Jan. 30, 1968 A. R. OLSON 3,366,529

NEEDLED NONWOVEN FABRICS AND METHOD OF MAKING THE SAME

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Fig. 1

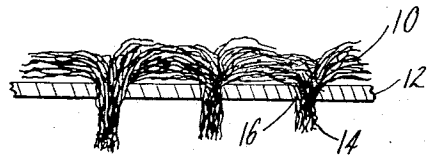


Fig. 2

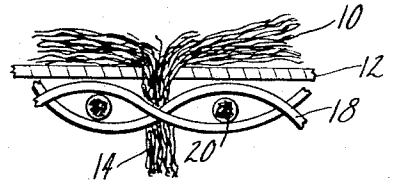


Fig. 3

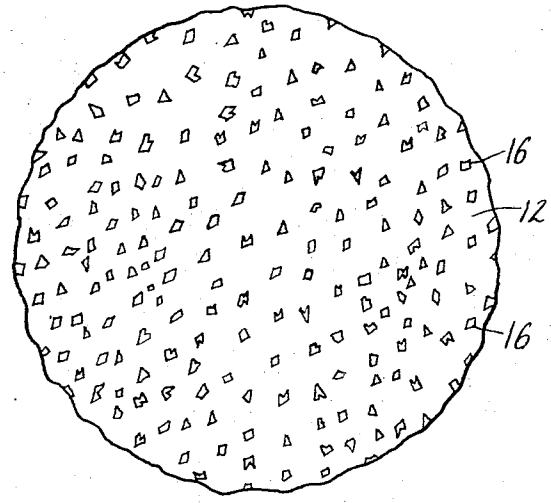
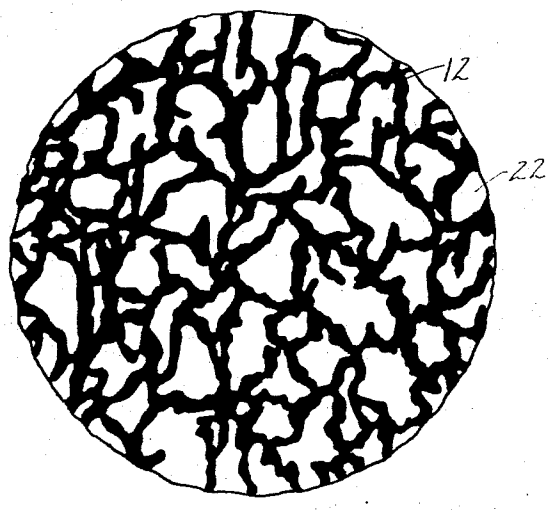


Fig. 4



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NEEDLED NON-WOVEN FABRICS AND METHOD OF MAKING THE SAME

Arthur R. Olson, Walpole, Mass., assignor to The Kendall Company, Boston, Mass., a corporation of Massachusetts

Continuation of application Ser. No. 415,338, Dec. 2, 1964. This application Feb. 21, 1967, Ser. No. 617,719
13 Claims. (Cl. 161—67)

ABSTRACT OF THE DISCLOSURE

A porous and delamination-resistant needled non-woven fabric of one layer of textile-length, unspun and unwoven fibers having fibrous bundles disposed in a direction normal to the fabric and one layer of a retractable, polymeric, thermoplastic film material. The film is in the form of a unified, porous, reticulate network of interconnected, irregular filaments composed solely of the film substance. Some of the fibrous bundles extend through the film network and are bonded to it by the film substance. A substrate layer of fabric or foam may be added with the film network between it and the fiber layer.

These fabrics are produced by assembling a fleece of textile-length fibers arrayed in a plane, disposing the fleece on a continuous film of thermoplastic polymeric material retractable relatively to the fleece and needling the fibers of the fleece through the film and any substrate layer on its other side. This produces a multiplicity of openings through the film and groups some of the fibers into fibrous bundles directed through the film openings, in a direction normal to the main plane of the film, and into any substrate layer. The assembly is then heated to retract the film while restraining it by the multiplicity of fibrous bundles through it to convert the film into the unified, porous, reticulate network of interconnected irregular filaments composed solely of film substance, to provide at least 50% open area and with the thickness of the filaments at least 5 times the thickness of the original film.

This application is a continuation of my copending application Ser. No. 415,338, filed Dec. 2, 1964, now abandoned.

This invention relates to needle-punched nonwoven fabrics, and more particularly to fabrics of this type which are internally reinforced by an open, porous reticulate network of thermoplastic material serving to bond the structure into a coherent, abrasion-resistant fabric.

In distinction to so-called bonded nonwoven fabrics, made by saturating an unspun and unwoven fibrous fleece with an aqueous polymeric binder, nonwoven fabrics made by a needle-loom process depend for their integrity on a mechanically-induced reorientation and interlocking of some of the fibers in a fleece. Needled nonwoven fabrics, therefore, do not suffer from the stiffening effect and the matting-down of fibers customarily associated with wet bonding. They have a soft hand and drape, easy conformability and a degree of elongation, high loft, low density, and high insulating value, properties which render them uniquely useful in applications, such as garment linings, to which bonded nonwoven fabrics are not so well suited.

The mechanical interlocking of fibers in a needled nonwoven fabric, however, is not as strong a bond as is developed in bonded nonwoven fabrics. Therefore, for uses where tensile strength and abrasion resistance are requisites, as in an exposed liner for boots, shoes, or other apparel, needled nonwoven fabrics are frequently reinforced with a layer of fabric, polymeric foam, film, or combinations of such materials, as described for instance in U.S. Patent 3,059,312, to Jamieson. Combinations of needled fibrous webs with layers of other material are referred to as needled laminates in this application.

Even in the case of such laminates, however, tensile strength and, more particularly, surface durability and abrasion resistance, leave much to be desired. Some of the fibers are deflected by the needling operation from their normal orientation in the plane of the fabric so that they are aggregated into fibrous bundles extending down through the fibrous layer and through any reinforcing substrate which may be present. The bonds thus formed, however, are still mechanical in nature and are transient, in the sense that fibrous bundles are wedged into a substrate which yields slightly as it receives the thrust of the fiber-laden needle, and then recovers upon withdrawal of the needle to clasp the fibrous bundle with a firmness which varies with the elastic nature of the particular substrate employed. Surface friction or abrasive action on the face of such needled products, such as results from body action against such a surface, gradually decreases the degree of interlocking of the fibers with each other and with the substrate if present, so that the fibers pluck out and are shed from the nonwoven fabric surface.

Therefore it has been proposed to increase the internal integrity of such needled nonwoven fabrics or needled laminates by saturating with a binder. This, however, frequently alters the nature of the product so that the desirable loft and softness are lost, particularly in view of the concentration of binding agent which occurs on the surfaces due to binder migration during drying. Methods have also been advanced for the use of coagulants or gelling agents, to minimize binder migration. So far as I am aware, however, no methods previously proposed have succeeded in producing a needled nonwoven fabric or laminate which is soft, lofty, porous, and conformable, and which has a high degree of internal integrity enhancing the tensile strength and resistance to fiber shedding, while still preserving the desirable fleece-like free fibrous character of the surface. It is with improvements in the art of bonding together the fibers which make up needled nonwoven products that the present invention is concerned.

I have found that if a fibrous fleece or batt is needled through a film composed of thermoplastic and heat-retractable polymeric material, and the assembly is then subjected to a temperature above the softening point of the film but below the point at which the film becomes completely fluid, as set forth below, the film is transformed from a lightly-apertured but generally impervious layer to a very open and porous reticulate network of fused polymeric material which bonds the internal fibrous layer of the fabric into a coherent, abrasion-resistant fabric of high tensile strength. At the same time, the film substance is maintained as a discrete and self-sustaining network: it is not diffused throughout the fleece, and in cases where the film has been needled to one surface of a fibrous fleece, that surface is heat-sealing due to the localized concentration of thermoplastic substance.

In Canadian Patent 680,521, to Whytlaw, a process is described in which a fibrous fleece is needle-punched into a thermoplastic film, and the assembly is subsequently heated to within the softening range of the film, to cause the film to bond to the fibrous bundles around the peripheries of the apertures in the film through which the fibrous bundles have been thrust. It is emphasized in said patent, however, that the film is of a continuous and unbroken nature between the fibrous bundles, so that if both the film and the fibers have low moisture absorption, the fabric is said to possess moisture barrier characteristics; if the fibers are absorbent, the film base is said to serve as a moisture barrier and the punched fibers

transmit air but not moisture. It is preferred by Whytlaw that the heating process be accompanied by pressure, so that the fibers are embraced by the softened film substance and the fibers and film form an integral structure. It is also known, according to British Patent 967,159, to heat such a combination of a thermoplastic film, with a fibrous fleece needled therethrough, until the film has become completely fluid. This has the effect, however, of causing the film to permeate the fleece, and as set forth in said patent, the film character is lost. The diffusion of the film substance throughout the fleece causes a stiffening or bonding action to affect substantially all of the fibers, with the accompanying decrease in loft, softness, and drape.

As will be set forth more fully below, the present invention contemplates heating the film-fiber assembly not just to the softening range, but above the softening point of the film while below the point of complete fluidity, with the unexpected formation of a unique network of fused polymeric material of very high porosity and no moisture-barrier properties.

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

FIGURE 1 is a magnified cross-sectional view of a fibrous fleece needled to a base film of thermoplastic and heat-retractable material.

FIGURE 2 is a magnified cross-sectional view of a fibrous fleece needled through a thermoplastic and heat-retractable film and also through an underlying fabric substrate.

FIGURE 3 is a representation, magnified 4 times, of approximately one square inch of film through which a fibrous fleece has been needled, and from which the fibrous material has been dissolved out prior to heat-treatment. FIGURE 3 is not idealized, but is a tracing of an actual photograph of a film so treated.

FIGURE 4, also a tracing of an actual photograph, is a representation, magnified 4 times, of a piece of the reticulate thermoplastic network into which the film of FIGURE 3 is transformed by heating the composite film-fiber assembly above the softening point of the film substance, followed by dissolving out all the fibers.

Referring to FIGURE 1, a fleece or batt **10** of textile-length fibers is shown as having been needle-punched through an underlying film of thermoplastic and heat-retractable material **12**, so that some of the fibers are gathered into the form of fibrous bundles **14** which are oriented essentially normal to the plane of the fabric and protrude through apertures **16** which have been formed in the film. By textile-length fibers is meant those fibers of length such that they can be handled and formed into a fleece by conventional textile equipment such as cards, garnetts, air-lay machines, and the like. Any textile fibers may be used in this invention, provided that their melting point is higher than the melting point of the film. The choice of fleece-forming device used will depend on whether it is desired to have the fibers predominantly parallelized in the machine direction, as from a card, or isotropically arrayed as from an air-lay machine.

FIGURE 2 is similar to FIGURE 1, except that the fibrous bundles **14** pass through an additional substrate in the form of a fabric composed of warp yarns **18** and filling yarns **20**.

As film base, any polymeric material in film form may be employed, provided that it is thermoplastic and heat-retractable: that is, in the softening process, the film tends to shrink and retract. Certain film-forming polymeric materials are naturally heat-retractable due to their chemical nature, while other films are retractable due to their having been unilaterally or biaxially oriented during their manufacture. Suitable films are those prepared from plasticized cellulose esters such as plasticized cellulose acetate, films prepared from vinyl polymers such as polyvinyl chloride, polyvinylidene chloride, copolymers of vinyl chloride and vinyl acetate, and polyolefine films such as polyethylene and polypropylene. The thickness of the film will depend on the degree of internal reinforcement desired. Generally, the use of a film 0.001 inch thick will at least double the strength of a needled nonwoven product made according to this invention, with thicker films giving even more reinforcement and resistance to fiber shedding.

A wide variety of fabric substrates may be used, if desired, in the practice of this invention, varying from open-meshed lightweight cotton gauze to heavy nylon monofilament screening. In place of fabric, added insulating value may be realized through the use of foamed polymeric material such as polyurethane foam, or both foam and fabric may be used. Novelty is not claimed for any particular pre-assemblage of textile fibers with a reinforcing substrate or substrates, but resides in the uniquely porous configuration of the thermoplastic and heat-retractable film after processing, together with its bonded union to the fibrous fleece and substrate, if the latter is used.

The above-described fibrous fleece is superimposed upon the thermoplastic film plus any additional substrates desired, and the assembly is then needle-punched, preferably in a continuous operation, by passing it through a needle loom. Such devices are well-known in the art and are not shown. The result of such an operation is to thrust fibrous bundles down through apertures formed in the film, so that the lower face of the assembly is studded with fibrous bundles protruding from said face. The tracing of FIGURE 3, magnified 4 times, was made by needling, in a Hunter loom, a layer of rayon fibers superimposed upon a layer of polyethylene film 0.001 inch thick, both superimposed on a layer of 32 x 28 cotton gauze. The assembly was passed through the loom twice, at a rate of about 160 strokes per square inch per passage, making a total of somewhat over 300 penetrations per square inch of film. Both the rayon fibers and the cotton gauze were dissolved away by solvent and swelling techniques not affecting the film, to leave the base film **12** of FIGURE 3 perforated with minute apertures **16**. In this condition, the base film is still essentially non-porous, being 75% or more continuous film with the apertured area constituting 25% or less of total film.

If the fiber-free apertured film of FIGURE 3 is now heated to its softening point while free from restraint, the film area as a whole will undergo some shrinkage and the holes will be substantially closed. In combination with needled fibrous bundles thrust through the film, however, the film is not free to shrink in area, but is restrained by the presence of the bundles. Heating of the film to its softening point causes the film to draw together around the fibrous bundles, particularly if pressure is employed. By this process, the fibrous bundles are more firmly bound to the film, but the film remains continuous and unbroken between the punched fibers, forming a moisture barrier.

I have found that quite different and unexpected results are obtained if the assembly of film and fibers, plus substrates if used, is heated not just up to the softening point but actually into or beyond that point but below the point at which the film becomes completely fluid. FIGURE 4 represents the fiber-film fabric assembly from which the film of FIGURE 3 was produced, after heating to 115° C., a figure above the softening point of polyethylene, and after removal of fiber and fabric as before. In FIGURE 4, the film substance **12** is no longer in the form of a continuous film, but has retracted into an open, porous reticulate network marked by large and irregular holes **22**. The film has been converted from 75% or more closed area to 75% or more open area. The number of openings in the film has decreased by over 50%, and their average size has greatly increased. At the same time, the thickness of the network of FIGURE 4 is about 0.012 inch, measured by a Starrett gauge No. 170, as compared with a thickness of 0.001 inch for the film of FIGURE 3. In this softening and retracting process, there is a pronounced bonding of the fibers, rein-

forcing the integrity of the fabric, and a greatly increased resistance to delamination or fiber shedding without any sacrifice in the desirable loft, softness and porosity of the material. In general, it is preferred that the film be at least 50% open area.

The invention will be illustrated by the following examples:

Example 1

A fibrous web of 1.5 denier viscose rayon fibers, weighing 168 grams per square yard, was needled through a polyethylene film 1 mil thick by passing twice through a Hunter needle loom at a total needle penetration rate of about 300 per square inch. The product was then heated to 320° F. for one minute in an oven.

Before heat treatment. the fibers could readily be separated from the film by pulling, and the tensile strength was 6.3 pounds per inch wide strip. The air porosity was low, after heating, the fibers resisted removal from the film by pulling, the tensile strength was 23.5 pounds per inch wide strip, and the porosity was substantially equal to the porosity of a similar needled sample containing no film.

An additional advantage derived from the process of this invention lies in the fact that products made with no secondary substrate, as in Example 1, are heat sealable. When the product of Example 1 was folded upon itself with the faces bearing the polyethylene network facing each other and the two layers were pressed with a hot sealing iron, a very strong bond was formed, and the two layers could not be separated without total destruction of the fabric. After removal of the rayon fibers with sulfuric acid, there was left two layers of polyethylene film, strongly sealed together, each resembling the reticulated plastic network of FIGURE 4. Since both networks are very porous, a heat-sealed bond of this type is also very porous, transmitting air and moisture vapor very readily.

The process of this invention, therefore, is advantageous when it is desired not just to increase the tensile strength of a needled nonwoven product, but to render the product capable of heat-sealing to itself or to other materials with the formation of a bond that is tenacious and air permeable. The air-permeable heat-sealed bond appears to be due to the fact that once the punctured film has been transformed into a reticulated network, the properties of which are described more fully below, so much film substance has been retracted into the peripheries **12** of the large and irregular openings **22** (FIGURE 4) that there is little or no tendency for the openings to become closed over under the influence of heat and normal heat-sealing pressures. In the field of needle-punched nonwoven blankets, for example, this allows the heat-sealed application of inexpensive selvages, or of decorative patterns of other materials to the blanket surface, or of the anchoring of heating filaments between layers of the product of Example 1 to produce an inexpensive electric blanket.

Example 2

This was similar in all respects to Example 1 except that the fibrous fleece was 156 grams per square yard of 3 denier acrylic fibers. The unheated sample had a tensile strength of 5.7 pounds per inch wide strip. The heated sample was much more resistant to fiber shedding and had a tensile strength of 12.8 pounds per inch wide strip.

Example 3

A fibrous web of 5.5 denier rayon fibers, weighing 165 grams per square yard, was needled through a layer of 1.5 mil polyethylene film and through a layer of 32 x 28 cotton gauze which underlaid the film. The needling operation was conducted as in Examples 1 and 2.

When the fibrous layer and the gauze-film layer were placed separately in the jaws of an Instron machine, the needled assembly showed a delamination strength of 1.8 pounds per inch wide strip. After heating the product as in Example 1, the delamination strength was 5.0 pounds per inch wide strip.

Before heating, the product had a porosity of only 42 cubic feet of air per square foot per minute at one-half inch pressure drop, most of the transmission being through the needled fibrous bundles disposed in their individual apertures. After heating the product to above the melting point of the film, the air porosity increased almost tenfold, to 398 cubic feet of air per minute.

All three of the above products were soft, strong, porous, and conformable, with a textile drape and hand.

Example 4

A fibrous web of 3 denier polyethylene terephthalate fibers weighing 76 grams per square yard was needled through a layer of 1 mil polyethylene film and through a layer of nylon mesh screening underlaying the film. The nylon screen was composed of woven nylon monofilaments, in a 24 x 20 count, and weighed 200 grams per square yard. Needling was as in Example 1.

In the material as prepared, the fibrous layer could be more or less readily pulled away from the film-nylon mesh substrates. After heating as in Example 1, it was impossible to separate the fibrous layer from the substrates without breaking a substantial percentage of the fibers. The air porosity was 335 cubic feet of air per minute.

In each of the above examples, dissolving out all ingredients except the polyethylene left a porous, open-meshed network of polymeric thermoplastic filaments, irregular in contour and interconnected to define irregularly shaped apertures. The filaments of the network (12 in FIGURE 4) were from five to ten or more times as thick as the thickness of the film from which they had been derived, but the network was so open and porous that it was quite flexible, and did not detract from the softness and the drape of the reinforced needled nonwoven fabrics and laminates. The needled fibrous bundles extending downwardly through the fibrous fleece and through the film, and through the substrate if present, are not individually disposed each through a separate and discrete aperture with unbroken film extending between apertures, as is the case before treatment, but are anchored firmly to the edges of the polymeric filaments which compose the irregular network. In the case of Examples 3 and 4, where a fabric substrate was used, the polymeric network was in turn firmly bonded to the fabric substrate, and could not be mechanically removed therefrom without destroying the network or the fabric. If the fabric substrate is removed by solvent or swelling action, the pattern of the fabric is found to be engraved in intaglio on the underside of the porous polymeric network derived from the film, the pattern being actually "undercut" in places attesting to the flow of film substance around the yarns of the fabric substrate.

Apart from its utility in strengthening needled nonwoven fabrics and rendering them heat-sealable, as set forth above, a reticulated plastic network as illustrated in FIGURE 4 has independent utility in its own right as for example a replacement for film which has been locally slit and then expanded, or pressure-embossed and then stretched, to form an apertured plastic film used for packaging or decorative purposes. Such products are well known in the packaging art, and are made by mechanically stretching a suitable plastic film into which a patterned set of discontinuities has been introduced into the film substance. The process of this invention provides a reticulate plastic network in a relatively simple manner and without the need for expanding tenters or other stretching devices, as illustrated by the following example.

Example 5

A sheet of 1 mil polyethylene film was run through a needle loom and punctured at a rate of approximately 300 penetrations per square inch. If such a film is heated while free to move, it will shrivel and shrink in overall

area, and the majority of the perforations will tend to become smaller.

If, however, the film is restrained from exerting any substantial overall area shrinkage during the heating process, as by confining it between two wire metal screens of 14 x 14 mesh, with a highly crimped weave, while heating to 320° F. for three minutes, the reticulate structure of FIGURE 4 is obtained. In said structure, the minute punctures of FIGURE 3 have been replaced by a pleasingly irregular pattern of larger openings, fewer in number, and rimmed at their peripheries by interconnected plastic filaments of substantial strength and thickness compared to the original film.

It is desirable in this process that the restraint against shrinkage be applied locally over the face of the punctured film, so that it is exerted at a multiplicity of points within the area of the film. The use of peripheral restraint alone is liable to lead to the formation of a very few large openings and a product of decreased utility. The use of layers of wire screen, or similar rough surfaces, seems to afford a multiplicity of discrete points across the face of the film, at which points the shrinkage tendency is locally impeded, so that the punctures in the film do not seal up while the film is passing through the retraction-temperature zone, but instead the film regions around the punctures are locally tensioned, this tension plus the surface tension of the softened film drawing the polymer into the desired configuration shown in FIGURE 4.

Although the above examples illustrate a needling operation conducted in one direction, it will be apparent to those skilled in the art that needling through both the upper and lower surfaces of a laminate may often be desirable. This is especially true when it is desired to attach a fibrous web or fleece to both faces of a film, as in the formation of a blanket material such as is illustrated in the following example:

Example 6

Two fibrous webs of 3 denier randomly-arrayed viscous fibers weighing 120 grams per square yard were needled, one web on each face, into a polyvinylidene film one mil thick by two passes through the Hunter loom as in previous examples, needling first from one face of the assembly and then from the reverse face. The laminate thus formed had a tensile strength of 5.7 pounds per inch-wide strip, and was difficult to breathe through. After heating to 375° F. for one minute, the material had a tensile strength of 13.7 pounds per inch-wide strip, and was substantially as easy to breathe through as a pair of needled webs containing no film.

Such a characteristic degree of attachment of needled fibrous webs to a substrate is exceptional, especially when combined with a high air porosity, making such products eminently suited for use as garment linings, porous supportive elements for the foundation garment and brassiere trades, blankets, and the like.

Having thus described my invention, I claim:

1. A porous and delamination-resistant needled nonwoven composite fabric comprising

at least one layer of textile-length unspun and unwoven fibers with at least some of said fibers aggregated into fibrous bundles disposed in a direction generally normal to the plane of said fabric and

at least one layer of a heat retractable polymeric, thermoplastic film material in the form of a unified, porous, reticulate network consisting solely of interconnected irregular filaments composed solely of the substance of said film,

said film material having a lower melting point than said fibers,

at least some of said fibrous bundles extending through said film material network and being bonded thereto by the substance of said film.

2. A fabric as claimed in claim **1** wherein said film network provides at least 50 percent open area.

3. A heat-sealed laminate comprising

at least one layer of a product according to claim **1**,

said layer being bonded by means of said network of thermoplastic polymeric material to a second layer of material by means of heat and pressure.

4. A porous and delamination-resistant needled textile-laminate comprising

at least one layer of textile-length unspun and unwoven fibers and

at least one secondary substrate layer

some at least of said fibers being aggregated into fibrous bundles disposed in a direction normal to the plane of said fabric and extending downwardly through said layer of fibers and through said substrate layer,

at least one layer of a heat retractable polymeric, thermoplastic film material in the form of a unified, porous, reticulate network consisting solely of interconnected irregular filaments composed solely of the substance of said film interposed between said layer of textile fibers and said substrate layer

at least some of said fibrous bundles extending through said film material network with said textile fibers and said substrate layer being bonded thereto by the substance of said film, said film material having a lower melting point than said fibers.

5. The product according to claim **4** in which the secondary substrate is a fabric.

6. The product according to claim **4** in which the secondary substrate is a layer of foamed elastomeric polymer.

7. A method for producing a porous and delamination-resistant needled textile nonwoven fabric which comprises

assembling a fleece of unspun and unwoven textile-length fibers, said fibers being predominantly arrayed in a plane,

disposing said fleece on a continuous layer of continuous film of thermoplastic polymeric material heat-retractable relatively to said fleece,

said thermoplastic polymeric material having a lower melting point than said fibers,

needling at least some of the fibers of said fleece through said continuous film,

thereby producing a multiplicity of openings through said film and grouping some of said fibers into the form of a multiplicity of fibrous bundles directed through said fleece and through said film openings in a direction generally normal to the main plane of the film,

and heating the assembly above the softening point of said thermoplastic heat-retractable film but below the point at which the film becomes completely fluid for a period of time sufficient to retract said film relatively to said fleece while restraining it by said multiplicity of fibrous bundles directed through said film to convert said film into a unified, porous reticulate network consisting solely of interconnected irregular filaments composed solely of the substance of said film,

at least some of said fibrous bundles extending through said film material network and being bonded thereto by the substance of said film.

8. A method as claimed in claimed **7** wherein the open area of said network is at least 50 percent thereof and the thickness of said filaments is at least 5 times that of the original film.

9. The process of producing a heat-sealed laminate which comprises

producing a nonwoven fabric according to claim **7**,

and sealing said fabric to a second layer of material by means of heat and pressure.

10. The process according to claim **9** in which said second layer of material is another layer of nonwoven fabric.

11. A method for producing a porous and delamina-

tion-resistant needled textile nonwoven fabric which comprises

assembling a fleece of unspun and unwoven textile-length fibers, said fibers being predominantly arrayed in a plane,

disposing said fleece on a continuous layer of continuous film of thermoplastic polymeric material heat-retractable relatively to said fleece,

said thermoplastic polymeric material having a lower melting point than said fibers,

disposing the fleece and film on a substrate layer,

needling at least some of the fibers of said fleece through said continuous film and said substrate layer,

thereby producing a multiplicity of openings through said film and grouping some of said fibers into the form of a multiplicity of fibrous bundles directed through said fleece and through said film openings in a direction normal to the main plane of the film into the substrate,

and heating the assembly above the softening point of said thermoplastic heat-retractable film but below the point at which the film becomes completely fluid for a period of time sufficient to retract said film relatively to said fleece and substrate layer while restraining it by said multiplicity of fibrous bundles directed through said film to convert said film into a unified, porous reticulate network consisting solely of interconnected irregular filaments composed solely of the substance of said film,

at least some of said fibrous bundles extending through said film material network with said textile fibers and said substrate layer being bonded thereto by the substance of said film.

12. The process according to claim **11** in which the substrate is a fabric.

13. The process according to claim **11** in which the secondary substrate is a layer of foamed elastomeric polymer.

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ROBERT F. BURNETT, *Primary Examiner.*

R. H. CRISS, *Assistant Examiner.*