Oct. 22, 1957 W. C. APPLETON ET AL 2,810,281

TEXTILE ARTICLES AND PROCESSES FOR MAKING SAME

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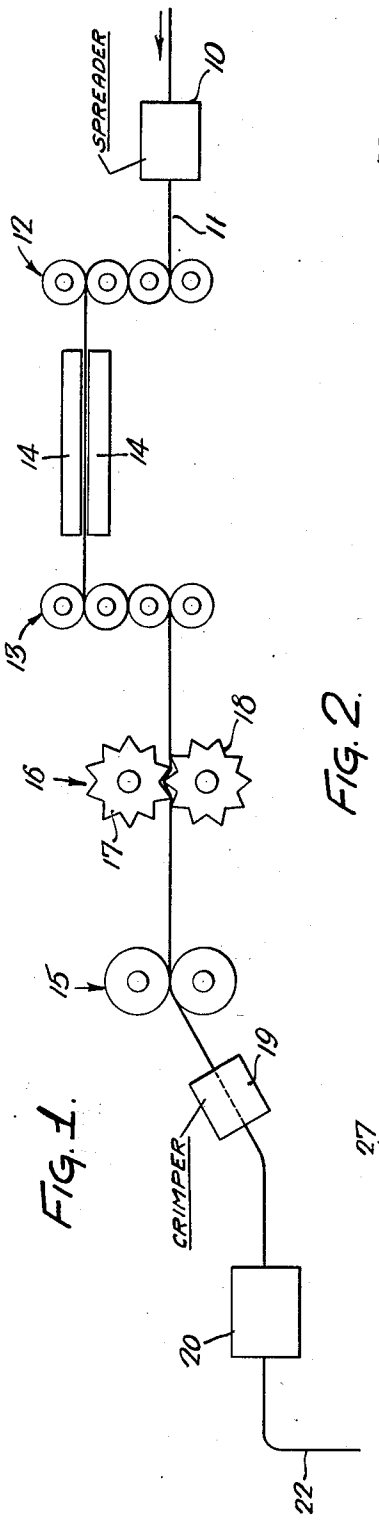

FIG. 1.

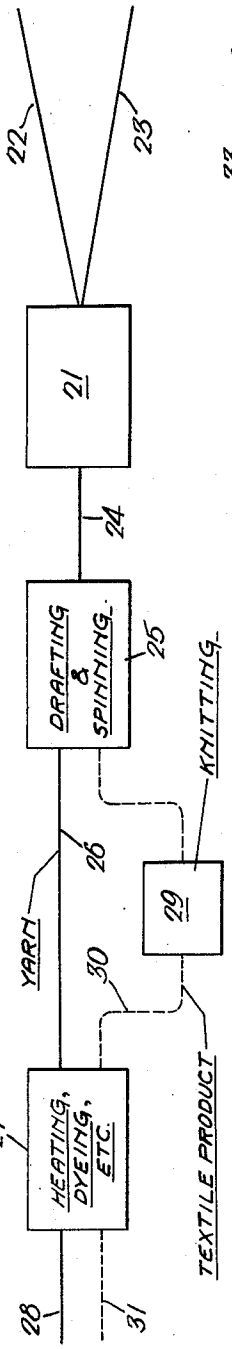

FIG. 2.

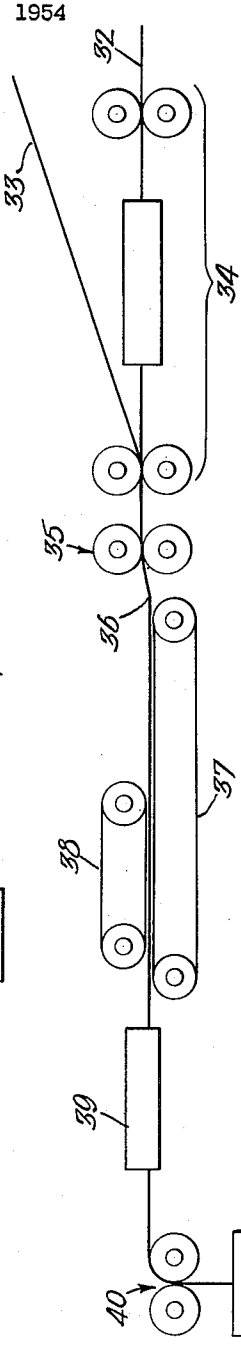

FIG. 3.

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TEXTILE ARTICLES AND PROCESSES FOR MAKING SAME

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15 Claims. (Cl. 66—202)

This invention relates to improvements in textile yarns composed of acrylonitrile polymer fibers, and more particularly acrylonitrile polymer fibers of the type sold by E. I. du Pont de Nemours & Company under the trademark "Orlon," or other fibers which in certain respects noted below have similar properties. As indicated in United States Patent 2,445,042, to Silverman, "Orlon" fibers are fibers of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule.

Acrylonitrile polymer filaments as originally formed are characterized by low molecular orientation, and consequently the filaments have relatively low tensile strength. Tensioning or stretching the fibers under heat has the effect of increasing orientation and therefore improving tensile strength. Such stretching also introduces a relatively high residual shrinkage capacity. The susceptibility to shrinkage of the tensioned fibers may be reduced and for practical purposes substantially eliminated by heating and relaxing the fibers under conditions in which they are free to shrink. Another characteristic of acrylonitrile polymer fibers is their relative straightness and smoothness of surface. This characteristic appears also in a yarn produced from this fiber so that the yarn lacks "character" and "loft." The properties of acrylonitrile polymer fibers are clearly set forth in United States Patent 2,686,339 to Holt, who therein proposed a single-operation method of relaxing and crimping the fibers to reduce their susceptibility to excessive shrinkage and to afford a degree of coherence facilitating their production into yarn on conventional textile equipment. The crimping, however, does not correct the essential lack of "loft" and "bulk" which has been characteristic of yarns made from this fiber and which has been largely responsible for the relatively limited commercial use of these yarns.

In the present invention, we propose to utilize certain of the inherent properties of these fibers to overcome the disadvantageous effects of other of the properties in the production of a yarn which is not only superior in essential respects to the prior yarns made from the same fiber but which is also superior in important respects to textile yarns of other composition. In so doing we have greatly increased the utility in the textile field of acrylonitrile polymer fibers, and fibers having similar characteristics.

More specifically, the invention contemplates the provision of a yarn composed of acrylonitrile polymer or similar fibers, which yarn is characterized by high bulk, loft, strength and dimensional stability, and a pronounced cashmere-like quality.

The invention has for an object also the provision of a yarn of the stated composition and characteristics comparing not unfavorably in cost with the prior yarns of like composition and relatively low bulk and loft, and the invention comprehends a novel and economical method of treating and processing the fibers from their

original continuous filament form through the several steps which produce the spun yarn end-product.

In accordance with the invention, the continuous filaments oriented and stabilized as described above and in the form of a tow, are heated and simultaneously stretched to an extent rendering them dimensionally unstable and susceptible to a relatively high percent of longitudinal shrinkage. The fibers are then reduced to staple lengths without however destroying the continuity of the resulting sliver. The sliver of staple fibers thus produced is then subjected to heat sufficiently high and for a sufficient duration to relax the fibers and to give them a desired degree of dimensional stability.

The stretched and subsequently relaxed staple fibers of this sliver are then combined in predetermined percentage and in preparatory spinning equipment with the fibers of a sliver which have been heated, stretched and reduced from filament to staple form as described above, but which have been permitted to remain in unrelaxed or tensioned condition and which therefore have the dimensional instability of fibers in that state. The resulting composite sliver of staple fibers is then processed in conventional manner to produce a finished yarn product. When this yarn is subjected to heat, the tensioned fiber content shrinks while the previously relaxed and hence relatively stable fibers remain dimensional substantially or relatively unchanged. This shrinkage of a predetermined percent of the fiber content of the yarn, occurring in the longitudinal direction, affords in major part the high bulk and loft which are characteristic of the yarns made in accordance with the invention. The effect results primarily from the puckering and fulling effect of the relaxed and previously stabilized fibers which occurs with the shrinkage of the tensioned fibers, and in part from the fact that the relaxing of both groups of fibers results in shrinking of the fibers accompanied by an increase in denier size so that a yarn composed of such tensioned and subsequently relaxed fibers will exhibit appreciably greater loft and bulk than a yarn composed of the same fiber which has not been subjected to this treatment. The final heating or bulking operation may take place before or after the yarn has been made into textile fabric, and in either case may be effected by steaming the yarn or fabric, or in and as a result of a dyeing or other process involving application of heat to the fibers.

The method of this invention described in general terms above, is susceptible of a high degree of control in the character of the yarn product. The degree of dimensional stability obtained in the fibers in the relaxing operation is in substantial degree a function of the temperature and duration of treatment. In general, assuming adequate duration, the relaxed fibers will be substantially free from shrinkage under temperatures no higher than that of the relaxing operation. Obviously any degree of residual shrinkage at the temperature employed in the subsequent bulking and lofting operation may be had. Also, the inherent shrinkage in the heat-tensioned but unrelaxed fibers is a function in part of the degree of stretch to which these fibers have been subjected, and the degree of shrinkage is therefore determinable within substantial limits. The bulk and loft properties of the yarn product is therefore controllable by manipulation of these variables, as well as by regulation of the relative percentages in the combined sliver of the relaxed and unrelaxed components.

The reduction of the continuous fibers to staple form may take place before or after the relaxing operation and before or after the combining of the relaxed and unrelaxed fibers. Thus, whereas in the procedure described above, the reduction occurred after the heat-tensioning operation and prior to the relaxing operation

involving one of the groups of fibers, in other procedures the reduction of the continuous filaments to staple length may occur after the relaxing of the one group and before but preferably after the combining of the two groups. Also, whereas in the procedure initially described all of the component fibers of the end product will have been subjected to both tensioning and relaxing operations, which is desirable, the high bulk end product may in the other procedures comprise fibers which have not been stretched and subsequently relaxed.

It is to be noted that the aforedescribed preferred method of this invention involves a uniform treatment of a single composition or class of fiber wherein the individual fibers undergo essentially the same series of operations although in different order as to the two primary groups. All of the filaments are subjected in their continuous state to a stretching operation which, in preferred procedures, is a common one; all of the filaments are reduced to staple lengths, preferably also in a common operation; and all of the fibers are eventually relaxed by like process but at differing periods in the procedure as a whole. This not only affords economy of production, but also an end product having a high degree of uniformity in fiber composition and properties and in structure.

The invention may be more specifically described with reference to the attached drawings wherein:

Figs. 1 and 2 are diagrammatic views of apparatus for producing yarn by a preferred procedure according to the invention, and

Fig. 3 is a diagrammatic view of apparatus for producing the yarn by a modified procedure within the scope of the invention.

With reference to Fig. 1, a suitably sized tow **11** of continuous oriented and stabilized polyacrylonitrile filaments of say three denier, preferably spread and flattened and with the component filaments loosened by suitable means indicated generally at **10**, is passed between two sets of pinch rolls, **12** and **13**, respectively, and through an intermediate heating area in which the yarn is heated to a temperature of say 280° F. The heating means may take the form, for example, of a pair of electrically or otherwise heated plates **14** forming therebetween a heating zone of say 320° F. through which the tow is passed longitudinally at a rate of speed of approximately 75 feet per minute. In this operation dry heat is preferred as affording a relatively high degree of dimensional instability (shrinkage capacity) for a given percentage of stretch. The rolls of the set **13** are operated at a higher peripheral speed than those of the set **12** so that the heated filaments are stretched in their passage between the sets of rolls and through the heating zone to the extent of approximately 66 percent with a consequent decrease in denier from 3 to 2. The filaments then pass through a reduction zone wherein they are divided individually into staple fibers of preferably varying lengths up to, say, a 6 or 7 inch maximum. This reduction to staple form is accomplished without destroying the continuity of the tow or sliver, and in the present instance we have shown stretch-breaking apparatus for accomplishing this result operating on the principle disclosed in United States Patent 2,419,320 of J. L. Lohrke. The apparatus comprises a pair of delivery rolls **15** which are operated at a somewhat greater peripheral speed than the rolls **13** so that the filaments of the tow are placed under a predetermined tension, and between the rolls **13** and **15** the filaments are acted upon by a pair of breaker rolls **16**, these rolls having prominent ribs **17** and **18** respectively which intermesh and have the effect of sharply laterally displacing or kinking and further stretching the filament. This action of the breaker rolls either ruptures the filaments or establishes in each a point of rupture at which the tension under which the filaments are placed performs the disrupting operation. The fibers produced in this manner are not only of varying lengths, but also of varying cross sectional shapes at their end portions. During the rupturing process, some of the ends are split longitudinally, and some are tapered to varying degrees.

Thereafter, the sliver is preferably subjected by suitable means indicated generally at **19** to a transverse condensing and crimping operation to give it increased cohesiveness and to facilitate handling in the subsequent operations. The sliver of tensioned staple fiber is passed to a steam or other heating chamber **20**, either by continuous progression or in batch form, wherein the fibers are subjected alternately to vacuum and the action of steam at say 10 lbs. pressure at a temperature of approximately 240° F. for a period of 16 to 20 minutes. In this operation, for example, an initial two minute period of vacuum may be followed by a like period of pressure, followed by a second two minutes of vacuum, then six minutes of pressure, and a final four minutes of vacuum. Under this vacuum-pressure heat treatment the fibers, now maintained under conditions affording freedom for shrinkage, are relaxed and shrink, the residual shrinkage capacity being say 3%. Also, the denier of the fibers is increased to approximately 2.25, and the sliver exhibits a materially improved softness and feel.

The sliver of relaxed staple fibers thus obtained is now combined with a sliver of like staple fibers which has been processed from the tow in the manner described above up to but excluding the relaxing operation in chamber **20**. In this sliver therefore the fibers remain in the tensioned or stretched condition. The fiber content of the two slivers may be such that in the combined sliver the relaxed fibers will constitute say 60% of the combined fiber. This combining operation may be conducted economically and efficiently on apparatus known and readily available in the art and indicated generally in Fig. 2 of the drawings by the reference numeral **21**, the two slivers being identified by the reference numerals **22** and **23** respectively and the combined sliver by the reference numeral **24**.

The combined sliver may now be drafted and spun in conventional drafting and spinning machinery **25** to afford a yarn comprising relaxed fibers and stretched but unrelaxed fibers in the relative proportions of 60% and 40% respectively. This yarn **26** may be heated by steaming or in a dyeing or other treatment, as at **27**, to a temperature sufficiently high and for a period sufficiently long to shrink the unrelaxed fiber content and to afford the stabilized high bulk product **28** of the invention. A temperature and period of exposure corresponding to those employed in the aforedescribed relaxing operation might be used, and in such case the finished yarn will exhibit substantial dimensional stability under exposure to that or any lesser temperature. Preferably the heating of the yarn which results in the characteristic high bulk condition will take place in the steaming or dyeing of the textile articles produced from the yarn, and in that case the unbulked yarn **26** is made into fabric or textile article in conventional manner and on conventional textile machines and the product then processed as described above, and as indicated generally in broken lines in Fig. 2, wherein the reference numeral **29** indicates a knitting machine including the machinery for preparing the yarn for the knitting operation; **30** the knitted product; and **31** the end product after the bulking operation at **27**. Allowance is made for the shrinkage in the yarn and the textile product which accompanies the heating or bulking operation. Such shrinkage in knitted circular jersey goods, for example, may be in the neighborhood of 25%. Such allowance for shrinkage and also for the increased bulk may include the use of somewhat finer counts of yarn than employed with conventional yarns of the same class of fiber, adjustment of stitch size toward relative looseness, adjust-

ment of tension etc., all in accordance with principles well understood in the art.

In another example, one of two tows **32** and **33** of suitable denier size, affording when processed and combined as described below a sliver of tensioned and untensioned staple fibers in desired relative percentages, is passed to a heating and stretching unit **34**, see Fig. 3, and thence in the tensioned state to a rotary helical cutting device **35** which reduces the filaments to staple length. The second tow is passed directly to the cutting device. The two tows spread and in superimposed relation are subjected simultaneously to the action of the cutter **35**. In this case, continuity of the resulting composite sliver **36** is maintained by means of aprons **37, 38** which receive and convey the sliver and at the same time, by reason of a differential movement, tend to relatively longitudially displace the fibers to consolidate the sliver. The aprons pass the sliver to a conical roll or scroll **39** which acts in effect to roll the sliver transversely on itself and to thereby in effect condense the sliver for passage thereof to nip rolls **40** and from the latter to a crimping box **41** whereby the composite sliver is further consolidated for subsequent processing into yarn. When subjected to heat in a subsequent steaming or dyeing operation, either as yarn or in fabric form, the heat-stretched or tensioned fibers are relaxed and shrunk as described above to produce the high bulk product.

The invention, as indicated, pertains not only to acrylonitrile polymer fibers, as exemplified for example by those commercial products sold by E. I. du Pont de Nemours & Company and The Chemstrand Corporation under their respective trademarks "Orlon" and "Acrilan," but also to other fibers having the characteristics which are utilized by the present invention in the provision of an improved yarn product. Thus, any fiber which can be internally tensioned and rendered dimensionally unstable when stretched under heat, and which can be relaxed and shrunk and stabilized in response to reheating, such for example as ethylene glycol terephthalic acid polyester fiber, may be used in the practice of the invention. Such an ethylene glycol terephthalic acid polyester fiber is sold by E. I. du Pont de Nemours & Company under the trademark "Dacron." Moreover, the invention is not restricted to yarns of uniform fiber composition, and its utility extends obviously to yarns composed of blends of differing fibers, some of which may possess properties foreign to those of the class immediately involved and whose presence in the yarn does not prevent the aforedescribed characteristic behavior of the acrylonitrile polymer or like fiber which results in the improved yarn product.

As to the relative percentage of the stable and unstable fiber components of the yarn, while this may vary within wide limits, it should be noted that the tensile strength of the finished yarn is dependent in relatively large part upon the fibers of the unstable and shrinkable component. The relative percentage should be determined with this fact in mind. With polyacrylonitrile (Orlon) yarns, the 60–40 percentage mentioned above will yield a desirably high bulk product of good tensile strength, although a yarn having an unrelaxed fiber content of 30% will still show adequate tensile strength for commercial usage. Where the unrelaxed fibers of the composite yarn are composed of ethylene glycol terephthalic acid polyester fibers (Dacron), which have a tensile strength materially in excess of that of the acrylic fibers, a relatively small percentage, say ten percent or even less, of the unrelaxed fibers will afford adequate tensile strength in the finished product. Obviously, where the relaxed and unrelaxed complementary fibers are blended with a strength conferring fiber of other composition, the relative percentages of the said complementary fibers, insofar as the strength properties of the finished yarn is concerned, may be of little or no significance.

We claim:

1. A twisted yarn composed of a blend of two groups of staple-length textile fibers of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, which fibers in response to stretching can be made to assume a first state of relatively great dimensional instability and which can be relaxed to a second state of relative stability with accompanying longitudinal shrinkage by subsequent application of heat, the fibers of one of said groups being in said first state, and the fibers of the other of said groups being in said second state, whereby, when the yarn is heated, the fibers of said one group shrink and cause puckering of the fibers of said other group to increase the bulk and softness of the yarn.

2. A sliver containing a blend of two groups of staple-length textile fibers of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, which fibers, when stretched from the oriented and stabilized condition, are made to assume a first state of relatively great dimensional instability and capacity for subsequent longitudinal shrinkage when heated, and which, when subsequently so heated and shrunk, assume a second state of relatively relaxation and dimensional stability coupled with an appreciable gain in softness of feel over the fiber prior to stretching, the fibers in one of said groups being in said first state, and the fibers of the other of said groups being in said second state.

3. A twisted yarn adapted to be bulked by the application of heat thereto, comprising a blend of two groups of staple-length textile fibers of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, which fibers, when stretched from the oriented and stabilized condition, are made to assume a first state of relatively great dimensional instability and capacity for subsequent longitudinal shrinkage when heated, and which, when subsequently so heated and shrunk, assume a second state of relative relaxation and dimensional stability coupled with an appreciable gain in softness of feel over the fiber prior to stretching, the fibers of one of said groups being in said first state and constituting at least 30% by weight of said yarn, and the fibers of the other of said groups being in said second state, whereby, when said yarn is heated, the fibers of said one group shrink and cause puckering of the fibers of said other group to increase the bulk and softness of the yarn.

4. A twisted yarn adapted to be bulked by the application of heat thereto, comprising a blend of two groups of staple-length textile fibers of the type produced by stretch-breaking continuous filaments, said fibers being of varying lengths and having end portions of varying across sectional shapes, the fibers of one of said groups being highly stretched heat-shrinkable synthetic fibers, and the fibers of the other of said groups being relatively unshrinkable, whereby, when the yarn is heated, the fibers of said one group shrink and cause puckering of the fibers of said other group to increase the bulk and softness of the yarn.

5. A sliver containing a blend of two groups of staple-length textile fibers of the type produced by stretch-breaking oriented and stabilized continuous filaments of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, which fibers, when stretched from the oriented and stabilized condition, are made to assume a first state of relatively great dimensional instability and capacity for subsequent longitudinal strinkage when heated, and which, when subsequently so heated and shrunk, assume a second state of relative relaxation and dimensional stability, said fibers being of varying lengths and having end portions of varying cross sectional shapes, the fibers of one of said groups being in said first state, and the fibers of the other of said groups being in said second state.

6. A twisted yarn adapted to be bulked by the application of heat thereto, comprising a blend of two groups of staple-length textile fibers of the type produced by stretch-breaking oriented and stabilized continuous filaments of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, which fibers, when stretched from the oriented and stabilized condition, are made to assume a first state of relatively great dimensional instability and capacity for subsequent longitudinal shrinkage when heated, and which, when subsequently so heated and shrunk, assume a second state of relative relaxation and dimensional stability, said fibers being of varying lengths and having end portions of varying cross sectional shapes, the fibers of one of said groups being in said first state, and the fibers of the other of said groups being in said second state, whereby, when said yarn is heated, the fibers of said one group shrink and cause puckering of the fibers of said other group to increase the bulk and softness of the yarn.

7. A twisted yarn adapted to be bulked by the application of heat thereto, comprising a blend of two groups of staple-length textile fibers of the type produced by stretch-breaking oriented and stabilized continuous filaments of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, which fibers, when stretched from the oriented and stabilized condition, are made to assume a first state of relatively great dimensional instability and capacity for subsequent longitudinal shrinkage when heated, and which, when subsequently so heated and shrunk, assume a second state of relative relaxation and dimensional stability, said fibers being of varying lengths and having end portions of varying cross sectional shapes, the fibers of one of said groups being in said first state and constituting at least 30% by weight of said yarn, and the fibers of the other of said groups being in said second state, whereby, when said yarn is heated, the fibers of said one group shrink and cause puckering of the fibers of said other group to increase the bulk and softness of the yarn.

8. A process for producing a high-bulk yarn from oriented and stabilized continuous filaments of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, comprising stretching some of said filaments and reducing them to staple fibers to form a group of dimensionally unstable fibers which can be relaxed to a relatively stable state with accompanying longitudinal shrinkage by subsequent application of heat, reducing others of said filaments to staple fibers to form a group of dimensionally stable fibers, and then blending said groups of fibers together to form a sliver.

9. A process for producing a high bulk yarn from oriented and stabilized continuous filaments of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, comprising stretching said filaments and reducing them to staple fibers of relatively great dimensional instability and which can be relaxed to a relatively stable state with accompanying longitudinal shrinkage by subsequent application of heat, heating a group of said staple fibers to relax them, and then blending said group of relaxed fibers with a group of said unstable fibers to form a sliver.

10. A process for producing a high bulk yarn from oriented and stabilized continuous filaments of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, comprising stretching said filaments and reducing them to staple fibers of relatively great dimensional instability and which can be relaxed to a relatively stable state with accompanying longitudinal shrinkage by subsequent application of heat, heating a group of said staple fibers to relax them, then blending said group of relaxed fibers with a group of said unstable fibers to form a sliver, twisting said sliver to form a yarn, and then heating the yarn to shrink said unstable fibers.

11. A process for producing a high-bulk synthetic yarn from tows of continuous artifical filaments of the type which may be rendered dimensionally unstable by stretching and which may be relaxed to a relatively stable state with accompanying longitudinal shrinkage by subsequent application of heat; comprising stretch-breaking the filaments of two tows to form two slivers of staple fibers, the fibers in each of said slivers being of varying lengths and of varying cross sectional shapes at their end portions and having a capacity for longitudinal shrinkage upon the application of heat; heating one only of said slivers to shrink and relax the fibers therein; then blending the two slivers together; twisting the resulting blended sliver to form a yarn; and then heating the yarn to shrink the fibers formerly constituting the other of said slivers.

12. A process for producing a high-bulk yarn from tows of oriented and stabilized continuous filaments of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, which filaments may be rendered dimensionally unstable by heating and stretching them and which may be relaxed to a relatively stable state with accompanying longitudinal shrinkage by subsequent application of heat; comprising heating, stretching, and stretch-breaking the filaments of two tows to form two slivers of staple fibers, the fibers in each of said slivers being of varying lengths and of varying cross sectional shapes at their end portions and having a capacity for longitudinal shrinkage upon the application of heat; heating one only of said slivers to shrink and relax the fibers therein; then blending the two slivers together; twisting the resulting blended sliver to form a yarn; and then heating the yarn to shrink the fibers formerly constituting the other of said slivers.

13. A process for producing a high-bulk yarn from tows of oriented and stabilized continuous filaments of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, which filaments may be rendered dimensionally unstable by heating and stretching them and which may be relaxed to a relatively stable state with accompanying longitudinal shrinkage by subsequent application of heat; comprising heating, stretching, and stretch-breaking the filaments of two tows to form two slivers of staple fibers, the fibers in each of said slivers being of varying cross sectional shapes at their end portions and having a capacity for longitudinal shrinkage upon the application of heat; heating one only of said slivers in the presence of steam to shrink and relax the fibers therein; then blending the two slivers together; twisting the resulting blended sliver to form a yarn; and then heating the yarn in the presence of moisture to shrink the fibers formerly constituting the other of said slivers.

14. A process for producing a knitted fabric of pronounced bulk and softness of feel from tows of oriented and stabilized continuous filaments of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule; comprising heating and stretch-breaking the filaments of two such tows to form two slivers of staple fibers, the fibers in each of said slivers being of varying lengths and varying cross sectional shapes at their end portions and having a capacity for longitudinal shrinkage upon the application of heat; heating one only of said slivers to shrink and relax the fibers therein; then blending the two slivers together in such proportions that the fibers of the other of said slivers constitutes at least 30% by weight of the resulting blended sliver; twisting the blended sliver to form a yarn; knitting said yarn to form a fabric; and then heating the fabric to shrink the fibers formerly constituting said other of said slivers.

15. A knitted fabric comprising a plurality of twisted yarns each composed of a blend of two groups of staple-length textile fibers of a polymer of acrylonitrile containing at least 80% by weight of acrylonitrile in the polymer molecule, which fibers in response to stretching

can be made to assume a first state of relatively great dimensional instability and which can be relaxed to a second state of relative stability with accompanying longitudinal shrinkage by subsequent application of heat, the fibers of one of said groups being in said first state, and the fibers of the other of said groups being in said second state, whereby, when the fabric is heated, the fibers of said one group shrink and cause puckering of the fibers of said other group to increase the bulk and softness of said yarns and said fabric.

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