June 14, 1966 N. S. NEWMAN ETAL 3,255,509

METHOD FOR PRODUCING NEEDLED TEXTILE STRUCTURES

Filed Dec. 23, 1963

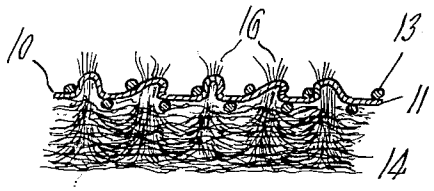


Fig. 1.

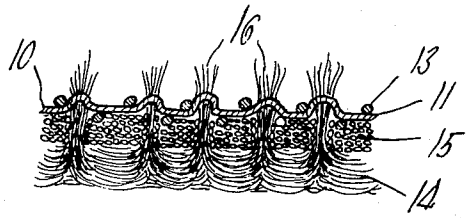


Fig. 2.

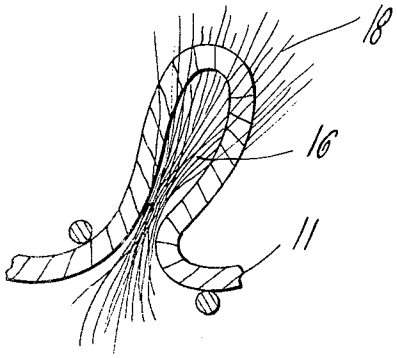


Fig. 3.

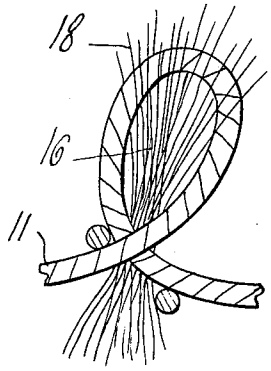


Fig. 4.

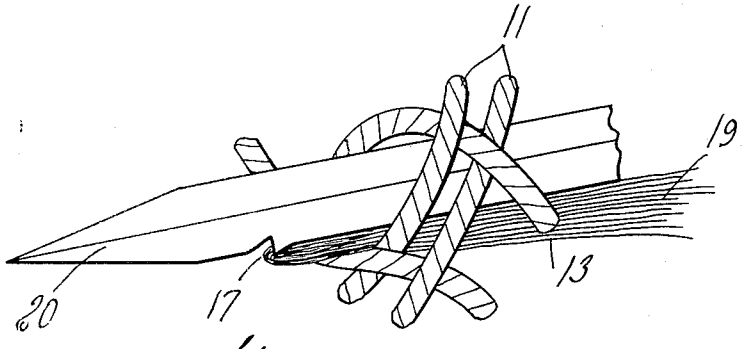


Fig. 5.

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3,255,509 METHOD FOR PRODUCING NEEDLED TEXTILE STRUCTURES

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This invention relates to composite needle-laminated textile structures for interlining and insulating purposes. More particularly, it relates to laminates of fiber to fabric, or three-component laminates of fiber-foam-fabric, of substantial elastic conformability and high tensile strength.

Composite laminated structures are known in which a fibrous fleece is needled to a fabric base, or in which a layer of elastomeric foam is sandwiched between the fibrous and the fabric components to form a three-ply laminate. Laminates of the latter type are disclosed in U.S. Patent 3,059,312, to Jamieson. However, prior art structures of either the two-ply or the three-ply type are generally categorized as inextensible, and though they may be flexible, they display little or no elongation or recovery due to the dominance of the inextensible fabric base with which the foam and the fibrous fleece are combined. Such prior art needled laminates have been proposed for a wide variety of uses, such as floor coverings, insulating felts, papermakers' felts, and the like, where their non-elastic nature is not a critical deterrent to their use.

Attempts have been made to create inexpensive interlinings by needling a fibrous fleece to a knitted fabric reinforcement, to provide some extensibility to the combination, but the effect of the needling operation almost invariably is to puncture some of the yarns of the knit fabric, with consequent ravelling, lack of support, and local loss of fabric elongation and recovery where yarns have been severed.

Similar considerations apply to the use in such an application of truly elastic reinforcing fabrics—i.e., fabrics woven from covered elastomeric threads. In addition, such fabrics are too expensive for interlining use.

In utilizing needled laminates in such applications as linings or interlinings for garments, it is desirable that the laminate have a ready elongation, so that it can be shaped and sewn into place to conform to the garment shape. In some instances, it should also have quick recovery from applied stresses to prevent bagging or distortion, in which case the laminate should also be stable: that is, it should be able to withstand repeated elongation and recovery without separation of the component layers and without developing holes, runs, or fray in the fabric layer. Prior art laminates are deficient in one or more of the above respects.

We have found that lining materials of excellent quality may be produced by needling together a fibrous fleece, and a woven fabric which has been treated so that it is marked by a ready elongation or extensibility in the warp or filling direction, or both. This assembly may also include a layer of foam, if recoverability and added insulating value are desired. This extensibility may conveniently be effected in a cellulosic fabric, for example, a cotton sheeting, print cloth, or Osnaburg, by a slack mercerization process in one or both directions, as set forth in an article entitled "Special Elastic Properties of Cotton Yarn and Cloth Mercerized without Tension," by Goldthwait and Murphy, Textile Research Journal, pages 47–57, January 1955. The use of slack-mercerized fabric in the process of this invention has led to unexpectedly superior results, as set forth below.

In general, the slack mercerizing process is effected by treating a cellulosic fabric with caustic of mercerizing strength while the fabric is maintained substantially without tension in either the filling direction, the warp direction, or both. Shrinkage in the untensioned direction or directions results, the extent of the shrinkage being generally governed by the twist multiple of the yarns and by the cover factor of the fabric, which in turn is related to the size of the yarns and the number of yarns per inch. The thus shrunken fabric is then washed free of caustic and dried under such conditions as to retain a substantial part of the shrinkage imparted by the slack mercerizing process.

The relatively recent availability of solvent-resistant polyester foams has created a great deal of interest in the utilization of such materials as thermally-insulating linings for garments, and/or shaping interlinings for garments. However, the limited tensile strength of unsupported foams has required that they be strengthened by laminating to a stronger element: hence, it is common practice to laminate together a sheet of, say, polyurethane foam with a layer of fabric. A wide variety of woven or knitted fabrics may thus be combined with foam, either by a solvent-based adhesion process or by melting the surface of the foam to a plastic condition at or about the point of combination as described in U.S. Patent 2,957,793 to J. W. Dickey. Such processes are expensive, however, and their use is generally confined to applications where the foam serves as interliner and the fabric is the outer or wearing face of the garment.

In the utilization of laminates for interlining purposes, each element in the combination plays a specific role. In the case of three-ply laminates, the foam contributes bulk, resilience, insulating value, and elastic recovery, combined with light weight. Used alone, however, foam is deficient in tensile strength, generally running from 1.5 pounds to 3.0 pounds per inch-wide strip $\frac{3}{32}$ inch thick, depending on quality. The less expensive foams, though of good insulating properties, are low in tensile strength, especially when needled to a fibrous fleece, and do not serve as a strong, durable lining material.

For esthetic reasons, as well as for added insulating value, it is common practice to needle a fleece or layer of fibers to foam for applications of this nature. The fibrous layer imparts a rich textile appearance to the foam, and may be made to simulate a pile fabric or fleece lining, or may be closely needled to resemble a suede. Additionally, the fiber layer protects the foam from the yellowing or aging which is characteristic of the effect of ultraviolet light on foams. In general, however, foam-fiber needled combinations are lacking in sufficient tensile strength to be used above as garment linings, and are of practically unrestricted elongation: that is, the presence of the fibrous layer does not restrict the tremendous capacity for elongation of the foam.

To strengthen foam-fiber combinations, they are frequently combined with a woven textile fabric. This, however, not only leads to an inextensible and non-comformable laminate in the case of conventional woven fabrics, but to a substantial decrease in the tensile strength of the fabric, as explained below.

It is the essence of this invention that marked and unexpected improvements are effected in needled fiber-fabric or fiber-foam-fabric laminates if a slack-mercerized fabric capable of substantial ready elongation of from say 15% to 75%, as defined hereinbelow, is used in place of conventional woven or knitted fabrics. In the case of the two-ply laminate, a marked conformability under stress is realized. In the case of the fiber-foam-fabric laminates, this same ready conformability is accompanied by substantially complete recovery when stress is released.

Additionally, although the initial modulus of elongation

of either type of laminate of this invention is low, at or about the point at which the slack-mercerized fabric is extended to the count or to the area which is possessed before the slack mercerization process, there is a pronounced resistance to further deformation, so that by suitable choice of slack-mercerized fabric, a laminate can be produced which has a built-in elongation limit. Such laminates, we have found, possess an unexpected resistance to delamination or separation of fiber from fabric, and to fiber shedding.

Finally, we have found that slack-mercerized fabrics survive the puncturing effect of a needling operation to a surprising extent, with a high and unexpected preservation of their inherent tensile strength, as set forth more fully hereinbelow.

It is a basic object of this invention to provide a conformable needled textile laminate capable of substantial ready elongation but with a built-in elastic limit, said laminate simultaneously possessing a substantial ultimate tensile strength. It is a further object of this invention to provide laminates of the above nature which are resistant to delamination, and which are further characterized by rapid and substantially complete elastic recovery from applied stresses.

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

FIGURE 1 is a magnified cross-sectional view of a fiber-fabric laminate of this invention.

FIGURE 2 is a magnified cross-sectional view of a fiber-foam-fabric laminate of this invention.

FIGURES 3 and 4 are representations, highly magnified, of single yarn loops and some of the fibers thrust therethrough, characteristic of the pebbled texture on the surface of the fabric layer employed in this invention, after needling.

FIGURE 5 is a perspective veiw, highly magnified, of a needle thrust through the yarns of a slack-mercerized fabric.

Slack mercerization of cellulosic fabrics, as described in the above-cited Goldthwait article and in U.S. Patents 2,379,574 and 2,404,837, is marked by a pronounced shrinkage of the fabric. If the fabric is held under warpwise tension in the process, the shrinkage, and subsequent elongation potential, is across the filling direction. Since most textile operations of washing, drying, etc., exert warpwise tension, and since elongation in one direction makes a fabric suitable for a majority of applications, slack-mercerized fabrics which are stretchable only in the filling direction are most readily made. It is, of course, possible to develop stretch in both warp and filling directions, and such a process is known in the art.

If the process is carried out on an open-meshed fabric such as surgical gauze of 24 x 20 or 20 x 12 count, the shortening and kinking of the yarns tends to cause a series of twisted or kinked crunodal loops between the yarn intersections, due to the freedom of movement of the yarns in open-meshed fabrics. Such behavior, characteristic of fabrics of a cover factor of 5 or less, imparts a pebbled appearance to the fabric surface.

In the case of more tightly woven fabrics, such as sheetings and print cloths, with cover factors of 8 and higher, the yarn span between yarn crossings is not long enough to allow the formation of a yarn loop or kink. The yarn retraction tendency in such cases is satisfied by the yarn assuming an exaggerated crimped or waved configuration, of an amplitude depending on the weave of the fabric and the severity of the shrinkage treatment. Such fabrics after slack mercerizing are characterized by a relatively smooth and even surface, free from the pebbly kinks associated with low-count slack-mercerized fabrics.

If a layer of fibers is needled into a conventional piece of medium-count fabric, such as a 64 x 60 print cloth or a 44 x 40 sheeting, it is expected that a certain amount of yarn breakage will inevitably occur as the barbs or points of the needle engage the yarns of the fabric. In a 64 x 60 print cloth made from 30's yarns in the warp and 40's yarns in the filling, the spacing between warp yarns is of the order of .008 inch, and between filling yarns. .010 inch. Needles commonly used in needle looms range from .025 to .035 inch in diameter. Since the yarns in a conventional print cloth are relatively inextensible, and since the points of a large number of needles in a bank usually descend onto the fabric simultaneously, yarn breakage is a concomitant damaging factor. Not only is the base fabric generally weakened, but localized areas are developed where the adherent fibrous layer is poorly supported, leading to material which is irregular in tensile properties from point to point.

We have found that when a slack-mercerized fabric of a construction count similar to a conventional print cloth or sheeting is subjected to a needling operation to unite it to a layer of fibers, there is minimal yarn breakage, no formation of local weak spots, the strength of the needled assembly is at least as great as the strength of the unneedled base fabric, and the fibrous layer adheres to the fabric with an unexpected tenacity. Such a structure is shown in FIGURE 1, wherein a layer of fibers **14** has been needled into a slack-mercerized fabric **10** comprising warp yarns **13** and filling yarn **11**, with the formation of numerous unbroken loops **16**, which are stuffed with fibers, and which impart a pebbled texture to the backface of the fabric.

A single loop **16** is shown in magnified form in FIGURES 3 and 4. The yarn **11**, when in the unneedled slack-mercerized fabric, may be considered to have been disposed horizontally. The thrust of an impinging needle point carrying a burden of fibers **18** has displaced the yarn **11** into a loop form **16**, with the fibers **18** of the fibrous layer interlocked with the yarn loop. The loop may be a plain bight, as in FIGURE 3, or may be crunodal, as in FIGURE 4. Both types of loop are met with in this invention, the crunodal type being presumably due to the twisting tendency of slack-mercerized yarns. It will be noted in FIGURES 3 and 4 that the fibers **18**, in passing through the loop **16**, pass on both sides of the yarn **11** to extend outwardly from the loop.

Apparently the reaction of the crimped yarns of a slack-mercerized print cloth to the direct thrust of a needle barb is one of elongation, with the result that the crimp is locally removed from a very short length of yarn and an open yarn loop is formed protruding from the face of the fabric. If the needle barb impingement is glancing rather than direct, the needle thrust has a lateral component, and the loops formed extend at an angle which is less than perpendicular to the face of the fabric. Loop orientations are thus randomized, but the important consideration is that they remain closed loops, the yarn is not ruptured, and upon the application of stress to the laminate it is found that the base fabric has not been appreciably weakened as a conventional fabric of comparable construction would have been.

Not all of the needle thrusts in the action of a bank of needles will result in direct impingement on a yarn, with loop formation. The majority of the thrusts will carry the needle, with its burden of fibers, through the interstices formed by the warp and filling yarns. This is shown in FIGURE 5, where a needle **20** with a barb **17** is thrust between the warp yarns **13** and the filling yarns **11** of a slack-mercerized fabric, the fibers carried by the needle being indicated by the fibrous bundle **19**. The yarns **11** and **13** of the slack-mercerized fabric have a high degree of elasticity compared with the yarns of a conventional fabric. They are therefore capable of substantial elongation, and tend to respond to the thrust of the needle-point by elastic deformation rather than by permanent lateral displacement. FIGURE 5 illustrates this type of elastic deformation, wherein the yarns **11** and **13** bend around the needle shank as the needle passes through the fabric. This elastic deformation is recoverable, so that upon the removal of the needle shank, the

yarns **11** and **13** will contract, narrowing the opening created by the needle shank, and locking the fibrous bundle **19** to the fabric. In the practise of this invention it has been observed that when a layer of fibers of a specific type is needled into a slack-mercerized fabric, the bond between fibers and fabric is substantially stronger than that resulting from the needling of a similar layer of fibers to a non-slack-mercerized fabric of comparable construction. Therefore the laminates of this invention have increased resistance to delamination and to fiber shedding, often allowing the omission of the back-coating operations conventionally used to provide increased anchorage of fiber to fabric.

A further consequence leading to an increased fiber-fabric bond stems from the loop-formation shown in FIGURES 1 and 2, and in enlarged detail in FIGURES 3 and 4. In the process of stretching a slack-mercerized fabric to which a layer of fibers has been needled, the loops **16** of FIGURES 1 through 4 tend to disappear. Due to the peculiar nature of the yarns in a slack-mercerized fabric, loops formed from such yarns are under stress, and have the potential to return to the plane of the fabric since they are still inherently elastic. It will be noted that when a loop is formed, as shown in FIGURES 3 and 4, the fibers **18** pass along both sides of the yarn **11**. The elastic retraction of the loops **16**, brought about gradually through repeated small deformations of the laminate when used as a conforming interliner, means that the loops gradually work themselves down into the face of the fabric, whereby the fibers passing on both sides of the yarn loop are uniquely and firmly interlocked into the fabric.

The following example will illustrate one method of making the product of this invention.

EXAMPLE 1

A 42 x 36 bleached cotton sheeting was slack mercerized, allowing both warp and filling shrinkage. The final count of the slack-mercerized fabric was 60 x 54, the tensile strength was 24.2 pounds per inch-wide strip in the warp direction and 14.1 pounds in the filling, and the elongation at break was 35% in the warp and 64% in the filling direction, the "ready" elongation, realized by moderate stretching by hand, being in excess of 25% in the warp and 50% in the filling.

By "ready elongation" is meant the elongation that may readily be realized when the elasticized fabric is pulled out by hand to its approximate original dimensions, with a corresponding decrease in the excess crimp which the process has induced into the yarns. For standardization purposes, ready elongation is herein defined as the elongation realized when a weight of five pounds is applied to a strip of material one inch wide. It should be realized that conventional, non-slack-mercerized fabrics will show a certain amount of elongation when tested for tensile strength. The total elongation, or "elongation at break" of a slack-mercerized fabric is the sum of the elongation built into the fabric by shrinkage plus the normal elongation at break displayed by the fabric before the slack mercerizing process, and is generally substantially higher than what we have here termed "ready elongation."

The slack-mercerized fabric was laminated to a fibrous wool fleece weighing 100 grams per square yard by passing the combination twice through a Hunter needle loom with pitch and rate of advance set so that each square inch of fabric was subjected to 184 needle impacts per square inch on each pass. The tensile strength of the needled laminate was 24.8 pounds in the warp and 21.7 pounds in the filling, while the elongation was 33.7% in the warp and 56% in the filling, again with "ready" elongation of over 25% warp, 50% filling.

By the needling process, a portion of the fibers of the fleece were forcibly reoriented in a direction normal to their substantially horizontal orientation and were thrust through the fabric layer to become intimately interlocked with and adherent to the fabric by a penetration-in-depth through the interstices of the fabric.

The slack-mercerized fabric, after the needling operation was marked by a series of pebbly yarn loops or bights, where the yarns had been pushed out of the plane of the fabric. A 5-inch square, containing about 300 warp yarns and 270 filling yarns, was carefully ravelled out, yarn by yarn, to detect yarn breakage. A total of 4 yarn breaks, out of 570 yarns was found. This remarkably low incidence of yarn breakage, of less than 1%, is indetectable in effect on the fabric tensile strength. Moreover, when a set of 4 adjacent warp yarns was deliberately severed and the fabric was stressed, it was noted that there was no propagation of the discontinuity thus created. The kinky, crimped nature of the yarns which had been slack-mercerized to a large extent prevented yarn slippage in the vicinity of the cut ends, the discontinuity did not enlarge, and the cut yarns served as load-bearing members due to their intense crimp-induced interengagement with the filling yarns. This behavior is in sharp and unexpected contrast to the behavior of conventional woven fabrics of comparable count, and in particular contrast to the behavior of knit goods.

When the product of Example 1 was stretched 25% in the filling direction (45% of its ultimate elongation), recovery was 80%. Repeated cycling, however, gave increasingly lower recovery values. The product is suitable for use in applications where a high degree of elongation and conformability are desirable, as in shoulder padding for garments.

EXAMPLE 2

A 44 x 40 bleached cotton sheeting was slack-mercerized, allowing both warp and filling shrinkage. The final count of the fabric was 58 x 51, and it had a ready elongation of 31% in the warp direction and 27% in the filling direction, elongations at break being 37% in the warp and 40% in the filling. Tensile strengths were 42 pounds in the warp and 39 pounds in the filling.

Using the same needle loom settings as in Example 1, this slack-mercerized fabric was needled to a layer of carded Dynel fibers (Union Carbide) weighing 80 grams per square yard. The tensile strength of the needled laminate was 41 pounds in the warp and 33 pounds in the filling, per inch wide strip, with elongations of 24% in the warp and 33% in the filling, with over 15% "ready" elongation in each direction.

When 395 yarns, equally divided between warp and filling, were ravelled from this fabric, a total of 5 yarn breaks, or 1.3% breakage, was found.

EXAMPLE 3

Example 2 was duplicated exactly except that a non-slack-mercerized sheeting of 56 x 48 count was used. The total elongation at break was only 11% warp, 13% filling, with negligible "ready" elongation. When 140 warp and 140 filling yarns were ravelled from this fabric, a total of 25 yarn breaks, or 9%, was found.

In certain applications for lining or insulating material, it is desirable that elongation be combined with elastic recovery. Since slack-mercerized fabrics are characterized by high elongation but eventual low recovery on repeated cyclic loading, we provide a truly elastic lining or insulating material by combining with the fiber-fabric laminate of Example 1 a layer of foamed elastomeric material, as in Example 4.

EXAMPLE 4

A three-component laminate, as illustrated in FIGURE 2, was prepared by needling a carded fleece of Dynel fibers weighing 80 grams per square yard, through a layer of elastomeric foam **12** and into a layer of slack-

mercerized bleached cotton sheeting as in Example 1. The foam was a polyester foam, Type 5200, 3/32 inch thick, a product of General Foam Corporation. Alone, it has an elongation of 300% and a tensile strength at break of 2.25 pounds per inch wide strip. The three components, superimposed as shown, were needled together with the same machine settings used in Example 1. The finished laminate had a tensile strength of 29 pounds in the warp direction and 28 pounds in the filling direction, with a 31% warp elongation and 56% filling elongation, over 25% of the warp elongation and 50% of the filling elongation being readily realized by hand-stretching. By the needling process, a portion of the fibers of the carded fleece were forcibly reoriented in a direction normal to their substantially horizontal orientation and were thrust through the layer of foam and through the fabric layer, so that the three elements of the laminate were intimately interlocked by the penetration-in-depth of some of the fibers of the fleece through the foam and through the interstices of the fabric.

When elongated 25%, the material recovered over 90% of its original length upon release of the load. Unlike the material of Example 1, however, the laminate of Example 2 recovered to the same degree after repeated elongation and relaxation cycling. It has a high thermal insulating value, and is suitable for use in garments where the lining is subjected to repeated stresses followed by stress release, as it recovers its dimensions readily and repeatedly.

A wide variety of cellulosic fabrics may be slack-mercerized to yield stretchable, readily conformable base fabrics suitable for use in this invention. The choice of fabric will be dictated by the particular use to which the laminate is to be put. In general, as we have noted above, fabrics of the "gauze" category, having counts from 14 x 10 to 32 x 28, and composed of 30's and 40's yarns, will be of such an open weave that a crepe-like pebble is formed by spontaneous looping of the yarns between yarn interstices. To some extent, the cover factor of the fabric, defined as the number of yarns in a warp or filling set divided by the square root of the yarn size, on the cotton system, is an indication of the amount of open space in a fabric. This in turn is an index of the freedom of movement of individual yarns to respond to the shrinking effect of the slack mecerizing process, neglecting the influence of weave structure. The following Table I lists the properties of a variety of slack-mercerized fabrics, all of which were prepared by passing the base fabrics through a solution of 20% sodium hydroxide at 0° C. while allowing substantially complete fabric relaxation in warp and filling.

The apparatus used comprised an open tray of caustic soda and a conveyor belt for removing the shrunken fabrics, as described in the United States Patent 2,688,864, of September 14, 1954, to H. A. Secrist, together with tensionless rinsing and drying equipment.

Table I

Fabric Structure	Shrinkage, percent		Ready Elongation, percent		Original Cover Factor	
	Warp	Filling	Warp	Filling	Warp	Filling
44 x 40 Sheeting	24	21	31	27	10	9
64 x 56 Print	24	24	31	31	10	10
80 x 80 Batiste	23	18	30	22	11	11
96 x 64 Jeans	15	11	18	12	20	14
112 x 56 Broadcloth	18	7	22	8	18	8

The influence of cover factor may be seen from the above table. In relatively open fabrics, such as print cloth and sheetings with cover factors of about 10, a ready elongation of around 30% may be realized in both warp and filling. In a fabric like the 112 x 56 broadcloth, however, the warp cover factor is 18. This means that the warp yarns are so close together that only 8% shrinkage took place across the filling direction or width of the fabric, it being understood that the warp cover factor affects the filling direction shrinkage and the filling cover factor affects the warp shrinkage. In general, we find that fabrics with a cover factor of 8 to 15 yield after slack mercerizing fabrics with ready elongations of from 40% down to 15%, and such a range is preferred for interlining use. For many purposes, elongation in only one direction is necessary, which may be accomplished by using normal processing tensions in, for example, the warp direction, while allowing the filling to contract.

The fibers employed in the preparation of the laminates may be natural or synthetic. Preferably they are of textile length—that is, long enough to be formed into a fleece or batt by conventional dry-assembling textile equipment such as cards, garnetts, air-lay machines, and the like. In the case of synthetic fibers a convenient length is from one-half inch to about one and one-half inches: the natural wool fibers of Example 1 were several inches long.

It will be obvious to those skilled in the art that modifications of the above-described invention may be made without departing from the spirit thereof. Thus, a layer of fibers may be needled into both sides of a slack-mercerized fabric, or a multiplicity of layers of fiber, fabric, and foam may be needled together, subject only to the penetration limits of the needles in the loom.

Having thus described our invention, we claim:

1. In a process for enhancing the tensile strength and delamination resistance of fabric laminates comprising needling at least one layer of textile-length fibers into a woven cellulosic fabric base, the improvement which comprises

shrinking the woven cellulosic fabric base prior to the needling operation by a slack-mercerizing process, said shrinkage being such as to allow at least 15% subsequent elongation in at least one direction of said fabric,

whereby the resistance of the yarns of the woven cellulosic fabric to being severed by the needling operation is increased.

2. The method of claim 1 in which the slack mercerizing and shrinking of the cellulosic fabric is carried out in the filling direction.

3. The method of claim 1 in which the cover factor of the base fabric before slack mercerizing is between 8 and 15.

4. In a process for enhancing the tensile strength and delamination resistance of fabric laminates comprising needling at least one layer of foam and at least one layer of textile-length fibers into a woven cellulosic fabric base, the improvement which comprises

shrinking the woven cellulosic fabric base prior to the needling operation by a slack-mercerizing process, said shrinkage being such as to allow at least 15% subsequent elongation in at least one direction of said fabric,

whereby the resistance of the yarns of the woven cellulosic fabric to being severed by the needling operation is increased.

5. The method of claim 4 in which the slack mercerizing and shrinkage of the cellulosic fabric is carried out in the filling direction.

6. The method of claim 4 in which the cover factor of the base fabric before slack mercerizing is between 8 and 15.

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