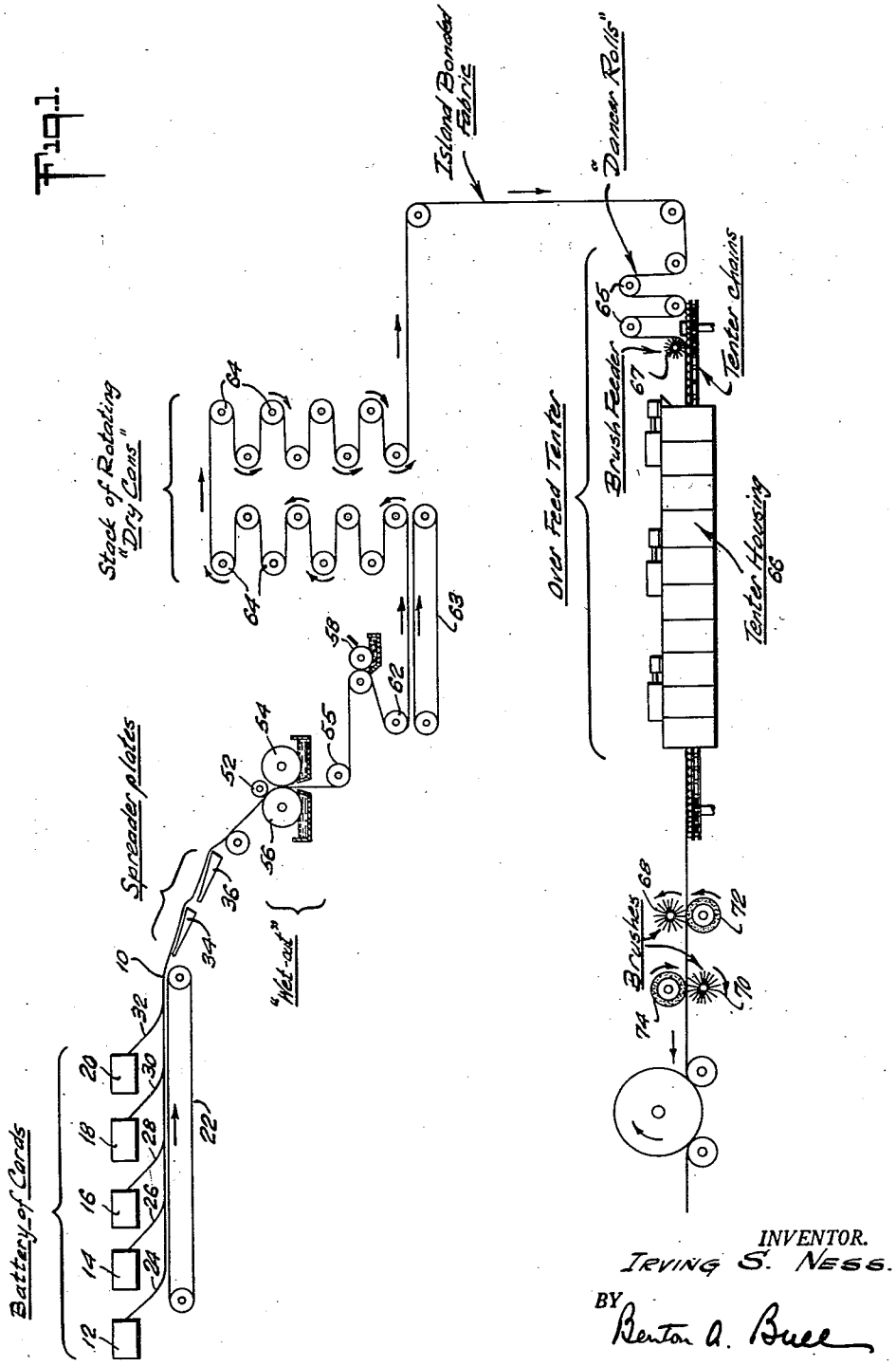
June 4, 1957 I. S. NESS 2,794,750

NON-WOVEN FABRIC AND METHOD OF PRODUCING SAME

Original Filed April 7, 1952 2 Sheets-Sheet 1

Fig. 1.



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NON-WOVEN FABRIC AND METHOD OF PRODUCING SAME

Original Filed April 7, 1952 2 Sheets-Sheet 2

Fig.2.

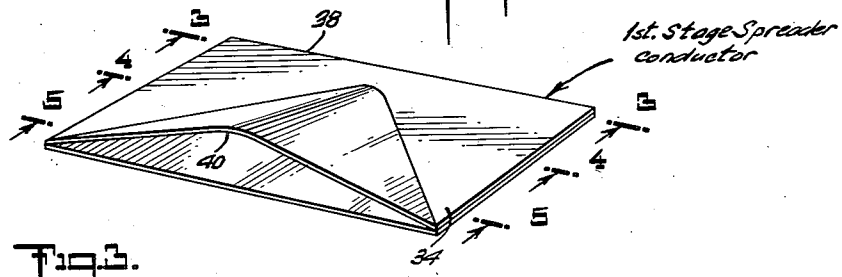


Fig.3.



Fig.4.



Fig.5.

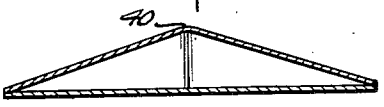


Fig.6.

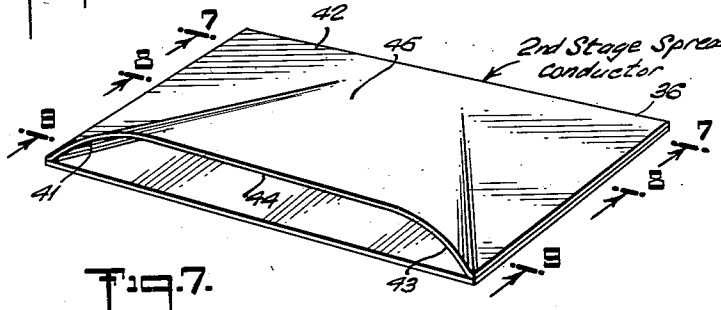


Fig.7.

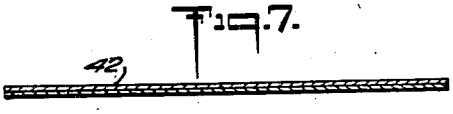


Fig.8.



Fig.1A

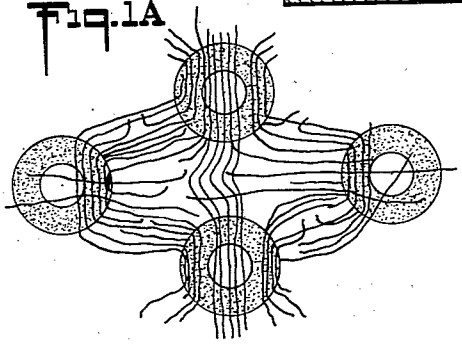
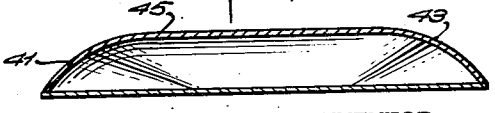


Fig.9.



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United States Patent Office 2,794,750 Patented June 4, 1957

2,794,750

NON-WOVEN FABRIC AND METHOD OF PRODUCING SAME

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Continuation of abandoned application Serial No. 280,967, April 7, 1952. This application January 31, 1955, Serial No. 484,994

18 Claims. (Cl. 117—7)

This application is a continuation of our copending Serial No. 280,967, filed April 7, 1952, now abandoned.

The present invention relates to textile fabrics and is more particularly concerned with so-called "nonwoven" fabrics, i. e., fabrics produced from textile fibers without the use of conventional weaving or knitting operations. The invention is of primary importance in connection with "oriented" nonwoven fabrics composed of unspun textile fibers, the major proportion of which are substantially oriented or predominantly "parallelized" in one direction.

Nonwoven fabrics are conventionally manufactured at the present time by producing a more or less continuous web of loosely associated textile fibers disposed in sheet form (using any one of a variety of well-known procedures) and then bonding the sheet or web 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., a conventional cotton card) to form a web or sheet of loosely associated fibers weighing approximately 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., in the direction in which the product moves continuously from the sheet-forming machine. In such a web, the degree of fiber orientation may range from about 70% to about 90%; in other words, from about 10% to about 30% of the fibers will be "nonoriented" or randomly disposed while the remainder will be substantially parallelized in the machine direction.

The bonding operation by which such a web is converted into a fabric may be accomplished in one of several different ways. One way is to impregnate the web over its entire width with various well-known bonding agents such as natural or synthetic resins. Another method is to print nonwoven webs with continuous straight or wavy lines of binder extending transversely across the web. A more recent innovation (hereinafter referred to as "island bonding") involves imprinting on the web a discontinuous binder pattern comprising discrete, physically separated areas of binder arranged in a staggered pattern such that each area is "hinged," "jointed," or "articulated" with its neighboring areas by a bundle of unbonded lengths of substantially parallel fibers. In such an island bonded fabric every line parallel to the direction of fiber orientation passes through at least three discrete binder areas within a distance along said line equal to the average length of the fibers comprising the web. Where the individual "islands" of binder are very close together so that the binder covers a major proportion of the lateral surface of the web, the resulting fabric has substantial tensile strength in the cross direction, with very little, if any, elastic or cross-elongation

characteristics. The fabric is flexible in that it may be folded or bent back and forth upon itself. However, it may be likened to a fabric made from a multiplicity of interlocking metal plates: It is strong but inelastic, and lacks the softness, loft, and hand of a typical textile fabric. Where, however, the individual "islands" are physically separated from each other, but nevertheless hingedly interconnected by bands of unbonded lengths of fibers, with the binder covering only a minor proportion of the lateral surface of the web (not substantially in excess of about 35%), desirable textile-like properties are obtainable, together with a number of interesting and important physical properties, the nature and degree of which are dependent in part upon the particular binder geometry employed. If the individual binder areas or "islands" are elongated, particularly if their major axes are inclined obliquely with respect to the direction of fiber orientation, and if the binder area does not cover substantially more than about 35% of the total lateral surface of the web, the resulting fabric may be stretched crosswise to a substantial degree; yet it possesses a high degree of elasticity (i. e., instantaneous recovery or "snap-back") when the stress in the crosswise direction is released.

If the individual binder areas or "islands" are substantially symmetrical and the lateral surface covered by the binder areas does not substantially exceed about 10–25% of the total lateral surface of the web, the fabric is characterized by a pronounced capacity for lateral extension when the fabric is stressed in the cross direction. A fabric of this type wherein the binder areas are annular or ringlike in configuration is particularly attractive as a textile substitute because of softness, loft, and drape.

The present invention relates to island bonded fabrics of the foregoing general types. Although not limited thereto, it is particularly concerned with island bonded fabrices that are characterized by pronounced capacity for lateral extension when stressed in the cross direction. In other words, the invention is especially applicable to island bonded fabrics made from substantially oriented webs, wherein the physically separated but hingedly interconnected binder areas occupy not substantially more than about 35% of the total lateral surface of the web.

When an island bonded web of high lateral extensibility is stretched crosswise, three highly significant changes take place in the fabric.

1. In the first place, a major reorientation of the originally parallelized fibers is effected with the formation of an open, lacelike, netlike, or reticular structure, particularly in the case of lightweight fabrics. This reorientation is accompanied by what may be termed a "serpentine effect" due to the development or generation of a series of parallel, sinuous, or serpentine bands of fibers arranged side by side in a common plane, in apposition to each other, each band being the substantial reflection or mirror image of the two adjacent bands on either side, the bands being united into a reticular structure by binder areas located at their points of apposition.

2. In the second place, the "collapse" of the binder pattern in one direction, which accompanies its extension in the cross direction, produces what may be called a "quilting effect," i. e., some of the oriented fibers tend to buckle or pucker out of the plane of the fabric proper, with the development of a uniform, quilt-like pattern of tiny "pillows" on the surface of the fabric.

3. In the third place, a substantial proportion of the nonoriented fibers in the original web, when subjected to tensional stress as the web is extended crosswise, are either ruptured or pulled out of the binder areas. The thus released ends of the originally nonoriented fibers produce what may be called a "peach fuzz effect," i. e., the released ends of the fibers tend to bend out of the plane of

the fabric proper, forming a uniform nap, down or "peach fuzz" on the surface of the fabric.

These three effects (i. e., the "serpentine" effect, the "quilting" effect and the "peach fuzz" effect) all combine to improve (among other things) the softness, loft and textile-like properties of the basic fabric, overcoming its "paperlike" surface appearance and texture.

Dimensional stability may be given to the resulting stretched fabric by rebonding it in its laterally extended condition. Depending in part on the degree to which the basic fabric was stretched before rebonding, the ratio of long strength to cross strength of the resulting fabric differs markedly from the coresponding ratio of the fabric from which it was made. Indeed, if the basic or starting fabric is stretched to a substantial degree (e. g., 170% of its original width) before rebonding, the normal ratio of long-to-cross tensile strength may actually be reduced to unity or even reversed. It is thus possible to convert a non-isotropic, oriented fabric into a pseudo-isotropic fabric, the fibers of which are reoriented into a multiplicity of sinuous bands.

The present invention is based in part upon an analysis of the basic factors involved in the operations briefly characterized above. Regardless of the purpose for which the cross stretching operation is carried out, the original web from which the basic fabric is made should preferably contain nonoriented or randomly disposed fibers to a substantial degree, as well as the oriented or parallelized fibers which undergo the "serpentine action" during the cross-drafting process. The basic web should, of course, contain a sufficient proportion of substantially parallelized fibers to permit lateral extension of the web on the "lazy tongs principle," with the development of sinuous fiber bands united into a netlike structure by the binder area infused into the bands at their points of apposition. This is also a basic prerequisite for the quilting action mentioned above. However, in a stretched or brushed fabric, the "peach fuzz effect," and to some extent the "pseudo-isotropic effect" in a stretched and rebonded fabric, are influenced by the proportion of nonoriented or randomly disposed fibers present in the original web. In other words, a greater "peach fuzz effect" and, to some extent, a greater "pseudo-isotropic effect" is attainable provided the basic starting material comprises an oriented web which contains a substantial although minor proportion of non-parallel or randomly disposed fibers along with the parallelized fibers which comprise the major component of the web.

One of the objects of the present invention is to provide a laterally extensible, island bonded, nonwoven fabric that is characterized by a substantially greater capacity for undergoing the "peach fuzz effect" and the "pseudo-isotropic effect" when the fabric is treated in accordance with the methods described above.

Still another object is to provide means by which to reduce the degree of cross-drafting that is necessary in order to reverse the long-to-cross tensile strength ratio of an island bonded fabric in the manufacture of a pseudo-isotropic nonwoven fabric by cross-drafting the prebonded web and then rebonding the fabric in its extended condition.

A further object is to provide a simple and economical means and method by which to control within limits the degree of orientation of an oriented, unbonded web of textile length fibers as a step in the manufacture of a laterally extensible, island bonded, nonwoven fabric from a substantially oriented web of such fibers.

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

Fig. 1 is a side elevation schematically showing the preferred process in accordance with the present invention;

Fig. 1A is a plan view, on an enlarged scale, diagrammatically showing a portion of the fabric of the present invention wherein the binder segments are annular or

ringlike in configuration, after the fabric has been uniformly stretched beyond its elastic limit in a direction transverse to the direction of fiber orientation;

Fig. 2 is a perspective view of the primary cross drafting device generally indicated in Fig. 1 by the reference character **34**;

Fig. 3 is a cross section along the line **3—3** of the cross drafting device of Fig. 2;

Fig. 4 is a cross section along the line **4—4** of the cross drafting device of Fig. 2;

Fig. 5 is a cross section along the line **5—5** of the cross drafting device of Fig. 2;

Fig. 6 is a perspective view of the secondary cross drafting device generally indicated in Fig. 1 by the reference character **36**;

Fig. 7 is a cross section along the line **7—7** of the cross drafting device of Fig. 6;

Fig. 8 is a cross section along the line **8—8** of the cross drafting device of Fig. 6; and

Fig. 9 is a cross section along the line **9—9** of the cross drafting device of Fig. 6.

Referring now to the drawings, especially Fig. 1, the process of the present invention starts with an unbonded web **10** comprising substantially parallelized, textile length fibers. Webs of this type may be produced by any of the methods well known in the art, but I prefer to use several conventional cotton cards **12**, **14**, **16**, **18** and **20**, arranged in tandem or series over an apron conveyor **22**. The tenuous webs (**24**, **26**, **28**, **30**, **32**) from each card are continuously plied on the apron conveyor **22** with the webs produced by the other cards in the series, forming the multi-ply web **10**. Other means for producing the basic web **10** may, of course, be used if preferred.

Regardless of how produced, the unbonded web **10** will contain a minor proportion of nonparallelized fibers as well as a major proportion of substantially parallelized fibers oriented in the "machine direction," i. e., in the direction in which the web moves continuously away from the web-forming machine. Where the web-forming device comprises one or more cotton cards, the degree of orientation may vary from about 75% to as high as about 95%, particularly if the web is appreciably drafted in the machine direction after it is formed. However, in accordance with the present invention, a lower degree of orientation is preferred, for which reason drafting in the long or machine direction is desirably avoided so far as possible.

In accordance with the present invention, preferably immediately after the web is formed but in any event before the web is island bonded to produce the laterally extensible fabric, it is subjected to a two stage cross drafting operation, preferably in the dry state, by passing the web from the apron conveyor **22** onto and over the surface of two highly polished, bowed conductor spreader plates, generally indicated as **34** and **36**.

The first spreader conductor plate, as more particularly shown in Fig. 2, presents to the advancing web a supporting surface that is initially substantially flat along its leading edge **38**, but which rises relatively steeply but smoothly in the central portion of the plate to a crowned lip **40**. The cross section of the first spreader conductor plate **34** at successive locations along its ascending ridge is diagrammatically shown in Figs. 3, 4, and 5. The first plate, therefore, cross drafts the web initially in the central portion of the web and gradually extends the cross drafting in a wavelike fashion outwardly toward the lateral edges of the web.

The advancing web, after passing under tension over the crowned lip **40** of the first plate, then comes in contact with the second spreader conductor plate **36**. As shown more particularly in Fig. 6, the second plate also initially presents a substantially flat surface at its leading edge **42**. As the web advances across the second plate, it rises in the central portion on a gently rising plateau **45** which falls off relatively steeply at the

lateral shoulders 41 and 43, the plateau becoming wider and progressively higher as the web advances toward the bowed lip 44. The cross section of the second plate at progressive locations along its ascending plateau 45 is diagrammatically shown in Figs. 7, 8, and 9. The ascending plateau 45 and the shoulders 41 and 43 (Figs. 6, 8, and 9) of the second spreader conductor plate complete the spreading action originally effected on the first plate, primarily at the central portion of the web, carrying the stretching in a gentle, wavelike action outwardly from the center toward the lateral portions of the web. With a 40 inch standard card, for example, the two stage cross drafting operation may increase the width of the web from 40 inches to, say, about 46 to 50 inches and simultaneously effects some reorientation of the fibers composing the web.

Particularly in the manufacture of lightweight webs weighing from about 100 to 300 grains per square yard, a two stage cross drafting operation is essential to obtain satisfactorily uniform results. Initially, stretching should be effected at the central portion, thereafter gradually extending it toward the edges of the web in a gentle, wavelike manner. With such lightweight webs, the two stage cross drafting should be carried out with continuous, curved conductor spreader plates, preferably made of highly polished metal. Bowed rods and similar devices which present substantially only a curved line of contact rather than a plane of contact fail to produce a uniformly stretched, lightweight fabric substantially free of weakened areas.

Referring again to Fig. 1, after passing over the first and second spreader conductor plates 34 and 36, the web 10 passes over the idler roll 50, under the squeeze roll 52, and into the nip of the wet-out rolls 54 and 56 where the web becomes saturated with water. The wet-out web then moves under an idler roll 55 and into the nip between the intaglio print roll 58 and the backing roll 60 where it is imprinted with a discontinuous binder pattern such as the articulated, multiannulate binder pattern more particularly described and claimed in the copending application of Ness, Lints, and Petterson, Serial No. 280,963, filed April 7, 1952, now United States Patent No. 2,705,688, issued April 5, 1955.

After the printing operation, the web passes around idler roll 62 onto the transverse apron conveyer 63 to the stack of rotating drying cans generally indicated by 64, these cans being heated by suitable means (not shown) to about 250° F. in order to facilitate drying of the fabric.

The subsequent operations performed on the fabric depend upon the end-use for which the fabric is intended. In Fig. 1, the fabric coming from the dry cans is diagrammatically shown as passing over overfeed dancing rolls 65, under the brush feeder 67 into a conventional overfeed tenter 66 wherein the fabric is subjected to a cross stretching operation.

After emerging from the tenter 66, the web may, if desired, be subjected to a brushing operation by passing it over and under the cylindrical brushes 68 and 70 rotating in the direction indicated by the arrows, the opposite side of the web resting against felt covered idler rolls 72 and 74. The finished fabric is then collected on the wind-up roll 76.

If desired, the tentering operation may be omitted, or the brushing operation may be omitted, or both may be used. In some instances it may be preferable to rearrange the tenter and the brushing operations so that brushing is effected before tentering.

Where a rebonding operation is subsequently effected, as in carrying out the pseudo-isotropic web and pseudo-cross lay processes, provision may be made for effecting these operations immediately after the tentering or brushing operations or both; for example, by inserting in the production line, another wet-out roll in combination with a print nip roll and a stack of drying cans, immediately before the final wind-up roll 76. Various equivalent web forming, printing or drying devices (including those described, for example, in the Joshua Goldman Patent 2,039,312, the Joseph Goldman Patent 2,407,548, and the Esther Goldman Patent 2,545,952) may be substituted for the specific devices diagrammatically represented in the drawings as a means of illustrating a preferred manner of carrying our invention into practice. All these and other modifications that are readily apparent to those skilled in the art should be understood as included within the spirit and scope of the invention, as defined in the appended patent claims.

We are aware that the use of spreader bars has heretofore been proposed as a step in the preparation of the web used in the manufacture of a nonwoven fabric. Thus, for example, Joseph Goldman in his Patent 2,407,548 proposed to use a series of curved bars so positioned as to "commence the spreading action at the sides and gradually extend the spreading action to the center of the web." In his process, the spreading action was "merely sufficient to remove ripples and cause the web to lie flat without substantially pulling the fibers laterally away from each other." Our process, in contrast to that of the Goldman patent, has for its object the cross drafting of the web to a degree sufficient to effect reorientation of the fibers. In our experience, cross drafting to such a degree cannot be uniformly effected by use of curved bars, no matter what their configuration or how they are positioned relative to one another. A uniformly stretched web in which the fibers are laterally moved can be produced if the web is cross drafted over a series of curved conductor spreader plates so designed and related that: (1) the cross drafting is carried out in at least two stages initially at the central portion of the web, after which the fibers are pushed laterally from the center toward the sides in a gentle, wavelike manner; and (2) the web is supported by the smoothly curved surfaces of the conductor spreader plates during lateral extension. Our process, therefore, differs from the Joseph Goldman process not only in its purpose but also in the extent or degree of cross drafting effected, the order in which the cross drafting steps are carried out, and the means employed to effect each of said steps. In none of these respects is our process, or the means employed to carry it out, the equivalent of those used by Joseph Goldman.

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.

I claim:

1. A process which includes providing an unbonded web comprising a major proportion of substantially parallelized textile fibers and a minor proportion of nonparallelized textile fibers; cross drafting said unbonded web in an amount sufficient to increase the proportion of nonparallelized fibers in the web; and converting said web into a self-sustaining, laterally extensible fabric by discontinuously bonding the web with a multiplicity of uniformly spaced, discrete areas of binder, physically separated from, but hingedly interconnected with, each other, said binder areas occupying not substantially more than about 35% of the total lateral surface of said web.

2. A method which includes providing an unbonded web comprising a major proportion of substantially parallelized textile fibers and a minor proportion of nonparallelized textile fibers; cross drafting said unbonded web in an amount sufficient to increase the proportion of nonparallelized fibers in said web; converting said web into a self-sustaining, laterally extensible fabric by discontinuously bonding the web with a multiplicity of uniformly spaced, discrete areas of binder, physically separated from, but hingedly interconnected with, each other, said binder areas occupying not substantially more than

about 35% of the total lateral surface of the web; and then cross drafting said bonded, laterally extensible fabric after the binder has set, in order further to decrease the degree of orientation of the fibers comprising the web.

3. The method of claim 2 wherein the cross drafting of said bonded, laterally extensible fabric increases the width of the fabric by at least about 70%.

4. The method of claim 2 wherein the cross drafted fabric is rebonded in order to fix the reoriented fibers in their reoriented relationship.

5. A method which includes providing an unbonded web comprising a major proportion of substantially parallelized textile fibers and a minor proportion of nonparallelized textile fibers; cross drafting said unbonded web to a degree sufficient to increase the proportion of nonparallelized fibers in the web; converting the web into a self-sustaining, laterally extensible fabric by discontinuously bonding the web with a multiplicity of uniformly spaced, discrete areas of binder, physically separated from, but hingedly interconnected with, each other, the binder areas covering not substantially more than about 35% of the total lateral surface of the web; and then brushing said web in a direction parallel to said parallelized fibers in order to develop a downylike nap on the surface of said web by raising the ends of a substantial proportion of the nonparallelized fibers.

6. A method which includes providing an unbonded web comprising a major proportion of substantially parallelized textile fibers and a minor proportion of nonparallelized textile fibers; cross drafting said unbonded web in an amount sufficient to increase the proportion of nonparallelized fibers in the web; converting said web into a self-sustaining, laterally extensible fabric by discontinuously bonding the web with a multiplicity of uniformly spaced, discrete areas of binder physically separated from, but hingedly interconnected with, each other; and uniformly cross drafting said bonded fabric after the binder has set, to a degree sufficient further to decrease the degree of orientation of the fibers and to develop a downylike nap on the surface of said fabric.

7. The method of claim 6 wherein the cross drafted fabric is then rebonded in order to impart dimensional stability to the cross drafted fabric.

8. The method of claim 6 wherein said cross drafted fabric is plied with and united to an unbonded web comprising a major proportion of substantially parallelized textile fibers.

9. The method according to claim 1 wherein said cross drafting is carried out in at least two stages, the first stage being accomplished in the central portion of said web and the second stage being accomplished along the lateral portions of said web.

10. The method of claim 1 wherein said cross drafting is carried out in at least two stages by passing the web under tension successively over two supporting curved surfaces, the first surface having a central crowned ridge progressively increasing in width and height from the leading edge to the following edge, the other curved surface having a central level plateau progressively increasing in width and height from the leading edge to the following edge.

11. A process which includes providing an unbonded web comprising a major proportion of substantially parallelized textile fibers and a minor proportion of nonparallelized textile fibers; treating the unbonded web to increase the proportion of nonparallelized fibers in the web; and then converting said web into a self-sustaining, laterally extensible nonwoven fabric by discontinuously bonding the web with a multiplicity of uniformly spaced discrete areas of binder, physically separated from, but hingedly interconnected with each other by substantially unbonded lengths of fibers, said binder area occupying a minor portion below about 35% of the total surface area of said fabric.

12. A process as defined in claim 1 wherein the textile fibers are cotton.

13. A process which includes providing an unbonded web comprising a major proportion of substantially parallelized textile fibers and a minor proportion of nonparallelized textile fibers; cross drafting said unbonded web in an amount sufficient to increase the proportion of nonparallelized fibers in the web; and converting said web into a self-sustaining, laterally extensible fabric by discontinuously bonding the web with a multiplicity of uniformly spaced, discrete areas of binder, physically separated from, but hingedly interconnected with each other, said binder areas occupying not substantially more than about 25% of the total lateral surface of said web.

14. A process which includes providing an unbounded web comprising a major proportion of substantially parallelized textile fibers and a minor proportion of nonparallelized textile fibers; cross drafting said unbonded web in an amount sufficient to increase the proportion of nonparallelized fibers in the web; and converting said web into a self-sustaining, laterally extensible fabric by discontinuously bonding the web with a multiplicity of uniformly spaced, discrete areas of binder, physically separated from, but hingedly interconnected with each other, said binder areas occupying from about 10% to about 25% of the total lateral surface of said web.

15. A process which includes providing an unbonded web comprising a major proportion of from about 75% to about 95% substantially parallelized textile fibers and a minor proportion of from about 25% to about 5% of nonparallelized textile fibers; cross drafting said unbonded web in an amount sufficient to increase the proportion of nonparallelized fibers in the web; and converting said web into a self-sustaining, laterally extensible fabric by discontinuously bonding the web with a multiplicity of uniformly spaced, discrete areas of binder, physically separated from, but hingedly interconnected with each other, said binder areas occupying not substantially more than about 35% of the total lateral surface of said web.

16. A process which includes providing an unbonded web conmprising a major proportion of from about 75% to about 95% of substantially parallelized textile fibers and a minor proportion of from about 25% to about 5% of nonparallelized textile fibers; cross drafting said unbonded web in an amount sufficient to increase the proportion of nonparallelized fibers in the web; and converting said web into a self-sustaining, laterally extensible fabric by discontinuously bonding the web with a multiplicity of uniformly spaced, discrete areas of binder, physically separated from, but hingedly interconnected with each other, said binder areas occupying not substantially more than about 25% of the total lateral surface of said web.

17. A process which includes providing an unbonded web comprising a major proportion of from about 75% to about 95% substantially parallelized textile fibers and a minor proportion of from about 25% to about 5% of nonparallelized textile fibers; cross drafting said unbonded web in an amount sufficient to increase the proportion of nonparallelized fibers in the web; and converting said web into a self-sustaining, laterally extensible fabric by discontinuously bonding the web with a multiplicity of uniformly spaced, discrete areas of binder, physically separated from, but hingedly interconnected with each other, said binder areas occupying from about 10% to about 25% of the total lateral surface of said web.

18. A process as defined in claim 17 wherein the textile fibers are cotton.

References Cited in the file of this patent

UNITED STATES PATENTS

2,055,411	Hurst	Sept. 22, 1936
2,207,279	Alderfer	July 9, 1940
2,407,548	Goldman	Sept. 10, 1946