

Nov. 16, 1965

J. J. SUCH ET AL

3,218,381

PROCESS FOR MAKING APERTURED NON-WOVEN FABRIC

Filed Feb. 15, 1963

3 Sheets-Sheet 1

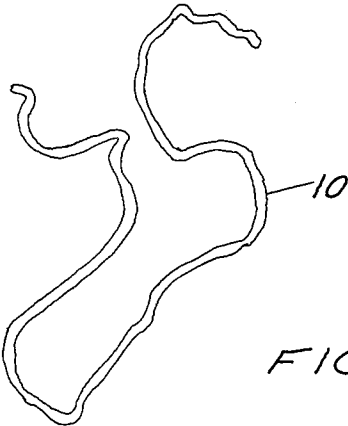


FIG. 1

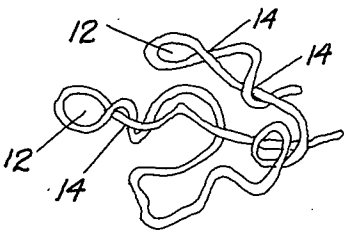


FIG. 2

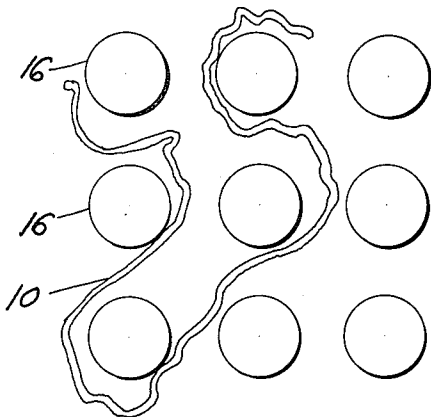


FIG. 3

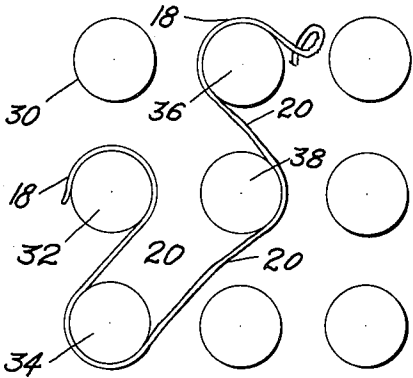


FIG. 4

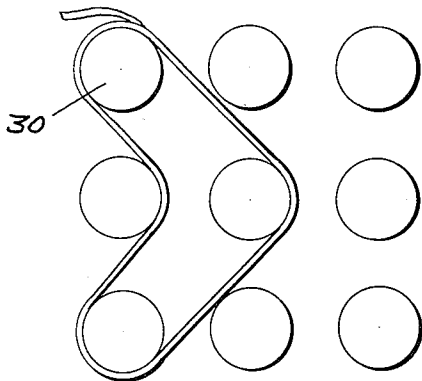


FIG. 5

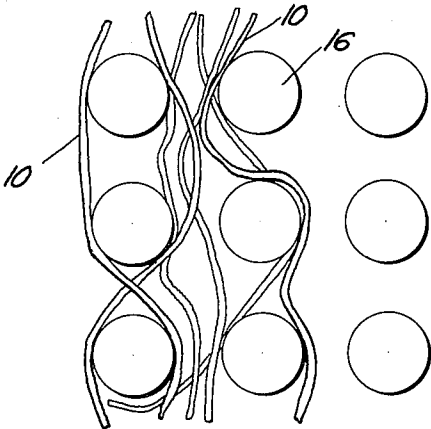


FIG. 6

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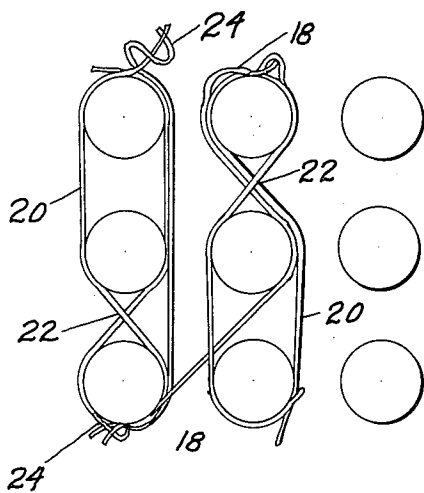


FIG. 7

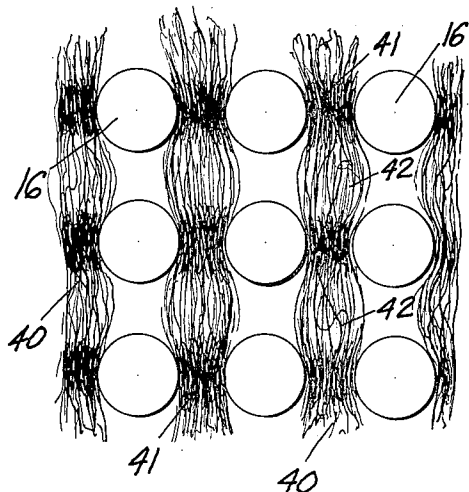


FIG. 8

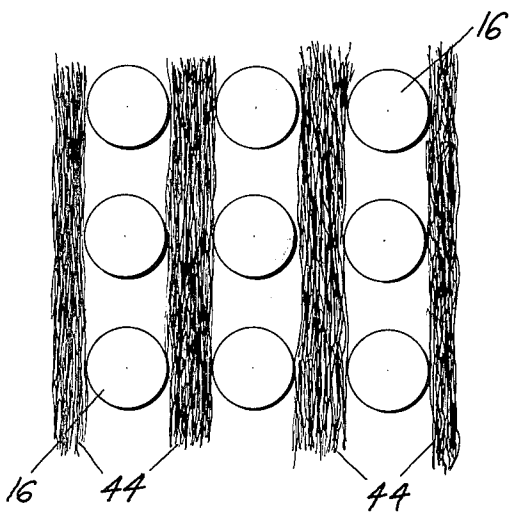


FIG. 9

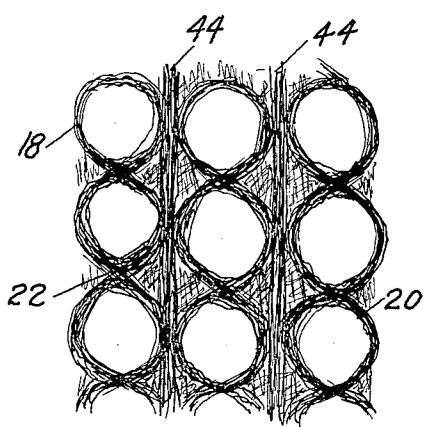


FIG. 10

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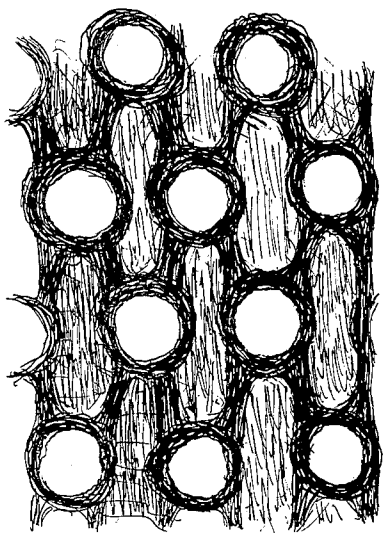


FIG. 11

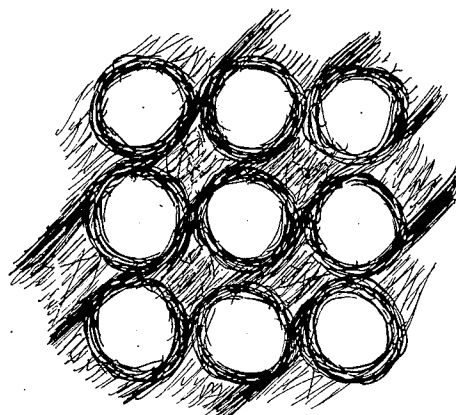


FIG. 12



FIG. 13

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PROCESS FOR MAKING APERTURED NON-WOVEN FABRIC

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Filed Feb. 15, 1963, Ser. No. 258,879

10 Claims. (Cl. 264-103)

This invention relates to the production of apertured non-woven fabrics. More particularly, it relates to the production of apertured non-woven fabrics prepared from retractable textile fibers by a process which yields an apertured material wherein the apertures are fibrously reinforced and are interconnected by tensioned bundles of partially-retracted fibers extending between apertures.

Apertured non-woven fabrics are widely used as a substitute for woven gauze-like fabrics, particularly in one-use applications such as sanitary napkin covers, wiping and cleaning cloths, throwaway towels, and the like. They are commonly prepared by displacing the fibers in a fibrous web mounted on a special type of foraminous support, the displacement being effected by fluid forces, by pins thrust through the web, or by a combination of both. Such processes are described in Brewster Patent 1,978,620; in Kalwaites Patent 2,682,251; Griswold Patent 3,025,585; and Gelpke Canadian Patent 617,135.

In general, prior art apertured non-woven fabrics bear only a limited resemblance to fabrics made from actual yarns by a weaving process. The nature of prior art processes is such that the fibers are displaced laterally away from what may be termed a resist area, and are organized into generally flat bands. The definition of the aperture is recognizable, but is not clear-cut, since the aperture is generally traversed by at least a few undisplaced fibers. The fibers, having been physically displaced away from the vicinity of the aperturing area, are described as being in unstressed condition, with no tendency to return to their original positions. In general, these prior-art aperturing processes bend the fibers away from the resist areas without effecting a significant change in the fine-scale crimping, in the case of synthetic fibers, or without straightening out the natural kinks and reversals of twist found in natural fibers. This bending away from resist areas may be regarded as a reversible process, made possible by the generally flexible nature of textile fibers, and effecting no appreciable change in the inner structure of the fiber. The fibers in such products are in general in a flaccid and relaxed state.

We have found that non-woven fabrics with very clear-cut apertures can be made by a process which is essentially the reverse of prior art processes involving lateral displacement. Not only are such products esthetically superior to prior art apertured non-woven fabrics, but the fibers are aggregated into a reinforcing configuration around the peripheries of the apertures so that the vicinity of an aperture becomes a strong point, rather than weak link, in the strength pattern of the fabric. Simultaneously, the strength and elongation of the product are substantially altered, as will be set forth below.

In general terms the process of this invention involves the formation of a web or fleece of retractable textile-length fibers, and subjecting the web to an operation which tends to release the inherent retractive forces in the fibers while the web is held under local restraint, as for example, by being impaled on a pin block. This is a stress-creating rather than a stress-relieving process, and the net result is that many of the fibers become tensioned. In such a process, however, the natural tendency for the fibers to retract is to a considerable extent impeded by the pins in the block. Not only is there little or no over-

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all area shrink, but the fibers are drawn together and contracted into reinforcing configurations.

It is therefore an object of this invention to provide a process for aperturing a web of retractable textile-length fibers by subjecting the web to a process which retracts and straightens the fibers while the web is being restrained on a bed of pins or the like.

It is a further object to provide a process for forming an apertured non-woven fabric characterized by fibrously-reinforced apertures.

It is an additional object of this invention to provide an apertured non-woven fabric characterized by fibrously-reinforced apertures interconnected by bundles of parallelized, tensioned fibers.

Other objects of the invention will be evident from the detailed description and examples hereinbelow.

The invention will be more clearly understood by reference to the accompanying drawings, in which:

FIGURE 1 represents a single fiber, with releasable retractive forces, suitable for use in this invention.

FIGURE 2 represents the fiber of FIGURE 1 after the retractive forces have been released while the fiber was free to move in any desired direction.

FIGURE 3 represents the fiber of FIGURE 1 impaled on a set of pins.

FIGURE 4 represents the fiber of FIGURE 3, showing the result of retractive forces released while fiber movement is impeded by the pins.

FIGURE 5 represents an alternative configuration of the fiber of FIGURE 4.

FIGURE 6 represents the distribution of a cluster of six fibers from an oriented web, arrayed on a pin block.

FIGURE 7 represents the fibrous cluster of FIGURE 6 after release of the retractive forces in the fibers.

FIGURE 8 represents a very highly oriented fibrous card web arrayed on a set of pins.

FIGURE 9 represents the web of FIGURE 8 after release of the retractive forces in the fibers.

FIGURE 10 represents a product of this invention.

FIGURE 11 represents another typical product of this invention.

FIGURE 12 represents a product made in a manner similar to the product of FIGURE 10, but with the fibers oriented in a northeast-southwest direction.

FIGURE 13 represents the state of aggregation of the fibers around a typical aperture of the fabrics of this invention, in cross section.

All of the drawings are enlarged for clarity, and the fiber-length-to-width ratio is minimized to show fiber behavior more clearly.

As a base material for the practice of this invention, we employ a web or fleece of retractable textile fibers delivered by conventional fiber-dispersing mechanisms such as a card, garnett, air-lay machine, or the like, the choice of mechanism being at least in part dictated by the degree and the angle of orientation it is desired that the fibers shall assume. As will be seen more clearly hereinbelow, fiber orientation has a bearing on the nature of the final product.

By retractable fibers we mean fibers which, although stable in carding operations and most conventional fiber-treating processes, are nevertheless in a state of internal stress which may be at least in part released by an appropriate treatment. The release of stress is usually accompanied by a certain amount of fiber shrinkage, but even more pronounced is the disposition of the fiber, in the retracting process, to twist, loop, bend, curl, and generally distort along its length. The behavior of some such typical retractable fibers, when allowed to retract in sheet form with no impediments to retraction, is set forth in Secrist Patent 2,774,129, wherein the retractable fibers are

natural cellulosic fibers and the releasing agent is sodium hydroxide of an appropriate concentration.

A product of this sort, while suitable for a variety of applications, has two characteristics which restrict its use. First, it is of relatively low strength, unless bonded or saturated with a binder. Second, it has a very high elongation, and is readily deformable. Although advantageous for some applications, ready extensibility in a non-woven fabric is a drawback where strength and dimensional stability are desired.

To a considerable extent, this extensibility reflects a basic lack of internal organization of the fibrous structures from which non-woven fabrics are commonly made. In a so-called isotropic web, made for example on a Rando-Webber, the fibers are oriented almost equally in all directions. Garnett webs are also substantially randomized: carded webs are more oriented, but even in the case of carded webs, one can speak only of an average degree of orientation, since the fibers are curled, crimped, and bent so as to follow a tortuous path through the web. When a tensile stress is applied to such a fibrous web, only a certain number of fibers are involved. In webs of the above sort, the fibers bearing the stress are only casually engaged with neighboring fibers. Although the fibers may cross and recross each other, the strength of the fibrous web depends on the summation of the fiber-to-fiber frictional forces developed by point contact. Furthermore these point-to-point contact forces do not act in unison in opposing a stress. Since the fibers are not organized, and since few if any of the fibers involved in the stress have identical contours, only a few point-to-point frictional contact forces need be overcome at any one time to permit the steady and gradual disengagement of one fiber from another, one after another, until complete rupture of the fibrous web has occurred. There is no concerted action of the fibers in opposing stress, only the action of one individual fiber after another in transient opposition. This is one reason why prior art non-woven fabrics are either characterized by high elongation and low tensile strength, or else are bonded in an effort to overcome these defects.

Even with bonded materials, however, similar considerations prevail. The bonding is effective only where it unites one fiber with another, at crossover points. Although such a bond is stronger than a mere fiber-to-fiber frictional crossover bond, the bonds are still broken one by one under applied stress, and still do not act in unison.

Quite different considerations prevail in the yarns of a woven fabric. Here the fibers are highly parallelized by a series of drafting operations and are twisted to bring them into close contact with each other. This straightening of the fibers, and the substitution of length-to-length for point-for-point frictional contact, has the recognized advantage of tremendously increasing the tensile strength of the fibrous organization.

To the extent that a straightened, yarn-like configuration can be built into a non-woven fabric, with a substantial proportion of the fibers lying in side-by-side intimate contact, the tensile strength and resistance to deformation of the product will increase. This we accomplish in the present invention by a process which may be referred to as internal drafting. By internal drafting we mean that the dispersed and convoluted fibers in a fibrous web are subjected to a three-stage process:

(1) The fibers, which are potentially retractable, are prevented from moving in independent and random directions by restricting their motion with a set of impedance points, as by impaling the web on a pin block.

(2) The impeded web is subjected to the action of a force which releases the retractable mechanism of the fibers, causing the fibers to draw together into tensioned bundles organized into a pattern comprising interconnected, substantially straight segments.

(3) The releasing force is removed from the rearranged web, whereby the fibers are frozen into a new configured

organization of tightened, tensioned bundles, said fibers being in intimate contact with each other along a substantial portion of the straightened and parallelized lengths.

When we speak of the fibrous bundles as being tensioned, we do not mean that if a bundle is cut, the ends will spring apart like a cut rubber band. Rather, it is meant that the fibers are drawn into taut bundles which will respond to an applied stress by an instantaneous resistance of the fibers acting in unison, rather than responding by elongation of the web and slippage of fiber past fiber. By the process of this invention, a considerable proportion of the fibers have been tightened and drawn straight by enforced straight-line contraction.

An unimpeded retraction will cause a randomized fiber response, whereas the process of this invention channels and canalizes the response into the formation of an integrated and load-bearing network. The physical structure and the general properties of such a product differ from those of products made by unimpeded, disorganized shrinkage, and also differ from the properties of apertured non-woven fabrics made by lateral displacement of fibers. In this latter case, the fibers are in a flaccid, unstressed state of organization, and are incapable of substantial load-bearing unless bonded.

The process of this invention therefore produces an artificial straightening and partial tensioning of the fibrous sections lying between pins, with an artificial curvature of the fibrous sections which terminate in the immediate vicinity of the pins. By this process a new configuration is imparted to the fibers which is now the stable configuration, as a result of which our apertured products have a marked tendency to maintain their apertured configuration even when unbonded and when subjected to swelling and moderate agitation in water. By contrast, conventional non-bonded apertured fabrics when gently shaken with water will rapidly lose their apertured appearance and will revert to a disorganized clump of fibers.

In addition to the action of chemical swelling agents on fibers sensitive thereto, heat has a similar effect on certain retractable fibers such as Dacron 61, a Du Pont polyethylene terephthalate fiber, and on plasticized cellulose acetate fibers, as well as on fibrous copolymers of polyvinyl chloride and polyvinyl acetate, of the type known as Vinyon, a product of American Viscose Corporation. Polyvinyl alcohol fibers which have not been formaldehyde-treated to a state of complete water insensitivity also show definite retraction and twisting when immersed in water.

Other suitable fibers and releasing mechanisms to which said fibers are susceptible will readily occur to those skilled in the art.

As is known, the uniform and unimpeded retraction of such fibers, interlaced in a web or fleece, is accompanied by a substantial area shrinkage and the formation of a felt of interlocked fibers, said felt being heavier per unit area than the starting web, and being of a plain, untextured surface.

By contrast, the normal fiber reaction in the process of this invention is impeded in a controlled manner. It may be better understood from a consideration of the behavior of a single retractable fiber in a retraction process. FIGURE 1 represents a single fiber 10, selected at random from a carded fibrous web. Its irregular contour may be natural, as is the case with cotton fibers, or may be induced by the mechanical treatment and the air currents of the carding operation.

FIGURE 2 represents the type of fiber contour that may be expected from the release of the retractive forces of the fiber of FIGURE 1 when the fiber is free and unrestrained: it represents what would happen, for example, if the fiber were of polyvinyl alcohol and were immersed in water. It is apparent that the fiber has twisted and bent upon itself to form loops 12, and has twisted upon its own axis as at 14. In unrestrained retraction, it is believed to be the interlocking interplay of a multitude of such fibers

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that imparts strength and integrity to felts made thereby.

FIGURE 3 represents the fiber of FIGURE 1, identical in contour, but impaled on a block of pins 16, the points of which may be assumed to be protruding from the page. FIGURE 4 represents the fiber of FIGURE 3 after its retractive forces have been released while the fiber was restrained on the pin block. Not being free to curl and kink ad libitum, the retracting fiber tends to wrap its ends around the fixed pins, as at 18, and to straighten itself out into a tensioned and constricted path made up of segments following the periphery of the pins as at 18, and straight-line segments running from pin to pin, as at 20.

It should be appreciated that the behavior of the fiber of FIGURE 4 is representative only, with the left-hand end of the fiber shown as engaging with the pin 32 and the right hand end with the pin 36, said ends having moved counterclockwise and clockwise, respectively. If the unpredictable movements of the fiber end-segments had been reversed, both ends might have wound up associated with pin 30, as shown in FIGURE 5. The elements that retracting fibers have in common in the practice of this invention is a tendency to reinforce the peripheries of nearby resist areas and to be tensioned into substantially straight lines between resist areas.

The behavior of a cluster of fibers is more complex, as is shown in FIGURES 6 and 7, but is characterized by the same general tendency of the fibers to be compacted in an encircling and reinforcing configuration around the pins, and to be drawn into tensioned bundles extending between pins.

It will be noted that the fibers in FIGURE 6 are highly oriented in a north-south direction when their retractive tendencies are released. Their behavior as shown in FIGURE 7, is the behavior of the very few fibers, impeded only slightly by inter-fiber friction, and to that extent FIGURE 7 is somewhat idealized. It does illustrate the presence of tensioned fibers 20 extending between pins, and also illustrates an X-like configuration 22 where fibers cross each other, due either to their initial configuration in the web or to their particular response to the releasing action of the retraction process.

In the actual products made by the process of this invention, the inter-fiber frictional forces, generally disregarded in FIGURE 7, must be taken into account, as the following consideration will show. In a typical assembly of carded synthetic fibers, 3 denier, $1\frac{1}{2}$ inches long, weighing 30 grams per square yard, there are approximately 1,825 fibers per square inch. Similar calculations indicate a comparable, or higher, figure for cotton. A typical pin block useful in this invention comprises a set of pins $\frac{1}{16}$ inch in diameter set in square formation, 12 pins per inch. In that regard, the fiber-populated area of FIGURES 6 and 7, being two pins wide and three pins deep, represents an area of $\frac{1}{24}$ of a square inch. In the retraction of a 30-gram web, approximately 76 fibers would be packed into the populated area of FIGURE 6, instead of the six fibers shown. Under such conditions, the fiber-end entanglement shown at 24 of FIGURE 7 is decreased, since adjacent fibers restrict the freedom of motion of fiber ends.

In actual practise, therefore, impeded retraction of a 30-gram web leads to a pattern in which there is a fibrous thickening or reinforcement around the peripheries of the pins or impedance points, interconnected by stressed fibrous bundles which may show a crossing configuration as at 22 of FIGURE 7, or may be predominantly organized into a configuration such as shown in FIGURE 10, 12, or 14, depending on the placement and spacing of the impedance points as well as on the orientation of the fibers.

The peripheral reinforcement around the pins or points used in this invention is perhaps in part due to the packing operation which the fibers undergo during the process, as described below. In the pin block previously mentioned, with pointed round pins $\frac{1}{16}$ inch in diameter

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spaced in square arrangement $\frac{1}{2}$ inch apart, there are 144 pins per square inch. Calculation shows that 44% of the base of a one-inch square of this nature is occupied by the bases of the pins: there is consequently a substantial crowding and bundling of fibers together, particularly in the vicinity of the pins. Such an effect is known in the art. We have found that if a pin-separated web of this sort, comprising retractable fibers, is then subjected to an operation which releases the internal stresses in the fibers, the fibers tend to draw together snugly around the pins, thus reinforcing the apertures. In such a process, the fibers in the immediate vicinity of the pins are prevented from moving in a multiplicity of random directions, characteristic of an unimpeded retraction operation, but are stressed into retracted reinforcement around the pin-like restraints.

It is important that the retractive operation be continued only while the fibers are restrained from unlimited free movement, and that the retracting operation be discontinued, or neutralized, while the fibers are still held under restraint. In the case of thermosensitive retractable fibers, this is readily accomplished by impaling a web of fibers on a pin block or similar device, heating the fibrous web until the desired degree of bundle-like configuration has been realized, and then cooling the rearranged web to set the fibers in their new configuration before stripping the apertured web from the block. In the case of retraction by chemical forces, it is convenient to impale a web of sensitive fibers on a pin block, expose the impaled web to the action of an appropriate reagent while the web is impaled, and while the fibers are in their new configuration, to wash out or neutralize the reagent so that there is no substantial tendency for the fibers to retract further. Drying may be accomplished while the fibers are still impaled, although this is not always necessary.

As mentioned above, the inter-fiber frictional forces must be taken into account in explaining the over-all behavior of a fibrous web in the process of this invention. This is especially true in the case of highly oriented webs, such as fibrous webs delivered from a flat-top card and subsequently drafted in the machine direction during processing. Such card webs may show a machine-direction strength that is six, eight, or ten times the cross strength, and are commonly spoken of as having an orientation ratio of six or eight or ten to one.

FIGURE 8 represents the result of impaling a hypothetical super-oriented carded web on a pin block. The fibers are represented as being so highly parallelized that there are no crossover fibers, only fibers oriented in the north-south direction. Such a web has never been met with in our experience, but the fibrous bundles 40 of FIGURE 8 do form one structural element in the behavior of carded webs. When such a hypothetical web is impaled on a set of pins 16, the fibers display a crowding tendency 41 between horizontally parallel pins, and a bulging tendency 42 in the region where pin spacing allows. When the fibers are tensioned by releasing their inherent retractive forces, they straighten out and draw together to form the fibrous bundles 44 of FIGURE 9, which are characteristically thicker and more densely organized than the bands 40 of FIGURE 8 into which the fibers were originally arrayed.

This concentrating and compacting effect seems to be characteristic of areas where the fiber density is greatest: that is, when the retractive forces of the fibers are released, activity and densification appear most intense in the areas where the fiber population is highest, and thick areas tend to grow even thicker at the expense of areas in which the fibers are fewer or farther apart.

It should be repeated that the tightly-organized tensioned bundles 44 of FIGURE 9 do not represent the whole product of the invention, but are a component of the network of bundles characteristic of this invention, and that such bundles are generally seen running in the

principal direction of fiber orientation, merging with other ramifying and reinforcing bundles which stem from fibers which are laid down in different orientation. In the case of extremely highly-oriented webs, however, the process of this invention may lead essentially to sets of parallel yarns, interconnected by a minimum of fibrous bridging from which the yarns can readily be broken away.

Normally, however, the appearance of the products of this invention also display the influence of the behavior of fibers running at various angles to the north-south axis, since even in an oriented card web there is a degree of fiber randomization. It is in this sense, then, that we speak of the bundles 44 of FIGURE 9 as being a component of the products of this invention. A distribution such as shown in FIGURE 8, with no fibers crossing between pins, is an idealized situation.

Example I

One typical product of this invention is shown in FIGURE 10. The product of FIGURE 10 was made by impaling a card web of Dacron 61 fibers, weighing about 15 grams per square yard, onto a block of pins in square array, the pins being $\frac{1}{16}$ inch in diameter at the base and being spaced 12 to the inch. A stream of hot air at about 400° F. was directed against the pin block, whereupon the fibers were seen to draw together into the configuration shown in FIGURES 10 and 11. Upon removal of the hot air stream the apertured web was removed from the pins. Heating was not severe or prolonged enough to effect fusion; rather, the stability and integrity of the product is due to the interconnecting ramifications of fibrous bundles.

As is shown in FIGURE 10, the products of this invention display, in an integrated and interconnected form, the typical bundle configurations which have been hitherto discussed individually. FIGURE 10 shows, for example, the aperture-reinforcing bundles 18 discussed in connection with FIGURES 4 and 7; the tensioned bundles 20 bridging the inter-pin spaces, in parallel or diagonal fashion, as shown in FIGURE 7; the X-like crossing 22 of such bundles, also previously shown in FIGURE 7; and the parallel inter-pin bundles 44 of FIGURE 9.

In addition to fiber orientation, the placement of the pins also has an effect on the nature of the bundles, as will be apparent to one skilled in the art. Such an effect is illustrated in FIGURE 12 and the corresponding photomicrograph FIGURE 13.

Example II

The product of FIGURE 11 was made by impaling a fibrous web of bleached absorbent cotton, weighing about 30 grams per square yard, on an arrangement of pins as shown. The pins were $\frac{1}{16}$ inch in diameter, set 0.110 inch on centers in a 60° equilateral triangular pattern. The web thus impaled was treated with 13% sodium hydroxide solution at 0° C., whereupon the fibers twisted, turned, drew together and compacted into the configuration shown. After rinsing, neutralizing, and drying, the apertured product was removed from the pin block.

Again the aperture-reinforcing bundles 18 of FIGURE 7 are seen. The bundles 46 of FIGURE 11 correspond to the bundles 44 of FIGURES 9 and 10, but due to the staggered placement of the pins, these bundles have been displaced into a slightly waved configuration.

By thus reforming the fibrous web into a pattern of tensioned fibrous bundles containing relatively straight load-bearing segments, a product is created which has quite different physical properties from the properties of products made by prior art retractive processes, and different from the properties of other apertured non-woven fabrics. This may be better understood by a comparison of tensile strengths and elongations, two physical measurements which help to characterize a non-woven fabric.

First of all, if the cotton web of Example II is impaled

on the pin block, there is a certain degree of fiber slippage as the web is apertured by the pins. The impaled web may then be wet out with water, dried, and removed from the block. Although the fibers are rearranged to some degree, in the absence of a bonding step such rearrangement will not survive even gentle hand manipulation. The strength of such a product is essentially the strength of the initial card web, and such products so far as we are aware have no commercial utility until they have been bonded. The fibers still react to an applied stress in an individual, one-by-one manner.

If the same web is not impaled on the pin block, but is treated with 13% sodium hydroxide solution at 0° C. in a free-shrinkage process, there is a large area shrink of over 80%, and a non-apertured felt-like product is formed, characteristic of the products of the above-mentioned 2,528,793 patent. In an actual experiment of this nature, the product of unrestrained shrinkage weighed 170 grams per square yard. A one-inch strip had a tensile strength in the machine direction of 2.54 pounds, in the cross direction of 1.32 pounds, or 0.015 pound and 0.008 pound per gram of fabric weight, respectively. The elongation at break was 120% in the machine direction, 123% in the cross direction. These figures are characteristic of the behavior of unsaturated non-woven felts of this type, wherein the fibers are intercurled and kinked together in essentially random fashion.

The product of Example II however was an apertured felt which had undergone internal fibrous rearrangement but no area shrink. It still weighed 30 grams per square yard. The fabric strength per gram of fabric weight was 0.083 pound in the machine direction, 0.012 pound in the cross direction, per one-inch wide strip. The elongation was only 9% in the machine direction and 49% in the cross direction.

Thus the difference between random unimpeded shrinkage and restrained shrinkage with reorganization into fibrous bundles is seen to bring about a five-fold strength increase in the machine direction, and a thirteen-fold decrease in the elongation. The product is still a soft, absorbent, unbonded non-woven fabric, but due to the peculiar organization of the fibers into tensioned, load-bearing bundles, the product has amazing strength and stability, and is suited for innumerable uses without the addition of any foreign binding substance.

In comparing the strength of the products of this invention with other apertured or non-apertured non-woven fabrics, it should be appreciated that fiber orientation should be taken into account. For this reason, we prefer to characterize strength by a geometric mean tensile factor, which is the square root of the product of machine direction times cross-direction strength, in pounds per inch of width, multiplied by the number of square yards in one pound of fabric, to normalize for weight differences. This factor, or

$$GMTF = \frac{454(M \times C)^{\frac{1}{2}}}{\text{Fabric weight in grams per square yard}}$$

wherein M represents the machine-direction strength and C the cross-direction strength.

In the above illustration, the fabric made by unimpeded shrinkage had a GMTF of 4.70: the fabric made according to this invention had a GMTF of 14.0, or a four-fold increase in the overall normalized strength measured in two orthogonal directions.

The influence of fiber orientation is further illustrated in FIGURE 12. In this product, the pin block of FIGURE 10 was used in connection with a web of cotton fibers laid down at an angle of 45°: that is, in a north-east-southwest direction. The cotton web was then treated like the cotton web of FIGURE 11. The arrangement of the fibrous bundles does not resemble the product of FIGURE 10, even though the same pin block was used in both cases. This can be understood if FIGURE 12 is rotated counter-clockwise 45°, so that the

northeast-southwest orientation of the fibers is shifted to a north-south orientation. It is then seen that the pin arrangement with respect to the direction of fiber orientation was that of a square with another pin in the center of the face of the square, like the five-face of a die. The presence of this central pin, in general, leads to the formation of sinuous bundles unless the spacing is so open that the bundles are not deflected by the overlap of staggered pins in adjacent rows.

From the foregoing discussion, together with the drawings and photomicrographs, it will be apparent that a wide variety of patterns of fiber bundles may be made by the proper selection of pin dimensions and pin contours, the spacing and arrangement of the pins, and the fiber orientation. In general, we find it preferable in encouraging an interlocking formation of bundles to have the majority of the fibers impeded by the presence of at least three pins; that is, the distance between adjacent pins should be not greater than one-half of the length of the average fiber. In this way, the majority of the tensioned fibers will comprise at least two curved sections which may be regarded as bights along the peripheries of pins, and at least two straight sections extending between pins. If all that is sought is a non-woven fabric with apertures reinforced by partially tensioned fibers, the pins may be spaced so far apart that the formation of bundles between apertures is not evidenced. A cross section through an aperture of this type is shown in FIGURE 13, where partially-tensioned fibers 50 are shown drawn and compacted together in a reinforcing grommet-like array around an aperture 52. It is characteristic of the products of this invention that the fibers reinforcing the apertures reproduce the shape of the pin—round, square, or triangular—with amazing fidelity, and that this new conformation is frozen into the fiber and cannot readily be removed.

The process may be carried out continuously, as will be apparent to those skilled in the art, by an apparatus such as shown and described in the patent to Greiner, 3,034,180, or modifications thereof. A web of sensitive retractable fibers may be impaled on a set of pins of desired shape, size, and placement, with the aid of a brushing mechanism if needed, the pins being mounted on a movable belt, screen or cylinder. While the fibers are thus impeded from free movement, the inherent retractive forces in the fibers are released, whereupon fiber rearrangement takes place as described above. The retracting operation is then halted, thermally or chemically, while the fibers are still in partially tensioned configuration due to their inability to overcome fiber-to-fiber friction and to overcome the barriers to free movement offered by the pins, after which the apertured and patterned non-woven fabric is removed from the belt.

Having thus described our invention, what we claim is:

1. The process for making an apertured non-woven fabric which comprises forming a web of retractable textile-length fibers, impaling said web on a set of pins to perforate and restrain said web, and subjecting said web to a process causing the fibers to retract while preventing any substantial over-all shrinkage of said web and discontinuing the retracting operation while the fibers are still held under restraint, whereby the fibers are retracted in tensioned form around the peripheries of said pins to form an apertured non-woven fabric with reinforced apertures.

2. The process for making an apertured non-woven fabric which comprises forming a web of textile-length fibers capable of retracting when heated, impaling said web on a set of pins to perforate and restrain said web, subjecting the thus-restrained web to a thermal process causing the fibers to retract while preventing any substantial over-all shrinkage of said web, cooling said web to a temperature at which the fibers no longer attempt to

retract, and removing said web from said set of pins.

3. The process for making an apertured non-woven fabric which comprises forming a web of textile-length fibers capable of retracting under the influence of a chemical swelling agent, impaling said web on a set of pins to perforate and restrain said web, subjecting the thus-restrained web to a chemical process causing the fibers to retract while preventing any substantial over-all shrinkage of said web, halting said chemical shrinkage process, and removing said web from said set of pins.

4. The process according to claim 3 wherein the fibers are naturally-occurring cellulosic fibers and the chemical shrinkage process is treatment with sodium hydroxide of mercerizing strength.

5. The process according to claim 3 wherein the fibers are water-sensitive polyvinyl alcohol fibers and the chemical shrinkage process is treatment with water.

6. The process for making an apertured non-woven fabric which comprises forming a web of retractable textile-length fibers, impaling said web on a set of pins spaced apart on the average by not more than one-half of the average fiber length, whereby said web is perforated and restrained, and subjecting the thus-restrained web to a process causing the fibers to retract while preventing any over-all shrinkage of said web and discontinuing the retracting operation while the fibers are still held under restraint, whereby the fibers are retracted into tensioned bundles defining a pattern of interconnected closed loops.

7. The process for making an apertured non-woven fabric which comprises forming a web of textile-length fibers capable of retracting when heated, impaling said web on a set of pins spaced apart on the average by not more than one-half of the average fiber length, whereby said web is perforated and restrained, subjecting the thus-restrained web to a thermal process causing the fibers to retract while preventing any substantial over-all shrinkage of said web, whereby the fibers are retracted into tensioned bundles defining a pattern of interconnected closed loops, cooling said web to a temperature at which the fibers no longer attempt to retract, and removing said web from said pins.

8. The process for making an apertured non-woven fabric which comprises forming a web of textile-length fibers capable of retracting under the influence of a chemical swelling agent, impaling said web on a set of pins spaced apart on the average by not more than one-half of the average fiber length, whereby said web is perforated and restrained, subjecting the thus-restrained web to a chemical process causing the fibers to retract while preventing any substantial over-all shrinkage of said web, whereby the fibers are retracted into tensioned bundles defining a pattern of interconnected closed loops, halting said chemical shrinkage process, and removing said web from said set of pins.

9. The process according to claim 8 wherein the fibers are naturally-occurring cellulosic fibers and the chemical shrinkage process is treatment with sodium hydroxide of mercerizing strength.

10. The process according to claim 8 wherein the fibers are water-sensitive polyvinyl alcohol fibers and the chemical shrinkage process is treatment with water.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,218,381

November 16, 1965

John J. Such et al.

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 2, line 75, for "2,774,129" read -- 2,528,793 --.

Signed and sealed this 19th day of July 1966.

(SEAL)

Attest:

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