July 31, 1962 K. J. HARWOOD 3,047,444

NON-WOVEN FABRIC AND METHOD OF MAKING THE SAME

Filed July 15, 1955 5 Sheets-Sheet 1

Fig. 1

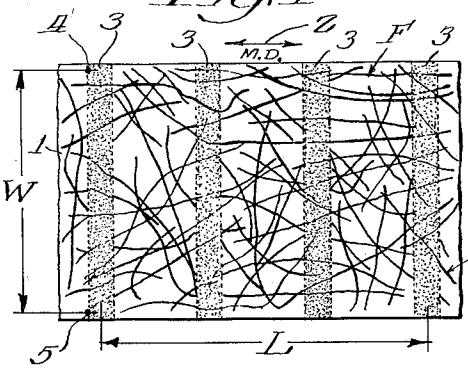


Fig. 3

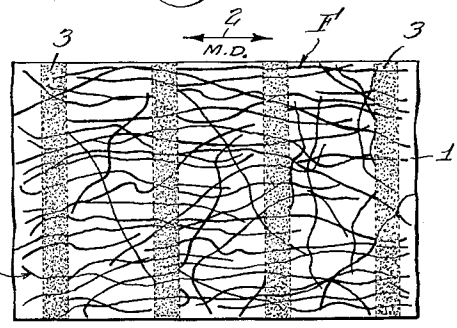


Fig. 2

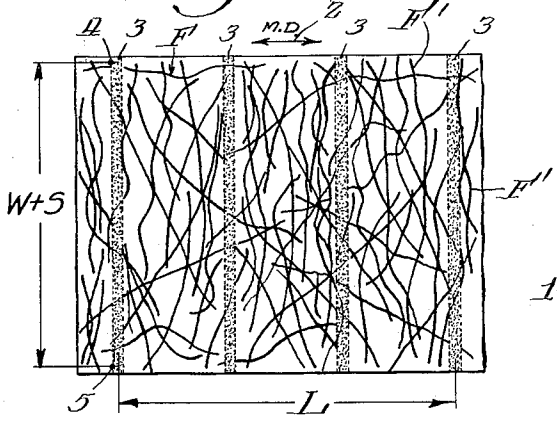


Fig. 5

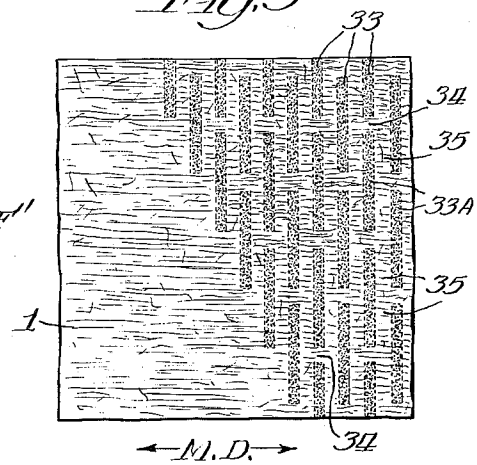


Fig. 4

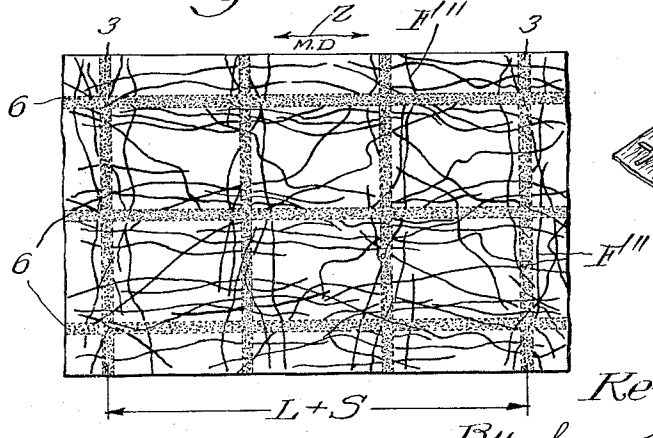
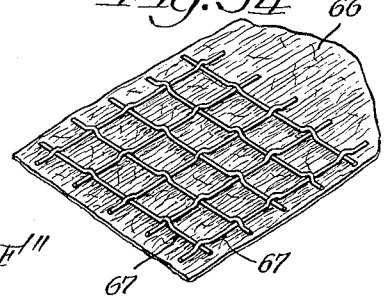


Fig. 34



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NON-WOVEN FABRIC AND METHOD OF MAKING THE SAME

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Fig. 6

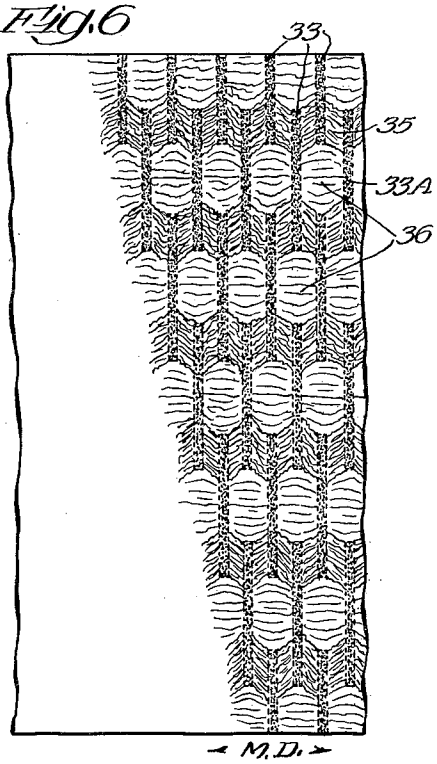


Fig. 8

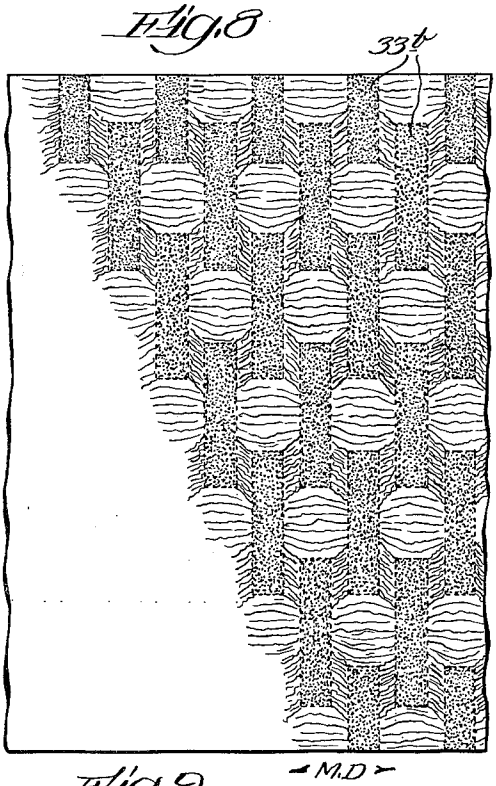


Fig. 7

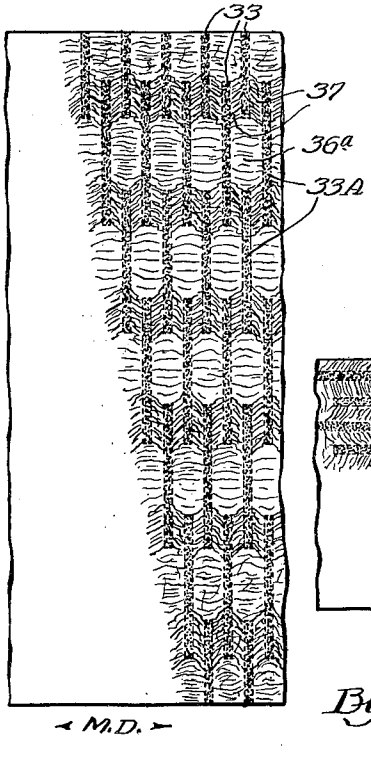


Fig. 9

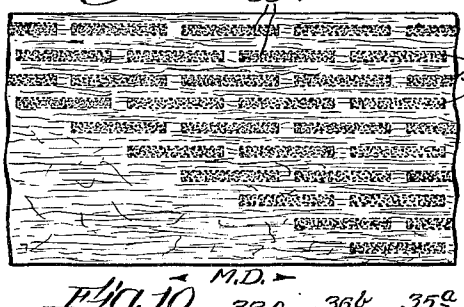
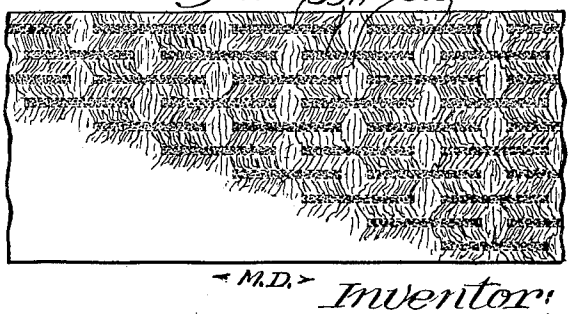


Fig. 10



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NON-WOVEN FABRIC AND METHOD OF MAKING THE SAME

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Fig. 11

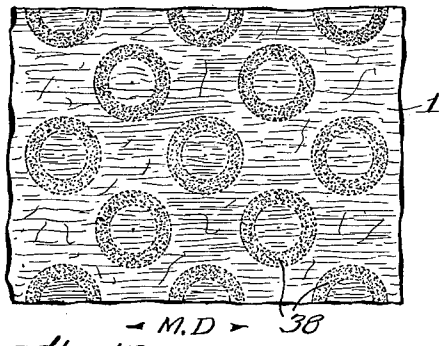


Fig. 13

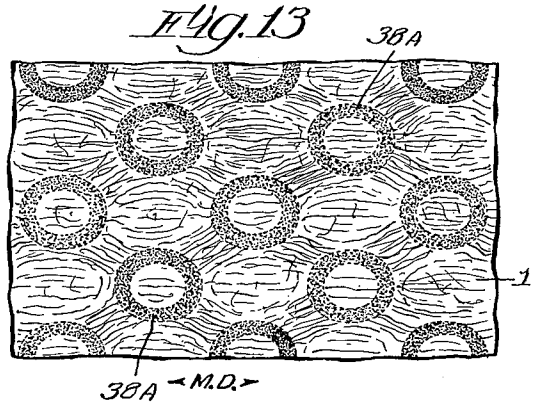


Fig. 12

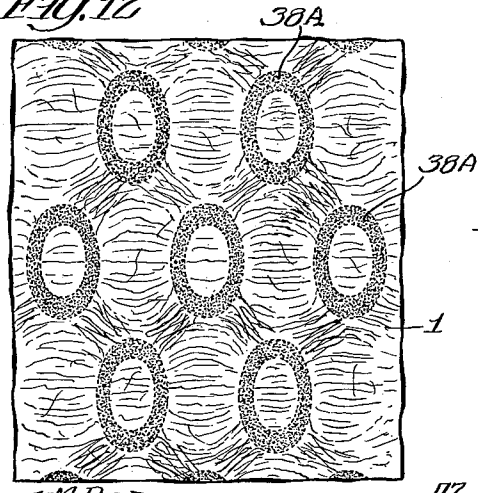


Fig. 14

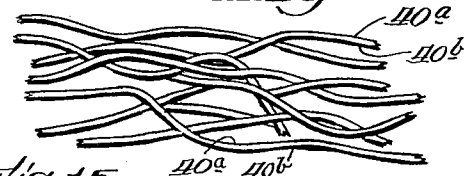


Fig. 15

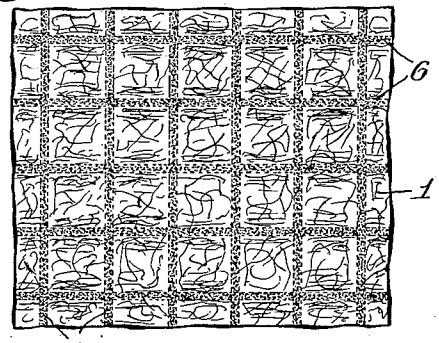


Fig. 16

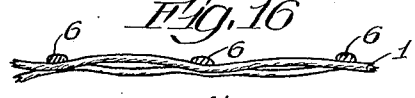


Fig. 17

Fig. 18

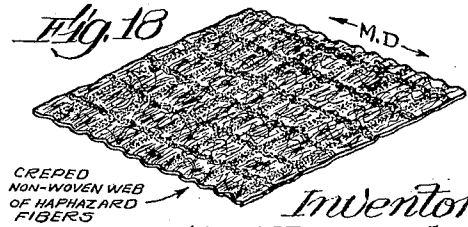


Fig. 19

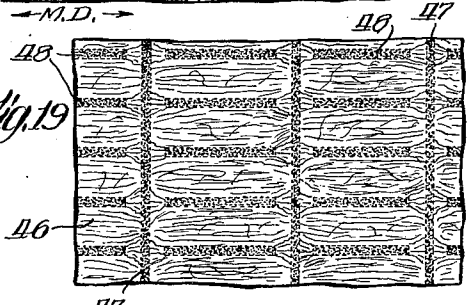
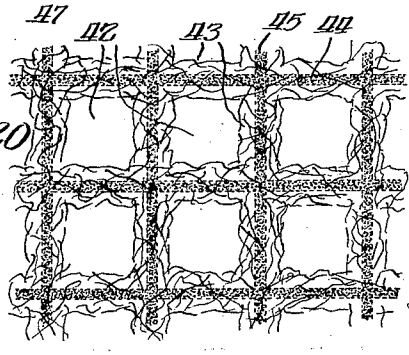


Fig. 20



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NON-WOVEN FABRIC AND METHOD OF MAKING THE SAME

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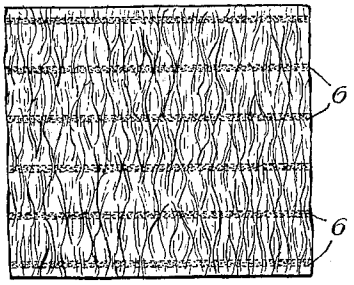
Fig. 21



CREPED TISSUE PAPER

Fig. 22

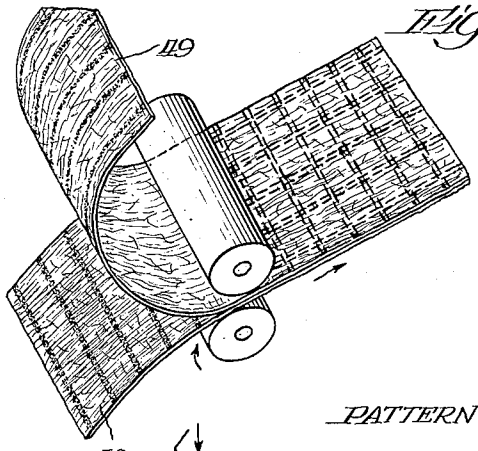


Fig. 23

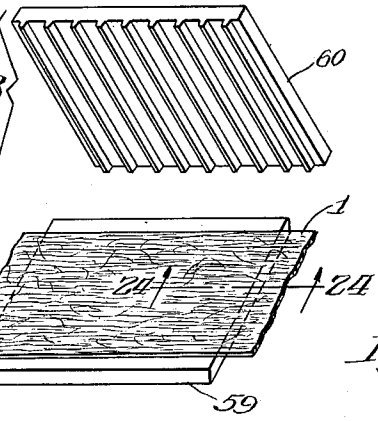


Fig. 24

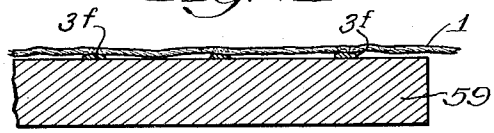
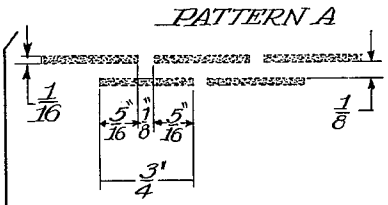
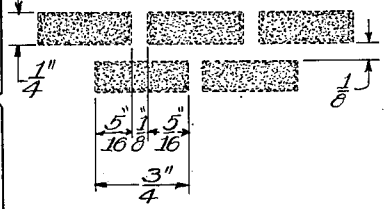


Fig. 25

PATTERN A



PATTERN B



PATTERN C

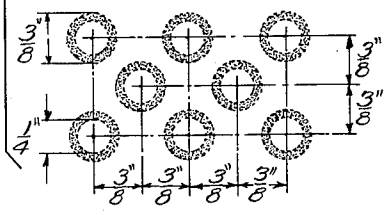
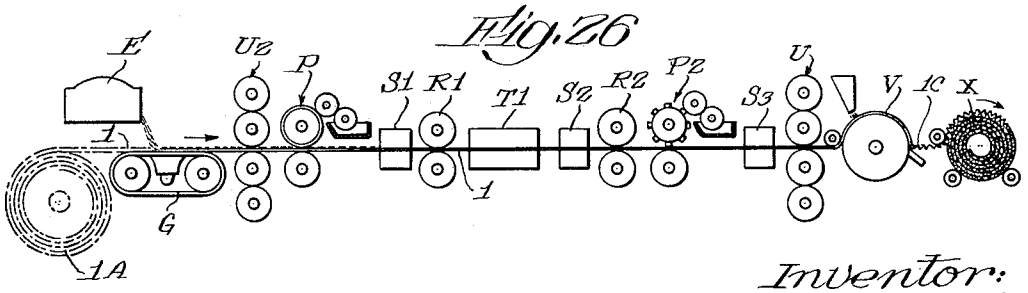


Fig. 26



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NON-WOVEN FABRIC AND METHOD OF MAKING THE SAME

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Fig. 27

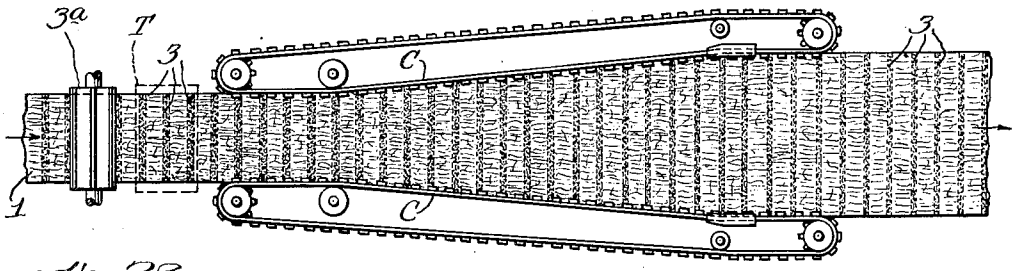


Fig. 28

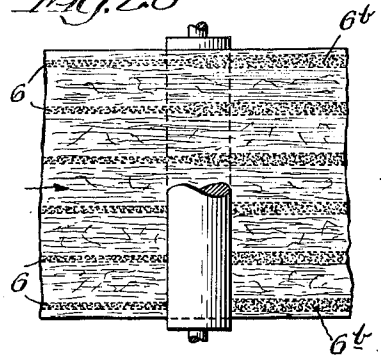


Fig. 29

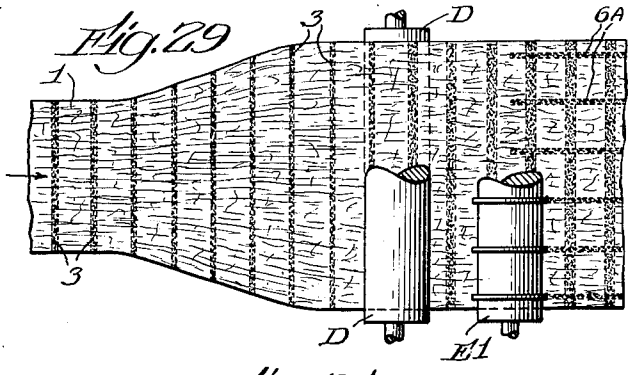


Fig. 30

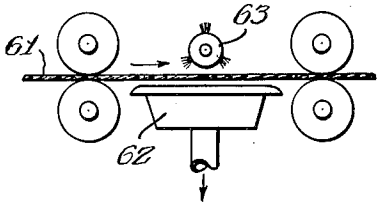


Fig. 31

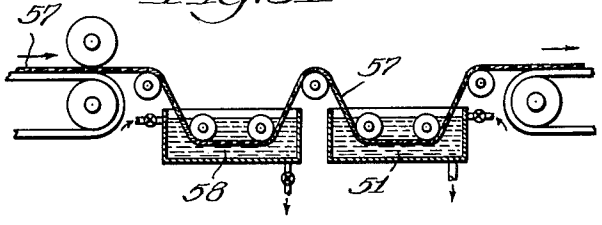
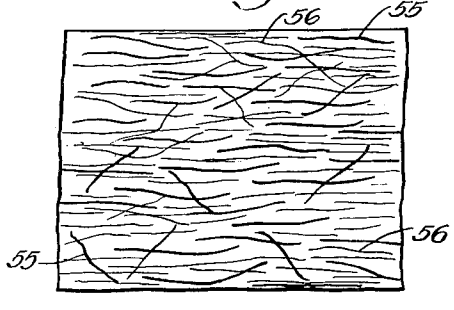


Fig. 33



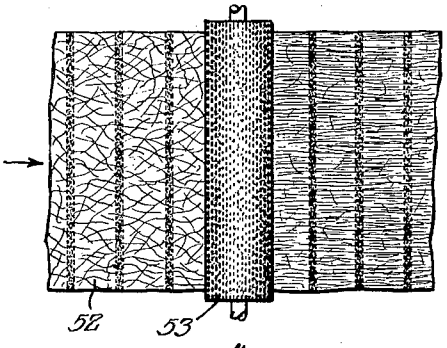


Fig. 32

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United States Patent Office 3,047,444 Patented July 31, 1962

3,047,444

NON-WOVEN FABRIC AND METHOD OF MAKING THE SAME

Kenneth J. Harwood, Neenah, Wis., assignor, by mesne assignments, to Kimberly-Clark Corporation, a corporation of Delaware

Filed July 15, 1955, Ser. No. 522,312
12 Claims. (Cl. 154—46)

This application is a continuation in part of my prior co-pending application Serial No. 177,741, filed August 4, 1950, now abandoned.

This invention relates to non-woven fabrics and to a method of producing the same, and it is mainly concerned with stretchable non-woven fabric which may embody natural or artificial fiber formed into a web or bat by carding, garnetting, air laying, waterlaying or other mechanisms and methods.

Non-woven fabrics of the character here contemplated are now quite well known and they are made from various kinds of fibers, some such fabrics consisting of a single kind of fiber and others consisting of mixtures of fibers of different kinds including mixtures of different artificial or synthetic fibers, and mixtures of natural and artificial fibers.

In the production of known non-woven webs of fibers, the desired fibers have been made into a web of the required thickness and density, and to give such webs self-sustaining strength, the fibers have been bonded to one another by the application of adhesive, generally in all-over patterns as by spraying, immersion in a bath, and similar methods which tend to impart stiffness to the fabric and also to reduce its porosity.

For many purposes, non-woven fabric would be much less costly or otherwise more advantageous than woven gauze and perhaps other fabrics currently in use, if the strength, porosity, softness and weight of the non-woven fabric could be made the equivalent of these characteristics of the woven fabric which is to be replaced, and provided that the feel of the non-woven fabric can also be made sufficiently smooth and soft. It now appears possible that some if not all of these characteristics can be attained to a higher degree of perfection in non-woven fabrics than in their woven counterparts.

It has also heretofore been proposed to produce non-woven fabric by preparing a carded web of cotton fibers or of synthetic fibers of substantial length and applying adhesive to the carded web in lines extending crosswise of the direction of the fibers in the web and sometimes additionally applying adhesive in lines extending in the direction of the fibers. Adhesive so applied tends to bind the fibers together to thereby strengthen the sheet, a substantial portion of the normal softness of an un-bonded, non-woven web being retained by limiting the area covered by the lines of adhesive to a small portion of the entire area of the web so that the normal softness of the web remains in the un-bonded fiber area.

Such adhesive line-bonded fabric probably more nearly approaches the characteristics of conventional woven gauze than non-woven fabrics in which bonding is effected in an all-over manner. However, such line-bonded fabrics are nevertheless deficient, especially in respect of porosity, and they are also usually somewhat heavier than is desirable for many purposes.

According to the present invention, the deficiencies of

adhesive, line-bonded, non-woven fabric as heretofore known, particularly the tensile strength, softness, feel, and porosity characteristics are significantly improved so that the fabric may advantageously be employed in various places where conventional woven gauze has heretofore been more or less universally used owing to the lack of any suitable substitute which could be obtained at the same or a lower cost than the gauze.

The objects of the present invention may accordingly be stated to be those of providing non-woven fabric material having a high degree of porosity while at the same time having tensile strength, softness and feel characteristics, and tear resistance which will permit the use of the fabric in place of conventional woven gauze; to provide a non-woven fabric material which because of its improved strength, feel, and other properties or characteristics may be advantageously employed for many purposes in addition to those for which gauze has heretofore been used; to provide a strong, non-woven web of fabric which is adaptable to uses heretofore served largely by light weight woven materials; and to provide such non-woven fabric which can be practicably produced at low cost so as to be economically feasible.

Various other objects and advantages of the invention will appear from the following specification and accompanying drawings in which there is described and illustrated non-woven fabric and methods of making the same according to the present invention.

In the drawings, wherein all of the figures are more or less schematic,

FIG. 1 is a face view of a piece of non-woven fabric in a preliminary or unfinished condition;

FIG. 2 is an illustration similar to FIG. 1 but showing the fabric improved according to one embodiment of the invention;

FIGS. 3 to 24 inclusive illustrate other examples of non-woven fabric products improved in accordance with the invention together with steps practiced in making some of the illustrated products;

FIG. 25 is a representation of selected printing patterns for purposes of identification hereinafter;

FIGS. 26 to 32 inclusive are schematic representations of apparatus and of method steps which may be used in connection with the manufacture of products according to the present invention; and

FIGS. 33 and 34 are representations of additional products according to the invention.

In FIG. 1 of the drawing, there is represented a patch or piece 1 of non-woven fabric which is formed of an air-laid web of cotton fibers F, the fibers being disposed in haphazard arrangement although exhibiting a tendency to be disposed longitudinally of the length of the fabric, that is to say, to be disposed in the direction in which the fabric is formed as it passed through the forming apparatus. This longitudinal direction is referred to as the machine direction and is indicated by the arrowed line 2. This web may be formed by an air laying process whereby there is produced a very lightweight, flimsy or tenuous web which may normally be incapable of sustaining itself. There are many uses for such material, but the lack of tensile strength in the material detracts from its utility for many purposes. Heavier and stronger webs may be formed by the said process but this application is especially concerned with, but not necessarily restricted to weak web structures as indicated. The web

may also be made by carding, garnetting, waterlaying and other methods.

In a simple form of fabric according to the invention, the air-laid web 1 is cross printed (printed crosswise of the machine direction), with continuous lines of binder or adhesive indicated at 3. These lines of adhesive may be applied with printing rules or by other means, the rules or other printing means having a width of around 1/32 of an inch as an example. Because of the absorbent characteristics of the web the adhesive applied in a narrow line as aforesaid, will spread somewhat into a line approaching 1/16 of an inch in width. The adhesive employed is of a character which while in soft and stretchable condition, due to the temperature and viscosity of the adhesive or to the presence of a solvent or other chemical means, can be stretched and which, when stretched, becomes strengthened in the direction of the stretch due to a realignment or rearrangement of the molecules of the adhesive. Some materials, for example, unoriented polyethylene, are yieldable or stretch strengthenable at ordinary room temperature without special treatment, and will remain stretched and strengthened without additional treatment to set the material. Adhesives or binders of this character may be employed for the purpose of the present invention.

It is, of course, known that certain synthetic materials are so lacking in tensile strength as to be practically without utility but by stretching the material under proper conditions, sufficient tensile strength is imparted thereto to make such materials useful for many purposes. Commercial products knowns as Nylon, Saran and Vinyon and viscose rayon are examples of such materials. Some cellulosic materials such as cellulose acetate, hydroxymethyl cellulose, carboxymethyl cellulose are other examples. In general, the known adhesives which are made stronger by stretching are thermoplastic resin polymers or copolymers in which molecular reorientation may be effected under activating conditions which will not adversely affect the fibers of the web. Such adhesives are usually of generally linear long chain structure. When binders or adhesives of this character are stretched within limits and under suitable conditions of temperature, viscosity, density, plasticizer content and perhaps other factors, the tensile strength of the said materials in the direction of stretching is increased. Binders or adhesives of this character serve the requirements of this invention. Some of these adhesives are of waterproof character and do not lose strength in the presence of water, while others, such as the hydroxymethyl cellulose and carboxymethyl cellulose have the ability to absorb a considerable amount of moisture yet remaining strong, this characteristic being highly desirable in some products.

After the lines 3 of the selected stretch strengthenable adhesive are applied to the web, the web is stretched crosswise within a predetermined range of stretching, say from 10 to 100% or more of its initial width, to thereby elongate the lines of binder and to increase the tensile strength of the binder lines in the direction of their lengths, and also increasing the cross direction strength of the fiber web. The range of stretching depends somewhat on the fiber lay in the web, the length of the fibers, and the kinds of fiber and adhesive employed, and in general, it may vary widely. Stretching within a range of 10% to 50% gives good results when the web is very light weight (10 to 12 grams of fiber per square yard) and made of fairly uniformly distributed fibers and the adhesive is a vinyl resin.

The cross stretching above described is preferably but not necessarily effected without reducing the length of the sheet. In FIG. 1 the initial length and width of a selected sample of the material is indicated by the dimensions L and W, respectively. The length dimension is shown from center to center of the outside lines of a group of four lines of adhesive. The width dimension is indicated between arbitrarily selected points designated 4 and 5 on one of the lines of adhesive. As shown in FIG. 2, the sample of material has been stretched crosswise to an increased width indicated as $W+S$, the length dimension L remaining the same as in FIG. 1.

This cross stretching of the printed web is a permanent stretching which serves to increase the width of the sheet or web and to reduce the weight of the finished web per square yard as compared with the weight of the unstretched printed web per square yard. The tabulated data in columns 17 and 18 hereof shows that in samples 1, 2 and 3 there referred to important weight reductions were obtained when the products were stretched only within a range of about 12 to 18%. By increasing the width of the web as explained, the fibers thereof are more or less separated or opened up so as to increase the porosity of the fabric. In this manner, it is practicable to attain porosity which compares favorably with that of conventional woven gauze having a basis weight which is in the vicinity of that of the printed and stretched non-woven fabric. This method of extending the non-woven fabric to increase its area provides a very practicable method of producing a usefully strong, very porous and light weight fabric.

The aforesaid cross stretching of the cross printed web also tends to increase the cross-direction strength of the web by reason of the incidental effect of causing gathering or bunching of some of the fibers along and in more or less parallel relation to the lines of binder as indicated at F' in FIG. 2. The groups of fibers thus formed have effective combined strength which is much greater than the effective strength of the individual fibers when spread out in sheet form. This bunching or grouping effect occurs because of the anchorage of most of the fibers in lines of adhesive so that force tending to pull such anchored fibers crosswise tends to strengthen the fibers out in line with their points of anchorage.

As a practical matter, long webs of cross printed material such as described, may be stretched crosswise by means of apparatus similar to a tenter (see FIGURE 27) used in the production of woven fabric for holding woven material to a predetermined width while drying. Suitable means such as a heated roll, heat radiators or an oven through which the web is drawn, may be employed in any suitable relationship to the stretching mechanism for softening the adhesive to permit its being stretched. In some instances, the stretching operation may be effected as a step in a continuous fabricating process, before the adhesive has hardened or set, or congealed. Heating or other extra softening treatment may not be required in such a continuous process. When softening is required, it may be effected by subjecting the adhesive to the action of a solvent or other chemical action instead of heat.

The stretch-strengthened cross printed web of FIGURES 1 and 2 may be produced by mechanism such as schematically represented in FIGURE 27. As there shown, a web 1 of fiber material drawn from a supply roll or received from an airlayer or other mechanism which produces the web, is acted upon by a printing mechanism represented at 3*a* which prints the transverse lines 3 of adhesive on the web. If the web is being taken from a supply roll, the adhesive will usually have been previously applied and set, and a suitable means indicated at T for treating the adhesive to condition it for stretching is provided. The cross printed web is then gripped along its opposite edges by suitable devices on the diverging chains C which act to stretch the web transversely and deliver it widened to the desired extent as indicated at the right hand side of FIGURE 27. The binder lines 3 on the web are of course elongated coextensively with the widening of the web and before the widened web is released from the chains C, the binder is permitted to set as a funtion of time or is suitably treated by cooling or otherwise to expedite the setting of the binder so that the web will remain substantially in the width to which it has been expanded.

For certain purposes which are hereinafter referred to, the widened web may be permitted to shrink or retract transversely to a limited extent before the binder is permitted or caused to set. Shrinkage or retraction such as just referred to will readily ocur, if permitted, as an incident to inherent elasticity in either or both the web and the binder lines. The conveyors C, will of course be appropriately guided to permit and control such retraction if desired.

Lengthwise extending (machine direction) stretch-strengthenable lines of adhesive may also be applied to webs of non-woven fibrous material, either in association with cross lines of adhesive or independently thereof. In FIGURE 4 there is represented the cross strengthened web of FIGURE 2 to which there has been applied machine direction lines 6 of adhesive, the web and lines 6 having been stretched lengthwise to the elongated dimension $L+S$. The web of FIGURE 4 is therefore strengthened in both machine and cross directions and its porosity has been increased by stretching the web in both directions. In some instances, fabrics having a net-like pattern of adhesive thereon (such as shown in FIGURE 4), may be stretched in the direction of the lines extending in one direction only and the lines extending in the other direction may be of binder or adhesive material the same as or different than that which is stretched for strengthening purposes. If the net forming lines of adhesive are disposed diagonally of the web, they will be stretched to a beneficial extent as an incident to stretching of the fabric in either machine direction, cross direction, or both.

Machine direction lines of adhesive such as 6 may be applied to a web in the manner schematically illustrated in FIGURE 26. As there shown the fiber web 1 delivered from a suply roll 1A, or formed by delivery from a carding or other web forming machine E on a forming screen or belt G, is guided between the printing and platen rolls of a printing device P which is so formed as to print the spaced lines 6 of stretch strengthenable adhesive lengthwise on the web 1. The adhesive may be permitted to set on the web or caused to set thereon by cooling or other means indicated at S1, and the web then passed between a pair of rolls R1 which are rotated at a peripheral speed which is substantially equal to the linear speed of travel of the web. As the web emerges from the rolls R1, the adhesive lines on the web may be reactivated by a suitable treating device T1, a heated drum, or other means, following which the web passes through another adhesive setting device S2 which is located immediately ahead of a pair of rolls R2 which are rotated at a higher peripheral speed than the rolls R1. The roll pairs R1 and R2 grip the web between them so that the higher peripheral speed of the roll pair R2 operates to stretch the web and its longitudinal lines of binder longitudinally to the extent desired, intermediate the roll pair R1 and the adhesive setting device S2.

The extent of stretching and the rate at which stretching is effected may be controlled by adjusting the peripheral speed of the roll pair R2, by adjusting the distance between the roll pairs R1 and R2 or the length of web in which stretching may be satisfactorily effected, by adjusting the condition of the adhesive, and by adjusting other factors. The rate at which stretching is effected has a bearing on the extent to which stretching or elongation may be effected and probably on the strengthening effect of the stretching. In general, a slow stretching action gives best results in respect of both the possible extent of stretching and the strengthening effect. The stretching rate may be governed by various matters such as the viscosity of the binder material, its temperature, and other characteristics of each particular kind of binder.

Crosswise lines of binder of stretch strengthenable or other material may be applied to the web as it emerges from the roll pair R2. Another printing mechanism is represented at P2 for that purpose. If stretch strengthenable binder is applied by the printing roll set P2, the web may be delivered to suitable cross stretching mechanism, for example, such as is represented in FIGURE 27. The web, whether or not streched crosswise, may then be guided through a suitable calender stack represented at U which will somewhat densify and smoothen the web and also flatten the adhesive lines and press them into the web so as to improve the fiber embedment in the lines of adhesive and thereby further increase the tensile strength of the web. If required, to prevent the calender stack U from picking up binder from the web, a binder setting device S3 may be positioned to act on the printed web before the web engages the calender stack. From this calered from the calender stack U, from the creping device represented at V by which the web is crinkled or creped transversely as indicated at 1C. The web may be delivered from the calender stack U, from the creping device V, or from any other part of the mechanism, to converting mechanism or to a windup mechanism to be wound into utility rolls such as indicated at X.

The calender stack U may be located to act on the fiber web before the web is acted upon by either or both of the printing mechanisms P or P2 or if desired, the calender stack U may remain in the position in which it is represented in FIGURE 26, and an additional calender stack or stacks may be provided ahead of either or both of the printing mechanisms P and P2, one such stack being represented at U2 ahead of the printer P.

If mechanisms such as represented in FIGURE 26 are employed without the cross printer P2, there will be provided a longitudinally stretched web in which longitudinally extending adhesive lines such as represented at 6 in FIGURE 4 are applied to the web and streched to increase the strength of the adhesive lines. The longitudinal stretching of the fiber web itself serves to separate or spread the fibers so as to increase the porosity of the web. Such longitudinal stretching tends to cause some of the fibers in the web to be more or less turned and stretched into parallelism with and collected adjacent the sides of the binder lines 6 to thereby further increase the strength of the web in the machine direction. The collecting or bunching of fibers incident to such turning or straightening of fibers is represented in FIGURE 4 wherein fibers rearranged into parallel relation to the binder lines 6, closely adjacent the latter, are indicated at F''.

The permissible extent of stretching of an uncreped non-woven web of fibers is usually somewhat more restricted in the machine direction than in the cross direction, even though the web be characterized as formed of haphazardly or randomly disposed fibers. This follows from the fact that as a practical matter, even though the fibers are air-layed or otherwise formed into a web by means usually considered to dispose the fibers in haphazard relationship, there is usually a significant amount of fiber disposed so as to extend in the machine direction. Relatively fewer fibers are disposed in stretched out condition extending transversely of the length of the web being formed.

However, a very light or thin carded fiber web (for example, one weighing around 3 grams per square yard) may be formed with so large a percentage of the fibers aligned in the machine direction of the web, that the tensile strength of the web in the cross direction is so low that the web cannot be conveniently handled or used for converting purposes. Binder lines may successfully be applied to such a flimsy web by maving the web formed on or delivered to a conveyor belt and printing, spraying or otherwise applying the binder to the web over a suitably supported portion of the conveyor. By applying stretch strengthable binder to such a web, in lines extending transversely of the web and transversely stretching the web to thereby elongate the binder lines under suitable conditions, the web can be made strong enough to be useful for many purposes and also, at the same time, made even lighter. The transverse stretching of the web and reduction of its weight per square yard is accom-

panied by separation of the fibers from each other, or in other words, an increase of the porosity of the web, which is highly desirable for many purposes, for example, for the production of sanitary napkin wrapper material.

Machine direction binder lines may be employed alone and some increase in strength will be attained merely as an incident to the presence of the binder and fiber bonding thereby attained, but the increase in strength can be significantly increased by employing stretch-strengthenable binder in the lines and stretching the fabric longitudinally to thereby strengthen the lines of binder as above explained. See the strength increase attained for sample 2 in the data tabulated in coulmns 17 and 18.

When a web is stretched in the predominant direction of its fiber content, the fibers are not broken or stretched but are slipped lengthwise of one another. This, like the above described transverse stretching, results in increased porosity of the web. When the web is made of fibers arranged in more or less parallel relationship, as by carding for example, machine direction lines of adhesive or binder may advantageously be somewhat wider in order that a larger number of fibers be engaged. It may be observed that in a carded web and in some air-laid and other webs, the fibers have a general tendency to run in the machine direction and that many of such lengthwise extending fibers are generally spaced crosswise for substantial portions of their lengths and that the width of adhesive application should be selected to procure the bonding of an adequate portion or number of the fibers.

One desirable form of web according to the present invention, is made by applying stretch-strengthenable adhesive to a tenuous web in lines extending in the machine direction of the web, stretching the web in that direction while preferably maintaining the normal width of the web, thereby to improve the porosity of the web and the strength of the lines of adhesive. The stretched web is then cross printed with a suitable binder material. The cross lines of binder serve to anchor the fibers in the new positions they are caused to assume incident to the lengthwise stretching. Such anchorage of the fibers substantially strengthens the web both lengthwise and crosswise. Ordinary types of binders which are not strengthenable by stretching may be used for the cross printing with a substantial benefit as indicated.

Good results are also obtained when an uncalendered web is printed in one direction with lines of adhesive, stretched, calendered, and then cross printed with binder which may or may not be stretch-strengthenable. Such a web is appreciably stronger than the same web from which the calendering operation is omitted, apparently because the calendering embeds the fibers into the lines of adhesive and irons out the web so that a continuous cross printed line can be applied. For example, as shown in FIGURE 29, a cross printed fiber web 1 is stretched transversely to elongate its lines 3 of adhesive; after the adhesive, is set, the web is calendered by a suitable calender D to press the fibers of the web into the stretched lines of adhesive and to densify the web and smooth its surface. Thereafter, a printing mechanism represented by the printing roll E1, may act on the calendered web to print longitudinally extending lines 6A of reinforcing adhesive on the web. The longitudinally extending lines of adhesive thus applied may be of a stretch-strengthenable character and the web stretched lengthwise to strengthen the longitudinal lines of adhesive, but this is not necessary, and good results are obtained by applying longitudinally extending lines of adhesive of other suitable types. The calendering of the web before printing the longitudinal lines of binder on the web, facilitates the application of sharply defined lines of binder and the application of a selected amount of binder uniformity throughout the lengths of the lines.

It is not essential that the lines of adhesive be continuous; they may be formed of a series of closely adjacent areas, such as, for example, a row or line formed of a series of aligned spots or dashes spaced from each other a short distance which is bridged by one or more fibers which connect such areas, or for a further example, two of more rows of dashes, the rows being arranged side by side in spaced relation to each other and the dashes of one row being preferably staggered relative to the dashes in the adjacent row or rows.

Examples of webs with discontinuous lines of stretch-strengthenable binder applied thereto are shown in FIGURES 5 to 13 inclusive and FIG. 19. In FIGURE 5 a calendered fiber web 1 which has a major portion of its fiber disposed in the machine direction of the web, is cross printed with spaced lines 33 of stretch-strengthenable binder, the lines being formed by a series of dashes or elongated line segments 33A which are spaced endwise. In the illustrated example, the lines 33 are formed as shown in "Pattern A" of FIGURE 25, but it should be understood that the dimensions and arrangement shown are not critical. For stretch-strengthening purposes, it is important that the areas 33A be interconnected by fibers. In some instances, such interconnection may be by means of fibers such as indicated at 34 which extend in the direction of the length of the lines but, when the web has a predominance of lengthwise extending fibers, it will more often be by means of some of the longitudinal fibers in areas indicated at 35 between mutually overlapping end portions of the staggered line sections 33A.

When the web 1 imprinted with binder in the discontinuous line pattern of FIGURE 5 is stretched crosswise to about double its width, the individual segments or sections 33A of adhesive will be lengthened and the space between the same will also be lengthened. When the web is stretched crosswise as indicated in FIGURE 6, any fibers 34 which connect adjacent ends of endwise separated sections 33A will be pulled straight in the direction of stretching and will transmit stretching force from one section 33A to the next. However, if the extent of stretching is great enough, said end to end connecting fibers 34 may be pulled out of one or the other of the adhesive sections 33A and the main transmission of stretching force from section to section is probably by the fibers in the areas 35. When the web is stretched, the fibers in the areas 35 will tend to assume slightly angular positions as illustrated and will be separated from each other to increase the porosity of the web. The fibers in the areas 36 intermediate adjacent ends of the sections of each line, will also be pulled into more spaced relation so that said areas 36 will be made very open. Hence, the transverse stretching of the web increases its porosity throughout its area while at the same time the line sections 33A are stretched or elongated so as to cause an increase in the tensile strength of such sections in the direction of stretching. The transverse stretching just described is preferably accomplished while preventing contraction of the web in its lengthwise direction. It may be observed that in the example represented in FIGS. 5 and 6, the adhesive line sections were not stretched to the same extent as the web, but that said sections were nevertheless stretched a substantial amount which effected strengthening of said adhesive sections in direction in which they were stretched.

If adhesive is applied in the discontinuous line pattern of FIGURE 5 to a web of the character indicated, and cross stretching is effected while permitting the web to contract longitudinally as shown in FIG. 7, the adhesive line sections will, of course, be stretched and thereby strengthened transversely of the fiber web so as to strengthen it in the cross direction and the areas indicated at 36*a* intermediate the ends of longitudinally aligned adhesive sections 33A will again be made very open. However, the lines 33 of adhesive will come closer to each other and in the fiber areas intermediate overlapping portions of adhesive sections in adjacent lines, the fibers will be somewhat more consolidated or bunched as indicated at 37 in FIGURE 7 (to produce a wavy yarn like grouping of fibers) which further increases the transverse tensile strength of the web. This "bunching" of

fibers does not necessarily reduce the porosity of the web in the bunched fiber areas since there is also some fiber separation effected incident to the elongation of the adhesive line sections. Hence increase or decrease in porosity will depend somewhat on the extent of stretching effected and the extent to which the fabric is permitted to neck down crosswise of the direction of stretching.

The adhesive applied in the narrow line pattern illustrated in FIGURE 5 is preferably applied in such manner that each line section will have a continuous film of adhesive on one side of the web. This may be accomplished by applying the adhesive in such a viscous condition that it will not have a great tendency to flow along the fibers or in the capillary spaces between the fibers of the web.

It is not, however, necessary that a film be formed on a surface of the web. The stretch-strengthenable adhesive may be applied in fairly thin consistency so as to penetrate the web and a sufficiently continuous film of adhesive may be formed within the thickness of the web to permit stretch strengthening of the adhesive areas in the manner already explained. When it is desired that the adhesive be contained largely within the thickness of the web, it is preferred that the adhesive pattern cover a somewhat larger portion of the area of the web. As represented in FIGURE 8, the adhesive pattern B of FIGURE 25 is applied to the web, the adhesive being in a consistency which permits it to penetrate the web and to be contained within the same in areas **33***b* without any pronounced surface film. The web shown in FIGURE 8 has been stretched transversely and results in a highly porous transversely stretched web similar to that of FIGURE 6 so far as fiber arrangement is concerned. When the adhesive is applied in such a manner that it is taken up almost wholly within the thickness of the web and without a pronounced surface film, even the adhesive areas tend to open up and become somewhat pervious, whereas in the surface film adhesive arrangement of FIGURES 5 and 6 the narrow adhesive areas may be made deep enough to remain unbroken when stretched. However, even though the adhesive in the area **33***b* are made pervious, there remains a net-like continuity of the adhesive from end-to-end of each section so that stretch-strengthening may be effected.

FIGURE 9 illustrates the application of discontinuous lines of adhesive to the web in the machine direction of the web, the adhesive pattern being that represented at A in FIGURE 25. If the web is formed of fibers deposited haphazardly with no predominant fiber direction it will be stretchable in the machine direction about as much as in its cross direction. However, if the web is of the character often referred to as carded, a majority of the fibers will extend lengthwise and its capacity for stretching lengthwise will be somewhat less than its capacity for transverse stretching. When a carded web is imprinted as represented in FIGURE 9 with pattern A and stretched to increase its length by about 25% as shown in FIG. 10, significant strengthening and porosity increase is obtained as indicated at **35***a* and **36***b* incident to the stretching of the adhesive areas and incident to separation of the fibers which occurs by reason of the stretching of the web. The stretching is preferably effected while maintaining the width of the fabric in order that the greatest increase in porosity of the web be obtained.

Test data indicating tensile strength improvement incident to stretching of samples according to FIGURE 6, 8 and 10 are given in the accompanying chart in columns 19 and 20.

The printing pattern need not embody elongated line-like sections but may be formed of any shaped areas applied in such proximity to each other that they are interconnected by fibers so that when the web is stretched in a selected direction the stretching force will be transmitted from one adhesive area to an adjacent area through the interconnecting fibers. This requires that the adhesive, during stretching, must retain a sufficiently strong grip on the fibers to prevent them from being pulled out of the adhesive, although some degree of movement of the fibers within the adhesive area is not necessarily precluded. The yield point of the adhesive or binder should be lower than the tensile strength of the fibers in order that the adhesive be stretched rather than the fibers broken.

An example of adhesive application not involving line-like elements in the conventional sense, is shown in FIGURE 11 where circular ring shaped stretch-strengthenable adhesive areas **38** are imprinted on the web **1**. If the web **1** is of a carded fiber structure, it may be stretched in either the cross direction as represented in FIGURE 12 or in the machine direction as shown in FIG. 13 or both. If it is stretched in the cross direction somewhat greater stretching is usually possible and the circular adhesive area **38** will be stretched into ovals as represented at **38A**, having their long axes in the direction of stretching. Similarly, if the web is stretched in the machine direction as represented in FIGURE 13, the extent of stretching will usually be somewhat less than in the cross direction but a similar effect, but to a lesser degree, will be obtained, the circular areas of adhesive being elongated in the machine direction. Fibers which connect portions of the printed areas most nearly aligned in the direction of stretch will usually be pulled to somewhat greater parallelism intermediate the interconnected areas so as to open some areas of the web to impart somewhat of a net-like pattern to the web somewhat as represented in FIGURES 12 and 13.

The pattern of adhesive represented in FIGURE 11 is illustrated in detail in pattern C of FIGURE 25.

The adhesive may also be imprinted in solid areas of a round, square or other regular or irregular formation, the important thing being that the adhesive areas be disposed in such proximity to each other that they will be interconnected by fibers as above explained so that stretching applied to the web will be transmitted from one adhesive area to another so that the stretching of the adhesive areas is effected by stretching of the web to increase the tensile strength of the adhesive areas in the direction in which they are stretched. If the fibers in a web are bonded together strongly enough by an impregnated or otherwise suitably distributed binder or sizing agent, it is not essential that the separated areas of stretch-strengthenable adhesive be interconnected by individual fibers which extend continuously from area to area. Two or more fibers secured to each other with sufficient strength to prevent separation thereof under stretching force applied for stretch-strengthening purposes, may function as individual continuous fibers for transmitting stretching force from one adhesive area to another, and interbonded fibers which function in this manner are considered to be within the scope of the reference herein to area interconnecting or space bridging fibers.

Non-woven fabric imprinted with adhesive may be creped as above explained in connection with FIGURE 26 and this creping may be effected either before or after stretching the material. Creping of the material after it is stretch-strengthened, tends to soften the material and to improve its drape and feel properties. Also, the described fabrics may be subjected to many of the conventional textile fabric treatments to attain various surfaces or to impart various qualities to the fabric.

A creped carded fiber product reinforced by longitudinal and crosswise lines of stretch-strengthened adhesive is represented in FIGURE 18, the material having been stretched both lengthwise and transversely to strengthen the lines of adhesive binder.

A crepe tissue paper product is represented in FIG. 21, the crepe tissue paper having lines **6** of stretch-strengthenable adhesive thereon extending in the machine direction of the web and transversely of the creping therein, and the web with the lines of adhesive thereon having been stretched longitudinally to remove a substantial por-

tion of the creping which was initially in the web; such stretching effects significant stretch-strengthening of the lines of adhesive and the longitudinal tensile strength of the stretched tissue web is reinforced by said strengthened lines of adhesive.

A stretch-strengthened, amplified-porosity, non-woven web of fiber may also be made with stretch-strengthenable adhesive applied in the form of a continuous filling, sheet or film over the entire area of the fiber web. A continuous sheet or film of the adhesive, together with the fiber web may be subjected to stretching in any desired direction to attain strengthening effects similar to those attained by stretching lines of adhesive as described. If the fiber web is impregnated with adhesive in the condition referred to as desirable in connection with Pattern B (FIG. 25), or if the adhesive is applied as a surface film or sheet and is made thin enough, stretching of the adhesive and the fiber web will not only spread the fibers to increase porosity of the web but will also cause the adhesive to develop a multiplicity of pin-holes or similar pores or openings to produce a permeable, stretch-strengthening-adhesive-reinforced fiber web.

Another procedure for combining stretch-strengthenable material with a web of fiber is to coat a suitable plate or roll surface with a thin overall film or with spaced bands of the desired stretch-strengthenable material (for example, a film having a thickness of one-half mil, i.e., .0005 inch, or less), and then depositing on this plate in engagement with said adhesive, a web, preferably uncalendered, of fibers, for example, a web having a basis weight of the order of 5 to 10 grams per square yard. This web is pressed into the adhesive after it is partially dried, by suitable roll or other pressure means. Because the fibers in the web are discontinuous and separated, especially when the web is uncalendered, a correspondingly discontinuous pattern or film of adhesive will be taken up by the fiber web as it is separated from the coated plate or roll.

Such a product is represented on an enlarged scale in FIGURE 14 where fibers are shown at **40***a* and adhesive at **40***b* by heavy shading along portions of the lengths of some of the fibers. Because of the interweaving of the fibers, they haphazardly cross one another in such a relationship that many irregular or meandering lines of adhesive will be formed, some probably extending continuously across the surface of the fabric and others discontinuously but interconnected by fibers. Such continuous and discontinuous lines of adhesive may be stretched to strengthen the adhesive in accordance with the principles already explained. The adhesive film being thin, not all of the web fibers will pick up adhesive. This fabric is quite porous and it may be stretched for strengthening purposes, thereby also increasing the porosity and effecting some reorientation of the fibers. Any fibers remaining free of attachment to the film may be removed by appropriate treatment.

A web having adhesive applied thereto in a diamond-shaped pattern or any other net-like pattern, for example, in a rectilinear pattern as represented in FIGURES 4 and 15, can be caused to exhibit a puffed characteristic obtained by permitting the web to shrink slightly from a stretched condition, thereby causing the fiber surrounded by lines of binder to more or less pucker or puff from the normal plane of the web. Many, if not all, of the stretch-strengthenable binders suitable for the purpose of this invention, and many other binders which are not stretch-strengthenable but, which may be used for some purposes in connection with this invention, have a definite tendency to shrink or retract from the maximum stretched condition which they reach in the process of fabricating webs according to this invention; this retracting capacity may be taken advantage of to produce the said puffed type of fabric. If the longitudinally and transversely printed fabric represented in FIGURES 4 and 15 is subjected to cross stretching to cause its longitudinal lines 6 of binder to be separated to a predetermined distance as represented in FIGURE 16 and is then permitted to retract to a limited extent, as above referred to and as represented in FIGURE 17, some of the fibers which extend between said longitudinal lines of adhesive will be caused to buckle or pucker when said longitudinal adhesive lines 6 return to the closer relationship represented in FIGURE 17. The stretching and retraction may be effected in the longitudinal direction if preferred, or it may be effected in both directions for greater effect. Shrinkage or retraction can, however, be controlled by maintaining the stretched web under tension until the adhesive has dried or set and it may also be reduced by embodying a small amount of fiber in the adhesive material.

For producing a highly porous web according to the present invention, it is desirable that the unstretched web be as porous as possible when the stretch-strengthenable adhesive is applied. When the web with the adhesive thereon is stretched under suitable restraint against reduction of one dimension of the web as an incident to enlargement of another dimension thereof, porosity of the web will be significantly increased.

Methods and mechanisms have been devised by which non-woven webs of fiber may be formed with the fibers deposited in various patterns which provide web areas in which there is almost a total absence of fibers, such areas being more or less surrounded by areas in which there is a sufficient deposit of fibers to form an integrated, lace-like or patterned web. Such patterned webs can be so formed as to initially be very, very porous or open. Such a web is represented in FIG. 20, the pattern being a rectilinear net-like pattern which provides openings indicated at **42** which are almost free of fibers, while the net-work portion **43** of the web may be very porous, for example, comparable in porosity, with a non-woven fiber web having a basis weight as low as 1½ or 2 grams per square yard.

A non-woven fiber web having the illustrated rectilinear net-work pattern may be reinforced by continuous or discontinuous lines of stretch-strengthenable binder applied along either or both the longitudinal and cross direction areas of fiber concentration as indicated at **44** and **45** respectively. The patterned web with adhesive thereon as just explained, may be stretched in either or both the longitudinal and cross directions to strengthing the lines of binder and to stretch out the fiber web so as to increase its permeability. Fiber realignment will also occur to some extent as explained above in connection with FIGURES 1 to 4 to also increase the tensile strength of the web. The pattern in which the fibers are deposited to form the starting web is variable through a wide range and some patterns may facilitate the formation of discontinuous, stretch-strengthenable binder lines.

Combinations of continuous and discontinuous binder lines may be employed. For example, in FIG. 19, there is illustrated a stretchable fiber web **46** having continuous lines **47** of stretch-strengthenable binder extending crosswise of the web, and discontinuous lines **48** of such binder extending in the machine direction of the web. In this instance single sections of the discontinuous lines are located intermediate adjacent cross lines of binder, but such single sections are not essential and may be replaced by a series of round dots or other shaped areas provided that such areas are in such proximity to each other that they are effectively interconnected by fibers for transmitting stretching forces from area to area as explained above in connection with FIGURES 5 and 9.

Laminated webs may also be produced with increased strength due to stretching of lines of stretch-strengthenable adhesive. Such laminated webs may embody layers of different kinds of fibers and they may be produced in several ways. For example, as represented in FIG. 22, two webs **49** and **50** of fiber may be imprinted with lines of adhesive, extending crosswise on one web and lengthwise on the other, the webs then being assembled

with their printed faces in engagement with each other after the adhesive is too set to bond to additional fibers while retaining an affinity for its own kind of material. The webs will become bonded together mainly if not entirely in the small areas where the lines of adhesive cross one another. This will produce a very flexible web which can be made very pervious and very strong both crosswise and lengthwise by the described stretching procedure. The stretching may be effected on the individual webs before lamination or the laminated web may be stretched either or both lengthwise and crosswise.

The webs and adhesive thereon may be so selected or they may be brought together under such temperature or other conditions as to necessitate the application of pressure to cause the adhesive applied to one web to bondingly engage the fibers of the other web. A pair of webs, at least one of which has the desired adhesive thereon over its entire area or in lines or otherwise and under the aforesaid conditions, may be run between a pair of squeeze rolls at least one of which has a ribbed or other formation which will apply bonding pressure to small segments of the area or lines of adhesive and thereby produce spot bonding of the webs. The bonded webs may be stretched in the direction of the adhesive lines for strengthening purposes.

If the adhesive is applied in a fairly viscous state so that it remains largely on the interengaged surfaces of the respective webs, but little of the adhesive will be apparent on the faces of the laminated web, interattachment may be effected while the adhesive is in its initial fluid condition as applied or it may be effected after the adhesive has dried on the respective webs, the adhesive being, in that case, reactivated by the application of chemicals or heat. Whatever the pattern of adhesive and the degree of continuity or discontinuity of the bonding desired, the assembled webs may be pressed together under light or heavy, over-all or more or less localized pressure patterns to effect the desired extent of interattachment.

In producing laminated webs it is not essential that the assembled webs be placed with their printed faces in engagement with each other. The adhesive carried on the face of one web may be applied in sufficient quantity to penetrate through the web so as to engage able with fibers of other webs placed respectively on opposite faces of the adhesive carrying web, thereby to produce a three-ply web, adhesive application being limited to a single web. Regardless of the number of lamina employed, the web may be subjected to strength improving stretching operations in the direction of selected or all lines of adhesive and across the direction of any or all of said lines for the purpose of increasing the porosity of the fabric as already explained.

The adhesive pattern of FIGURE 5 (and in other patterns) may be applied to form adhesive film sections on one side of the web even though the viscosity of the adhesive is not so high as to prevent the adhesive from running along the fibers. This may be accomplished by the method represented in FIGURES 23 and 24 wherein a fiber web 1 is illustrated as being placed on a platen or plate 59 which has a very smooth and preferably a polished surface. A printing plate 60, having adhesive suitably applied thereto is then brought down into engagement with the web and the adhesive carried by the printing lands or recesses of the plate 60 is taken up by the web 1 and passes therethrough to the surface of the platen 59 on which it forms a film which adheres to the fiber web when it is stripped from the plate 59. The plate 59 may be in the form of a platen roll having a smooth and polished surface, and the printing plate may be in the form of a printing roller which cooperates with such platen roll.

Another method of attaining high porosity is to employ a web made of a mixture of long and short fibers and to apply binder in spaced lines or zones which will effectively anchor the long fibers but will leave the shorter fibers free of contact with the adhesive. After the longer fibers are bonded and either before or after stretching the web and binder, the unattached short fibers may be mechanically removed by suction or by blowing air through the web, by subjecting the web to a vibration or shaking, by brushing, or by a combination of these. For example, as shown in FIG. 30, a non-woven web 61 which contains a mixture of long and short fibers, and which is reinforced with stretch-strengthened binder, is suitably propelled and guided over a suction box 62 and subjected to a beating action by a rotary beater or agitator 63; the short fibers of the web which are not adhesively bonded to other fibers will be displaced and removed from the web.

When the web is made of a mixture of cotton fibers and soluble vinyon or other fibers which are soluble in chemicals which do not adversely affect the cotton fibers, the porosity of the fabric may be further increased by subjecting the fabric either before or after stretching to a solvent which will dissolve out the soluble fibers so as to leave only the cotton or other insoluble fibers. The effect of such removal of one kind of fiber will be in proportion to the amount of the soluble fiber employed in the initial mixture. Uniform porosity throughout the area of the web can be easily attained if the soluble fibers are uniformly distributed throughout the web. However, the web may be so prepared that the fiber to be removed is located in selected areas of the web which are to be made extra porous. A fiber dissolving operation of this kind is represented in FIG. 31 where a web 57 of the character referred to is shown as being suitably propelled and guided through a bath 58 of solvent and thence through a wash or other desired treatment bath 51.

Porosity of the printed, stretched web may also be increased by subjecting the web to a brushing operation which may be so effected as to cause the brushed fibers to assume positions more or less parallel to the lines of adhesive, or more or less perpendicular thereto, or in other desired relationship to the adhesive lines. This brushing may be effected before or after stretching or fiber dissolving operations.

Machine direction brushing on a cross printed web such as shown in FIG. 1, causes the fibers to assume a generally parallel machine direction arrangement as represented in FIG. 3. This operation is represented in FIG. 32 where a non-woven web 52 of haphazardly arranged fibers is propelled under a rotating brush 53 in contact therewith to rearrange the fibers of the web into parallel relation longitudinally of the web. This product is somewhat like a carded web except that it can be made of much lighter weight; also this product may be strengthened by cross stretching and thereby made still lighter and more porous as explained above in connection with FIGURES 1 and 2.

Brushing may be effected in the cross direction to position fibers in parallel relationship to cross direction lines of adhesive. Such brushing tends to greatly increase the bunching of the fibers together along the lines of adhesive as aforesaid, to thereby add further to the cross direction strength of the web. This cross-strength increase incident to cross brushing is, of course, in addition to the strength increase attained by cross stretching either before or after brushing as already explained.

A non-woven web comprising a mixture or blend of thermoplastic, stretch-strengthenable fibers and cotton or other non-thermoplastic fibers, may also be strengthened and made more pervious by stretching. Such a web is shown in FIGURE 33 wherein stretch-strengthenable thermoplastic fibers are represented by the heavy lines 55, the lighter lines 56 representing cotton fibers. This web may be suitably treated as by calendering or otherwise interbonding of the fibers at their crossings, and by heat or chemicals (including solvents) to condition

the thermoplastic fibers for strengthening by stretching. Stretching of the web will then effect stretching and strengthening of the thermoplastic fibers. The stretch-strengthening action on the thermoplastic fibers may involve stretching of thermoplastic fibers or filaments joined together to, in effect, provide lengths of stretch-strengthenable material which extend continuously over the web in the direction of stretch, and it may involve, in effect, the stretching of discontinuous lines of binder formed by thermoplastic or binder filaments joined to each other by cotton fibers. This product may be made very light in weight, highly porous or pervious, and exceptionally strong for its weight.

Instead of printing or otherwise applying the binder or adhesive in a suitable viscous or liquid form, the binder may be applied to the web which is to be reinforced, by means of thermo-plastic resinous threads, ribbons or similar filaments. One or more such filaments may be placed side by side to form the equivalent of lines of stretch-strengthenable adhesive such as the lines 3 and 6. In some instances a woven net of thermoplastic resin filaments may be applied to the web. Threads and other forms of such filaments may be applied to the web with the filaments in such surface-dry condition that handling of the filaments is facilitated, and they may be bonded to the web by the application of heat or other softening agents and pressure which will press the softened thermo-plastic filaments into such intimate engagement with the fibers of the web as to effect bonding of the filaments to the web. The web so prepared may then be stretched to elongate the filaments so as to strengthen the same and to amplify the porosity or perviousness of the web. This type of construction is represented in FIGURE 34 where a fiber web is indicated at 66 and a woven net of thermo-plastic, stretch strengthenable resinous material is indicated at 67. The net 67 is attached to the web as above explained or in any other suitable manner, and in FIG. 34 the combined web and net is represented as having been stretched in both machine and cross directions for strengthening and web opening purposes. However, the combined web and net of FIG. 34 may, if desired, be stretched in only one direction for binder strengthening and web opening purposes, the binder which remains unstretched serving to reinforce the web with such strength as is inherent in the unstretched binder. If thermo-plastic filaments are to be applied in two directions, it is not essential that they be interwoven. Filaments extending in one direction may be applied and bonded to the fiber web and filaments extending in a transverse direction may thereafter be applied and bonded to the web, and, if desired, stretching of one set of filaments may be effected before the other set is applied. Also, the filaments (and other forms of binder) which extend in one direction may be of a type or kind different than those which extend in another direction.

Calendering of the web after printing has the effect of reducing the depth and increasing the width of the lines of adhesive, some of the adhesive being thereby caused to flow into engagement with additional fibers whereby strength of the printed web is further increased.

For example, as shown in FIGURE 28, longitudinally extending adhesive lines 6 initially applied to a width of about 1/16 of an inch and largely surfaced on the web can be widened as represented at 6b by the action of a calender, the depth of the adhesive lines being incidentally reduced and flexibility of the adhesive increased. Another important benefit obtained by calendering is that the fibers of the web are forced into more intimate contact with the adhesive and more or less embedded therein, thereby insuring effective bonding of the fibers to the adhesive, and increasing the strength of the fabric. The widened lines of adhesive are best attained by calendering before stretching but good results may also be attained by calendering after stretching which is somewhat preferable for improving the bonding of the fibers in position as aforesaid, although this improvement may also be attained to a significant degree by calendering before stretching. The fabric may be calendered both before and after stretching to attain these benefits to the highest degree. The calendering operation is preferably carried out under a pressure which avoids pressure-bonding of the fibers directly to each other. Calender pressure of around 120 pounds per linear inch (gauge) is satisfactory and in the calendering operation the web is heated to a temperature of around 300° F. and propelled at a speed of around 15 feet per minute, for a web of viscose rayon with polyvinyl acetate as a binder. The said pressure, temperature, and speed factors, and other factors may vary with different kinds of adhesives.

Calendered webs appear to be somewhat stronger than uncalendered webs whether or not the printed lines are stretched, and are easier to handle in printing and other apparatus. The calendering or embossing may be in ornamental or other patterns. When the web is calendered or densified before printing, the adhesive has a greater tendency to spread out into wider lines. This spreading tendency may be restricted by increasing the viscosity of the adhesive.

A greater amount of adhesive may be applied in a line on an uncalendered web so that where heavy or deep lines of adhesive are desired, it is somewhat preferable that they be applied to the web before calendering. A densified web will, however, more readily receive a given amount in a line of selected width thereby facilitating the printing operation. This difference in adhesive receiving action between undensified and densified web may be utilized to produce webs having adhesive lines formed, in effect, of successive sections embodying different quantities of adhesive and the densified sections may be arranged in patterns of various kinds to produce special effects.

The fiber content of the web may consist of cotton, wool, silk, rayon and other natural and synthetic fibers or mixtures or blends of these. Fibers such as flax, sisal, hemp, jute, asbestos, and fiber glass may be used. Selection is made according to the end results desired and the capacity of the particular fibers to give the desired end results.

The lines of adhesive should be preferably so spaced that a large portion of the fibers will engage at least two such lines so as to be thereby anchored in the web. The printing may be effected on the webs either before or after calendering thereof.

The described stretch-strengthening operation may be employed in connection with many varied arrangements of webs, with various arrangements and kinds of fibers in the web or webs, and with various kinds of adhesives which have the indicated property of being strengthened by stretching. The stretching should, of course be effected within limits determined by the characteristics of the particular adhesive employed so as to remain within the range within which strengthening occurs. The increase in porosity may be effected by stretching the web whether or not stretch strengthened adhesive lines are applied and some stretching may be effected to increase porosity before adhesive is applied, and additional stretching may be effected after such application for the dual purpose of increasing the porosity and increasing strength.

In the foregoing explanation some reference has been made to stabilizing the stretch-strengthened adhesive by cooling or other appropriate treatment to prevent elements of apparatus from picking up adhesive to thereby avoid gumming up of the apparatus. It should, of course, be understood that when the adhesive is of such nature as to require treatment—including mere time treatment—to effect setting of the adhesive to preserve the stretched condition of the web and the adhesive component thereof, appropriate treatment should be employed for that purpose. Some resinous materials—for example, polyethyl-

ene, are immediately stable in stretched condition when stretched at normal room temperature.

Some reference has been made to stretching the web while restraining the same against reduction of its dimension transverse to the direction of stretching; this does not imply that unless the said transverse dimension is fully maintained, it will be reduced to an extent that the web opening effect in the direction of stretching will be fully counteracted by reduction in said transverse direction. To the contrary, many webs, when stretched in one direction, will incidentally be reduced or necked down in the transverse direction but only to a limited extent which is not sufficient to prevent the porosity or permeability of the web to fluids (gas and liquid) from being increased or amplified by the stretching.

In the foregoing explanation and in the appended claims, the words "adhesive" and "binder" are used interchangeably and without signifying adhesive properties other than are required for purposes of the invention as explained.

The desired principles of web strengthening and of increasing porosity may be employed in many forms without departing from the spirit of the invention.

Specific examples of adhesives which may be employed and strengthened by stretching are:

(*a*) Thermoplastic resin polymers of linear chain formation:

(1) Polyvinyl acetate (such as a Bakelite Corporation product known as "AYAF").

(2) Polyvinyl chloride

(3) Polyvinyl butyrate

(4) Polyethylene

(5) Polyamide (nylon)

(6) Cellulose acetate

(7) Hydroxymethyl cellulose

(8) Carboxymethyl cellulose

(*b*) Thermoplastic resin copolymers of linear chain formation:

(1) Polyvinyl chloride and polyvinyl acetate Bakelite Corporation's product known as "VYNW–2" consisting of 95% polyvinyl chloride and 5% polyvinyl acetate has been found satisfactory

(2) Vinyl chloride and vinyl acetate (vinyon)

(3) Vinylidiene chloride and vinyl chloride (Saran) These copolymers may embody various proportions of their respective polymers. For example (1) may be in proportions such as:

62% polyvinyl chloride and 38% polyvinyl acetate

87% polyvinyl chloride and 13% polyvinyl acetate

97% polyvinyl chloride and 3% polyvinyl acetate

Fiber lengths analysis of webbing known to be suitable for the purposes of this invention are given in the following schedule but without excluding from the scope of this invention other fiber lengths and proportions which may also be found satisfactory:

Lengths	Source of fibers				
	100% rayon		100% 1 5/32" middling cotton bleached		
	Web air-laid	Web unprocessed	Web air-laid	Web carded	Web unprocessed
Mean length, inches	1 5/16	1 5/16	.554	.696	.764
Percent 1 1/16" or longer	89.2	95.0	39.2	58.9	61.1
Percent 7/16" or shorter	7.0	3.7	48.0	32.5	29.2
Percent 3/16" or shorter	2.7	1.5	15.9	13.0	12.4
Percent 1/16" or shorter	1.1	.7	6.7	7.1	5.0

Data for four samples of material embodying the described invention are shown in the following tabulation:

	Sample 1	Sample 2	Sample 3	Sample 4
Adhesive Data:				
Kind	AYAF	AYAF	AYAF	VYNW–2.
Line continuous.				
Direction of lines (and of stretching)	Cross	Machine direction	MD and CD	MD and CD.
Line width	1/16"	1/16"	1/16"	1/16".
Line spacing (center to center)	1/4"	1/4"	1/4"	1/8".
Weight of adhesive lines on only, per square yard of web, before stretching, in grams.	3.6	3.0	3.00 MD 2.43 CD 5.43 Total	Not recorded.
Fiber Data:				
Kind	70% 1 1/16" rayon 3 denier, 30% 1 5/32 middling cotton bleached.	Same as Sample 1	Same as Sample 1	100% 1 5/32" middling cotton bleached.
Web formation	Carded	Carded	Carded	Air-laid.
Predominant fiber arrangement	Machine direction	Machine direction	Machine direction	Haphazard.
Basis weight per square yard without adhesive and before stretching, in grams.	12.6	15.18	15.18	Not recorded.
Total Basis Weight:				
Fiber and adhesive before stretching in grams per square yard.	16.2	18.18	20.61	Do.
Fiber and adhesive after stretching in grams per square yard	14.14	15.31	17.33	16.73.

Test Data re Webs with Continuous Binder Lines

	Sample 1	Sample 2	Sample 3	Sample 4
Test data:				
Width of test units, inches	2	2	2	2
Average tensile strength in direction of adhesive lines before stretching in grams	798	597	[1] 597	[1] 1,225
Average Tensile Strength in Direction of Adhesive Lines After Stretching, in grams	980	834	834	[2] 1,816
Percent of elongation of lines of adhesive	12	18	18	[3]
Average tensile strength in machine direction when after stretching in machine direction, sample was calendered and cross printed, in grams			1,090	2,452

[1] In MD. [2] After calendering. [3] Between 10% and 20%.

Test Data re Webs with Binder Applied in Discontinuous Pattern

	Sample 1	Sample 2	Sample 3	Sample 4
Binder:				
Pattern	A	A	A	B.
Kind	AYAT (vinyl acetate 20% sol. in ethyl alcohol).	AYAT 20% sol	Plastisol "GEON" 60% sol. (polyvinyl-chloride and dioctyl phthalate).	AYAT 10% sol.
Direction of line sections relative to predominant fiber lay.	Transverse	Parallel	Transverse	Transverse.
Web:				
Material	3-ply 50% rayon 50% cotton 17.7 grams per sq. yd.	Same as sample 1	Same as sample 1	4-ply 50% rayon 50% cotton 19.76 grams per sq. yd.
Weight proportions:				
Fiber	58%	40%	19%	60%.
Binder	42%	60%	81%	40%.
Tensile Strength in Grams:				
Web—With adhesive before stretching to strengthen (TI).	630–CD	779–MD [1]	777–CD	670–CD.
After stretching to strengthen	416–CD	884–MD [1]	715–CD	521–CD.
After stretching to strengthen and calendering (T2)	504–CD	1360–MD [1]	740–CD	580–CD.
Percent stretched (P)	100–CD	25–MD [1]	50–CD	100–CD.
Percent increase [2] in tensile strength per unit of fabric weight	60	118	44	73.

[1] Too weak to be tested in cross direction.
[2] Percent increase determined by formula:

$$\left(\frac{T2+\frac{P\times T2}{100}-1}{TI}\right)\times 100$$

NOTE.—Tests made on samples 1½ inches wide clamped between jaw pairs 2 inches apart at start of test.

I claim:

1. Webbing comprising a non-woven web of fibers having thereon a network of binder material, at least some of the binder in said network having the characteristic of being strengthenable by stretching and at least some of said binder tending to contract from a stretched condition when relieved of stretching forces, said web and said network of binder thereon having been stretched to elongate that portion of the network which becomes stronger when stretched, that portion which tends to contract from a stretched condition being contracted to a lesser extent than it was stretched, whereby some of the binder in said network is strengthened as an incident to said stretching and some of the fibers of said web are puckered as an incident to said contraction, a puffed characteristic being thereby imparted to the web.

2. A non-woven web of increased porosity and tensile strength comprising a non-woven fiber web and having spaced lines of a stretch-strengthenable thermoplastic resinous adhesive bonding some of the constituent fibers of said web together into a self-sustaining web, said adhesive having been stretched a sufficient amount to increase the strength thereof, and some of the fibers of said web as a result of the stretching being rearranged into positions more nearly parallel to the direction of stretching, thereby increasing the strength and the porosity of the web to values greater than the strength and porosity possessed by the web before stretching.

3. A non-woven web of increased porosity and tensile strength comprising a non-woven fiber web and spaced lines of a stretch-strengthenable thermoplastic resinous adhesive bonding some of the constituent fibers of said web together into a self-sustaining web, said adhesive having been stretched by an amount in the range from 10 to 50 per cent of the initial length of said lines, thereby increasing the strength of said adhesive, some of the fibers of said web as a result of said stretching being rearranged into positions more nearly parallel to the direction of stretching, thereby increasing the strength and the porosity possessed by the web.

4. A non-woven web of increased porosity and tensile strength comprising a non-woven fiber web and spaced lines of a stretch-strengthenable vinyl resin adhesive bonding some of the constituent fibers of said web together into a self-sustaining web, and said adhesive having been stretched a sufficient amount to increase the strength thereof, and some of the fibers of said web as a result of the stretching being rearranged into positions more nearly parallel to the direction of stretching, thereby increasing the strength and the porosity of the web to values greater than the strength and porosity possessed by the web before stretching.

5. A creped tissue paper web having binder discretely distributed thereon, said binder having the characteristic of becoming strengthened upon being stretched when in a predetermined condition, said web with said binder thereon in said predetermined condition having been stretched to increase the porosity of the creped tissue paper web and elongated and strengthen said binder to impart increased tensile strength to the web.

6. A non-woven web of fiber having binder discretely distributed thereon, said binder having the characteristic of becoming strengthened when stretched when in a predetermined condition, said binder being applied to said web in mutually spaced continuous lines which extend in one direction, and in mutualy spaced discontinuous lines which extend crosswise of the direction of said continuous lines, portions of said discontinuous lines being located in the spaces intermediate said continuous lines, and said web with said binder thereon in said predetermined condition having been stretched in the directions of said continuous and discontinuous lines of binder to increase the porosity of the fiber web and elongate and strengthen said binder lines so as to increase the tensile strength of the web in the directions of said lines.

7. The method of making an improved web product which comprises applying a stretch-strengthenable thermoplastic resinous adhesive composition in spaced lines on the surface of a non-woven web and jointly stretching said web and said adhesive while said adhesive is soft and in a stretchable condition to an extent sufficient to increase the strength of said adhesive and to increase the porosity of said web.

8. The method of making an improved web product which comprises printing spaced lines of stretch-strengthenable thermoplastic resinous adhesive onto a non-woven web and jointly stretching said web and said adhesive while said adhesive is soft and in a stretchable condition to an extent sufficient to increase the strength of said adhesive and to increase the porosity of said web.

9. The method of making an improved web product which comprises applying spaced lines of stretch-strengthenable thermoplastic resinous adhesive composition to a non-woven web and jointly stretching said web and said adhesive while said adhesive is soft and in a stretch-

able condition by an amount in the range from 10 to 50 percent of the original dimension of the web to which the lines were applied to thereby increase the strength of said adhesive and to increase the porosity of said web.

10. The method of making a strong, highly porous non-woven sheet, which method comprises the steps of providing a non-woven fiber web which contains a mixture of fibers comprising some fibers which are soluble by a selected treatment and other fibers which are substantially insoluble by such treatment, integrating said web with a pattern of stretch-strengthenable resinous material, stretching the integrated web and resinous material with the resinous material in condition to be strengthened as an incident to stretching thereof, and treating the web to dissolve out said soluble fibers.

11. A non-woven web comprising a mixture of stretch-strengthenable thermoplastic fibers and non-thermoplastic fibers, said fibers being securely and finally interbonded at crossings thereof to provide a stable integrated structure, and the web having thereafter been stretched to strengthen said thermoplastic fibers with the latter in condition for strengthening by stretching, whereby the tensile strength and the porosity of the web are increased.

12. The method of fabricating a fibrous web product consisting of the steps of intermixing non-thermoplastic textile fibers and thermoplastic fibers, treating said thermoplastic fibers in a manner to permit adhesion bonding thereof to the textile fibers, securely and finally bonding said thermoplastic fibers to the textile fibers to provide a stable integrated structure, thereafter maintaining said thermoplasic fibers in a condition to be stretch-strengthened, and thereafter stretching said web sufficiently to strengthen said thermoplastic fibers.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,047,444

July 31, 1962

Kenneth J. Harwood

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 3, line 31, for "knowns" read -- known --; column 5, line 5, for "ocur" read -- occur --; line 34, for "suply" read -- supply --; column 6, lines 12 and 13, strike out "calered from the calender stack U, from the" and insert instead -- calender stack, the web may be delivered to a --; column 9, line 41, for "area" read -- areas --; column 20, line 46, for "mutualy" read -- mutually --.

Signed and sealed this 22nd day of October 1963.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWIN L. REYNOLDS
Acting Commissioner of Patents