Nov. 7, 1961 G. L. MOLER 3,007,227

STAPLE FIBER BLENDS

Filed April 30, 1957

Fig. 1

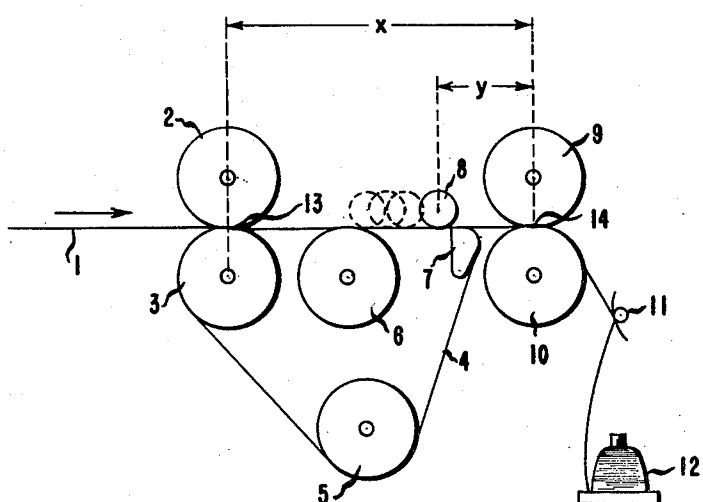
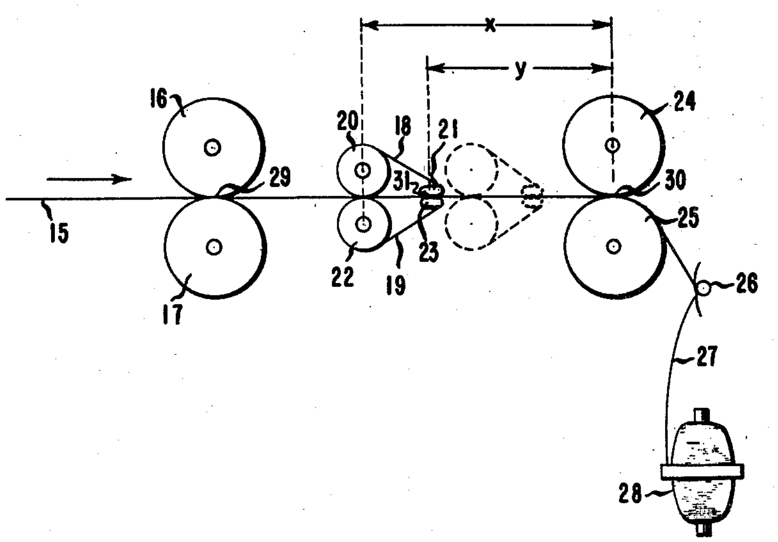


Fig. 2



INVENTOR

GEORGE LESLIE MOLER

BY Raymond E. Blomstedt

ATTORNEY

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STAPLE FIBER BLENDS

George Leslie Moler, Newark, Del., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

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This invention relates to certain novel blends of two or more staple fibers and particularly to the spinning of these blends into new and useful textile materials having improved properties.

It is conventional in the textile art to blend two different fibers in order to achieve certain specific properties in the resulting fabrics. When two different fibers are blended, it is almost always true that the fiber present in the larger proportion will impart to the blended yarn or fabric the physical properties most characteristic of this particular fiber, whereas the physical properties inherent in the fiber present in lesser proportion will be so masked or diluted that the latter properties will not be apparent in the yarn or fabric.

It is an object of this invention to produce novel staple fiber blends and yarns and to prepare from these novel blends and yarns fabrics and other textile materials having a combination of improved properties not heretofore available. A further object is to produce highly stretchable fabrics having elastic properties and composed of staple yarns made from a blend of a hard staple fiber with a minor proportion of a synthetic elastomeric staple fiber. Another object is to produce fabrics exhibiting the low stretch characteristic of the hard fiber component and the high recovery of an elastomer from a blend of a hard staple fiber with a minor proportion of a synthetic elastomeric staple fiber. A still further object is to provide a process for making a wholly synthetic fabric having elastic properties without resorting to the use of any natural rubber in the fabric. Other objects and their means of attainment will be apparent from the following disclosure.

In its broadest aspect, the present invention comprehends a blend of intermingled fibers of staple length comprised of a major proportion by weight of hard inelastic staple fiber and a minor proportion by weight of essentially straight elastomeric staple fiber wherein the elastomeric fiber is present in an amount sufficient to impart cohesiveness to the blend characterized by resistance to separation of the intermingled fibers and recovery upon release of separating stress, the elastomeric staple fiber having a breaking elongation of at least 100% and an essentially complete and quick recovery from stretching to an elongation less than its breaking elongation.

In accordance with this invention there are also provided fabrics made from yarns composed preferably of 5–30% by weight of a synthetic elastomeric staple fiber and 95–70% by weight of a hard staple fiber, the elastomeric fiber preferably having between about 3 and about 12 denier and a staple length of between about 0.75 and about 4.0 inches. The term "elastic fiber" will be used herein to refer to a synthetic elastomeric staple fiber having these dimensions. The hard staple fiber may be of any staple length or denier suitable for processing with conventional equipment. The invention also comprehends a fiber blend, sliver, card web or yarn composed of 5–30% by weight of the elastic fiber and 95–70% by weight of the hard fiber, as well as woven and knitted fabrics, and batts and non-woven fabrics made therefrom.

The novel high recovery yarns of this invention may be prepared by first blending hard staple fibers and elastic fibers to form roving, sliver, or the like and processing

on conventional equipment to form a yarn. However, the spinning apparatus used must be carefully adjusted in accordance with this invention to achieve the desired results.

In the drawing:

FIGURE 1 represents a generally schematic side view of the Saco Lowell spinning system; and

FIGURE 2 represents a schematic side view of the Casablanca spinning system.

The definitions of "hard fiber draft zone" and "effective draft zone" and the operation of the process of this invention generally may be better understood by reference to the drawings. FIGURE 1 represents generally a schematic side view of the Saco Lowell spinning system. A suitable staple fiber yarn bundle (roving, sliver, or the like) is passed through the nip **13** of back draft rolls **2** and **3** and along apron **4** which moves about tension pulley **5**, bottom back draft roll **3**, idler roll **6**, and nose bar **7**. The staple fiber bundle then passes under floating control roll **8** which rests upon the apron and rolls by means of frictional contact with the apron and the fiber bundle. After passing under the floating control roll, the staple fiber bundle moves through the nip **14** of forward draft rolls **9** and **10**, through pigtail **11**, and is wound up with twist on bobbin **12**. As indicated in the drawing, floating control roll **8** may be spaced at various distances "*y*" from nip **14** of forward draft rolls **9** and **10**, the distance being measured from nip **14** to the point of contact of floating control roll **8** with the fiber bundle. The distance "*y*" is termed herein the "effective draft zone." The distance "*x*" which is the distance between the nips of the most forward (in the direction of staple fiber bundle movement) successive pairs of positively driven draft rolls in the spinning system is defined herein as the "hard fiber draft zone."

FIGURE 2 represents a schematic side view of the Casablanca spinning system. A staple yarn bundle **15** is passed through the nip **29** of draft rolls **16** and **17** and then between top and bottom aprons **18** and **19**, respectively. Top apron **18** passes around positively driven roll **20** (pressure friction driven, gear driven, or the like) and cradle bar **21**. Bottom apron **19** passes around positively driven roll **22** and cradle bar **23**. After leaving aprons **18** and **19**, the fiber bundle passes through the nip **30** of forward draft rolls **24** and **25**, through pigtail **26**, after which it is wound up as twisted yarn **27** on package **28**. As indicated in FIGURE 2, the position of aprons **18** and **19** may be positioned longitudinally along the path of movement of the fiber bundle at various distances from the nip **30** of forward draft rolls **24** and **25**. This distance is adjusted in accordance with the effects desired in the yarn product. The distance "*x*" between nips of the most forward successive pairs of positively driven draft rolls in the spinning system is defined herein as the "hard fiber draft zone." The distance "*y*" between the nip **31** formed by aprons **18** and **19** as they pass about cradle bars **21** and **23** and nip **30** is defined herein as the "effective draft zone."

In the roving and drawing steps which precede the spinning step in the production of yarn, a draft zone is defined as the distance between two successive pairs of drafting elements, and each draft zone should be set longer than any hard or elastic fiber length entering the machine. In the spinning step, the "hard fiber draft zone" is defined as the distance between the nips of each successive pair of drafting elements, and each of these hard fiber draft zones should be set longer than the length of the longest hard fiber entering the spinning apparatus. The "effective draft zone" (for the elastic fiber in the spinning step) is defined as that distance from the nip of the most forward pair of drafting elements to the closest nip of the preceding elastic fiber holding means, the latter nip being always the most forward point where the roving is held in contact with the spinning apron, roll, or other roving supporting means. This elastic fiber holding means may be in the form of any conventional textile machinery used in drafting; such as driven rolls, floater rolls, single or double aprons, control rolls, and the like, or in other words any suitable means for holding the elastic fiber that will allow the next succeeding pair of drafting elements to stretch said fiber all the way back to said holding means. No means is provided for holding the hard fiber at this point. In roving, drawing and spinning the drafting elements referred to may comprise positively driven pairs of rolls or aprons positioned in a variety of geometrical relationships moving at successively increasing speeds in order to reduce the diameter of the fiber bundle and parallelize the fibers therein.

The properties of the yarns and fabrics of this invention can be adjusted to obtain high recovery, highly elastic products on the one hand and high recovery, low stretch (hard) products on the other. This is especially surprising in view of the fact that all these yarns and fabrics may have the same fiber composition and are composed of only a small proportion of elastomeric staple fiber.

The proportions of elastic fiber in the novel blends of this invention may vary from 5–30% by weight of total fibers in the blend. As will be more fully understood in the examples given below, even small proportions of the elastic fibers will result in striking improvements in certain properties of yarns and fabrics made from these blends. In processing the fiber blends on conventional textile machinery, it has been found more practical to employ between 10% and 25% of the elastic fiber in the blend, although special equipment may be selected to more readily accommodate broader ranges of the elastic fibers. If the proportion of the elastic fiber in the blend is raised sufficiently beyond 30%, fiber processing operations into yarn become more difficult to control and the resulting yarn and fabric quality suffers; for example, when 50% elastic fiber is used. However, it may sometimes be desirable to process blends of more than 30% elastic fiber into non-woven fabrics. Regardless of the proportion of elastic fiber employed in the original blend, spun yarns may be woven, knitted, or otherwise processed into various fabrics containing lower than the original proportion of elastic fiber by suitable dilution with one or more hard fiber yarns.

The novel fiber blends of this invention may be processed into yarns and fabrics having a wide range of different properties. The stretchability of the yarns and fabrics is determined by the proper draft zone settings during spinning and is almost always independent of the proportion of the elastic staple fiber present in the initial blend, which is 5–30% by weight elastic fibers. However, two critical variables must be controlled during spinning of the yarn. In order to prepare high stretch, high recovery yarns of this invention, the "effective draft zone" must be maintained shorter than the length of the elastic fiber being processed, and the "hard fiber draft zone" must be maintained longer than the length of the hard staple fiber being processed. Unless these two draft zone limitations are observed, optimum stretch properties are not obtained in the product. On the other hand, the same fiber blend may be spun into a yarn possessing low stretch, high recovery properties by maintaining the "effective draft zone" at least as long as the length of the elastic fiber being processed, and the "hard fiber draft zone" longer than the length of the hard fiber being processed.

Preferably, where possible, the elastic fiber length should be equal to or shorter than the hard fiber length, so that in drafting steps prior to spinning (i.e., drawing and roving), the shorter elastomer lengths will be carried along in the processing of the blends and will not affect

processing of blends prior to spinning. For the same reason, it is preferred that the "hard fiber draft zone" be longer than the "effective draft zone" in spinning high stretch yarns.

Synthetic elastomeric and hard staple fibers may be blended for use in this invention using any of the conventional textile machinery or methods, such as hopper-fed woolen blenders, cotton pickers, blending on a Rando-Webber, card blending, blending at the draw roving or spinning frames, plying two or more yarns on a twister, or blending in the weaving or knitting step.

The fiber blends of this invention may be processed into tow, sliver, batts, yarns and other forms of textile materials on conventional textile machinery, so long as the drafting conditions described above are observed. These blends may be spun on any staple spinning system; that is, cotton, cotton American, woolen, or worsted (French or English). In a typical series of fiber processing steps, the desired proportions of elastic fiber and hard staple fiber may initially be blended on a woolen type fiber blender, processed through a cotton picking machine to give a uniform lap, carded to open up the fibers and obtain a web and then condensed into sliver. The sliver is then put through conventional drafting steps of drawing, roving, and spinning with the limitations more specifically set forth above. The resulting spun yarn may be processed further into various knitted and woven fabrics, or the fiber blend may be converted into batts and then non-woven fabrics, if desired.

It is preferred in processing the fiber blends in this invention to maintain all drafting zones prior to spinning at lengths longer than the staple fibers in the blends. although there may be special circumstances under which one or both drafting zones ("hard fiber" and "effective") may be shorter than the corresponding fiber length to obtain special effects in the resulting yarns. Prior to spinning, no stretching of the elastomeric fiber normally occurs. With this arrangement it is possible to handle sliver and roving blends in the same manner as 100% hard fiber, thereby preserving good uniformity and minimizing breaks and excessive tension on sliver or roving.

Typical conventional drafting apparatus suitable for use with the fiber blends of this invention include double aprons of the Casablanca type (FIGURE 2) for holding the sliver or roving, as well as different roller types of drafting apparatus with or without floater rolls with a single apron to hold the sliver or roving, such as is sold by Saco Lowell (FIGURE 1). Prior to spinning, the bundle of elastic and hard fibers is attenuated to form a bundle of smaller diameter without any change either in staple fiber diameter or length. In other words, individual fiber stretching is excluded in the drawing and roving steps. However, in the spinning step the elastic fibers in the blend are preferentially stretched by suitable adjustment of the "effective draft zone" when a high stretch product is desired. When it is desired to produce a low stretch yarn, the effective draft zone in the spinning operation is adjusted so that the elastic fibers in the blend are not intentionally stretched.

In spinning the fiber blends of this invention, it is preferred to maintain the point of twist insertion (i.e., yarn focal point) as close as possible to the nip of the most forward draft rolls in order to obtain the maximum permissible tension in the stretched elastic fibers as they emerge from the "effective draft zone," or in other words to obtain the maximum stretch possible in the yarns produced. This means in effect that the yarn spinning tension will be higher and traveler weights slightly heavier than normally used when processing wholly hard fiber yarns. It will be obvious to those skilled in the art, however, that this yarn focal point may be adjusted if desired to produce a variety of properties in the yarns and fabrics produced; i.e., changes in tactile hand, visual appearance, bulk, and the like. In the case of very fine yarns, the yarn spinning tension will still be greater than what is conventional for hard fiber yarns and yet the traveler may be of customary weight. In addition, when spinning any one staple blend on identical spinning equipment with constant effective and over-all draft zones, the following variables affect staple yarn elasticity as indicated:

(1) At constant yarn twist multiplier, increasing cotton count increases yarn elasticity.

(2) At constant yarn twist, increasing cotton count (i.e., decreasing twist multiplier) decreases yarn elasticity.

(3) At constant cotton count, increasing yarn twist (i.e., increasing twist multiplier) increases yarn elasticity.

(4) Yarn elasticity varies directly with floater roll weight.

In plying, yarn elasticity initially decreases rapidly with addition of opposite direction ply twist (e.g., Z in singles, S in ply), then levels off as balanced ply twist is approached, and then the elasticity increases gradually as further twist is added.

One of the important features of this invention is the provision of fiber blends which permit the manufacture of high recovery yarns and fabrics having a wide range of stretchability from low stretch to high stretch properties. For example, it is now possible for the first time to prepare a wide range of light weight to heavy weight staple fiber fabrics which have the appearance, tactile hand, cover and comfort of conventional staple fabrics plus high recovery and stretch properties as desired. There have not been available heretofore light weight elastic fabrics having the above composition or combination of properties. By suitable adjustment of the composition and drafting procedure in accordance with this invention, a wide variety of elastic textile materials may be produced in addition to various high recovery textile materials having certain other advantages. The stretchy yarns have much higher bulk than those yarns made from 100% of the same hard fiber, and the stretchy yarns of this invention may be made without many of the conventional processing steps required heretofore to produce stretchy continuous filament yarns; e.g., without the need for specialized drawing, covering, twisting, crimping, heat setting, or shrinking.

The significant distinction between the blends of this invention having high stretch properties and those having low stretch properties is that in the case of the blends having high stretch, the elastomer fiber is the load-bearing member during extension, whereas in the case of blends having low stretch properties the hard fiber is the load-bearing member during the extension part of the cycle. During the recovery part of the cycle, the elastomer fiber is the major factor contributing to the high degree of recovery exhibited in both types of products. The terms "high stretch" and "low stretch" are terms employed to compare the stretch properties of the yarns and fabrics of this invention relative to the stretch properties of the yarns or fabrics of the same construction containing only hard fibers. In other words, a fabric prepared from a blend of elastic and hard fibers and spun with the correct critical effective draft zone setting for producing high stretch properties exhibits a stretchability higher than that of the same fabric construction prepared from 100% hard fibers. By adjusting the draft zone setting to produce a fabric having low stretch properties, there is obtained a fabric which stretches the same order of magnitude as the stretch in a 100% hard fiber control fabric, although of course the fabric containing the elastic fiber possesses a higher recovery than the control fabric.

Examples of suitable elastic or stretchy products of this invention include woven, knitted and non-woven fabrics for use in universal fitting apparel (socks, polo shirts, underwear, bathing suits, gloves, elastic cuffs, sweaters, waistbands, suits, coats, dresses, skirts, action sportswear, leotard-type outerwear, and accessories such as tapes, webbings and other woven, non-woven, or knit apparel fabrics), household products (form-fitting upholstery, slip covers, sheets, carpets, mattress coverings, and narrow tapes and webbings for a wide variety of uses), industrial products (transportation upholstery, woven and non-woven felts, tapes and webbings for varied applications), and medical products (surgical bandages, supports, elastic dressings, surgical stockings, and splint tapes).

Low stretch, high recovery fabrics of this invention may be made into outer-apparel (sweaters, knit jersey, and woven, knit, or non-woven suitings and dress goods), household items (rugs, carpets and upholstery) and industrial products (woven, non-woven, and knit compression or impact bearing structures).

In the case of low stretch, high recovery products, the imposition of an external stress causes the fabric to deform, within the limit of fabric construction, to the limit of the load-bearing hard fibers present in the fabric. The elastomer fiber component, being a low modulus material, does not aid in this deformation. Therefore, in uses where it is desirable that the fabric resist stretching (i.e., elongation) upon application of external stress, the low stretch group of products tends to retain their shape. However, upon release of the applied stress the elastomer fiber comes into play and contributes to a higher degree of recovery in the blend or fabric (i.e., super-recovery) than is possible when the elastomer is not present.

The hard inelastic staple fiber used in this invention may be any hard staple fiber suitable for processing on conventional textile equipment. The term "inelastic" as used herein is intended to apply to any fiber having relatively low stretch characteristics as compared to the stretch characteristics of the elastic fibers disclosed herein. The hard inelastic staple fiber may be prepared from any synthetic fiber-forming materials, such as polyesters (e.g., polyethylene terephthalate), polyamides (e.g., polyhexamethylene adipamide, polyhexamethylene sebacamide, polycaproamide, and copolymers of various amides), acrylic polymers and copolymers (e.g., polyacrylonitrile, copolymers of acrylonitrile with vinyl chloride, vinylidene cyanide, vinyl pyridine, methyl acrylate), vinyl polymers (e.g., vinyl chloride/vinyl acetate copolymer), polymers and copolymers of tetrafluoroethylene, monochlorotrifluoroethylene, and hexafluoropropylene, polyethylene, cellulose derivatives (e.g., cellulose acetate, regenerated cellulose, ethyl cellulose, cellulose triacetate), glass, or from any natural fiber, such as cotton, wool, silk, jute, linen, or a blend of two or more hard fibers.

The term "elastic" as used herein has the meaning conventionally given to that term in the art and is applied herein to describe a synthetic elastomeric staple fiber capable of at least 100% elongation before breaking. Elastic fibers utilized in this invention preferably will undergo between about 500% and about 800% elongation before breaking and have a modulus (force required to stretch to a specified elongation) of about 0.05 gram per denier or less. This is in contrast to hard fibers which are generally characterized by a modulus between about 18 and about 85 grams per denier and which usually will stretch no more than about 20–40% before breaking. The elastic fibers of this invention are not only characterized by very high stretchability but also by very quick recovery (almost instantaneous) to the original uncrimped condition. Stretchability of the elastic fiber does not depend upon crimping or twisting.

The elastic fiber utilized in this invention may be any synthetic elastomeric staple fiber having a denier between about 3 and about 30 and a staple length between about ¾ inch and about 4 inches. A condensation elastomer will usually form fibers having a tensile form recovery above about 75% and a stress decay below about 35% when measured by two test procedures described below. Segmented elastomers, which comprise the broadest class of polymers meeting these requirements, are prepared by starting with a low molecular weight polymer (i.e., one having a molecular weight in the range from about 700 to about 3500), preferably a difunctional polymer with terminal groups containing active hydrogen, and reacting it with a small co-reactive molecule under conditions such that a new difunctional intermediate is obtained with terminal groups capable of reacting with active hydrogen. These intermediates are then coupled or chain-extended by reacting with compounds containing active hydrogen. The low molceular weight starting polymer may be a polyester or polyesteramide and the co-reactive small molecule is a diisocyanate. A large variety of co-reactive hydrogen compounds may be used in preparing the segmented condensation elastomers. Among the most practical chain-extending agents are water, diamines, and dibasic acids.

U.S. 2,692,873 describes similar products in which the starting polyesters have been replaced by polyethers of a corresponding molecular weight range. A number of macro-molecular compounds, such as polyhydrocarbons, polyamides, polyurethanes, etc., with suitable molecular weights, melting point characteristics, and terminal groups, can serve as the starting point for preparing segmented elastomers of this type. The diisocyanate may be replaced with other difunctional compounds, such as diacid halides, which are capable of reacting with active hydrogen. Elastic copolyether ester fibers are obtained by condensation of a polyether glycol, an aliphatic glycol, and an aromatic dibasic acid, or suitable derivative and forming a fiber from the polymer. Use of a fiber of an elastomer of this type is illustrated in the examples.

Fibers of other types of condensation elastomers are also suitable. U.S. 2,670,267 describes N-alkyl-substituted copolyamides which are highly elastic and have a suitable low modulus. A copolyamide of this type, obtained by reacting adipic acid with a mixture of hexamethylenediamine, N-isobutylhexamethylenediamine, and N,N'-isobutylhexamethylenediamine, produces an elastomer which is particularly satisfactory for the purposes of this invention. U.S. 2,623,033 describes linear elastic copolyesters prepared by reacting glycols with a mixture of aromatic and acyclic dicarboxylic acids. Copolymers prepared from ethylene glycol, terephthalic acid, and sebacic acid have been found to be particularly useful. Another class of useful condensation elastomers is described in U.S. 2,430,860. The elastic polyamides of this patent are produced by reacting polycarbonamides with formaldehyde.

Elastic fibers having the proper denier and length as described above and prepared from fiber-forming addition polymer such as, for example, copolymers of butadiene/styrene, butadiene/acrylonitrile and butadiene/2-vinyl pyridine, polychlorobutadiene, copolymers of isobutylene with small proportions of butadiene, chlorosulfonated polyethylene, copolymers of monochlorotrifluoroethylene with vinylidene fluoride, and the like, may be employed.

The fiber blends, yarns, fabrics, and other textile products prepared in accordance with this invention may be given the customary finishing treatments where necessary or desired, such as scouring, washing, drying, pressing, dyeing, heat-treating, and softening.

The following examples illustrate specific embodiments of this invention for preparing high stretch, high recovery products as well as low stretch, high recovery products. All proportions are by weight unless otherwise specified.

EXAMPLE I

A blend of acrylic staple fibers and copolyester elastomer staple fibers is used to prepare a sweater having high recovery properties. The blend contains (1) 30% of a staple fiber (2 inches long, 2 denier per filament, drawn 4×) formed from a copolymer of 94% acrylonitrile and 6% methyl acrylate and having a residual shrinkage of about 15%, (2) 45% of the same acrylic staple fiber but having a residual shrinkage of about 2%, and (3) 25% of copolyetherester elastomer staple fiber (1½ inches long and 3 denier per filament). The copolyetherester fiber is composed of 40% ethylene glycol terephthalate and 60% tetramethylene oxide glycol terephthalate. The three fibers are sprayed with 1% of a suitable lubricating and antistatic finish, then sandwich-blended, made into laps on a cotton picker, carded into sliver, drawn, then converted into roving. The roving is spun into an 18.5/1 cotton count yarn (10 Z twist) and 2-plied 5 S. In all draft zones in the aforementioned processing steps, both the effective and the hard fiber draft zones are set longer than any of the staple fibers in the blend. The yarn is knit into a sweater at 13 courses per inch on a 12 cut, 36 gauge, 17 inch, 4 feed Jacquard sweater body machine. A control yarn of 100% acrylic fibers (2 inches long, 2 denier per filament, 70% of which have 2% residual shrinkage and 30% of which have 15% residual shrinkage) is knit into a sweater on the same machine, also at 13 courses per inch. Both knitted fabrics are boiled off under relaxed conditions and then steamed in a relaxed condition for 30 seconds to remove wrinkles. Subjectively, the fabric containing the copolyetherester elastomer fiber felt much softer and had better cover, compression and bounce than the control fabric containing no elastomer fiber. Table I shows that the fabric recovery properties of the fabric containing the small proportion of elastomer staple was substantially superior to the control fabric.

Table I

	Control (Course x Wales)		Test (Course x Wales)	
Fabric Construction	23 x 17		26 x 17	
Tensile Form Recovery (percent) (50% Elongation)	49	38	79	70

EXAMPLE II

A blend of staple fibers containing 50% polyacrylonitrile staple fiber (1½ inches long, 3 denier per filament and drawn about 4×) and 50% elastomer staple fiber (6 denier, 1½ inches long) made from a copolyester of 40% poly(ethylene oxide) terephthalate and 60% ethylene terephthalate is prepared on a small card and fed into a commercial synthetic-fur knitting machine. Staple fibers (1½ inches long, 3 denier per filament) of 100% polyacrylonitrile are treated similarly as a control. The test blend and control are then sheared to simulate a mouton fur. Subjectively, the test sample feels softer tactily than the 100% conventional hard fiber control. Compressional recovery data show that the fur containing 50% elastomer is substantially superior to the control, as indicated in Table II.

Table II

	Control 100% Hard Fiber Mouton Fur	Test 50/50 Hard fiber/Elastomer Mouton Fur
Percent Recovery from Deadweight Compression	82	98

EXAMPLE III

A woven fabric useful for dress goods is prepared using the following filling and warp yarns:

Test filling yarn:

- 80% polyhexamethylene adipamide staple (3 denier per filament and 2 inches long)
- 20% copolyetherester elastomer staple (same as Ex. I except 6 denier per filament)
- Finish applied to both staples

Cotton-American system
Yarn count: 25/2 cc.
Twist:
Singles 25 Z
Ply 12 S

Test warp yarn:
100% polyhexamethylene adipamide (3 denier per filament and 1½ inches long)
Finish applied
Cotton-American system
Yarn count: 20/2 cc.
Twist:
Singles 20 Z
Ply 12 S

Plain weave fabrics (30 warp and 36 filling) are woven from yarns spun on a Whitin Casablanca spinning frame with a hard fiber draft zone set at 4$^{11}/_{16}$ inches and effective draft zone set at ⅞ inch. All draft zones prior to spinning are set longer than any of the staple fibers in the blend.

A control fabric of the same weave and count is prepared on the same machines from 100% polyamide staple fibers (1½ inches long and 3 denier per filament in the warp yarn and 2 inches long and 3 denier per filament in the filling yarn).

Weave: Plain
Loom count: 30 warp x 36 filling
Control warp yarn: Identical to test warp yarn
Control filling yarn: Identical to test filling yarn except made from 100% polyamide

The resulting fabrics are finished simultaneously in a 30-minute beck scour, extracted, and Palmer dried at 10 p.s.i. steam. After finishing, the test fabric has more stretch in the filling direction (40% stretch vs. 12.5% stretch by a hand test) and has superior recovery compared with the 100% polyamide control. In addition, this fabric exhibits greater ability to retain its resistance to stretch (i.e., lower stress decay) than does the control fabric at a given elongation, which fact is indicative of superior shape retention in wear performance of the test fabric over the control.

Table III

	Control Fabric	Test Fabric
Tensile Recovery (percent) 25% Elongation	41	78

EXAMPLE IV

A blend of staple fibers is prepared containing (1) 60% acrylic staple (2 denier per filament and 2 inches long) having a residual shrinkage of about 2%, (2) 25% acrylic staple (3 denier per filament and 2 inches long) having a residual shrinkage of about 15%, and (3) 15% elastic copolymer fiber (6 denier per filament and 1½ inches long). The two acrylic staple fibers are the same as those used in Example I. The elastic copolymer is prepared by condensing poly(tetramethylene oxide) glycol (40 parts) having a molecular weight of 1,000 with 20 parts of methylene bis(4-phenylisocyanate). The polyether diurethane having isocyanate terminal groups is reacted with 2 grams of hydrazine monohydrate in N,N-dimethylformamide to produce a copolymer with an inherent viscosity of 2,2 in m-cresol solution. Filaments are dry spun from this copolymer and cut to the designated staple length.

Two percent of a lubricating and antistatic finish is sprayed on each of the fibers. The three fibers are blended on a woolen blender and processed via Cotton-American system as follows: 2 passes Whitin picker, roller carded, 2 passes drawing frame (Saco Lowell), 1 pass roving frame (Saco Lowell). At this point, the roving is split into two separate lots for processing on Saco Lowell spinning frame (FIGURE 1). All draft zones prior to spinning are set at a distance longer than any of the staple fibers in the blend.

Lot A is spun with draft rolls set as follows:

	Inches
Hard fiber draft zone	3¾
Effective draft zone	1½

A low stretch, conventional appearing, high recovery 18/1 cotton count sweater yarn is produced from an over-all spinning draft of 14×.

Lot B is spun with draft rolls set as follows:

	Inches
Hard fiber draft zone	3¾
Effective draft zone	½

A stretchy 30/1 cotton count sock yarn is produced using an over-all spinning draft of 25.8×.

Table IV shows several yarn properties indicating the versatility of a single staple blend of this invention when processed under the critically different effective draft zone settings; two entirely different yarns are produced from the same initial staple blend. Lot A is a yarn having high recovery and low stretch, and lot B is a yarn having high recovery and high stretch.

Table IV

	Low Stretch Yarn, Lot A	High Stretch Yarn, Lot B
Cotton Count	18/2	30/2
Twist Multiplier—singles	2.4	3.3
Twist Multiplier—2 ply	1.6	2.3
Twist Multiplier—Ratio	3/2	3/2
Tenacity (grams per denier)	1.4	1.4
Percent Stretchability:		
As-spun	2.3	56
Boiled Off	9.8	140
Percent Recovery from stretch:		
As-spun	92	77
Boiled Off	82	90

A control yarn spun under the same conditions as lot A is prepared from a blend of 60% 3 denier per filament, 2 inch acrylic staple (2% residual shrinkage) and 40% 3 denier per filament, 2 inch acrylic staple (15% residual shrinkage), both acrylic staple having the same composition as that in Example I.

Two sweaters were knit on a 12-cut Lieghton Transfer machine, one from lot A low stretch, superior recovery yarn and one from the 100% acrylic control yarn. The test sweater and control sweater were dyed beige and finished simultaneously by commercial procedures to produce a finished course x wale construction of 18 x 16. When compared with the control sweater, the test sweater showed substantially improved tensile recovery, indicative of better shape retention in the body, neckband, waistband and sleeve cuffs of the sweater. In addition, the test sweater containing elastic fiber requires only half the loading force of that required by the control sweater in order to stretch it widthwise (course direction) by 50%. This reflects the superior ease of putting on the test sweater as well as the improved comfort of this garment over a broader range of body dimensions than the control sweater will satisfy. Also, the test sweater has a softer more "cashmere-like" hand than the control sweater.

EXAMPLE V

A series of seven yarns of different fiber composition as shown in Table V are prepared using essentially the same conditions as those described for the yarn of Example III. The effective draft zones for spinning yarns E, F, and G are set shorter than the length of the elastic copolymer fiber in each blend. After spinning, all yarns are scoured 30 minutes in carbon tetrachloride, then boiled off 30 minutes in water containing 1% wetting agent, and dried.

Yarn bulk is determined for each sample of yarn at the two loads given in Table V. The table shows that yarns made from blends of hard fiber and elastic fiber (i.e., yarns D, E, F, and G) have superior bulk whether spun into high stretch or low stretch yarns, as compared with corresponding control yarns containing no elastic fiber.

Table V

Sample	Composition	Yarn Type	Nominal Count (Taut)	Yarn Bulk (cc./gm.) [1]	
				At 0.1 gm. load	At 0.5 gm. load
A	Cotton	Conventional	40/1	1.54	1.41
B	100% low shrinkage acrylic fiber (Ex. I)	do	25/2	3.65	3.36
C	60% of B and 40% high shrinkage acrylic fiber (Ex. I)	High Bulk	18/2	6.90	5.98
D	60% of B, 25% high shrinkage acrylic fiber (Ex. I) and 15% copolymer fiber (Ex. IV).	Low Stretch	18/2	7.48	7.01
E	Same as D	High Stretch	30/2	8.83	7.81
F	85% cotton and 15% copolymer fiber (Ex. IV)	do	40/1	5.36	2.96
G	80% cotton and 20% copolymer fiber (Ex. IV)	do	40/1	5.79	4.45

[1] Cubic centimeters per gram.

EXAMPLE VI

One end of roving (2 hank) prepared as in Example IV from a blend of 60% low shrinkage acrylic fiber, 25% high shrinkage acrylic fiber and 15% elastic fiber, and two ends of roving (4 hank) composed of a blend of 80% (2 d.p.f., 2½ inches) and 20% (4½ d.p.f., 2½ inches) acrylic staple fibers of Example I (both having a residual shrinkage of about 2%) are fed simultaneously to a Saco-Lowell spinning frame. The machine settings for spinning are as follows:

Hard fiber draft zone	3⅛" (longer than hard fiber).
Effective draft zone	¾" (shorter than elastic fiber).
Draft	17.2X.
Twist	19 Z.
Traveler	#24.

As shown in Table VI, a high stretch 17/1 cc. yarn containing 92.5% acrylic fiber and 7.5% elastic fiber was produced from this blend. This high stretch yarn was particularly useful for knitting into men's half hose. Without the elastic staple fiber or the proper effective draft zone setting, a high stretch yarn is not produced, as shown in Table VI.

Table VI

Property	High Stretch Yarn	Control Yarn (no elastic fiber)
Cotton Count	17/1	17/1
Twist Multiplier	4.6	4.6
Twist	19 Z	19 Z
Tenacity (g.p.d.)	1.6	1.6
Percent Stretchability:		
As-spun	163	below 10
Boiled Off	233	below 15

EXAMPLE VII

This example illustrates how a high stretch yarn containing 20% elastic fiber may be diluted by weaving into a fabric containing as little as 4% elastic fiber while imparting high recovery and high stretch to the fabric.

A blend is prepared from 80% (2 d.p.f., 2½ inches) acrylic staple fiber made from the same compositions as described in Example I and having a residual shrinkage of about 2%, and 20% (6 d.p.f., 2¹⁄₁₆ inches) elastic staple fiber made from the same elastic copolymer composition as that described in Example IV.

A suitable lubricating and antistatic finish is applied to both fibers. The elastic fiber is given a preliminary opening and then blended with the acrylic fiber on a woolen blender and processed on a Cotton-American system as follows: 2 passes Whitin picker, roller carded, 2 passes drawing frame (Saco-Lowell), 2 passes roving frame (Saco-Lowell). Drawing roll settings are 1–2=3", 2–3=2¹³⁄₁₆" and roving roll settings are 1–2=2⅞", 2–3=³⁄₁₆". All draft zone settings prior to spinning are longer than either fiber in the blend. Spinning is done on a Saco-Lowell spinning frame with the following settings:

Hard fiber draft zone	3"
Effective draft zone	¾"
Draft	20.4X
Twist	30 Z
Traveler	#23

These settings produce a high stretch 40/1 cotton count yarn which is then two-plied 10 S. This yarn has 1.4 grams per denier tenacity and 234% stretchability with 86% recovery after relaxation (boiled off). The yarn is dyed yellow in skein form.

Fabrics are then woven utilizing this yarn and a control yarn identical to the 100% acrylic control yarn of Example IV as filling yarns in a 75 denier black acetate warp.

FABRIC I

Warp—75 denier black acetate (commercial yarn)
Filling—270 denier (40/2 cotton count) stretchy yellow yarn (20% elastic fiber)
Loom construction—180 ends x 50 picks
Weave—5 shaft satin

FABRIC II

Warp—75 denier black acetate (commercial yarn)
Fillings:
(A) 270 denier (40/2 cotton count) stretchy yellow yarn
(B) 550 denier (18/2 cotton count) acrylic control yarn (undyed)
Loom construction—180 ends x 50 picks
Weave—5 shaft satin, alternating 20 picks of A with 20 picks of B.

The fabrics are given a crab scour at 140° F. in water and detergent, pin tenter dried at 250° F. relaxed, semidecated for 3 minutes steam and vacuumed one minute. Finished fabric I weighs 7.2 oz./yd.^{2} and has 95% hand stretch. Finished fabric II weighs 10 oz./yd.^{2} and has 50–60% hand stretch. Both fabrics exhibit high recovery and high stretch characteristics making them especially suitable for use as bathing suits, sheath-type dresses and upholstery slip-covers. The composition of fabric I is 40% acrylic/50% acetate/10% elastic copolymer, while that of fabric II is 56% acrylic/40% acetate/4% elastic copolymer. Both fabrics have a tensile form recovery from 50% elongation of 88%. By mixing various proportions of high stretch yarns with low stretch yarns, fabrics having different surface textures may be achieved. For example, fabric I described above is flat and smooth in appearance while fabric II is alternating puckered and flat stripes.

EXAMPLE VIII

Two non-woven felts are prepared, one from rabbit fur and the other from a mixture of fur and a synthetic elastic copolymer. Before felting, each fiber is opened up and blended by hand carding. The fur or fiber blend is felted by feeding the staple fibers to a standard Abbott felting machine which simultaneously works the fibers mechanically while applying heat and moisture for the cycles indicated below.

Sample A consists of 75% by weight of rabbit fur blended with 25% by weight of 3 d.p.f., ½ inch–¾ inch elastomer fiber, said elastomer fiber being the same composition as the elastic copolymer fiber described in Example IV. This blend of fur and elastic copolymer is processed wet in the Abbott felting machine for 10 minutes at 70° C. Sample B consists of 100% rabbit fur and is used as a control, this fur being processed wet in the Abbott felting machine for 5 minutes at 55° C. followed by a 10-minute cycle at 51° C. Sample A upon testing shows a felt density of 0..23 gram per cc., whereas sample B shows a density of 0.16 gram per cc. In comparing qualitatively the delamination tendencies of the two felts, sample A shows no delamination, whereas sample B shows a slight tendency to delaminate on flexing.

The relative delamination tendencies of the two felts show that the elastic copolymer does not inhibit felting as most synthetic fibers do, but actually enhances the felting of the fur. Addition of the elastic copolymer to the fur increases the density and therefore the hardness and compactness of the felt structure. Of significant importance is the fact that none of the felt structures containing the elastic copolymer shows any tendency to delaminate, which is a common fault with most blends of fur with synthetic hard fibers processed by normal felting techniques of heat, moisture, and mechanical working. It should be noted that even the 100% fur felt shows slight delamination under the test conditions and that this tendency is eliminated by addition of elastic copolymer to the fur.

EXAMPLE IX

Several samples of staple fibers are taken from the card slivers during processing of the staple, and these samples are shaped by hand into a staple pellet and subjected to the Busse compressional recovery test.

Table VII

Staple Composition	Percent Recovery (15 min.)	Percent Recovery (24 hr.)
A. 100% acrylic staple (control of Example I)	40	60
B. 75% A and 25% copolyetherester elastomer of Example I	55	73
C. 100% polyamide staple (control filling of Example III)	111	133
D. 50% C and 50% copolyetherester staple of Example III	200	229

Since the Busse test correlates pile retention with recovery, these data are indicative of the improvement which an elastic fiber contributes in crush resistance and recovery performance of rugs, furs, felts, stuffing, and any other non-woven structure where the staple fibers are compressed together or bent tightly upon one another and recovery from this condition is desirable.

There follows a description of each test used in the examples to measure the designated properties of blends, yarns, and fabrics.

The breaking tenacity in grams per denier is the tensile stress of a yarn specimen at rupture. This value is measured on a Suter tensile tester. All yarn samples are conditioned and tested at 65% relative humidity and 70° F. The gauge length of the specimen is 10 inches. The yarn sample is mounted at the specified gauge length under approximately 0.1 gram per denier load and the lower jaw of the tester is dropped at a rate of 12 inches per minute.

The tensile form recovery is the recovered elongation expressed as a percentage of the imparted elongation for fibers, yarns, and fabrics. This property is measured on fabrics for example, using an Instron tensile tester using test specimens which are 1 inch wide and allowing a gauge length of 1 inch between the jaws of the tester. All fabric samples are moisture conditioned and tested at 65% relative humidity and 70° F. All elongation rates for the samples are 100% per minute. The test specimen is mechanically conditioned by elongating it by 10% of its original length and then allowing it to recover immediately before testing. The specimen is then extended the designated percent elongation, held at that elongation for one minute and then allowed to recover at the same rate as it was extended.

The stress decay of the fiber, yarn, or fabric is determined using the same apparatus as described above for determining tensile form recovery employing the same test samples. During the period the textile sample is held at the specified elongation for one minute as outlined in the above test, the force necessary to maintain this elongation changes with time. The ratio of this incremental change in force to the original force necessary to obtain the specified elongation, expressed as a percentage, is designated as the stress decay of the sample.

The yarn bulk in cc./gm. is the equivalent of the specific volume of a yarn which is equal to the inverse of the yarn density in gm./cc. The measurement is carried out at 65% relative humidity and 70° F. The average yarn diameter is measured optically under the designated loads. The average yarn weight is measured under the same loads. By knowing the length of yarn used, the specific volume or bulk is then calculated in cc./gm. of the yarn at the designated loads.

The recovery from dead-weight compression in percent is the ability of a pile type structure to recover from a crushing load. The test is carried out at 65% relative humidity at 70° F. A pressure of 15 p.s.i. is applied to the test specimen on a flat horizontal surface for 18 hours. The pressure is then removed and the specimen thickness is measured after a designated recovery time (48 hours), and the recovery is expressed as a percentage of the original specimen thickness. All thickness measurements are made with an Ames gauge at 0.32 p.s.i.g.

The stretchability of a yarn and the recovery of a yarn, both expressed as percent, are a measure of the ability of a yarn to extend or stretch under a designated load (force) and recover from such stretching. The yarn is prepared (as-spun or boiled-off) in skeins by winding the yarn at a load of approximately 0.1 gram per denier (g.p.d.). The number of turns per skein equals

$$\frac{5000}{\text{yarn denier}}$$

This gives a total denier of 10,000 for the yarn bundle when skeins are suspended from two-gram hooks and another two-gram hook is added to the bottom loop of each skein. The initial skein length is designated IL. A weight of 1,000 grams is added to the bottom hook on the skein for 30 seconds. As close to the end of the 30-second interval as possible, the extended skein length is measured and designated EL. The 1,000-gram weight is removed, leaving the two-gram hook on the skein, and the skein is permitted to recover for 15 minutes. The recovered skein length is designated RL. The following calculations are then made:

$$\text{Percent stretchability (at 0.1 g.p.d. load)} = \frac{EL-IL}{IL} \times 100$$

$$\text{Percent recovery from stretch} = \frac{EL-RL}{EL-IL} \times 100$$

The felt density is a measure of the weight per unit volume in grams per cubic centimeter of the felt which indicates its compactness and hardness. The density is calculated from the thickness of the sample, measured at 3.2 p.s.i. with an Ames gauge, and the weight per unit area of the felt.

The delamination tendency of the felt sample is a qualitative rating of the tendency of the felt to separate into layers when flexed by hand as if the fibers were merely placed together in a temporarily compacted mass without true interlocking of the fiber structure.

The Busse compressional recovery test measures the ability of a pellet or plug of staple fibers to recover from compressional forces and is expressed in percent. The apparatus used in the Busse test is described in Textile Research Journal, 23, 84 (1953). The test is performed at 65% relative humidity and at 70° F. A tuft of staple fibers weighing 0.3 gram is taken from a sliver or batt and placed in a metal cylinder which is 0.2 square inch in area. The tuft of staple is formed into a loose pellet by compressing it with a light wooden rod at approximately 0.2 p.s.i. The initial height of the loose pellet is then measured under this load. The wooden rod is then replaced with a steel rod and a loading force of 1,000 p.s.i. is applied to the pellet for one minute. This compressed pellet of fiber is then removed from the cylinder and allowed to recover for designated time intervals. The recovery in percent at these time intervals is calculated from the ratio of the recovered pellet height to the initial pellet height. Because of the removal of the rod before the final measurement, the recovery may be greater in some cases than the initial height.

The claimed invention:

1. A blend of intermingled fibers of staple length comprising a major proportion by weight of a hard inelastic staple fiber, and a minor proportion by weight of essentially straight synthetic elastomeric staple fiber, said elastomeric fiber being present in an amount sufficient to impart cohesiveness to said blend characterized by resistance to separation of said intermingled fibers and recovery upon release of separating stress, said elastomeric fiber having a breaking elongation of at least 100% and an essentially complete and quick recovery from stretching to an elongation less than its breaking elongation, said synthetic elastomeric staple fiber having a denier of less than about 30.

2. The staple fiber blend of claim 1 in the form of a fabric.

3. The staple fiber blend of claim 1 in the form of a non-woven fabric.

4. The staple fiber blend of claim 1 in the form of a woven fabric.

5. The staple fiber blend of claim 1 in the form of a high stretch woven fabric.

6. The fiber blend of claim 1 in the form of a strand.

7. The fiber blend of claim 1 in the form of a high recovery, high stretch yarn.

8. The fiber blend of claim 1 wherein said elastomeric fiber is a segmented elastomer having a tensile recovery above about 75% and a stress decay below about 35%.

9. The fiber blend of claim 1 wherein said elastomeric staple fiber is present in said blend in an amount from about 5% to about 30% by weight of said blend.

10. The fiber blend of claim 9 wherein said elastomeric staple fiber has a length between about ¾ inch and about 4 inches and is present in an amount from about 10% to about 25% by weight of said blend.

11. A cohesive blend of intermingled fibers of staple length comprising from about 95% to about 70% by weight of a hard inelastic staple fiber, and from about 5% to about 30% by weight of essentially straight synthetic elastomeric staple fiber having a breaking elongation of at least 100%, a denier between about 3 and about 30, a stretch modulus substantially less than said hard fiber, and an essentially complete and quick recovery from stretching to an elongation less than its breaking elongation.

12. A fiber blend of claim 11 wherein said elastomeric fiber is segmented elastomer having a tensile recovery above about 75% and a stress decay below about 35%.

13. The fiber blend of claim 11 wherein said elastomeric fiber has a breaking elongation of at least about 500% and a stretch modulus of up to about 0.05 gram per denier.

14. The fiber blend of claim 12 wherein said elastomeric fiber is a polyurethane fiber.

15. A fiber blend of claim 11 wherein said hard inelastic staple fiber has a stretch modulus of from about 18 to about 85 grams per denier and a breaking elongation not greater than about 40%.

16. A spun staple fiber yarn composed of a blend of 95–70% by weight of hard inelastic staple fiber, and 5–30% by weight of essentially straight elastic synthetic elastomeric staple fiber having a length between about ¾ inch and about 4 inches, a denier between about 3 and about 30, a stretch modulus of up to about 0.05 gram per denier and high stretchability characterized by an elongation before breaking of at least 100% combined with an essentially complete and quick recovery from stretching to an elongation less than its breaking elongation independent of effects due to crimping and twisting, the elastomeric fibers being stretch positioned relative to the hard fibers to provide a yarn of controlled stretchability and high recovery from stretching wherein the hard fibers become load bearing to limit the amount of stretch before reaching said break elongation of the elastomeric fibers when tension is applied to the yarn, and wherein the hard fibers become bulked by said recovery of the elastomeric fibers when tension on the yarn is released.

17. A yarn as defined in claim 16 wherein the length of the hard fibers is at least equal to that of the elastomeric fibers.

18. A yarn as defined in claim 16 wherein the elastomeric fibers have an elongation between about 500% and about 800% before breaking.

19. A yarn as defined in claim 16 wherein the elastomeric fibers have a tensile form recovery above about 75% and a stress decay below about 35% from 100% elongation.

20. A yarn as defined in claim 16 wherein the yarn has a tensile form recovery of at least 70% from 50% elongation when tested in the form of fabric.

21. A yarn as defined in claim 16 wherein the yarn has at least 56% stretchability at 0.1 gram per denier load and at least 77% recovery from stretch.

22. The yarn of claim 16 wherein said hard inelastic staple fiber has a stretch modulus of from about 18 to about 85 grams per denier and a breaking elongation not greater than about 40%.

23. A high recovery, high stretch yarn comprised of a blend of intermingled fibers of staple length comprising a major proportion by weight of a hard inelastic staple fiber, and a minor proportion of essentially straight synthetic elastomeric staple fiber having a breaking elongation of at least 100%, an essentially complete and quick recovery from stretching to an elongation less than its breaking elongation, a length of at least ¾ inch and a denier from about 3 to about 30, said elastomeric fiber being stretch positioned in said yarn and being present in an amount sufficient to provide high recovery from stretching.

24. The yarn of claim 23 wherein said elastomeric staple fiber is present in an amount from about 5% to about 30% by weight of said blend.

25. The yarn of claim 23 wherein said hard inelastic staple fiber has a stretch modulus of from about 18 to about 85 grams per denier and a breaking elongation not greater than about 40%.

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