June 10, 1969 R. M. CONTRACTOR ET AL 3,449,486
METHOD FOR PRODUCING A THERMALLY SELF-BONDED
LOW DENSITY NONWOVEN PRODUCT
Filed May 31, 1967 Sheet 1 of 3

FIG. 1

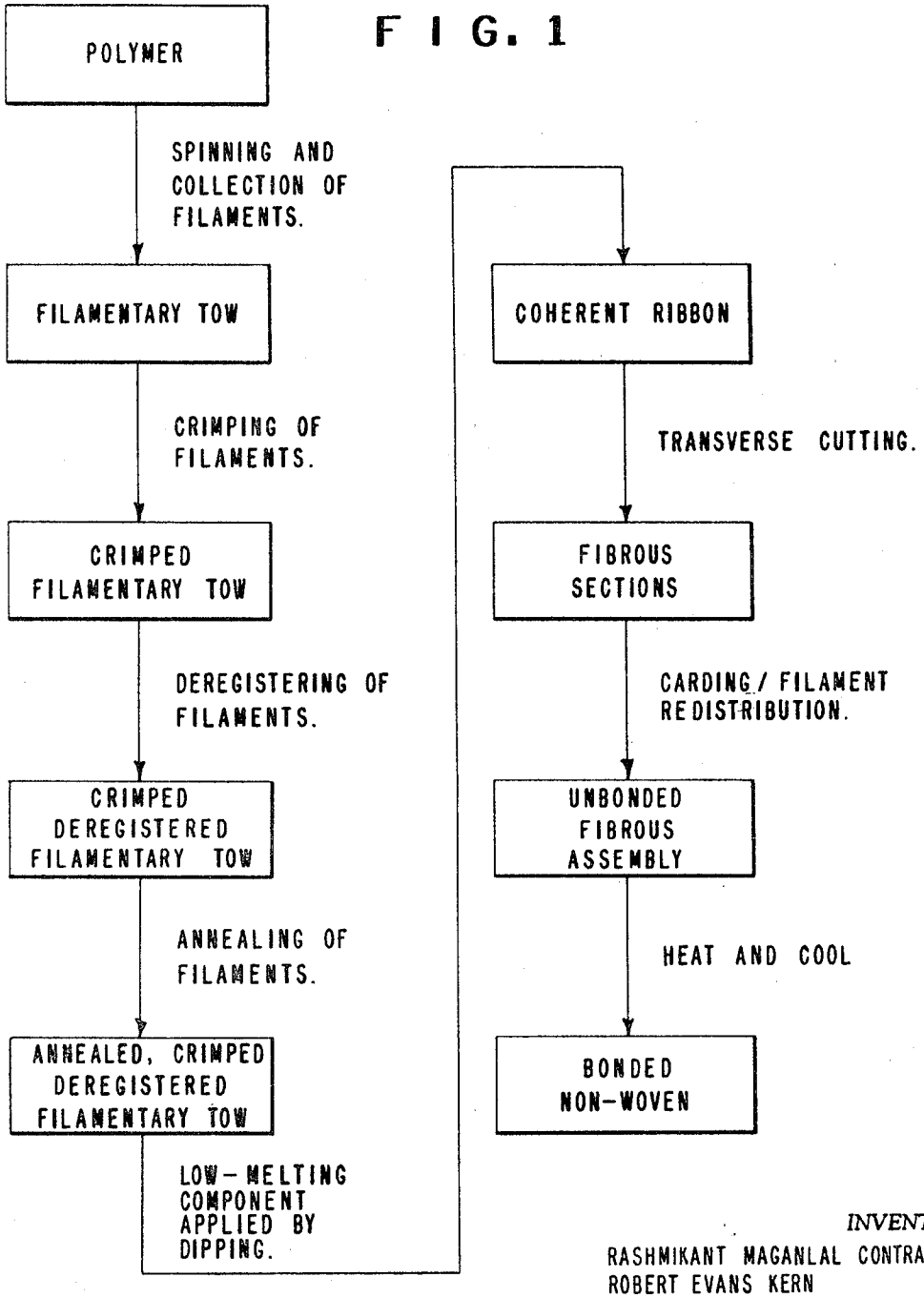

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FIG. 2

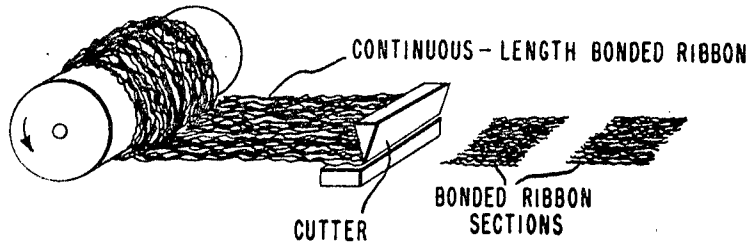
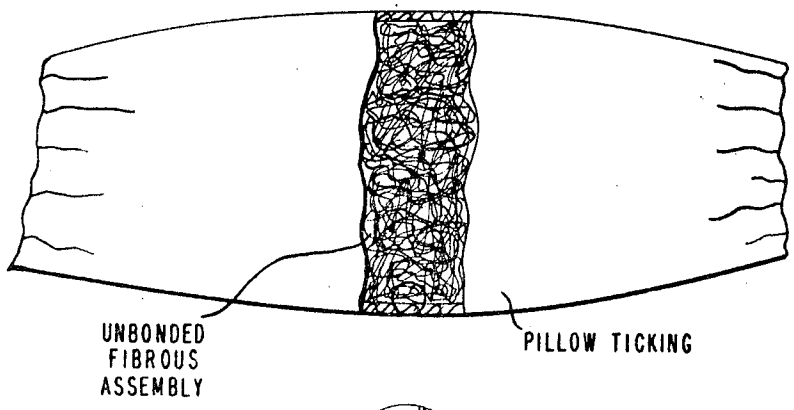


FIG. 3



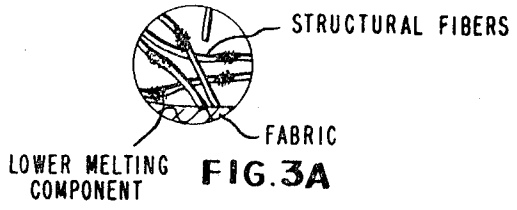


FIG.3A

FIG. 4

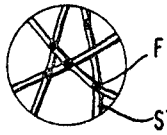


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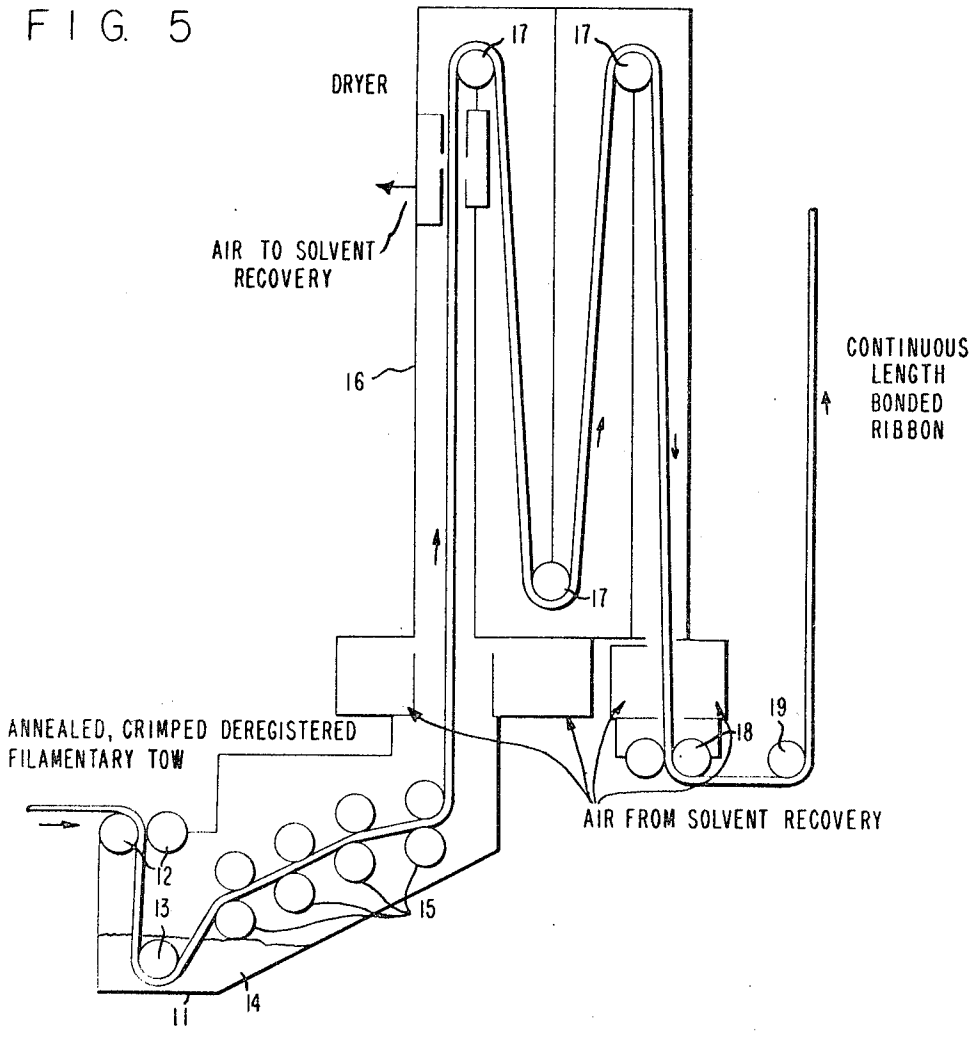
FIG. 5



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3,449,486

METHOD FOR PRODUCING A THERMALLY SELF-BONDED LOW DENSITY NONWOVEN PRODUCT

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Continuation-in-part of application Ser. No. 554,550, June 1, 1966, which is a continuation-in-part of application Ser. No. 410,766, Nov. 12, 1964. This application May 31, 1967, Ser. No. 649,778

Int. Cl. D04h 3/16, 1/58; B32b

U.S. Cl. 264—115 5 Claims

ABSTRACT OF THE DISCLOSURE

A bonded, low density, nonwoven fibrous product is made by preparing an assembly of binder-coated, crimped, annealed, staple-length, synthetic fibers, mechanically working (e.g. carding) the assembly to break fiber-to-fiber bonds and to uniformly distribute the binder, then heating to fuse the binder at fiber cross-over points.

CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a continuation-in-part of our application Ser. No. 554,550, filed June 1, 1966, which is in turn a continuation-in-part of our application Ser. No. 410,766, filed Nov. 12, 1964, both now abandoned.

BACKGROUND OF THE INVENTION

Field of the invention

This invention relates to the preparation of a high bulk, thermally self-bonded, fibrous product and to an unbonded assembly of crimped, stabilized filaments useful as an intermediate for the production thereof.

Prior art

Various procedures have been developed in recent years involving the utilization of so-called "fiber-fill" in the provision of bonded fibrous batts, webs and other nonwoven products of the bulky type suitable for quilted fabric interliners, pillow-fillings and the like. Perhaps most notable among these procedures is that involving the preparation of a batt of the fiberfill and subsequent spraying of the batt with an adhesive to bond the filaments into a coherent structure. While such structures have achieved some degree of importance in the textile industry, numerous processing problems and product limitations have nevertheless arisen. Even when a thin article such as a web is to be produced, a substantially greater buildup of binder occurs on the surface than does on the inside and this inefficient utilization of binder detracts from softness or other aesthetically desirable properties and is, of course, uneconomical. For thicker webs or batts, there is a practical limit of thickness beyond which it is difficult to obtain any degree of penetration of binder into the middle thereof, at least without greatly overloading the structure with binder. Inadequate or nonuniform bonding throughout the structure may result in inadequate strength or inferior compressional properties.

SUMMARY OF THE INVENTION

In accordance with the invention there is provided an unbonded assembly of crimped, staple-length filaments which have been so prepared that once formed into a desired shape, a brief exposure to heat will result in a uniformly bonded product. The assembly has the advantages of fiberfill but in addition is self-bondable. The need for spraying the nonwoven assembly is obviated because the binder is pre-affixed to the filaments. Moreover, the binder is evenly distributed throughout the filaments, hence can be used more sparingly to give property advantages while at the same time affording superior product uniformity. Still a further advantage of the assembly is that the fibers become strongly adhered to one another by fusion bonds, yet the filaments have been prestabilized so that the assembly will undergo little or no densification during the bonding step.

In one embodiment of the invention there is provided an unbonded assembly, having a density of up to about 1 lb./ft.^{3}, of individually distinct, staple-length filaments, said filaments comprising an oriented filamentary component of a fiber-forming, synthetic, organic polymer and integral therewith as a coating along at least a portion of the exterior thereof an unoriented, lower-melting, synthetic thermoplastic polymer component, said lower-melting component having a polymer melt temperature which is at least 70° C. but is below the fiber stick temperature of the filamentary component, the weight ratio of said filamentary component to said lower-melting component being essentially constant throughout the three dimensions of the assembly, said filaments having an average length of at least one inch, being characterized by a retractive coefficient of no more than about 30 and being crimped so as to provide an average crimp frequency of at least 3 crimps per inch and an average crimp index of at least 5%.

In effect the fibrous assembly as above-described is ready for bonding; that is, (a) the heat-activatible binder or so-called "lower-melting" component has already been applied, (b) the filaments have been crimped to provide bulk and/or other properties, (c) the filaments have been stabilized (hence have a low "retractive coefficient" as hereinafter defined) to minimize latent shrinkage or crimpability forces that might tend to excessively densify the product upon bonding, and (d) the filaments have been redistributed, i.e. nearly all filament-to-filament bonds broken up and the filaments blended to a highly uniform low-density mass, e.g. below 1 lb./ft.^{3}, usually as low as 0.6 lb./ft.^{3} or even 0.1 lb./ft.^{3}. Various methods for producing the unbonded fibrous assembly and bonded nonwoven products therefrom will be discussed below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a flow diagram of various steps, in one sequence, leading to the unbonded fibrous assembly and then to the bonded nonwoven product.

FIGURE 2 shows schematically the ribbon cutting step of FIGURE 1 in which fibrous sections are produced.

FIGURE 3 shows schematically a pillow in which a fabric ticking has been stuffed with an unbonded fibrous assembly of the invention.

FIGURE 3A is an enlarged representation of the encircled portion of FIGURE 3 and shows that the indi-

vidual filaments have a discontinuous coating of low-melting component thereon but are not bonded to one another.

FIGURE 4 shows schematically an enlarged view of the filamentary stuffing of FIGURE 3 after bonding.

FIGURE 5 shows schematically one form of a tow coating procedure.

DETAILED DESCRIPTION OF THE INVENTION

Composition of the polymeric components

As indicated above, the unbonded assembly of the invention utilizes two components, structural filaments and a heat-activatible adhesive referred to herein as the lower-melting component. The filaments comprise an oriented, filamentary component of a fiber-forming, synthetic, organic polymer having a relatively high fiber stick temperature. The lower-melting component comprises an unoriented synthetic thermoplastic polymer and it has a polymer melt temperature which is at least 70° C. but is below the fiber stick temperature of the filamentary component.

The filaments employed are commonly available synthetic polymer filaments of the type produced by spinning and drawing. Normally, the filaments may have a denier within a wide range, for example, from 1 to 50 denier per filament. Frequently, however, the most desirable aesthetics, e.g. softness, are achieved in bonded nonwoven products made from filaments having a denier in the range of approximately 1 to 15 denier per filament. The cross-section of the filaments will normally be round, but may be prepared so that it has other cross-sectional shapes; such as elliptical, trilobal, tetralobal, and like shapes.

The filamentary component may comprise a variety of synthetic, organic polymers, such as polyolefins, acrylonitrile polymers and copolymers, polyesters, polyamides, vinyl polymers and copolymers, polyurethanes, polyformaldehyde, cellulose acetate and the like. It should have either a higher polymer melting temperature than the lower-melting, bondable component, or should be of such a character that it has high heat stability and can be regarded as having no melting or softening point under ordinary use conditions. The general term "fiber stick temperature" is accordingly used. The filamentary component need not be thermoplastic but must be of fiber-forming molecular weight.

By synthetic polymer is meant a material synthesized by man as distinguished from a polymeric product of nature. The class of synthetic polymers, thus excluding for example cotton and viscose rayon, has several advantages for cushioning applications over polymers of nature. They generally have a high elastic recovery; this being defined as the amount by which a fiber recovers after application and removal of a force (stress) causing deformation. Synthetic fibers usually show an elastic recovery of 90–100% from 2% extension as compared to, for example, as little as 74% for cotton. The synthetic polymers as a class also generally exhibit superior resistance to stress decay and lower moisture regain properties.

The second or lower-melting component should comprise a thermoplastic polymer and have a polymer melt temperature above about 70° C. but below the fiber stick temperature of the filamentary component. This will ensure, first, that thermal bonding can occur without destroying the filamentary component, and, second, that the bonds will not be destroyed by moderately high temperatures of the kind normally experienced during use, i.e. usual laundering and drying procedures. Preferably, the polymer melt temperature of the lower-melting component will be at least 5° C. below the fiber stick temperature of the filamentary component to facilitate the thermal bonding procedure.

The lower-melting component is latently bondable such that upon fabrication of the filaments into the form of the desired fibrous assembly, e.g. a batt or web, mere application of heat will cause this component to soften and/or melt. Upon cooling, bonds will thus be formed with neighboring fibers, whether or not the latter contain a bondable component associated therewith. Thus it is frequently desirable to incorporate ordinary staple filaments, either of natural fibers or of synthetic fibers, in the fibrous assembly.

The lower-melting component may be selected so that it is fiber-forming, and normally this would be the case. On the other hand, it can also be non-fiber-forming, e.g. be a polymer of relatively low molecular weight. Typical thermoplastic polymers which can be used as the lower-melting component include polyolefins, acrylic resins, acrylic terpolymers, polyesters and copolyesters, polyamides and copolyamides, vinyl polymers and copolymers and the like.

For some applications it is desirable that the filaments of the assembly be provided with only small amounts, i.e. less than 15% by weight, of the lower-melting component in order to achieve certain properties such as softness of hand in the final bonded product. For other applications as much as 50% by weight or more of the lower-melting component may be used.

In a preferred embodiment of the invention the filamentary component and the lower-melting compoent will be derived from the same chemical class of polymers, for example, a polyester such as polyethylene terephthalate will be used to form the filamentary component whereas the lower-melting component will comprise a copolyester such as the copolymer of ethylene glycol with a mixture of isophthalic and terephthalic acids. Polyamides and copolyamides may similarly be used to advantage. The utilization of chemically related polymers in this manner is especially desirable because it gives rise to interfilament bonds of a particularly high adhesion level.

Either or both of the components may include conventional additives such as dyes, pigments, U.V. stabilizers, and antistatic agents.

Preparation of unbonded assembly and bonded nonwoven

The invention will now be described with reference to method embodiment illustrated in FIGURE 1 which is one of several methods which can be used. The method illustrated comprises the steps of (1) collecting into a continuous length bundle a plurality of filaments comprising an oriented filamentary component, as above described, (2) crimping the filaments to provide an average crimp frequency of at least 3 crimps per inch and an average crimp index of at least 5%, (3) separating the crimped filaments so that adjacent filaments touch only at spaced contact points, (4) applying to the crimped, separated filaments a coating of a lower-melting component, as above described, to thereby provide a continuous ribbon-like structure, (5) transversely cutting the continuous ribbon-like structure to provide fibrous sections of staple-length filaments, and (6) opening the sections, mechanically redistributing the staple-length filaments and providing a low-density assembly of individually distinct, filaments having throughout the three dimensions thereof an essentially constant weight ratio of the filamentary component to the lower-melting component, (7) it being further provided that at least prior to the preparation of the low-density assembly of step (6), above, the filamentary component is annealed at an elevated temperature in a substantially relaxed state to provide retractive coefficient of no more than about 30. Thereafter the thusly prepared assembly may be heated to a temperature in excess of the polymer melt temperature but below the fiber stick temperature and then cooled to thereby bond the filamentary components into the final nonwoven product.

In accordance with the invention, a supply of filaments is obtained by any of the usual procedures of dry-spinning, wet-spinning or melt-spinning a fiber-forming synthetic

organic polymer. Upon issuing from orifices of a spinneret into a quenching chamber the filaments are collected and drawn in the usual way. The drawing of the filaments serves to orient the polymer molecules and to provide strength and other properties. Conveniently, filaments will be obtained from a series of spinnerets, thereafter collected together into a continuous bundle of substantially parallelized filaments, e.g. a so-called "tow" and then drawn. As is frequently the case with freshly drawn filaments, they may be annealed to some extent, e.g. heated above their second-order-transition temperature while substantially relaxed, following the drawing operation.

The tow of filaments may then be subjected to a crimping operation by techniques known in the art. Typical among the mechanical crimping devices which may be employed for this purpose is the so-called "stuffing box" type of crimper which normally produces a zig-zag crimp. Alternatively, there may be used apparatus employing a series of gears adapted to apply a gear crimp continuously to a running bundle of filaments. Certain types of filaments can also be crimped other than by mechanical means, for example polyethylene terephthalate fibers may be provided with a helical crimp by the air quenching procedure described by Kilian in U.S. Patent 3,050,821. In this instance the crimping step is, in effect, performed concomitantly with the spinning operation and several bundles of crimped filaments are then combined to form the tow. In any case the crimped filamentary tow so produced may be a highly compacted product in which many of adjacent filaments are in phase with one another, i.e. pairs or groups of crimped filaments contact one another for substantial distances along their lengths. Accordingly it is generally necessary to thereafter treat the tow of crimped filaments in some manner to separate adjacent filaments from one another, i.e. so adjacent filaments touch only at spaced points. Advantageously this may be effected by deregistration in which adjacent filaments are rendered out of phase with one another.

For purposes of filament separation there may be used various devices of the kind commonly employed in the tow-treating art. In one of these the tow is subjected to an explosive expansion of compressed air using a specially adapted venturi nozzle as described in Caines et al. U.S. Patent 3,099,594. An alternate technique for separating and deregistering filaments of a crimped tow involves the use of rolls provided with a series of rigid surfaces which serve as gripping means for displacing filaments relative to one another. Apparatus of this type is illustrated in Mahoney et al. U.S. Patent 3,032,829 and in Dunlap et al. U.S. Patent 3,156,016. Still another form of apparatus which may be used for this purpose is that illustrated in Jackson U.S. Patent 2,929,392 involving the use of pairs of rolls to first straighten the crimped filaments and then to suddenly relax the tow and thereby effect "blooming."

The particular type of crimp, i.e. in terms of its dimensional characteristics, is not critical but rather can be selected depending upon the type of textile product to be ultimately formed. Thus the crimp may be essentially planar or zig-zag in nature or it may be a three-dimensional crimp. Whatever the nature of the crimp, the filaments should attain an average crimp frequency of at least 3 crimps per inch and an average crimp index of at least 5%.

The tow may vary widely in terms of its cross-sectional dimension and the number of filaments therein. Thus a bundle may be used wherein the number of filaments is in the range of 500 to 5,000,000.

Once the crimped and separated filamentary tow is produced, it may then be annealed at this stage to reduce the so-called "retractive coefficient" to a suitably low level, i.e. so that it is not in excess of about 30. The low retractive coefficient indicates that the filamentary component has been treated at some stage of its processing to remove most, if not all, of the latent crimping and shrinkage forces therefrom. During a subsequent thermal bonding treatment the individual filaments will undergo little or no relative movement or other dimensional change and thus compaction and densification of the assembly will be greatly minimized. Preferably, the retractive coefficient will be as close to zero as possible, i.e. up to 15 or so, to ensure only very modest densification during the thermal bonding treatment. In effect, the retractive coefficient expresses a relationship between the length of the filaments before and after they are exposed to a temperature above the polymer melt temperature of the lower-melting component but below the fiber stick temperature of the filamentary component.

Continuous textile strands as initially prepared may have a relatively high retractive coefficient. This is a result of drawing treatments performed subsequent to the spinning operation in order to reduce the denier of the spun filaments and to develop strength or other properties. The drawing treatment creates internal stresses within the filaments and these often tend to result in undesirably high level shrinkage and/or crimping forces should the filaments be heated above their second-order transition temperature, i.e. of the filamentary component. In accordance with the invention the filaments are stabilized, e.g., by annealing, to relieve these tendencies and thus lower the retractive coefficient. A low-density nonwoven batt can then later be prepared in which the filaments will undergo little or no relative movement upon heating to a bonding temperature—hence individual filaments become merely bonded to one another in generally the same low-density configuration as existed in the unbonded assembly and filament intertwining or entanglements are kept at a minimum. Of course, the actual percent bulk loss in bonding can very depending upon such factors as the unbonded batt density, filament denier, retractive coefficient level, etc.

For purposes of annealing the filaments, a temperature will normally be selected which is above the second-order-transistion point of the filamentary component but below its fiber stick temperature. Although the annealing temperature selected will depend upon the composition of the filamentary component, usually it will exceed 80° C. Hot air, hot water or steam may be used depending upon the type of filament. Normally, a few seconds or minutes of exposure at such a temperature is sufficient for annealing the filaments of the tow to remove the latent crimpability and shrinkage forces before further processing of the filaments. Individual filaments are, of course, under essentially no externally applied tension during the annealing step. If the filaments are of a type which develop crimp upon heating, then crimping and annealing may be effected simultaneously.

The annealed tow of crimped, separated filaments may be then coated to form a coating of lower-melting component along the exterior of the filaments. Spraying or dipping procedures may be used for this purpose and the resulting product will thus be bonded into an integral ribbon-like structure. The bonds are "adhesive" bonds as contrasted to the fusion bonds to be created upon later heating the coated filaments to a bonding temperature. The adhesive bonds so obtained will be intentionally broken at later stages of processing as the filaments are redistributed to form a uniform assembly. The advantage of coating the filaments following steps of crimping and deregistration is that the adhesive bonds occur mostly at spaced points rather than as continuous lengths of bonding areas which would be difficult to break in subsequent processing.

The bonded ribbon-like structure is obtained, in one embodiment, by causing a running length of the previously prepared tow to be momentarily immersed in a solution or dispersion of the lower-melting component. The choice of the solvent or other vehicle for this purpose is not critical, but, of course, it should be a nonsolvent for the filamentary component. Volatile inert liquids such as water, alcohols, esters, hydrocarbons, and halogenated

hydrocarbons are exemplary of the many materials which can be used. Advantageously, the freshly-coated tow will then be passed through a pair of resilient, driven nip rolls to squeeze excess solution or dispersion therefrom and to uniformly distribute the lower-melting component therethrough. After drying, preferably below the polymer-melt temperature of the lower-melting component, the coherent ribbonlike structure is obtained.

Spraying procedures may similarly be used in which a solution or dispersion of the lower melting-component is applied as a fine mist to the tow. Hence, for ease in processing, the use of a dip coating procedure is preferred.

The preparation of the bonded ribbon-like structure will be described in greater detail with reference to FIGURE 5. The annealed, crimped deregistered filamentary tow is guided into the dip tank **11** and compacted to remove air by a first pair of driven squeeze rolls **12** having a film sleeve thereon of polytetrafluoroethylene. The tow from the first pair of squeeze rolls **12** is led into and out of a solution **14** of the lower-melting component as it passes about bar **13** submersed in the solution. The tow then passes through a second series of weighted, driven squeeze rolls **15** to remove excess solution therefrom and return it to the dip tank **11**. The rolls **15** have a resilient rubber covering protected by a sleeve of polytetrafluoroethylene film. The tow then passes through dryer **16** by means of driven guide rolls **17** as heated air flows first, in the direction of tow travel and secondly, counter thereto. Finally the tow exits through driven squeeze rolls **18** and about driven guide roll **19** to be wound up or otherwise further processed.

If the solvent for the lower-melting component is a volatile liquid such as methylene chloride or 1,1,2-trichloroethane, as is preferred, then drying of the tow can be effected at a high rate of speed. For example, with air heated at about 120° C. to 160° C. or so, there is almost instantaneous drying of the tow, i.e. usually in less than about 2 seconds.

As the tow passes through the vertical dryer **16**, a low amount of tension is preferably maintained on the tow to ensure that the crimped filaments are not appreciably straightened out as the lower melting component is solidified. The retention of crimp is important during the dip coating procedure in order to facilitate the subsequent carding operation. The minimum tension is provided by driving rolls **17** at a slightly lower speed than squeeze rolls **15**, thus ensuring that any loss of crimp, i.e. straightening, of the filaments occuring in the dip tank **11** (because of the weight of solution thereon) is restored before the lower-melting component solidifies. Tension during drying should preferably not exceed about 0.009 gram per denier. Excess tension is likewise avoided as the tow passes between rolls **15** to minimize loss of crimp.

The amount of lower-melting component applied to the tow can be adjusted to a desired level by appropriately changing either its concentration in the solution or dispersion, the pressure applied by the squeeze rolls, or the speed of the tow being coated.

The continuous, bonded, ribbon-like structure, above-described, may vary considerably in its characteristics. Usually it will be relatively dense as contrasted to the high bulk nonwoven product which can later be formed after thermal bonding. Densities in excess of 1 lb./ft.^{3} are not uncommon for the ribbon-like structure. Its cross-sectional dimensions may vary from a few inches, or even less, to several feet in width. Normally its thickness will only be a fraction, e.g. one fifth or less, of the width dimension. Desirably it will at most be only a few filaments in thickness.

The coating process will result in a difference in orientation between the two components. Thus the drawn filamentary component will be relatively highly oriented whereas the lower-melting component will be a relatively unoriented coating along the exterior of the filaments. The coating may typically be non-uniform, e.g. with varying thickness, or even discontinuous. However, the term "discontinuous" is not meant to imply that the lower-melting component is necessarily in particulate form along the exterior of the filaments. Thus in fact it may be in the nature of a filmy coating covering large areas of the filaments—with discontinuities existing only on a microscopic scale.

The ribbon-like structure is, as a next step, reduced to staple-length by cutting it at intervals transversely to its longitudinal axis, as shown in FIGURE 2. As a result, so-called "fibrous sections" are thus produced, in each of these the parallel alignment of filaments is preserved. By this operation the filaments themselves are reduced to a highly uniform staple length. The tow may be conveniently cut by any of the well known types of staple cutters. The length of the fibrous sections, i.e. in the direction parallel to the direction of filament alignment, can be of ordinary staple fiber length, e.g. about 1 inch to 6 inches.

As will be apparent from the foregoing, an advantageous feature of the invention is that the above-described steps, starting with spinning and including that of coating, can all be performed with a continuously running tow. From the standpoint of a commercial operation this not only represents a high degree of process efficiency, because adhesive is not applied to individual articles, but also it affords improved product uniformity.

As a next step in the preferred process embodiment of the invention, the fibrous sections are opened and the individual staple-length filaments distributed; that is, separated from one another and intimately blended. Adhesion bonds are broken but substantial portions of the lower-melting component remain affixed to the filaments. There is thus obtained a loose bulky assembly of individually distinct, crimped, stabilized, coated staple filaments which throughout its three dimensions is highly uniform in terms of the ratio of filamentary component to lower-melting component. The latter characteristics, in particular, distinguish the bonded nonwoven products of the invention from attempts in the prior art to obtain bulky, adhesive coated non-woven products. The essentially constant ratio of the two components means that bonding can also be essentially uniform such that compressional and other properties will not materially vary through the thickness of the structure. Perhaps most importantly, the uniformly bondable characteristic means that a fabricator of finished textile articles can produce a wide variety of products by the simple expedient of heating shaped assemblies.

An ordinary card or garnett card machine is particularly suitable for effecting mechanical redistribution of the filaments of the cut, staple-length fibrous sections. The combing action of the typical card cloth cylinder employed therewith serves to effect rupturing of the adhesive bonds while at the same time uniformly blending the fibers to a bulky fibrous assembly, e.g. in the form of a batt or web. Once redistributed in this or other ways, the individual filaments can be formed into a product of the desired characteristics by other techniques as well, for example batts may be processed on a Rando-Webber machine or other known air-laydown machines, i.e. a Duo-Form machine.

One advantage of this invention is that highly bulked nonwoven products can be obtained. With such low density products it is particularly important for functional purposes that the bonding be substantially uniform throughout. Bonded products having densities below 1.5 lbs./ft.^{3}, in fact as low as 0.2 lb./ft.^{3}, are readily obtainable. Moreover, only a relatively modest increase in density will have occurred during bonding.

The step of thermally bonding the unbonded fibrous assembly is accomplished by merely heating the assembly to a temperature in excess of the polymer melt temperature of the lower-melting component. The latter softens or

melts and, upon cooling, bonds are formed at fiber cross-over points throughout the three dimensions of the structure, as indicated generally in FIGURE 4.

As above-mentioned, ordinary filaments, i.e. uncoated or monocomponent filaments, may be blended with the coated filaments in forming the unbonded assembly. The ordinary filaments would have a maximum retractive coefficient of 30 and a fiber stick temperature above the polymer melt temperature of the lower-melting component of the coated filaments. Such ordinary filaments may comprise 0 to 95% by weight of the unbonded assembly.

The sequence of processing steps illustrated in FIGURE 1 and discussed above is advantageous from the standpoint of ease and economy. However, it will be apparent that numerous variations are possible, but within certain limits. In particular, the annealing step can be performed at any convenient stage of processing following drawing to reduce the retractive coefficient to about 30 or less. In one respect it is advantageous for this step to be performed after crimping and before coating since high annealing temperatures can then be used without fusing the lower-melting component. On the other hand it is also entirely practical to effect annealing after coating. Even if the polymer melt temperature of the lower-melting component is exceeded during annealing and some fusion occurs, the bonds in the ribbon-like structure can usually be broken during a subsequent mechanical redistribution step, e.g. carding. Two or more annealing steps can also be used, for example one following drawing and another following coating. The staple cutting operation can also be performed at various stages, although it will be apparent that coating, crimping and annealing steps are more easily carried out using a continuous filament tow. Other such variations will also be evident.

When the lower-melting component is to be applied to a loose array of fibers other than a tow, e.g. to a carded web or other form of opened filamentary structure, filament separation is effected by the carding operation and tow derigistration is unnecessary. For example, a carded web of crimped, annealed, staple filaments may be simply sprayed with the lower-melting component and the web then recarded to break up bonds, redistribute the lower-melting component uniformly, and thus produce an unbonded fibrous assembly. As another example, fibers of the lower-melting component can be blended with the structural fibers and the blend heated to melt the binder fibers and coat the structural fibers, the blend is then carded to break fiber-to-fiber bonds and redistribute the binder. In any case the number of so-called "married" fibers after carding and formation of the unbonded fibrous assembly should preferably not exceed about 2, as examined visually, per 100 grains of fibrous assembly having a density of 0.2 to 0.5 lb./ft.^{3}.

Characteristics of the assembly and uses

In one embodiment the product of the invention is an assembly of coated filaments which (a) are highly dissociated, i.e. the filaments are not thermally or adhesively bonded to one another but rather exist as individually distinct filaments, (b) are relatively highly crimped but nevertheless are stabilized so as to substantially prevent shrinkage and movement when subjected to a thermal bonding treatment, and (c) possess by virtue of the lower-melting component an ability to bond to themselves or to other fibers when heated above the polymer melt temperature of that component. Advantageously, at least a major proportion by weight of the assembly should comprise coated filaments as above defined—but this is not essential to all uses.

As an article of commerce the assembly is suitable in widely diverse applications. In this respect it is to be understood that the term "assembly" is not intended to designate any particular geometrical shape or even any particular arrangement or size of the filamentary structures therein, for these are aspects that can be appropriately selected depending upon the intended use of the assembly.

The assembly of filaments may be conveniently provided in the form of a continuous length web of staple fibers, which can be supplied to the textile industry for conversion into textile structures of the desired type, e.g. into nonwoven batts, slivers, and yarns, or into knitted, tufted, and woven fabrics. For such uses the filaments of the assembly may be blended with various proportions of ordinary staple fibers which are not selfbondable themselves.

In one embodiment of the invention, the assembly of filaments in used to produce a bonded block of fibers which are aligned in the same direction. This is then sliced perpendicular to the direction of the fibers to produce porous, self-supporting fiber-on-end sheets, as described in Koller U.S. 3,085,922. Examples XV to XVII hereinafter show the preparation of such structures. Alternatively, the assembly of filaments may be processed on a garnetting machine and then cross-lapped to entangle the fibers into a nonwoven batt structure, which may be bonded by heating the batt above the polymer melt temperature of the lower-melting component. Nonwoven products may be formed into thin batts for use as such or the batts may be stacked on top of each other to provide thick articles which are then subjected to a bonding temperature. The nonwoven products may be formed such that the filaments are arranged therein to have fiber-on-end, fiber-on-side or random alignment. Also they may, following or during bonding, be laminated to various backing materials for additional support or for further processing into still other textile products.

The products of this invention are useful for processing into a wide variety of nonwoven, woven, knitted and tufted textiles for a variety of applications, but are particularly suitable for the manufacture of bonded, nonwoven textiles, either quilted or unquilted. They are also suitable for use in making pillow fillings, fillings for sleeping bags, cushions, quilts, comforters, coverlets, mattresses, mattress pads, mattress toppers, furniture and auto upholstery, bedspreads, pile fabrics for industrial and apparel uses, blankets, women's robes, sport jackets, car coats, interlinings, outerwear, floor covering materials, tiles, carpets, bath mats, molded articles, and the like.

For the preparation of pillows, cushions and other articles it is also entirely practicable as shown in FIGURE 3 to use the unbonded assembly for filling a fabric or other covering followed by heating the entire structure to effect bonding.

Advantages summarized

A most fundamental advantage of the novel assembly of the invention is that it can be formed to a desired shape by the textile converter and bonded, by mere application of heat, with little or no change in shape. Another advantage of the invention is that it provides an assembly of filaments which are specially adapted to the formation of nonwoven textile structures having a combination of outstanding properties. When the assembly is fashioned into a textile article and then subjected to the thermal activation temperature of the lower-melting component, a bonded product is obtained in which the bonds are uniformly distributed throughout the three dimensions thereof. This permits the manufacture of nonwoven products having a combination of hitherto unobtainable properties; namely, the textiles can have a lower density, and they tend to be softer and have better drape properties than nonwoven textiles of the prior art. Products having a density of less than 1.5 lbs./ft.^{3}, in many cases as low as 0.2 lb./ft.^{3} and below are obtained. By virtue of a relatively uniform distribution of bond points throughout the three dimensions thereof, a high degree of height retention and load support properties are obtained in the

product. The uniform three-dimensional bonding provides superior resistance to dimensional changes, resistance to clumping, resistance to fiber leakage, and resistance to matting after repeated washings or dry cleanings. The invention is also useful for making bonded yarns for woven, knitted and tufted fabrics which will show less pilling and which will require less yarn twist in manufacture.

Test procedures

Retractive coefficient, RC, may be defined by the equation

$$RC=\frac{L_o-L_a}{L_o}\times 100$$

where L_0=the length of the coated filament in inches when subjected to a load of 2 mg./denier per filament, based upon the denier of only the filamentary component; and L_a=the length of the filament in inches under the same load after exposure to a temperature above the polymer melt temperature of the lower-melting component but below the fiber stick temperature of the structural fiber component. For purposes of the measurement, the temperature selected will usually be the minimum temperature required to sufficiently soften or melt the lower-melting component to form effective fiber-to-fiber bonds. In the examples which follow, the temperature selected will be the same as the bonding temperature. Conveniently, the measurement is made after exposure to a temperature between 1 and 20° C. above the polymer melt temperature. (Only a nominal difference in RC would be experienced within this range.) The values of L_o and L_a are measured on a cathetometer while the load is applied to the filament on a Model LG Precision Balance (Federal Pacific Electric Co.). An average is taken from measurements on five filament specimens.

Polymer melt temperature, PMT, is in the case of essentially amorphous or essentially crystalline polymers, the temperature at which a sample of the lower melting component leaves a molten trail when moved across a heated metal surface with moderate pressure. Polymers containing substantial amounts of amorphous and crystalline regions are more accurately tested for polymer melt temperature by ascertaining the melting of the last crystal of a sample when heated, e.g. on a hot stage microscope using crossed optical polarizers (in the literature this is sometimes referred to as indicative of crystalline melting point).

Fiber stick temperature is described in Beaman and Cramer, J. Polymer Science, 21, 228 (1956).

Crimp frequency is determined by counting, under a magnifying glass, the number of crimps in the fiber while under a tension of 2 m./denier. The fiber is then extended until it is just straight (observed visually) and the extended length is measured. The crimp frequency, expressed as crimps per inch, based on the extended length of the filament, is calculated. An average is taken from measurements on five filament specimens.

Crimp index is determined by measuring the length of a filament first under a tension of 2 mg./denier and then under a tension of 50 mg./denier. Crimp index is the change in length expressed as a percentage of the uncrimped length. An average is taken from measurements on five filament specimens.

Drape test, or flexural rigidity is measured according to ASTM D-1388–55T.

Softness test, ILD 25% (indentation load deflection at a deflection of 25%), involves measuring the load in pounds necessary to produce a 25% deflection of the sample. The load in lbs. is calculated on the basis of a 50 square inch deflection area. The testing apparatus consists of a Schiefer Compressometer (Frazier Precision Instrument Co., Silver Spring, Md.) modified for use as a dead-weight thickness gauge. The procedure consists of placing a sample on the gauge, reading the initial thickness and then adding weights to the pressure foot of the gauge until the sample is deflected 25%.

The following examples further iillustrate the practice of the invention. Parts and percentages are by weight unless otherwise stated.

EXAMPLE I

Polyethylene terephthalate polymer (abbreviated 2G–T) is melt-spun, drawn and crimped in accordance with Kilian U.S. Patent 3,050,821 to produce filaments of 4 denier/filament. The procedure involves air quenching the filaments as they exit from orifices of a spinneret, drawing the filaments in superheated steam and then relaxing the tension. Upon release of the tension of drawing, it is observed that the filaments exhibit a high level of three-dimensional crimp, referred to as a reversing helical crimp. The filaments from several spinnerets are combined to produce a filamentary tow having a total denier of about 50,000.

After crimping, the tow is annealed in an air oven at 160° C. for one minute to relax the filaments, to effect further crimping and to lower the retractive coefficient. The tow is then opened by hand from a cylindrical to generally flat tow. This is then deregistered to separate filament groups. For this purpose, there are used two sets of positively driven nip rolls of the type more particularly described in Dunlap et al. U.S. Patent 3,156,016. These pressure nip rolls have a diameter of 2⅞ inches and are 14 inches long. In each set of rolls, one has a series of helical threads whose ridged surfaces are 0.017 inch wide. The other is a smooth-surfaced elastomer covered roll. Upon pulling the tow under tension through the nips of the rolls, "married" groups of adjacent filaments are rendered out of phase with one another to deregister the crimps.

The deregistered tow is then given a second annealing treatment at 227° C. for 15 minutes in an air oven. This is just below the fiber stick temperature of the 2G–T which is 230° C. and well above the second-order-transition temperature of 80° C.

The opened and deregistered tow is then passed through a dip tank containing a 5% by-weight solution of a copolyester in 1,1,2 trichloroethane and then squeezed free of excess solution. Apparatus generally similar to that of FIGURE 5 is used for this purpose. The copolyester has a polymer melt temperature of 208° C. and is a copolymer of 79 parts by-weight ethylene glycol terephthalate and 21 parts ethylene glycol isophthalate (abbreviated 2G–T/2G–I). The tow is found to pick up 10% of the lower-melting copolyester component, based on filament plus copolyester. The tow is dried at 65° C. under minimal tension to produce an integral, flat bonded ribbon-like structure which is continuous in length and has a cross-section dimension of 5 by 0.1 inch.

The ribbon-like structure is next reduced to 2 inch length sections by cutting it in the transverse direction using a Pacific Converter. The filaments at this stage have a crimp index of 20, a crimp frequency of 14 crimps per inch and a retractive coefficient of only 6.

The adhesive-bonded fibrous sections are next treated to mechanically distribute the filaments, break the bonds and thereby obtain a highly uniform, low-density assembly of individually distinct, staple-length filaments. For this purpose, carding of the fibrous sections is effected on a commercial garnett carding machine.

The unbonded assembly of filaments produced by carding is cross-lapped to form a batt whose dimensions are 23 by 17 by 0.79 inches. The batt is then bonded in an air oven under the conditions indicated in Table 1. As further indicated therein, only modest densification occurs during the bonding step—the overall density being extremely low. Most importantly, the bonded nonwoven product so obtained is uniformly bonded throughout such that its properties are also constant in all portions.

Table 1

Batt bonding temp. (° C.)	227
Batt bonding time (mins.)	15
Density (lbs./ft.^{3})—Carded	0.11
Density (lbs./ft.^{3})—Bonded	0.18
Softness, ILD 25% (lbs.)	0.6
Drape, flex. rig (mg.–cm.)	312

EXAMPLES II–V

A bonded ribbon-like structure is produced as in Example I except that both before deregistration and after dipping (omitting annealing at 227° C.) the tow is annealed at 221° C. for 5 minutes under minimal tension in an air oven rather than at 227° C. for 15 minutes. The ribbon-like structure is then cut to 3-inch long fibrous sections on a Beria cutter.

The fibers have a crimp index of 26%, a crimp frequency of 15 crimps per inch and a retractive coefficient of 3.

The fibrous sections are opened using a Kirschner opener having a three-blade beater bar.

The annealed staple fibers are then carded into a web on a Proctor & Schwartz 740 carding machine to effectively break up interfilament bonds and evenly distribute the filaments. The card web is then fed onto a card cloth cylinder which separates the fibers in the web from one another. The fibers are then transferred from the cylinder to an air stream by jets of air and collected on a perforated belt having a vacuum slot underneath it. Four batts of varying density are prepared.

The air-laid batts are then bonded at 218° C. for five minutes in an oven having forced air directed upward against the batt so as to minimize the tendency for compaction to occur. The properties of the carded batts and bonded structures are shown in Table 2.

TABLE 2

	Batt Density Before Bonding	(lbs./ft.^{3}) After Bonding	Percent Density Increase in Bonding
Example:			
II	0.11	0.115	5
III	0.12	0.13	8
IV	0.18	0.225	25
V	0.20	0.24	20

EXAMPLES VI–VII

Helically crimped, deregistered 2G–T filaments are produced in accordance with Example I except that the drawn tow has a total denier of about 860,000 and no heat is applied to the fibers after drawing. The tow is then sprayed with a 6% solution of 79/21 2G–T/2G–I in 1,1,2 trichloroethane to produce a bonded tow structure having a 2G–T/2G–I content of 9% based on the total weight of fiber and 2G–T/2G–I. The bonded tow is then divided into two parts a "Control" and VI/VII. The control part receives no heat treatment and part VI/VII is annealed at 215° C. for 10 minutes under minimal tension in an air oven. Both parts are then cut to 2" long fibrous sections using hand shears.

The control part filaments, which have had no annealing, have a crimp index of 15%, a crimp frequency of 9 crimps per inch and a retractive coefficient of 37. The part VI/VII filaments have a crimp index of 28%, a crimp frequency of 13 crimps per inch and a retractive coefficient of 3. The bonded fiber sections from each of the parts are separately carded into batts on a sample card to uniformly distribute the staple filaments and to break up the filament-to-filament bonds. A pair of batts are formed from the control part item to have a density of 0.3 and 0.6 lb./ft.^{3}, respectively, after carding. A similar pair of batts is formed from the part VI/VII item.

The four batts are then bonded in an air oven at 218° C. for 5 minutes. As shown in Table 3, the control part batts, whose fibers had no annealing, lose 25–50% of their bulk during bonding. However, the part VI/VII batts, whose fibers were annealed at 215° C., show little or no densification during bonding.

TABLE 3

	Control	Part VI/VII
Annealing Temp. (° C.)	None	215
Bonding Temp. (° C.)	218	218

	Sample A	Sample B	Sample VI	Sample VII
Density (lbs./ft.^{3}):				
Carded	0.3	0.6	0.3	0.6
Bonded	0.6	0.8	0.35	0.6
Percent Bulk Loss in Bonding	50	25	14	0

EXAMPLES VIII–IX

A tow of melt-spun, drawn,[1] crimped, 2G–T filaments is produced as in Example I. The filaments are then cut to 2" staple length, annealed at 160° C. under essentially no tension for 1 minute and divided into two portions, part VIII and part IX. Part VIII is further annealed at 221° C. for 5 minutes in a relaxed condition in an air oven. Both parts are then separately carded into webs to separate the filaments.

The webs are sprayed with a 5% solution of a copolymer of vinyl chloride and vinyl acetate (about 87:13 ratio, polymer melt temperature of 136° C.) in methylene chloride. DeVilbiss Type AGA Series 517 spray guns are used to deposit a fine mist of the solution on the webs. The webs are then air dried. Part VIII has a content of 22% by-weight of the copolymer and part IX had a content of 25% by-weight. The sprayed webs are then opened on a Clark Wool Picker and carded on a garnett carding machine to break up interfilament bonds and evenly redistribute the filaments. The garnetted batts are then heat-bonded in an air oven at 150° C. for 15 minutes.

The sprayed fibers of part VIII have a crimp index of 16, a crimp frequency of 12 and a RC value of 2 and those of part IX have a crimp index of 22, a crimp frequency of 10 and a RC value of 4. As shown in Table 4, the batt density of part VIII after carding is 0.13 and that of part IX was 0.14. After heat bonding, the density of part VIII, which had the additional, higher-temperature annealing step, is 0.16 lb./ft.^{3} and that of part IX, which received only the lower temperature annealing step is 0.21 lb./ft.^{3}. Because of the extremely low carded batt density, however, this is not excessive densification.

TABLE 4

	Part VIII	Part IX
Annealing Temp. (° C.)	160,221	160
Bonding Temp. (° C.)	150	150
Density (lbs./ft.^{3}):		
Carded	.13	.14
Bonded	.16	.21
Softness, I.L.D. 25% (lbs.)	0.3	0.4
Flexural Rigidity (mg. cm.)	30	105

EXAMPLES X–XI

A tow of melt-spun, drawn, crimped, 2G–T filaments is produced as in Example IX. The filaments are then cut to 2" staple length, annealed at 160° C. for 1 minute under essentially no tension and divided into two portions, part X and part XI. Part X is further annealed at 221° C. for 15 minutes in a relaxed condition in an air oven. Both parts are then separately carded into webs to separate the filaments. The webs are sprayed as in Examples VIII–IX with a 5% solution of 79/21 2G–T/2G–I in methylene chloride to provide a content of 25% by-weight of the copolymer. After drying the sprayed webs are then opened on a Clark Wool Picker and carded on a Proctor & Schwartz No. 740 carding machine to break up interfilament bonds and evenly redistribute the

[1] In a spray of water at about 90° C. rather than steam.

filaments. The carded batts are then heat-bonded in an air oven at 221° C. for 15 minutes.

The sprayed fibers of part X have a crimp index of 26, a crimp frequency of 9 and a RC value of 6 and those of part XI have a crimp index of 20, a crimp frequency of 8 and a RC value of 15. As shown in Table 5, the batt density of part X after carding is 0.10 and that of part XI is 0.12. After heat bonding, the density of part X, which had the additional, higher-temperature annealing step, is 0.24 lb./ft.^{3} and that of part XI, which received only the lower temperature annealing step, is 0.32 lb./ft.^{3}.

TABLE 5

	Part X	Part XI
Annealing Temp. (° C.)	160, 221	160
Bonding Temp. (° C.)	221	221
Density (lbs./ft.^{3}):		
Carded	0.10	0.12
Bonded	0.24	0.32

EXAMPLE XII

A tow of melt-spun, drawn polyethylene terephthalate fibers having a denier per filament of 4.75 are crimped in a stuffing-box type crimper, annealed at 145° C. for 1 minute in an oven under essentially no tension, and cut to 2" staple length. The fibers are then exposed to a second annealing step at 221° C. for 15 mins. in a relaxed condition in an air oven. A web is formed, sprayed, carded and bonded using the same conditions as in Examples X and XI.

The density of the batt after carding is 0.10 lb./ft.^{3} and the density after bonding is 0.19 lb./ft.^{3}. The sprayed fiber has a crimp index of 15, a crimp frequency of 8 and a RC value of 5.

EXAMPLE XIII

A tow of melt spun, drawn, crimped, 2G–T filaments is produced as in Example IX. The tow is then cut to 2" staple length and annealed at 160° C. for one min. The fibers are then exposed to a second annealing step at 160° C. for 15 minutes. The fibers are then carded into a web and the web sprayed as in Examples VIII–IX with a 5% solution in methylene chloride of a copolyester to provide a content of 25% by-weight of the copolyester. The copolyester (abbreviated 2G–T/2G–10) is formed of a 55/45 ratio of ethylene terephthalate and ethylene sebacate units (polymer melt temperture is 159° C.). The sprayed webs are then opened on a Clark Wool Picker and carded on a Proctor & Schwartz No. 740 carding machine to break up interfilament bonds and evenly redistribute the filaments. The carded batts are then heat-bonded in an air oven at 160° C. for 15 minutes.

The sprayed fibers have a crimp index of 19, a crimp frequency of 10 crimps per inch and a RC value of 15. The density of the batt after carding is 0.15 lb./ft.^{3} and the density after bonding is 0.30 lb./ft.^{3}.

EXAMPLE XIV

A 1200 denier, 68 filament yarn composed of polyhexamethylene adipamide (abbreviated 66) filaments of trilobal cross-section and steam crimped in accordance with Belgian Patent 573,230 is cut to 2.5-inch staple length. The staple is annealed by exposure to water at 82° C. for 15 minutes followed by drying at 82° C. in an air oven to relax the filaments, to effect further crimping and to lower the retractive coefficient.

The dried staple is then opened on a garnett carding machine to separate the filaments. The carded web is sprayed with a 3% by-weight solution of "Versalon" 1112 (a polyamide marketed by General Mills Co.) in chloroform to provide a lower-melting component content of 22% based on the weight of fiber and lower-melting component.

The composite filaments have a crimp index of 17, a crimp frequency of 8 and a retractive coefficient of 2. The fiber stick temperature of the 66 fiber is 235° C. and the polymer melt temperature of the polyamide lower-melting component is 112° C.

The composite filaments are formed into a batt (about 0.4 lb./ft.^{3}) on a standard garnett carding machine. The batt is rolled up into a pillow-shaped structure weighing 14 oz. and placed in a pillow-shaped mold having a length of 24 inches, a width of 18 inches and a height which tapers from 7.5 inches at the center of the pillow to 0.5 inch at the edges.

The pillow-mold containing the rolled-up batt is placed in an air oven at 120° C. for 30 minutes. The bonded pillow obtained upon cooling is uniformly bonded throughout and has a density of 0.6 lb./ft.^{3}.

The foregoing procedure is repeated using as the lower-melting component an alcohol soluble terpolymer (polymer melt temperature 160° C.) formed by condensing together caprolactam, hexamethylene diamine, adipic acid and sebacic acid, such that there are substantially equal proportions of polycaproamide, polyhexamethylene adipamide and polyhexamethylene sebacamide in the terpolymer. A solution of 4% by weight terpolymer in 80/20 alcohol/water mixture by volume is used for this purpose to obtain comparable results and bonding is effected at 180° C.

EXAMPLE XV

This example illustrates the preparation of a fiber-on-end structure using an unbonded fibrous assembly in accordance with the present invention.

A blend of staple fibers of ethylene terephthalate polymer having a three-dimensional helical crimp (produced as in Example IX), 4 denier per filament and a staple length of 2 inches (5.08 cm.) are carded into a web with staple fibers of ethylene terephthalate polymer having a stuffer-box type of crimp, 1.5 denier per filament and a staple length of 1.5 inches (3.8 cm.). The final ratio of the staple fibers in the blend is 60/40 parts, respectively, by weight.

Both types of fibers are produced by melt spinning, crimping in the manner indicated, annealing at 160° C. for the helically crimped fiber and at 145° C. for the stuffer-box crimp item, and then cutting to staple length.

Several ends of carded sliver (approximately 200 grains) of the blend of two polyester fibers are spread out to a width of 10 inches (25.4 cm.), laid together in a parallel direction and sprayed with a methylene chloride solution of 2.5 weight percent of an ethylene terephthalate/ethylene isophthalate (79/21 molar ratio) copolyester (η_{rel}=29) having a polymer melt temperature of 208° C. The solution is deposited as uniformly as possible on the sliver in the form of a fine mist from a DeVilbiss spray gun (model GA–517–704–FF). The sprayed sliver is then recarded to obtain uniform distribution of the copolyester (15% on the weight of the coated fibers) and to remove most fiber-to-fiber bonds.

The sprayed 4 denier per filament fibers have an average crimp index of 20, a crimp frequency of 8 crimps per inch, and a retractive coefficient of less than 20. The sprayed 1.5 denier per filament fibers have a crimp index of 13%, a crimp frequency of 13 crimps per inch and a retractive coefficient of less than 10. The fibrous assembly has a density of about 0.2 lb./ft.^{3}.

The sprayed and recarded product in continuously wound onto a circular drum with a minimum of tension until a layer approximately ten inches (25.4 cm.) thick is obtained. This layer of fibers is cut in a line transverse to the direction of the fibers and removed from the drum to give a batt of carded fibers measuring approximately 40 inches (102 cm.) wide by 84 inches (2.13 meters) long by 10 inches (25.4 cm.) thick, having the fibers all aligned in the same general direction along the length of the batt. The batt is cut at 90° transverse to the direction of the fibers into sections 10 inches (25.4 cm.) long and 10 inches (25.4 cm.) thick. These segments were then carefully placed by hand into a perforated metal mold 40 inches (101.6 cm.) wide by 48 inches (122 cm.)

long by 10 inches (25.4 cm.) tall, having a lidded top, with the sides of the segments face-to-face so that the fibers were all aligned in the same general direction with the fiber ends directed towards the top and bottom of the mold. The mold was closed, placed in an oven, and heated at 220° C. (428° F.) for one hour. The fiber density of the block is 0.9 lb./ft.^{3} (14.4 g./l.). The bonded block is cut into thin wafers with a band knife slitter. Laminates are prepared from .156 inch (.4 cm.) thick wafers by spraying one side with an 11% by weight solution of ethylene terephthalate/ethyleneazelate (60/40 molar ratio) copolyester in methylene chloride to give a final loading of 1.0 oz./yd.^{2} (33.9 g./m.^{2}) adhesive (dry weight) on the wafer. The sprayed wafer is then brought into contact with a loosely woven cotton cloth in a heated zone and firmly pressed together by means of a pair of nip rolls, then allowed to cool. Examination of the structure of the wafer layer under the microscope reveals that the majority of the lower-melting polymer particles are in the form of small ellipsoids or spheres having an average major dimension of 0.0077 inch (0.02 cm.) and an average minor dimension of 0.004 inch (0.01 cm.). The particles are located at random along the fiber lengths, forming bonds at such points as where two or more fibers cross. The average number of fibers per particle, however, is determined to be 1.9. No discoloration is noted in wafer samples exposed for 20 and 40 hours in the Fade-Ometer. The products had a very soft hand and high resistance to dry cleaning. The laminate made in accordance with this example is useful for making a woman's bathrobe.

EXAMPLE XVI

This example also illustrates the preparation of a fiber-on-end structure.

Carded sliver of the blend of crimped polyester fibers described in Example XV is sprayed with a 5% solution of polyethylene terephthalate/ethylene azelate (60/40 molar ratio, polymer melt temperature of 170° C.) in 1,1,2 trichloroethane using a DeVilbiss (model JGA–502) hand spray gun equipped with an FX tip and a 704 air cap. A delivery pressure of 5 p.s.i. (351 g./cm.^{2}) and an atomizing pressure of 70 p.s.i. (4.9 kg./cm.^{2}) are employed. At this point the major portion of the copolymer (11% on weight of fiber) is present either as thin discontinuous sheaths around the fiber or as minute droplets. The dried sliver is recarded to break up fiber-to-fiber bonds and formed into a batt on a garnett machine.

The sprayed 4 denier per filament fibers have an average crimp index of 20, a crimp frequency of 8 crimps per inch and a retractive coefficient of <20. The sprayed 1.5 denier per filament fibers have a crimp index of 13%, a crimp frequency of 13 crimps per inch and a retractive coefficient of less than 10. The fibrous assembly has a density of about 0.2 lb./ft.^{3}.

The batt is cut into sections of a size appropriate to fit into a mold like that of Example XV [2] and packed to a fiber density of 0.9 lb./ft.^{3} (14.4 grams per liter), and heated for one hour at 190° C. (374° F.). The block is then sliced into 0.25 inch (6.35 mm.) thick wafers, laminated, and evaluated as described in Example XV. Examination of the structure under the microscope reveals the majority of the lower-melting polymer particles to be small ellipsoids and spheres of the order of 0.0015–0.0020 inch (.038–.051 mm.) in the smallest dimension. The resulting laminates are useful for a variety of apparel fabrics.

EXAMPLE XVII

This example relates to the use of an aqueous dispersion of lower-melting component and the preparation of a fiber-on-end product.

[2] Dimensions 8.75" (22.2 cm.) x 8.75" (22.2 cm.) x 5" (12.7 cm.) tall.

The structural fibers employed comprised a 60/40 blend of the fibers described in Example XV. An aqueous dispersion containing 14% by weight of a copolyester prepared from ethylene glycol and a 60/40 molar ratio of terephthalic acid and azelaic acid was formed (polymer melt temperature 170° C.). The polyester dispersion is applied to 135 grams of the carded web of the fiber blend of Example XV by spraying to give a weight gain of 24 grams after air drying. The sprayed web is garnetted twice to break up bonds, redistribute uniformly the copolyester and form a 9" wide batt. One hundred and six grams of the batt are cut into the 5" segments and packed in a 9" x 9" x 5" metal cage so that the fibers are parallel to the 5" dimension and heated in an oven for one hour at 180° C.

The sprayed 4 denier per filament fibers have an average crimp index of 20, a crimp frequency of 8 crimps per inch and a retractive coefficient of <20. The sprayed 1.5 denier per filament fibers have a crimp index of 13%, a crimp frequency of 13 crimps per inch and a retractive coefficient of less than 10. The fibrous assembly has a density of about 0.2 lb./ft.^{3}

The metal cage is disassembled and a bonded block of substantially parallelized crimped fibers having a fiber density of 0.9 lb./cu. ft. is removed. The block is sliced perpendicular to the direction of the fibers to give sheets ¼" thick. The sheets were light straw colored and of good strength. Lamination of the wafer to a cotton fabric with a thermoplastic copolyester adhesive as in Example XV gives a soft laminate. After being dry cleaned five times in a commercial dry cleaning system, the laminate has a pleasing appearance.

Microscopic examinations of the wafers show the copolyester to be distributed in small discrete droplets along the fibers with an average of two fibers per bonding particle. Analysis of the batt by extraction with methylene chloride indicates the presence of 15% soluble material.

EXAMPLE XVIII

The procedure of Example I is repeated except that a sample carding machine is used to form the nonwoven batt and just before carding, quantities of monocomponent 2G–T staple which had been annealed at 175° C. for 2 minutes then again at 227° C. for 15 minutes, in tow form, prior to its being cut, is blended with the coated staple. The monocomponent 2G–T fibers are of 2-inch (5.1 cm.) staple length, are 4 denier per filament, and have a crimp index of 32, a crimp frequency of 11 and a retractive coefficient of 1. Blends containing 40%, 80% and 95% of the monocomponent fibers are used and very soft, lightly-bonded, low-density structures are obtained. Batt densities are shown in Table 6.

TABLE 6.—BATT DENSITIES

[lb./ft.^{3} (g./cm.^{3})]

	40/60 Blend	80/20 Blend	95/5 Blend
Carded	0.26(0.004)	0.26(0.004)	0.26(0.004)
Bonded	0.29(0.005)	0.30(0.005)	0.31(0.005)

EXAMPLE XIX

Nylon (66) tow having a filament denier of three, total denier of 430,000 and a stuffing-box type of crimp is deregistered on the threaded-roll machine of Example I, then sprayed with a 5% solution of a copolyester of Example XIII dissolved in two parts methylene chloride and one part 1,1,2-trichloroethane to provide a content of 15%, by weight, of the copolyester. The tow is then cut to 2-inch (5.1 cm.) staple, annealed at 180° C. for 5 minutes in an air oven and carded on a sample carding machine. The properties of the fiber are listed in Table 7.

The carded batt is bonded at 160° C. for 5 minutes; batt properties are shown in Table 7.

TABLE 7

Fiber properties

Crimps per inch	15
Crimp index (percent)	12
R.C.	2

Batt density, lb./ft.^{3} (g./cm.^{3})

Carded	0.23 (0.004)
Bonded	0.27 (0.004)

EXAMPLE XX

The procedure of Example XIX is repeated except that conventional polyacrylonitrile tow (fiber stick temperature is 231° C.) having a filament denier of 3 and a total denier of about 500,000 is used. Fiber and batt properties are listed in Table 8.

TABLE 8

Fiber properties

Crimps per inch	9
Crimp index (percent)	9
R.C.	5

Batt density, lb./ft.^{3} (g./cm.^{3})

Carded	0.22 (0.004)
Bonded	0.40 (0.006)

EXAMPLE XXI

Polypropylene staple fibers (fiber stick temperature= 160° C.) having a denier per filament of 1.5 and a cut-length of 1.5 inches (3.8 cm.) are annealed at 150° C. for five minutes in an air oven, carded into a web on a sample card and then sprayed with a 5% solution of a 72/28 ethylene/vinyl acetate copolymer in toluene to provide a content of 25% by weight of the copolymer. The copolymer has a polymer melt temperature of 82° C. The sprayed web is recarded to separate the filaments. Fiber properties are listed in Table 9.

The carded batt is bonded at 90° C. for five minutes in an air oven. Batt properties are shown in Table 9.

TABLE 9

Fiber properties

Crimps per inch	12
Crimp index (percent)	15
R.C.	4

Batt density, lb./ft.^{3} (g./cm.^{3})

Carded	0.19 (0.003)
Bonded	0.21 (0.003)

EXAMPLES XXII–XXIII

Polyethylene terephthalate fibers, spun and drawn as in Example I are annealed at 175° C. for two minutes in an air oven, cut to 2-inch (5.1 cm.) staple length with hand shears and further annealed at 218° C. for five minutes. A discontinuous adhesive coating composed of 70/30 2G–T/2G–I copolymer (polymer melt temperature of 184° C.) is applied to the 2G–T fibers as follows:

The copolymer in the form of 2.3 denier per filament, 1-inch (2.5 cm.) staple length fibers is blended with the 2G–T fibers on a sample carding machine, then heated to 200° C. for five minutes in an air oven to melt the copolymer and thereby form droplets which coat the 2G–T fibers. The structure is then recarded to form an unbonded assembly of individually distinct coated filaments. Fibers having a copolymer content of 15 and 25% based on 2G–T plus copolyester weight are produced.

The coated fibers in batt form are heated to 200° C. for five minutes to produce a low-density, bonded structure. Fiber and batt properties are shown in Table 10.

TABLE 10

	Example XXII	Example XXIII
	Copolyester Content (Percent)	
	15	25
Fiber Properties:		
Crimps per inch	11	11
Crimp index (percent)	26	29
R.C.	7	10
Batt Density, lb./ft.^{3} (g./cm.^{3}):		
Carded	0.32 (0.005)	0.32 (0.005)
Bonded	0.33 (0.005)	0.40 (0.006)

EXAMPLE XXIV

The procedure of Example XXIII is repeated except that the temperature used in the second annealing step for the 2G–T fiber is 200° C., the lower-melting fiber is 1.5-denier, 1.5-inch (3.8 cm.) polypropylene (polymer melt temperature of 170° C.) and the temperature used for the fiber-coating and batt-bonding steps is 195° C. Fiber and batt properties are shown in Table 11.

TABLE 11

Fiber properties

Crimps per inch	9
Crimp index (percent)	13
R.C.	18

Batt density, lb./ft.^{3} (g./cm.^{3})

Carded	0.22 (0.004)
Bonded	0.35 (0.006)

EXAMPLE XXV

The procedure of Example XXIV is repeated except that the lower-melting fiber is 1.5 denier, 1.5-inch (3.8 cm.) polyvinyl chloride/acetate (about 87:13 weight ratio, polymer melt temperature of 141° C.) and temperature used for the fiber-coating and batt-bonding step is 165° C. Fiber and batt properties are shown in Table 12.

TABLE 12

Fiber properties

Crimps per inch	9
Crimp index (percent)	18
R.C.	17

Batt density, lb./ft.^{3} (g./cm.^{3})

Carded	0.22 (0.004)
Bonded	0.33 (0.005)

EXAMPLE XXVI

This example shows that there is a constant ratio of binder to fiber throughout the three dimensions of the nonwoven assembly of the present invention and compares the new nonwovens with nonwovens of the prior art made by surface spraying binder onto batts.

Samples are taken from Examples I, VI–VII, X, and XIII and the distribution of binder is determined. Results are given in Table 13A. For comparison 2G–T fibers are surface sprayed with binder in accordance with prior art teachings and the distribution of binder is determined. Results are given in Table 13B.

It is easily seen from the tables that the improved nonwovens of the present invention have far better resin distribution throughout their dimensions than the nonwovens of the prior art.

TABLE 13A

	Binder Composition	Binder Application Method	Weight Ratio of Binder Content[1] Top to Middle	Bottom to Middle
Example No.:				
I	2G-T/2G-I (79/21)	Tow Dipping	1.1:1	1.1:1
VI-VII	2G-T/2G-I (79/21)	Tow Spraying	0.9:1	0.8:1
X	2G-T/2G-I (79/21)	Web spraying	1.2:1	1.1:1
XIII	2G-T/2G-10 (55/45)	do	0.9:1	1.0:1

[1] Weight Ratio of Binder Content is determined by determining the weight of binder in samples taken from the top, middle and bottom of the batts after final carding and setting up the ratio "Top to Middle" and "Bottom to Middle." A small range within and between the two headings is indicative of even binder distribution.

TABLE 13B

Binder Composition	Binder Application Method	Batt weight oz./yd.^{2} (g./cm.^{2})	Weight Ratio of Binder Content[1] Top to Middle	Bottom to Middle
2G-T/2G-I (79/21)	Batt Sprayiug	2.2 (0.00))	2.3:1	3.5:1
2G-T/2G-I (79/21)	do	3.9 (0.013)	5.3:1	4.6:1
2G-T/2G-I (79/21)	do	5.7 (0.019)	4.2:1	5.8:1
Acrylic Resin	do	3.0 (0.010)	2.0:1	2.3:1
Do	do	4.4 (0.015)	4.7:1	4.8:1
Do	Web Spraying	2.0 (0.007)	[2]	[2]

[1] Weight Ratio of Binder Content is determined by determining the weight of binder in samples taken from the top, middle and bottom of the batts after final carding and setting up the ratio "Top To Middle" and "Bottom To Middle." A small range within and between the two headings is indicative of even binder distribution.

[2] Web was too thin to permit separation into top, middle and bottom layers. However, photomicrographs showed significantly more and larger binder particles on fibers taken from top and bottom layers than on fibers taken from the middle layer of the web.

The above data relates to polyester and acrylic compositions. Similar results are obtained with binders and fibers having other chemical compositions. Whenever the prior art techniques of spraying a batt or web with binder are followed, the batt or web acts as a filter with the result that more and larger binder particles are concentrated on the surfaces than in the interiors of the structure. On the other hand, whenever the teachings of the present invention are allowed, binder is distributed uniformly throughout the three dimensions of the product.

EXAMPLE XXVII

This example shows that the binder component of the new structures is unoriented as compared to the binder component of prior art nonwovens in which the binder is the sheath of a sheath/core bicomponent filament.

Samples were taken from the new nonwovens produced in preceding examples. The binder component was measured for its birefringence which is indicative of its degree of orientation.

Table 14A shows that the binder component of the new products has little or no orientation.

TABLE 14A

Example No.	Binder Composition	Binder Application Method	Specific Birefringence $\times 10^2$
I	2G-T/2G-I (79/21)	Tow Dipping	0.5
VI-VII	2G-T/2G-I (79/21)	Tow Sprating	1.7
XI	2G-T/2G-I (79/21)	Web spraying	1.3
XIV	Caproamide/Hexamethylene / Adipamide/Hexamethylene / Sebacamide Terpolymer	do	None
XX	2G-T/2G-10 (55/45)	Tow Spraying	0.3
XXI	Ethylene/Vinyl Acetate Copolymer	Web Spraying	None
XXII-XXIII	2G-T/2G-I (70/30)	Binder Fiber (Fuse & Recard)	None
XXIV	Polypropylene	do	0.3

For comparison, bicomponent fibers were produced according to well-known methods involving the extrusion of two different polymeric species through the same orifice of a spinneret. Table 14B shows the composition of these bicomponents and shows the Specific Birefringence of the binder polymer of the two-component fiber.

As shown in the table the binder polymers all exhibit high birefringence and high degree of orientation.

TABLE 14B

Description of Bicomponent Fiber[1]	Draw Ratio	Specific Birefringence $\times 10^2$ Compensator Method[2]	Becke' Line Method[2]
Polyesters:			
10//90 sheath//core 2G-T/2G-I (80/20)//2G-T	4.0	19.2	----
15//85 sheath//core 2G-T/2H-I(80/20)//2G-T	3.0	19.4	----
25//75 sheath//core 2G-T/2G-I(80/20)//2G-T	4.0	----	13.8
50//50 sheath//core 2G-T/2G-I(79/21)//2G-T	2.8	12.9	11.2
50//50 side-by-side 2G-T/2G-I(79/21)//2G-T	2.8	10.5	----
Nylons:			
60//40 side-by-side 66/6(85/15)//66	3.3	4.8	----
25//75 sheath//core 26-T/26-I(85/15)//66	3.5	----	3.4

[1] In this column the first numerals separated by the double slash (//) represent the weight ratio of copolymer to homopolymer in the filaments, be it a side-by-side or sheath//core bicomponents, as indicated, and the bracketed numerals indicate the weight proportion of each monomeric unit in the copolymer. Thus, the first item is a sheath-core bicomponent fiber having 90 weight percent of polyethylene terephthalate as its core and 10 weight percent of a copolymer of 80 weight percent ethylene terephthalate units and 20 weight percent ethylene isophthalate units as its sheath.

[2] The compensator method measures the average birefringence throughout the fiber; the Becke' line method measures the birefingence of the outer portion or sheath of the fiber. Thus, the Becke' line results above are measurements on the binder component of the bicomponent fiber.

For comparision, undrawn polyethylene terephthalate, 66 nylon, polypropylene and polyethylene fibers have specific birefringences of 0 whereas the same fibers drawn to 5 times their original length have birefringences of the order of 18.0, 5.9, 3.0, and 4.5 respectively.

The invention has been particularly described with reference to applications in which the bonded product is used for cushioning and filling purposes and as a pile fabric. In these or other uses natural or synthetic resins or elastomers may be applied by suitable methods to the self-bonded products of the invention to produce coated substrates, laminates, bonded felts and the like.

What is claimed is:

1. In a method for producing a thermally self-bonded, low density, nonwoven product by the steps of (1) preparing an assembly of crimped, separated staple-length filaments comprising an oriented, annealed filamentary component of a fiber-forming, synthetic, organic polymer, and integral therewith as a coating along at least a portion thereof an unoriented lower-melting synthetic thermoplastic polymer component, said lower-melting component having a polymer-melt-temperature which is at least 70° C. but is below the fiber-stick- temperature of the filamentary component, and (2) thereafter heating said assembly to a temperature in excess of said polymer-melt-temperature but below said fiber-stick-temperature and cooling the assembly to thereby bond the structure; the improvement, which comprises preliminary to step (2) mechanically redistributing said staple-length filaments into three-dimensional nonwoven assembly to provide throughout the three dimensions thereof an essentially constant weight ratio of said filamentary component to said lower-melting component.

2. Method according to claim **1** wherein the mechanical redistribution is effected by carding said staple-length filaments.

3. Method according to claim **1** wherein said staple length filaments have a retractive coefficient of no more than about 30, an average crimp frequency of at least 3 crimps per inch and an average crimp index of at least 5%.

4. Method according to claim **1** wherein said polymer-melt-temperature is within 5 to 50° C. of said fiber-stick-temperature and said retractive coefficient does not exceed about 15.

5. Method according to claim **1** wherein said filamentary component is polyethylene terephthalate and said lower-melting component is a copolyester.

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