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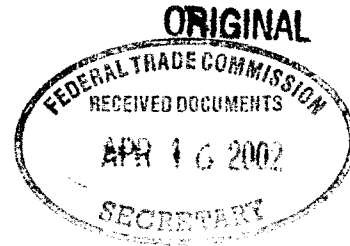
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April 15, 2002



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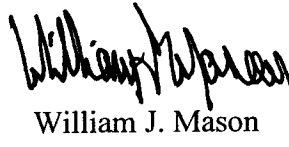
RE: 16 CFR Part 303 – Textile Rule 8 DuPont Comment – P948404

Dear Sirs:

I am enclosing a memorandum by my client Nan Ya Plastics Corporation, America commenting in opposition to the proposal by DuPont to establish an “elastrell-p” generic name.

Please contact me if you require further information, or if there is a public hearing scheduled on this matter.

Sincerely yours,

  
William J. Mason

WJM/lq  
Enclosures

## **16 CFR Part 303 -- Textile Rule 8 DuPont Comment -- P948404**

To: Office Of The Secretary - Federal Trade Commission  
From: Nan Ya Plastics Corporation, America  
Re: Opposition To Establishment of Elastrell-P Generic Subclass

### Introduction

Nan Ya Plastics Corporation, America ("Nan Ya") is a leading U.S. manufacturer of polyester for the packaging and textile industries. Its main products include polyester textile and bottle chips, staple fiber, and various yarns. As such, Nan Ya is a direct competitor of DuPont in the area of polyester fibers. Nan Ya believes that granting of the DuPont petition to add a generic subclass named "elastrell-p" would be contrary to the aims of the Textile Products Identification Act and to the interests of consumers, and would provide DuPont with an unfair competitive advantage.

### The DuPont Proposal

DuPont has petitioned the Commission to establish the generic name "elastrell-p" as an alternative to, and a subclass of, "polyester" by the addition of the following sentence to the current definition of polyester in Rule 7(c) to define T400 and similar fibers as a subclass of polyester:

"Where the fiber is a multicomponent and exhibits inherent (not mechanically induced) recoverable stretch of at least 35% upon loading with 185 mg/dtex and unloading to 5.4 mg/dtex when tested in accordance with ASTM test D6720, the term "elastrell-p" may be used as a generic description of the fiber."

In support of its petition, DuPont states that its T400 fiber is an inherently elastic, bicomponent, manufactured textile fiber consisting of two substantially different forms of polyester fibers. DuPont contends that the fibers have stretch and recover power superior to textured fiber, superior stretch and recovery properties, and a softer "silky" feel or "hand" than textured polyester fibers.

DuPont alleges that the T400 fiber will fill a growing and unmet demand for stretch garments, and that it would be confusing to consumers if T400 is called simply "polyester."

#### The DuPont Fiber Is Not Sufficiently Unique to Merit A Separate Generic Subclass

An inherent characteristic of bicomponent fibers, whether manufactured in a sheath and core configuration, or a side-by-side configuration, is the fact that the fiber assumes a spiral crimp due to differences in the characteristics, primarily relative viscosities, of the different polymers. The fiber retains a memory so that the fiber is inherently elastic, tending to return to its original coiled configuration upon release of stress. To produce elastic bicomponent fibers having characteristics adapted to their particular end use, the manufacturer controls the chemical compositions of the two components, and the conditions under which bicomponent fibers are produced.

Various bicomponent fibers, including bicomponent fibers in which both components are polyester, have been known in the textile industry since the early 1970s. To illustrate, U.S. Patent No. 3,671,379, issued June 20, 1972 to DuPont, based on an application originally filed on July 24, 1964, describes the preparation of bicomponent filaments in which both components are polyester. The '379 patent states that the filaments are useful in the manufacture of leotards,

swimwear, and fabrics where a high power of recovery from stretch is desirable. Test results show a stretch as high as 148% with a stretch recovery of 97%.

As a further illustration, a recent patent to Toray Industries, Inc., U.S. Patent No. 6,306,499, issued October 23, 2001, also describes the production of bicomponent filaments in which both components are polyester. The yarns are specifically designed so that the resistance to yarn stretch is low, while the recovery from stretch is high. The stretch recovery is said to be at least 60%, and preferably at least 70%. The yarns are used in textile materials including blouses, one-piece costumes, sportswear, etc. Copies of the DuPont and Toray patents are enclosed.

Bicomponent yarns in which both components are polyester are currently manufactured by several companies, including DuPont, KOSA, Fiber Innovation Technology, Inc., and Nan Ya. Polyester side-by-side bicomponent fibers manufactured by Nan Ya are sold for use in women's garments. These garments, depending on the particular fiber and the garment construction, have an elastic stretch and recovery in the range of 15% to 35%.

What may be unique about DuPont's fiber is the composition of the particular polyester polymers selected for the components, perhaps coupled with specific spinning and heat treatment conditions, to produce a polyester bicomponent fiber that exhibits properties especially suitable for use in stretch garments. However, these conditions, which may even be deemed patentable under the patent laws, result in a polyester bicomponent fiber with some properties that differ only in degree from the properties of other polyester bicomponent fibers, and not in a fiber that is worthy of being designated by a unique generic subclass.

In fact, since manufactured fibers generally have different properties developed by the manufacturer to meet different market niches, numerous fibers would qualify for their own subclass designation under the DuPont rationale. A manufacturer of a given fiber would only need to craft a set of parameters that described the particular fiber. Thus, any manufacturer of a polyester textile fiber, whether or not a bicomponent fiber, that had definable characteristics especially suitable for a particular textile application could equally argue that the fiber was entitled to a unique subclass. In fact, the same rationale equally applies to all textile fibers, and not just to polyester fibers, potentially resulting in a flood of petitions for special designations. If the standards proposed by DuPont were applied to all petitions, numerous new subclasses could result, effectively destroying the value to the consumer of the current designation system.

#### The Unfair Advantage To DuPont Of The Requested Designation

DuPont alleges in its petition that the purpose of the proposed designation will be to avoid consumer confusion. In fact, the real value of the unique designation, if granted, could be to give DuPont a heretofore-unavailable competitive advantage.

When a manufacturer develops a new fiber, the manufacturer normally seeks patent protection for the product and/or its process of manufacture. When marketing the product, the manufacturer designates the product by a unique trademark and spends significant funds in establishing a relationship in the mind of the consumer between the trademark and the unique properties of the product, motivating the consumer and any intermediate processors to purchase the particular fiber from the manufacturer.

Based on the availability of published applications, and taking into account the fact that DuPont is one of the leading patentees in the United States (acquiring over 1700 U.S. patents in

the last five years) there is no doubt that DuPont intends to protect its "unique" fiber and the process of its manufacture as extensively as possible. It would not be coincidental if at least some of the patent claims read much like the definition that DuPont has requested for the new subclass. If so, DuPont's patent protection would prevent other manufacturers from making or selling any fiber falling within the new subclass.

Thus, DuPont would enjoy a unique niche, being the only manufacturer that can sell a polyester fiber under the "elastrell-p" designation. The resulting competitive advantage to DuPont should be apparent. Instead of spending substantial marketing funds and time to establish a new fiber trademark, DuPont could simply emphasize the "elastrell-p" name in its labeling and advertising. No requirement for even a designation of the fiber as a "polyester" fiber would be required. No doubt, DuPont would not allow the consumer to overlook the fact that the name "elastrell-p" was a special designation granted by the U.S. government for its "unique" fiber.

Coupling of a proprietary trademark with the "elastrell-p" subclass name would permit DuPont to extend the advantage beyond the monopoly period afforded by patent protection. After approximately two decades of DuPont's exclusive sale of unique "elastrell-p" fiber under a particular trademark, the consumer will come to refer to the fiber subclass by DuPont's trademark. One need look no further than "Dacron" to find an analogy.

#### Adoption Of the New Subclass Would Create Consumer Confusion

It is respectfully submitted that consumers rely on the fiber designations primarily as a way to identify characteristics of the fiber that is attributable primarily to the chemical structure of the fiber. Thus, in the case of a fiber designated as a "polyester" fiber, the consumer expects

the fiber to exhibit such properties as stain resistance, chemical resistance, wrinkle resistance, abrasion resistance, good wicking properties, etc. Use of the designation "elasterell-p" for a fiber that is essentially a polyester fiber will cause confusion, instead of avoiding it as DuPont alleges.

Further confusion would be caused by the fact that manufacturers producing polyester bicomponent fibers with characteristics only slightly outside of the parameters proposed by DuPont, whether to achieve other desired properties or to avoid patent infringement, would be required to call their product "polyester" fibers, and would not be permitted to use the "elastrell-p" designation. The end result would be that polyester bicomponent fibers with similar characteristics would be sold to consumers by different manufacturers, but only DuPont would have the competitive advantage of identifying its product with the governmentally sanctioned "elastrell-p" designation.

Consumer confusion could result even if DuPont does not obtain patent rights that would prohibit competitors from using the "elastrell-p" name. Other manufacturers may wish to produce products that fall within the proposed definition, and continue to refer to the yarns as "polyester" yarns to inform the consumer of the properties of the yarns. Thus, the consumer could be faced with essentially identical products, one called "polyester" and the other called "elastrell-p."

#### Nan Ya Proposal

When DuPont's arguments and unsupported allegations are stripped away, the fact remains that DuPont's fiber is simply a bicomponent fiber in which both components are polyester. Such fibers are fully covered by existing regulations, since the chemical composition of the fiber is within the definition of "polyester" in § 303.7(c).

Designation of a unique subclass that could only be used by DuPont for a fiber that differs only in degree from other commercial bicomponent fibers is opposed for reasons stated above. However, it is recognized that there would be a value to the consumer if the consumer was informed that bicomponent fibers possessed, in addition to the properties associated with "polyester" fibers, additional properties associated with their bicomponent structure, in particular their inherent elasticity.

Existing regulations covering bicomponent fibers, called "biconstituent fibers" or "multiconstituent fibers," are found in § 303.10(c). However, this section of the regulations currently only addresses bicomponent fibers in which the two components fall within different existing definitions of textile fibers set forth in § 303.7. Thus, for example, a bicomponent fiber in which one component was nylon and the other polyester, could be designated as 100% biconstituent fiber (65% nylon, 35% polyester). However, bicomponent fibers in which both components are of the same fiber composition are not addressed.

Nan Ya proposes expansion of § 303.10(c) to include bicomponent fibers in which the two components are of the same fiber, e.g., a bicomponent fiber in which one component is of one polyester and the other component is of different polyester. With this modification, fibers of the type proposed by DuPont could simply be designated as "polyester bicomponent fibers," thereby advising the consumer of the fibers "polyester" characteristics, as well as of its bicomponent characteristics.

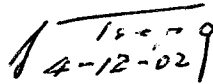
At the same time, since no manufacturer would have a monopoly over polyester bicomponent fibers generally, all polyester fiber manufacturers will be placed on an equal footing. Specifically, no single manufacturer will be permitted to have the sole right to sell a



fiber within a unique subclass. Instead, all manufacturers will continue to compete, using the congressionally mandated intellectual property tools of the patent and trademark laws.

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Respectfully submitted,

A handwritten signature in black ink, appearing to read 'Jung-Shung Tseng', with a date '4-12-02' written below it.

Jung-Shung Tseng

Assistant Vice President

Nan Ya Plastics Corporation, America

April 12, 2002

June 20, 1972

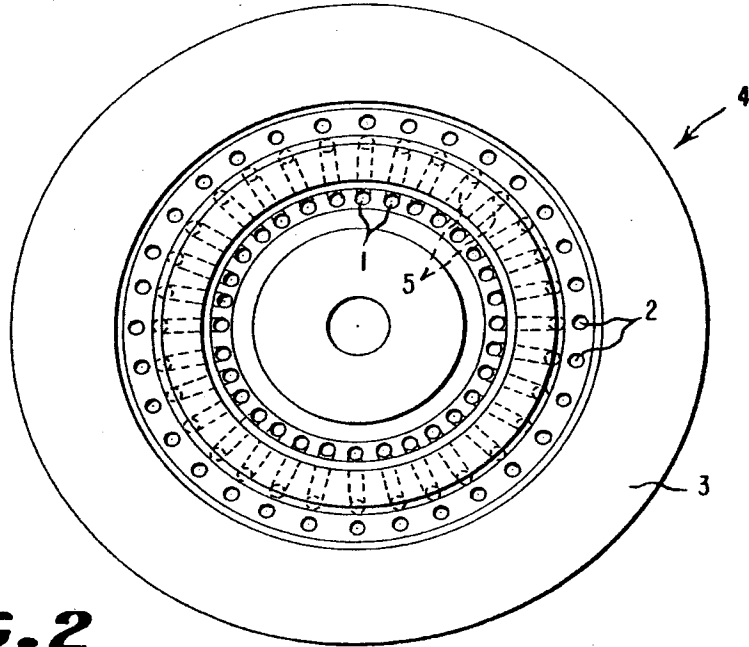
E. F. EVANS ET AL

3,671,379

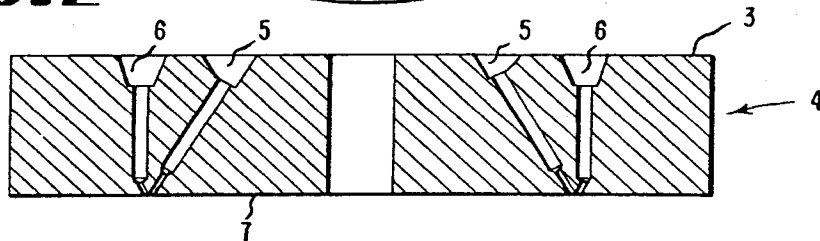
COMPOSITE POLYESTER TEXTILE FIBERS

Filed March 9, 1971

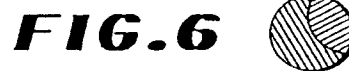
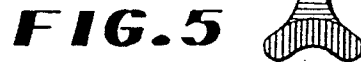
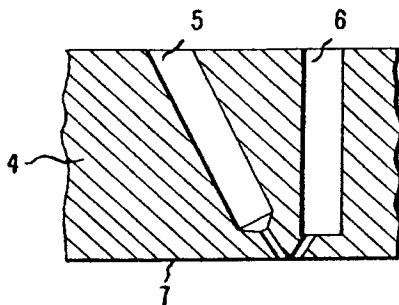
# FIG. 1



# FIG. 2



# FIG. 3



INVENTORS  
EVAN FRANKLIN EVANS  
NORWIN CALEY PIERCE

BY

*Gary A. Samuels*

ATTORNEY

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3,671,379

**COMPOSITE POLYESTER TEXTILE FIBERS**

Evan Franklin Evans, Kinston, and Norwin Caley Pierce, Greenville, N.C., assignors to E. I. du Pont de Nemours and Company, Wilmington, Del.

Continuation-in-part of application Ser. No. 747,420, July 10, 1968, which is a continuation-in-part of application Ser. No. 611,314, Jan. 24, 1967, which is a continuation-in-part of application Ser. No. 462,992, June 10, 1965, which in turn is a continuation-in-part of application Ser. No. 384,831, July 24, 1964. This application Mar. 9, 1971, Ser. No. 122,316

Int. Cl. D02g 3/02

U.S. Cl. 161—173

18 Claims

**ABSTRACT OF THE DISCLOSURE**

Helically crimpable and crimped bicomponent filaments comprising a laterally eccentric assembly of at least two synthetic polyesters. At least one of the components is a partly crystalline polyester in which the chemical repeat-units of its crystalline region are in a non-extended stable conformation that does not exceed ninety percent of the length of the conformation of its fully extended chemical repeat-units and is generally on the inside of the crimp helices formed when the assembly crimps, while at least one other polyester component is partly crystalline and the chemical repeat-units of the crystalline region more closely approach the length of the conformation of its fully extended chemical repeat-units. Yarns, fabrics, and the like produced from these filaments have a wide range of end uses.

**CROSS REFERENCES TO RELATED APPLICATIONS**

This is a continuation-in-part of our copending application Ser. No. 747,420, filed July 10, 1968, now abandoned, which in turn is a continuation-in-part of our copending application Ser. No. 611,314, filed Jan. 24, 1967, now abandoned, which in turn is a continuation-in-part of our application Ser. No. 462,992, filed June 10, 1965, now abandoned, which in turn is a continuation-in-part of our application Ser. No. 384,831, filed July 24, 1964, now abandoned.

**BACKGROUND OF THE INVENTION**

This invention relates to self-crimpable and crimped composite synthetic filaments and, more specifically, to such composite filaments which have the potential for development of a broad range of desirable crimp properties.

It is frequently desirable in applications of synthetic fibers to attain a degree of stretchability not inherently characteristic of fabrics made therefrom. In the past such stretchability has usually been attained by incorporation of an elastomer, such as natural rubber or a synthetic rubber, into the fabric structure. This alters tactility markedly and increases the weight of the fabric. Fabrication of woven, light-weight fabric with a useful degree of stretch has heretofore been impractically expensive. It is true that synthetic fiber yarns which have artificially induced crimpiness have some stretchability, but this has invariably been either of minor degree and of low recovery power and rate or so limited by twist-liveliness as to have no practical utility in light-weight flat fabrics. Such yarns may have, for example, either mechanically induced crimpiness, heat-set twist or spontaneous crimpability based on a bicomponent structure of the type more fully described below. Crimping confers bulkiness

but little practical stretch; yarns which have been twisted, heat-set and untwisted can yield fabrics having some stretch, but twist-liveliness of such yarns inevitably leads to curling or crepiness unless they are crimp-set in a separate operation or suitably plied to balance the inherent twist-liveliness, which process limits the utility of such a yarn to heavier weight woven fabrics.

Composite bicomponent filaments comprising two or more synthetic components which components differ in their ability to shrink, in an intimately adhering, coextensive relationship that is eccentric over the cross-section of the filament are known in the art. In U.S. Pat. No. 2,931,091, for example, it is shown that two condensation polymer components which differ in shrinkability can be copun, in either eccentric sheath-core or side-by-side relationship. Such a filament crimps helically when subjected to shrinking conditions in an essentially tensionless state, the number of crimps-per-inch being directly related to difference in shrinkage between components. Such crimp is useful in providing bulk and resilience in fabrics, stuffing materials, etc. However, bicomponent filaments have been severely limited in their ability to crimp against a restraining load such as that encountered in woven fabrics and lose very substantially in their ability to crimp when the fiber has been annealed to low shrinkage.

**SUMMARY OF THE INVENTION**

The present invention provides helically crimpable and crimped filaments comprising a laterally eccentric assembly of at least two synthetic polyesters, the first of said two polyesters being partly crystalline in which the chemical repeat-units of its crystalline region are in a non-extended stable conformation that does not exceed 90 percent of the length of the conformation of its fully extended chemical repeat-units and which assumes a position on the inside of the crimp helices formed when the assembly crimps, the second of said two polyesters being partly crystalline in which the chemical repeat-units of the crystalline region are in a conformation more closely approaching the length of the conformation of its fully extended chemical repeat-units than the first defined polyester.

The composite filament defined in the preceding paragraph provides a synthetic multi-component filament which is capable of developing a high degree of helical crimp against the restraint imposed by high-thread-count woven structures, which crimp potential is unusually well retained despite application of elongating stress and high temperature. It further provides a synthetic composite filament which surprisingly increases, rather than decreases, in crimp potential when annealed. It still further provides aesthetically pleasing fabric structures comprising such filaments which range from light-weight, flat fabrics with good stretch, stretch recovery and stretch power to bulky, wool-like staple fibers and low-stretch novelty fabrics which may exhibit crepe. It also provides a route to flat, continuous-filament or staple-containing fabrics of durable stretchiness without the problems associated with twist-lively yarns.

**DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a schematic, transparent view of a spinneret plate of the post-coalescence type;

FIG. 2 is a side view of cooperating channels in a spinneret assembly;

FIG. 3 is an enlarged view showing the face plate opening of channels of the type of FIG. 2; and

FIGS. 4, 5 and 6 are cross-sections of some of the type filaments that can be produced in this invention.

### 3

## DESCRIPTION OF THE INVENTION

The critical limitation in the composite filaments of this invention is the character of the two polyesters that must be present, namely, that the chemical repeat-units in the crystalline regions of one polyester must be in a non-extended stable conformation that is 90% or less of the length of the conformation of its fully extended chemical repeat-units, and the chemical repeat-units in the crystalline region of the other polyester must be in a conformation more closely approaching its fully extended conformation. These crystallinity requirements are met because they are a physical or structural characteristic of the special polyester that must be present. It should be understood that the term "partly crystalline" as used in defining the filaments of this invention serves to eliminate from the scope of the invention the limiting situation of complete crystallinity wherein the potential for shrinkage would disappear. Hence, the amount of crystallinity, defined by the term "partly crystalline," has a minimum level of only the presence of some crystallinity (i.e., that which is first detectible by X-ray diffraction means) and a maximum level of any amount short of complete crystallinity.

Although this invention is directed to composite filaments which contain at least two synthetic polyester component filaments as described above, it is preferred that the composite filaments are bicomponent filaments in which the two components are the aforescribed polyesters. Since it is these two components that are the critical elements in the filaments of this invention, such filaments will be discussed hereinafter primarily in terms of bicomponent filaments.

Before entering into a detailed discussion of the manner in which the two polyester components behave to achieve the crimpable or crimped bicomponent filaments comprising them, it should be pointed out that the term "laterally eccentric" as used herein is used in its commonly accepted connotation in the field of bicomponent filaments. Thus, the two polyester components are spun together in such a manner that each component forms, over the cross-section of the single bicomponent filament, a distinct zone which extends throughout the entire length of the filament in eccentric fashion, whereby only one, or part of, or all of the components take part in forming the surface of the single bicomponent filament. Thus, in one embodiment, the two components will be present in substantially constant ratio in the filament cross-section; while in another embodiment each component may vary in its cross-sectional ratio. The components may be in an eccentric sheath-core relationship, but, preferably, they will be present in the bicomponent filaments in a side-by-side relationship, such as is described in U.S. Pat. 2,931,091.

Thus, it is seen that the spontaneous crimping of the bicomponent filament is the result of differential changes in the length of the two polyester components which arise from a difference in the degree of their respective retraction after draw or their shrinkage after subsequent heat treatment or both.

Although the reason for the differential changes in length is not fully established and the invention should not be limited by a theoretical consideration, the discussion which follows may assist in understanding the invention. The differential in the changes in length of the two critical polyester components arises from the difference in the crystalline structure of the two polyesters, and it is believed that if an oriented polymer crystallizes in an extended conformation (as do most polyesters), i.e., one in which the conformation of the chemical repeat-units in its crystalline region closely approaches that of its fully extended chemical repeat-units, as the polymer crystallizes in the oriented state, repeat-units are transferred from a noncrystalline region of the polymer to a crystalline region and the orientation of units remaining in the noncrystalline region becomes less. Potential ability to shrink is

### 4

greater for fibers with more highly oriented noncrystalline regions than for fibers with lower orientation in the noncrystalline regions. Thus, the partially crystalline "extended-type" polymer loses potential ability to shrink as it continues to crystallize. If, on the other hand, the oriented polymer is one whose chemical repeat-units crystallize in a nonextended conformation, i.e., one in which the length of the chemical repeat-units of its crystalline region is shorter than that of its fully extended chemical repeat-units, then, during crystallization in the oriented state, as repeat-units are transferred from a noncrystalline region of the polymer to a crystalline region, the orientation of units remaining in the noncrystalline region becomes greater. Thus, further crystallization of such a "nonextended type" polymer results in a higher tendency to shrink upon relaxation.

From the foregoing discussion, it is seen that if a bicomponent filament is composed of the "extended-type" polymer and the "nonextended type" polymer in a laterally eccentric relationship, the difference in the conformation of their chemical repeat-units in the crystalline regions will result in the crimpable and crimped filaments of this invention. Maintenance of this differential shrinkage and retraction potential between the components of the filament requires geometrical stability in the crystalline chemical repeat-units of the high-shrinkage component, except for those rearrangements necessary to shrinkage. Otherwise, the potential energy required for crimping may be dissipated by molecular rearrangements to a more stable crystalline state (of lower shrinkage). In other words, when under stress, a partial disruption of the conformation of the crystalline region may occur which causes a rearrangement to a conformation in which the chemical repeat-units are in a more extended conformation. Thus, the term "stable" as used herein is meant that the nonextended chemical repeat-units of the crystalline region do not undergo an irreversible loss of dimensional recovery potential, i.e., they revert back to substantially their original "nonextended" conformation upon the release of the stress and with the application of heat.

It is also seen from the foregoing discussion that the unusual properties of the bicomponent filament of this invention will be fully realized if the overall orientation of the high-shrinkage component (i.e., the "nonextended" component) in its uncrimped amorphous state is greater than its orientation in its partially crystalline conformation. Orientation of the synthetic fiber may be accomplished in either or both of two ways: (1) by withdrawing the solidifying filament from the spinneret at a rate higher than its extrusion velocity, and (2) mechanical stretching of the solidified filament.

It is sometimes desirable, particularly when maximum crimp development is desired, that the high-shrinkage component be more highly oriented. It is obvious that the mechanical stretching step imparts the same draw ratio to both components and is therefore not highly effective in establishing an advantage in orientation for the high-shrinkage component. To insure that the advantage in orientation is accomplished, it is sometimes desirable that the high-shrinkage component be more highly oriented during spinning. This can be done by using a higher molecular weight (higher melt-viscosity) polymer for the high-shrinkage component. This same effect can be realized, however, by suitable use of melt-viscosity modifiers in one component, and such process variations are within the scope of this invention.

The use of a polyester which crystallizes in a nonextended conformation as the high-shrinkage component of the bicomponent filament provides substantial advantages over a combination of polymeric components which shrink unequally due to another difference such as in molecular weight, tensile recovery, glass transition temperature, etc. While the composite fibers known in the art possess differing degrees of potential shrinkability among components as a result of variations in response

of the components to manufacturing conditions employed, in no instance has such difference been found completely retained or, more strikingly, enhanced by stress and/or high temperature, as is the case with the composite filaments of this invention. A particularly advantageous property of the bicomponent filaments of this invention is their ability to crimp against a restraining load imposed by woven fabrics made therefrom. Stretchability and recovery from stretch can be adjusted over a wide range by choice of process variables as will be shown below.

Accordingly, and subject to the critical crystalline conformation requirements, it is apparent that the composite bicomponent filaments of the present invention can be composed of any number of any of the polyesters including polyester copolymers, that can be readily melt spun. It is especially preferred that the more extended polyester have the chemical repeat-units in its crystalline region in a conformation that is 95% or more of the length of the conformation of its fully extended chemical repeat-units. Suitable polymers can be found for instance, among the fiber-forming polyesters which are described in U.S. Pats. Nos. 2,071,250, 3,018,272, and 2,465,319, and various articles such as Wilfong, *J. Polymer Science*, 54, 385-410 (1960). "Non-extended" polyesters that are preferred (i.e., those that exhibit the critical shortened chemical repeat-units in their crystalline regions) are poly(trimethylene terephthalate), polytetramethylene terephthalate), poly(trimethylene dinaphthalate) (trimethylene dinaphthalate throughout the application means trimethylene 2,6-dinaphthalate), poly(trimethylene bibenzoate), copolymers of the above with ethylene sodium sulfoisophthalate, and selected polyester ethers. Poly(ethylene terephthalate), poly(cyclohexyl 1,4-dimethylene terephthalate), copolymers thereof, and copolymers of ethylene terephthalate and the sodium salt of ethylene sulfoisophthalate are the preferred polyesters for the other (more extended) component, but other polyesters such as the corresponding copolymers of ethylene terephthalate containing sebacic acid, or isophthalic acid as well as those containing recurring units derived from glycols with more than four carbon atoms in the chain can be used as well.

When ethylene sodium sulfoisophthalate is used in copolymerized form as one component of a copolyester, it is preferably the minor component, i.e., present in amounts of less than 5 mol percent and preferably present in amounts of about 2 mol percent.

The conformation of the chemical repeat-units in the crystalline region of a number of polymers have been deduced from X-ray and model data.

Table 1 gives the extended chemical and the crystalline repeat unit distances for a number of polyesters.

TABLE 1

Polymer repeat-unit	Repeat-distance (A.) <sup>1</sup>		
	Fully extended chemical	Crystalline chemical	Percent extended
Ethylene terephthalate.....	10.9	10.7	98
Trimethylene terephthalate.....	24.4	18.2	75
Tetramethylene terephthalate.....	13.4	11.7	87
Trans-Cyclohexanedimethylene terephthalate.....	14.7	14.2	97
Ethylene 2,6-dinaphthalate.....	13.4	13.1	98
Trimethylene dinaphthalate.....	14.5	11.5	79
Trimethylene bibenzoate.....	16.6	13.3	80
1,3-Cyclobutane dimethylene terephthalate.....	14.3	13.4	94
1,3-Cyclobutane dimethylene bibenzoate.....	18.6	18	97

<sup>1</sup> Repeat-distance=length of repeat-unit.  
<sup>2</sup> Two units.

Determinations of this nature are accomplished as follows: Measurement of the "Percent extended" parameter is done as follows (the order of steps A and B is immaterial):

#### Step A.—Measurement of crystalline repeat-distance

A parallel bundle of oriented and partly crystalline fibers is mounted in an X-ray beam with the fiber axis

perpendicular to the beam. A flat photographic film is placed in and perpendicular to the X-ray beam at a distance of  $a$  mm. from the fiber array on the opposite side from the X-ray source. The film is suitably exposed and developed to show a "fiber pattern" consisting of a family or more-or-less complete hyperbolae with its axis parallel to the fiber axis, i.e., on the so-called meridian. The distance on the film along this line from the primary-beam image to each hyperbola is measured and designated  $e_n$ ,  $n$  being the ordinal number of the layer line counting away from the equator as zero. The diffraction angle  $u_n$  is defined as  $u_n = \tan^{-1} e_n/a$ . The identity period (Crystalline Repeat) is then simply calculated from

$$\text{I.P.} = \frac{n\lambda}{\sin u_n}$$

where  $\lambda$  is the wavelength of the X-rays used. The above notation follows G. L. Clark, "Applied X-rays," McGraw-Hill, New York (1955), p. 401. The patterns from various polymers and particular values of  $e_n$ , of course, differ.

#### Step B.—Measurement of fully extended chemical repeat-distance

A molecular model of the polymer in question is made from a "Dreiding" scale model kit manufactured by W. Buchi, Flawil, Switzerland. The interatomic bonds along the chain are rotated so as to give the longest straight length along the molecular chain. The distance from any nucleus in the chain to the corresponding nucleus in the next repeat-unit is measured, converted to angstrom units, and designated the Chemical Repeat of the polymer.

#### Step C.—Calculation of percent extended

The Crystalline Repeat Distance from Step A (which is in angstrom units) is divided by the length calculated from measurements in Step B. The result is multiplied by 100 to give the percent extended.

If the result of Step C is greater than 100%, obviously the crystalline chemical repeat-unit consists of more than one chemical repeat-unit. The actual number can sometimes be estimated from geometrical considerations or from a more detailed analysis of the X-ray pattern. Since the crystal repeat must be an integral number of chemical repeats, assigning one chemical repeat therefore gives the maximum possible extension; if there are two chemical repeats, the percent extension would be halved, etc.

The art of preparing composite filaments is well developed and reference may be made to techniques already known for application to the composite filaments of this invention. A partial list of U.S. patents that may be referred to for this purpose includes Breen, 2,987,797; Radow et al., 3,039,174; Breen, 3,038,236; Taylor, 3,038,237; Breen, 2,931,091; and Zimmerman, 3,038,235. In addition, the various spinnerets described in those references as well as the manner of using them may be used in this invention. Others can, of course, be employed.

Referring now to FIGS. 1, 2 and 3, two polyester melts are separately metered (by means not shown) into the two rings of holes designated as 1 and 2, in FIG. 1, in spinneret 4. A sealing means (not shown) prevents mingling of the two melts at the back face 3 of spinneret 4. The two melts flow through individual channels 5 and 6 to the front face 7 of spinneret 4 where they merge into a side-by-side composite filament as they leave the spinneret assembly. The molecular weight of the polyesters used may vary widely and generally will be in the range conventionally employed in the synthetic fiber art. The filament generally is withdrawn from the spinneret at a speed that attenuates the filament, and is thereafter drawn. The conditions applied for drawing the spun composite filaments of this invention may vary in wide limits. In addition to the processes of drawing described in some of the examples given hereinafter, a hot pin may be used, or the yarn may be passed over heated rolls, as additional examples. In general, the precise amount of draw is established by use of

feed and drawing rolls which are driven at the appropriate differential in speed, care being taken to assure that the yarn doesn't slip on either. Two methods for assuring positive control of speed which are appropriate for feeding to or withdrawing from a drawing zone are described in U.S. 3,101,990.

Also, the temperatures at which the composite filaments are drawn may vary in wide limits and depend mostly upon the properties of the polyesters forming the composite filament and of the final desired results. As is the case in the production of conventional unitary filaments, the preferred drawing temperatures for the composite filaments of this invention may vary between room temperature and slightly elevated temperatures; for example, temperatures of about 100° C. or somewhat higher, may be used. Since in the present invention combinations of at least two different polyesters are employed, the specific drawing characteristic of each material should be considered in order to obtain best results. Drawing temperatures which are lower than the glass transition temperature (T<sub>g</sub>) of the several components may be employed where a separate plasticizing step is provided. Moreover, if desired, the drawing and subsequent heat treatment may be coupled in a continuous process to obtain the desired orientation and crystallization.

To obtain maximum crimp properties, the filaments should be crystallized by heating under conditions where in no shrinkage can occur. In other words, the crystallization is effected under conditions of tension which at least equal the forces developed in the filaments during the treatment. Crystallization or length stabilization of the filament components can therefore be accomplished by a heat treatment, i.e., an annealing treatment, of the taut filament. Only a short period of time at the annealing temperature is needed, for example, only a fraction of a second. Extended annealing times are not deleterious, and may be advantageously employed in some instances as will be shown. In the examples given hereinafter, the term "annealing" indicates that the yarn was exposed to the indicated temperature for about 0.1 to 0.5 second while held at constant length unless otherwise indicated.

The filaments as produced upon annealing may be used as such and crimp may be developed in the ultimate product. Alternatively, all the crimp may be developed first, and the crimped product then used, or it may partially be developed prior to use with additional crimp being developable in fabric form. Any conventional hot relaxing step such as a relaxed scour, known in the art, may be employed to develop the characteristic helical crimp.

As will be shown hereinafter, it is desirable for certain end uses, and particularly with staple fibers, to limit the crimp to less than the maximum obtainable. This can be accomplished in a variety of ways, including heat treatment under conditions permitting some relaxation. A preferred procedure for the production of staple fibers of this invention, i.e., short filaments, for use in spun yarn designed for use in knitted fabrics is to permit the drawn filaments to relax at an elevated temperature, e.g., 130–150° C., to develop a somewhat higher level of crimp than desired and then stretch the filaments slightly at room temperature followed by heating in the stretched state at a temperature appreciably higher than the temperature at which the crimp was developed, the degree of stretching being adjusted to give the desired level of crimp in the final product.

The temperature applied in either taut or relaxed treatments should generally be higher than the apparent minimum crystallization temperature of the higher shrinkage component. The apparent minimum crystallization temperature is defined as the lowest temperature at which the fiber may be heated to produce a substantial degree of crystallinity in its structure and is well known or can easily be determined for each polymer. A convenient method for determining the apparent minimum crystallization temperature (T<sub>i</sub>) is described, e.g., in

U.S. 2,578,899. Preferably, however, the apparent minimum crystallization temperature is determined by X-ray diffraction measurements on samples of filaments which have been drawn in cool water to prevent crystallization and which have been subjected to taut heat treatment at progressively increasing temperatures. X-ray diffraction patterns are suitably made using a Warhus camera, such as described by Statton, W. O., "Polymer Reviews," vol. 6, Chapter 6, Interscience Publishers, New York, N.Y. (March 1964). The degree of crystallinity may be judged by direct examination of the diffraction pattern or from radial densitometer traces along the equator of the X-ray diagram. Such a trace will show distinct peaks for fibers having a well-developed crystalline structure whereas with an amorphous structure or with very low degrees of crystallinity the peaks cannot be resolved. The apparent minimum crystallization temperature by this method is the minimum temperature of heat treatment at which a definite crystalline structure is detectable from direct examination of the X-ray diagram or at which distinct peaks are observable in the densitometer trace.

The important characteristic of those polyesters having the crystalline repeat distance 90% or less of the fully extended repeat distance that largely contributes the enhanced and highly unusual properties of the composite filaments of this invention is the effect on crimpability of heating at constant length. For the composite filaments known heretofore, heat treatment at constant length tended to destroy, or at least lessen, crimping characteristics. For the composite filaments of this invention, such heat treatment enhances the crimping characteristic, since the shrinkage differential of the two components will ordinarily be greater after the taut heat treatment than before.

It might sometimes be desirable to spin a bundle of filaments which comprises composite filaments containing the polyester components in various ratios through one and the same spinneret; for example, a bundle of two-component composite filaments which comprises filaments consisting of 20% by weight of the higher shrinkage component and 80% by weight of the other, a 30%/70% ratio, a 40%/60% ratio and a 50%/50% ratio, respectively. Such filament bundles containing composite filaments with various ratios of components can very conveniently be produced by utilizing the spinneret which is shown in FIGS. 6 and 7 of the U.S. Patent to Breen 3,118,011. As a generality and without regard to the type composite filament being produced, the nonextended component usually comprises 20 to 80% of the composite and the other components comprise the remainder. The denier of the resulting product will be that usually produced in this general art, and is not of significance to the invention.

The invention will be described further in conjunction with a series of examples. In the examples, except as otherwise indicated, the terms employed in evaluating polymers and fibers have the following meanings:

Relative viscosity refers to the ratio of the viscosity of a solution of which 100 ml. contains 10 grams of polymer in a solvent of 10 parts of phenol and 7 parts of 2,4,6-trichlorophenol (by weight) to the viscosity of the solvent itself, both measured at 25° C., using a capillary viscometer and expressed in the same units.

Intrinsic viscosity is defined as the limit of the fraction

$$\frac{\ln(r)}{c}$$

as concentration *c* approaches zero, where *r* is the relative viscosity as defined above, except that the relative viscosity is measured at several concentrations to facilitate extrapolation to zero concentration, and the solvent employed in this measurement is a mixture of three parts of methylene chloride and one part of trifluoroacetic acid (by weight). A more detailed discussion of methods of measuring relative and intrinsic viscosities is

given in Preparative Methods of Polymer Chemistry, Sorenson & Campbell, Interscience, 1961.

Skein shrinkage is determined by the following procedure:

(1) From the known denier of the yarn, calculate the number of turns of a skein reel required to achieve a skein with a denier of 1500 (167 tex.) (the circumference of the reel may be any convenient length), using the formula

$$T = \frac{1500}{d}$$

where T designates turns on the skein reel and d is denier of the yarn; round off to the nearest integral number of turns. Prepare and label a skein from each yarn to be tested. It will be obvious that such a skein must be considered as 3000 denier (334 tex.) when loaded as a loop.

(2) Hang the skein and apply a 300-gm. weight at the bottom of the loop. Exercise gently by raising and lowering four times. Wait 15 seconds and measure initial length of the skein ( $L_0$ ).

(3) Replace the 300-gm. weight with a 4.5-gm. weight and immerse the skein in boiling water for 15 minutes. Remove from bath.

(4) Remove the load and allow the skein to hang without load for 1 hour or more to dry. Replace the 4.5-gm. load, exercise by pulling down, and measure crimped length ( $L_c$ ).

(5) Reapply the 300-gm. load, exercise and measure extended skein length as in 2 above ( $L_e$ ).

(6) Calculate skein shrinkage by the formula

$$SS = \frac{(L_0 - L_e) 100}{L_0}$$

Crimp development—Calculate from data obtained in the skin shrinkage procedure by the formula

$$CD = \frac{(L_e - L_c) 100}{L_e}$$

Crimp elongation—Determine by the procedure employed in skein shrinkage with the addition of one more step: after measurement of  $L_e$  (Step 5), the 300-gm. load is replaced by the 4.5-gm. load and a second measurement of recovered length under the smaller load is made as in Step 4 of that procedure ( $L_r$ ). Crimp Elongation is calculated by the formula

$$CE = \frac{(L_e - L_r) 100}{L_r}$$

#### EXAMPLE I

This example illustrates batch preparation of poly(trimethylene terephthalate), coded herein PPT polymer.

Catalyst for this preparation is prepared as follows: Sodium (2.5 gms.) is dissolved in 300 ml. of n-butanol. Tetrabutyl titanate (37 gms.) is then added and the mixture diluted to 500 ml. with n-butanol.

Dimethyl terephthalate (5.45 kg.) and trimethylene glycol (4.54 kg.) are heated for 100 minutes at 225° C. in the presence of 99 cc. of the stock catalyst solution described above. During this time, 1.8 kg. of methanol are removed. The resulting low molecular weight material, to which a small amount of titanium dioxide has been added as a delusterant, is heated further, with stirring, for 6 hours at 250° C. under an absolute pressure of 0.4 mm. of mercury during which time the glycol evolved during further condensation is removed. The resulting polymer has an intrinsic viscosity of 0.71.

Poly(trimethylene terephthalate) can be made in a variety of ways, many of which are well-known in the art. Since the process detail employed in its manufacture is not critical to the utility of PPT polymer in practice of this invention, polymer made by several processes has been employed herein indiscriminately.

#### EXAMPLE II

This example illustrates a means of enhancing the molecular weight, as evidenced by an increase in intrinsic viscosity, of a polymer such as that prepared in Example I.

PPT polymer of less than 1.0 intrinsic viscosity is cut twice to pass through a 1/8 inch mesh screen, dried 6 hours at 150° C. and placed in a vessel through which inert gas is passed. The inert gas and vessel are heated to 180° for two hours, then to 200° C. for an additional 12 hours. The polymer and apparatus are then cooled and the polymer removed. The intrinsic viscosity of the finished polymer is 1.29. A second batch of this polymer is prepared and found to have an intrinsic viscosity of 1.36.

Polyethylene terephthalate (PET polymer) may be prepared by any of a variety of procedures known in the art, such as one of the methods taught by Whinfield and Dickson in U.S. Pat. 2,465,319, or one of the methods of Griffing and Remington described in U.S. Pat. 3,018,272. While each of these methods may have merit over another in some respect such as in the production of a whiter polymer or in improved space-time yield, these differences are not critical to the purpose of this invention. PET polymer employed in these examples has accordingly been derived from several procedures as dictated only by convenience and availability.

#### EXAMPLE III

Examples III and IV illustrates a preferred process for preparation of a bicomponent fiber of this invention.

The blended PPT polymers of Example II, and a PET polymer of 18 relative viscosity are cospun at 280° C. from a 34-hole spinneret similar to that described in FIG. 14 of U.S. Pat. 3,117,362; this is a pre-coalescence spinneret, that is, one in which the two melts are brought together just behind each extrusion capillary. The filaments are withdrawn from the spinneret at 468 y.p.m., drawn 4.70× (that is, to 470% of their original length) at 93° C., and annealed at 170° C. The 68 denier (7.6 tex.) yarn has a skein shrinkage of 12%, crimp development of 55% and crimp elongation of 106%.

#### EXAMPLE IV

A 34-filament bicomponent yarn is prepared from a PPT polymer of 1.2 intrinsic viscosity and a PET polymer of 20 RV in a ratio of 40/60, by cospinning at 280° C. from the post-coalescent spinneret shown in the drawing. The filaments are withdrawn from the spinneret and wound up at 820 yards per minute. The spun yarn is drawn 3.982× at 107° C. and annealed at 150° C. Properties of the yarn are: denier 63, tenacity 3.2 g.p.d., elongation to break 11%, skein shrinkage 16%, crimp development 52%, crimp elongation 95%. Contrary to the procedure generally used herein, the latter three measurements are made at 1.4 mg./den. restraint rather than the standard 1.5 mg./den. restraint. (See procedures for these measurements above in which a 4.2 gm. weight would be used wherever a 4.5 gm. weight is specified.) Another sample of the spun yarn drawn 3.982× at 107° C. is annealed at 175° C. The yarn has a skein shrinkage of 13%, a crimp development of 58%, and a crimp elongation of 106% (the last three measurements also being made at 1.4 mg./den. restraint).

#### EXAMPLE V

This example illustrates suitability of a copolymer as the outer component of the composite fiber of this invention.

A PPT polymer of 1.47 intrinsic viscosity and a copolymer of 98% PET and 2% ethylene sodium sulfoisophthalate of 15.5 relative viscosity, prepared by the general procedure of U.S. Pat. 3,018,272 are employed in this example.

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The two polymers are melted and simultaneously extruded at 288° C. as in Example III. The 34 composite filaments are withdrawn at 700 yards per minute, drawn to 365% of their original length at 94° C. in a water bath substantially as described in U.S. Pat. 3,091,805 and annealed at 190° C. at constant length. Properties of the 70-denier (7.8 tex.) yarn are: tenacity 3.5 g.p.d., elongation to break 16%, skein shrinkage 8%, crimp development 55%, and crimp elongation 103%.

## EXAMPLE VI

This example illustrates suitability of a copolymer as the inner component.

A 34-filament bicomponent yarn is prepared from a copolymer of PPT with 2 mol percent sodium sulfoisophthalate of 1.25 intrinsic viscosity and PET polymer of 20 RV in a ratio of 40/60, by cospinning from a post-coalescing spinneret at a temperature of 284° C. The filaments are withdrawn at 1080 yds./min., drawn in an 87° C. bath 2.37× (or 237% of their undrawn length) and annealed at 182° C. The properties of the yarn are: denier 72 (8 tex.), tenacity 1.7 g.p.d., elongation to break 17%, skein shrinkage 19%, crimp development 46% and crimp elongation 67%.

## EXAMPLE VII

This example illustrates the suitability of alternative polymers in the preparation of fibers of this invention.

In Table 2, the codes employed to represent the polymers have the following meaning:

PPB=poly(trimethylene bibenzoate)

PCHT=poly(trans-cyclohexanedimethylene terephthalate) (solid-state polymerized in accordance with Ex. II)

PPN=poly(trimethylene 2,6-dinaphthalate)-using as catalyst a mixture of Mn(OAc)<sub>2</sub> and Ti(OBu)<sub>4</sub>

PET=poly(ethylene terephthalate)

PBT=poly(tetramethylene terephthalate)

PPT=poly(trimethylene terephthalate) (solid state polymerized in accordance with Example II)

Except for the PET polymers and except as noted above, the polymers of this example are made in accordance with the procedure employed in Example I. They are all spun from post-coalescence spinnerets. Items *a* and *c* are drawn dry substantially as described in U.S. Pat. 3,101,990, in which process the yarn, lubricated with a textile finish, is passed at a uniform rate to and over a surface heated to the temperature indicated in Table 2 to heat the yarn to the desired drawing temperatures and then passed over a snubbing pin where drawing tension is applied by the drawing rolls which withdraw the yarn at the appropriately higher speed to produce the desired degree of draw. Item *b* is drawn by the process of Example V. Items *d* and *e* are drawn in a jet in which steam is introduced at a rate sufficient to open the bundle by turbulence and, thereby, heats each filament uniformly to drawing temperature. As is indicated in the data, some of the fibers are annealed at more than one temperature, illustrating the improved crimp development obtained at higher temperatures of annealing.

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## EXAMPLE VIII

This example illustrates further the unusual response of bicomponent fibers of this invention to annealing.

PET polymer of 19 relative viscosity and PPT polymer of 1.42 intrinsic viscosity are cospun at 287° C. from a post-coalescence spinneret. The filaments are withdrawn at 700 y.p.m. The spun yarn is drawn at several draw ratios and annealed, in some cases at several temperatures. Data are summarized in Table 3. It should be noted that Item VIII-c is a PET polymer homofiber which has been twisted, heat-set and untwisted by a commercial means available in the art. It is clearly seen that imposition of a small additional draw and heat-setting on Item VIII-b brings about a measurable improvement in crimp properties, while the crimp of Item VIII-c is essentially destroyed by an identical treatment.

TABLE 3

Item	Draw ratio	Anneal temp., ° C.	Skein shrinkage, percent	Crimp development, percent	Crimp elongation, percent	
VIII-a-----	2.11	None	7.9	6	7	
		120	5.3	8	9	
		140	4.0	11	12	
		160	3.0	12	14	
VIII-b-----	2.57	None	13.5	14	17	
		180	7.6	35	52	
		(1)	180	10.5	46	79
		(2)	216	4.3	39	63
VIII-c-----	2.91	None	6.2	6	7	
		180	18.3	18	21	
		180	11.6	51	94	
		None	18.9	19	27	
VIII-d-----	3.08	None	19.8	30	52	
		140	15.0	50	85	
		180	12.9	63	100	
		None	20.5	21	25	
VIII-e-----	3.20	None	14.9	61	130	
		180	14.9	61	130	

<sup>1</sup> 2.57×1.147=2.94.

<sup>2</sup> Draw ratio not known, approximately 3.2.

The next three examples illustrate the unsuitability of bicomponent fibers more typical of the art.

## EXAMPLE IX

A PET polymer of 22 relative viscosity and an 85/15 copolymer of PET/polyethylene sebacate (PET/PES) of 21.1 relative viscosity are spun from a post-coalescence spinneret at 280° C. to 34 side-by-side bicomponent filaments comprising 40% PET/PES and 60% PET. The filaments are withdrawn at 600 yards per minute. They are drawn at 90° C. to 460% of their original length.

A portion of the yarn is not annealed at high temperature. A second portion is annealed at 160° C. while held at constant length. Table 4 summarizes the yarn properties obtained.

TABLE 4

Property	Annealing temperature, ° C.	
	None	160
Denier (tex.)-----	67 (7.5)	67 (7.5)
Skein shrinkage, percent-----	22	5
Crimp development, percent-----	8.6	0.4
Crimp elongation, percent-----	3.8	0.4

TABLE 2

Item	Polymeric components, viscosity		Polymer ratio	Spin temp., ° C.	Draw ratio	Draw temp., ° C.	Anneal temp., ° C.	Den./ fil.	Tenacity/ elongation	Skein shrinkage, percent	Crimp development, percent	Crimp elongation, percent	
	Inner	Outer											
VII-a-----	PPB (.88)	PCHT (.67)	50/50	292	3.45	107	160	71/34	1.3/10	2	24	40	
VII-b-----	PPN (.67)	PET (18) †	50/50	268	3.28	92	180	73/34	1.2/7	2	31	64	
							135	99/34	2.4/16	9	17	22	
							160	99/34	2.4/17	5	22	30	
VII-c-----	PBT (1.1)	PET (20) †	40/60	278	4.216	110	None	60/34	3.8/15	16	19	20	
							110	125	60/34	4.2/13	16	23	24
							110	150	58/34	4.6/17	13	29	36
							110	175	58/34	4.2/13	11	33	47
							110	200	58/34	4.3/16	9	39	53
VII-d-----	PPB (.88)	PET (18) †	50/50	282	4.60	100	180	73/34	2.0/9	3	15	21	
							100	180	89/34	1.5/8	2	27	45
VII-e-----	PPT (1.34)	PCHT (.67)	50/50	308	3.57	100	180	89/34	1.5/8	2	27	45	

† Relative viscosity; all others intrinsic viscosity.

NOTE.—Items *a*, *b*, *d* and *e* spun at 600 y.p.m.; Item *c* spun at 640 y.p.m.



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It is seen that the crimp properties are not outstanding in this fiber in the absence of annealing, and essentially all tendency to crimp is lost by annealing to reduce the high shrinkage, at a temperature which leads to enhanced crimp characteristics in the fiber of this invention.

## EXAMPLE X

Two PET polymers, one of greater than 100 relative viscosity and the other of 21 relative viscosity are cospun at 297° C. through a 34 hole spinneret such as indicated in the previous examples. The fibers are withdrawn at 840 y.p.m.

The spun yarn is drawn at 100° C. at the maximum operable draw ratio, established by slowly increasing the draw ratio until the yarn breaks, then restringing at a slightly lower ratio (4.08). Samples of yarn are also prepared at somewhat lower ratios for comparison. Table 5 summarizes the data obtained.

TABLE 5

Item	Draw ratio	Anneal temp., °C.	Skein shrinkage, percent	Crimp <sup>1</sup> development, percent	Crimp <sup>1</sup> elongation, percent
X-a	4.08	None	12.6	1.2	1.4
		120	8.3	0.7	0.5
		140	5.8	1.3	0.9
		160	3.5	0.5	0.5
X-b	3.52	180	3.0	0.9	0.5
		None	11.6	1.0	1.2
X-c	3.08	180	1.7	0.7	0.7
		None	12.2	1.0	1.2
		180	1.7	1.0	1.1

<sup>1</sup> Differences indicated in these actual data are insignificant.

It is clearly seen that essentially no crimp is developed by the fiber of this example under the standard conditions for measurement of crimp development.

## EXAMPLE XI

In another evaluation of some of the yarns of Example X at zero load (vs. the standard 4.5 gm. load employed in all other evaluations), it is seen that a moderate level of crimp is achieved (Table 6). It is apparent that because of its inability to develop crimp under the nominal 1.5 mg./den. (4.5 gms./3000 den.) loading employed in the routine test, the fibers of this example will have no utility for preparation of bulky or elastic woven fabrics. Such a level of restraint, or more, is imposed by the fabric structure. Such bicomponent fibers may confer useful bulk and slight stretch in knits wherein restraint is less.

TABLE 6

Item	Draw ratio	Anneal Temp. °C.	Skein Shrinkage, percent	Zero-load crimp	
				Development, percent	Elongation, percent
X-a	4.08	None	10.3	15.6	10.7
		180	3.0	13.7	8.5
X-c	3.08	None	12.9	6.5	5.8
		180	5.5	18.6	12.5

The next two examples disclose alternative processes by means of which the unusual behavior of polyesters having non-extended crystallinity may be exploited in bicomponent fibers. Example XII illustrates preparation of yarn in which the ratio of the two polymeric components varies from filament-to-filament. Example XIII illustrates the utility of such non-extended crystallinity in bicomponent fiber having a random distribution of the two components both filament-to-filament and along any given filament.

## EXAMPLE XII

In one experiment, a PPT polymer and a PET polymer are cospun in a pre-coalescence spinneret similar to that employed in Example III, except that a doughnut-shaped

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meter plate is inserted above the ring of conduits feeding PET polymer to the point of coalescence. The meter plate is carefully aligned so that one hole in the meter plate is centered over each of the 34 PET-melt conduits. As is indicated in Table 8, the meter-plate holes vary in diameter so that the rate of flow of the PET melt toward the coalescence point varies widely. No change is made in the rate of pumping the melts to the spinneret, so that the overall denier and the denier-per-filament remain substantially constant, only the ratio of the two polymers in the individual filaments being variable. (PPT/PET ratio in the bundle as a whole is 40/60.) Spinning conditions and yarn properties are given in Table 8A. Examination of a cross section photomicrograph shows a polymer distribution among the filaments which is substantially in agreement with that calculated from the meter plate orifices (see Table 8).

TABLE 8

Hole diameter (inches)	Number of holes with this diameter	Percent of total	Calculated polymer ratio PET/PPT
5 mil	5	14.7	17/83
6	5	14.7	26/76
7	6	17.6	34/66
8	6	17.6	44/56
9	6	17.6	56/44
10	6	17.5	69/31

In a second experiment, the run is repeated using the same spinneret except that the meter plate is omitted. Spinning conditions and yarns properties for this experiment are also given in Table 8A.

TABLE 8A

	With meter plate	Without meter plate
PPT intrinsic viscosity	1.41	1.68
PET relative viscosity	18	20
Spinning temperature, °C.	275	285
Spinning speed, y.p.m.	717	587
Draw ratio	3.63	4.36
Draw temperature, °C.	93	93
Annealing temperature, °C.	180	185
Yarn denier	70	71
Tenacity, g.p.d.	3.1	4.3
Elongation, percent	9	24
Skein shrinkage, percent	9	15
Crimp development, percent	27	68

The yarns of Table 8A and a commercial PET yarn of the same count which has been twisted, heat-set and untwisted are each doubled and knitted into a 4½"-diameter tubing on a circular knitting machine. The fabrics are scoured in boiling water, dried and evaluated (results given in Table 8B) as follows:

**Bulk:** A single thickness of the fabric is laid on a base surface of precise flatness and a glass disc, having a weight of 3 gms./cm.<sup>2</sup> and precisely parallel faces, is laid on the fabric. Exact measurements of the height of the upper face of the disc from the base surface are compared with the height of the upper face of the disc when laid directly on the base surface. The volume of fabric beneath the glass disc is then determined by a simple calculation and compared with the weight of the same fabric area. Bulk is expressed in terms of cubic centimeters per gram.

**Stretch and recovery:** Values in Table 8B other than bulk are read from an Instron chart prepared as follows: The knit tubing denier is determined. The cross-head of an Instron is set at 2" separation and the fabric sample inserted. The instrument is run at 2" per minute (100% per minute) separation and the stress recorded on a chart moving at 10" per minute and registering a full scale deflection on application of a stress of 0.005 g./denier. Once full-scale deflection is reached, the cross head motion is immediately reversed and returned to the original 2" sep-

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aration. From the plots of stress vs. percent stretch, stretch recovery is read as

$$\frac{\text{recovered stretch}}{\text{total stretch}} \times 100$$

Work is the area under the curve and is calculated as

$$f \text{ stress (mg./denier)} \times dl_f \text{ (in.)}$$

where  $dl_f$  is change in fabric length.

Work recovery is calculated as

$$\frac{\text{work on recovery cycle}}{\text{work on stretch cycle}} \times 100$$

TABLE 8B

	Yarn with meter plate	Yarn without meter plate	Twist-heat-set Untwist PET
Stretch, percent (at 5 mg./den. stress)	111	112	75
Stretch recovery, percent	91	90	93
Work, mg. in./denier	4.4	5.6	3.2
Work recovery, percent	41	48	50
Bulk, cm. <sup>3</sup> /g.	8.7	4.5	8.7

It can be seen that the yarn with meter plate is nearly

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zero restraint. Microscopic examination of filaments prepared in this manner shows them to have varying distribution of the two polymers along their lengths and across their cross sections (including a few sections that are composed entirely of one individual polymer).

## EXAMPLE XIV

This example illustrates the importance of relative molecular weight between components to development of the desired crimp properties. In general, for maximum crimp development, it has been found that the higher shrinkage component must have the higher melt viscosity at the temperature of spinning. This is conveniently attained with a higher molecular weight as indicated by relative or intrinsic viscosities. Withing the spinnable range of molecular weights for the pair of components, the greater the difference in molecular weight the better the crimp properties.

A PET polymer having a relative viscosity of 19 is spun to 34 filament yarn with each of three PPT polymers similarly prepared to have differing intrinsic viscosities as noted. Data are summarized in Table 9. In items XIV-a, b and c, a 40/60 ratio of polymers is used, and the fibers are annealed at two temperatures, further illustrating the effect of this variable. In another experiment, a PPT polymer of 1.79 intrinsic viscosity is cospun in a 50/50 ratio with each of the two PET polymers, having different relative viscosities as noted. The effect of molecular weight ratio on properties for both series of experiments is summarized in Table 9.

TABLE 9

Example	XIV-a	XIV-b	XIV-c	XIV-d	XIV-e
Inner component	PPT	PPT	PPT	PPT	PPT
Intrinsic viscosity	1.09	1.34	1.48	1.79	1.79
Outer component	PET	PET	PET	PET	PET
Relative viscosity	19	10	19	20	29
Cross section ratio	40/60	40/60	40/60	50/50	50/50
Spin temp., ° C.	288	288	288	295	295
Spin speed, y.p.m.	544	544	544	850	860
Draw ratio	4.78	4.78	4.78	3.0	3.0
Draw temp., ° C.	95	95	92	192	92
Annealing temp., ° C.	195	140	195	140	185
Denier/(tex.)	70 (7.8)	71 (7.9)	71 (7.9)	70 (7.8)	73 (8.1)
Tenacity/elongation (gm./den.), percent	4.3/21	3.9/21	4.5/20	3.5/18	4.4/21
Crimp development, percent	35	9	45	20	58
Crimp elongation, percent	51	10	74	24	105
Skein shrinkage, percent	10	15	12	17	16

† Estimated value.

equal in stretch properties to that without it, and is clearly superior in bulk. Either fiber of this invention is superior to the commercial fiber in percent stretch and work, and essentially equivalent in other properties. The fiber made with the meter plate was equivalent to the commercial fiber in bulk.

## EXAMPLE XIII

A PPT polymer of 1.29 intrinsic viscosity and PET polymer of 18 RV are melted separately and fed in alternating increments of .043 gm. each to a standard all-screen spinning pack of the type commonly used in spinning homofiber yarns. The mixture is extruded through a spinneret of 100 holes, each 15 mils in diameter and 17 mils in depth, at 280° C. and wound up at 1001 yds./min. as two 50 filament yarns. The multifilament yarn is subsequently drawn 3.21× at 100° C. and annealed at 170° C. The drawn yarn is found to possess a randomly variable crimp among the individual filaments, and the crimp is accentuated by further heat treatment under low or

## EXAMPLE XV

This example illustrates performance in fabric found typical of the fiber of this invention.

Two bicomponent fibers, XV-a and XV-b, prepared from PPT of 1.4 intrinsic viscosity and PET of 21 and 20 relative viscosities, respectively, and the fiber of Example III (XV-d) are processed into plain taffeta fabrics. Table 10 summarizes the data obtained. A plain-weave fabric, XV-c, made of a PET yarn which had been twisted, heat-set and untwisted by a commercially available process is included for comparison.

It is apparent that the elongation, or stretch, and stretch-power of fabrics from the fibers of this invention (XV-a, b, d) are much higher than those of the fabric of the prior-art fiber. This improvement in elongation was obtained without sacrifice in recovery from maximum stretch. Furthermore fabrics XV-a, b, d, all had a smooth, flat surface similar to normal taffeta or broadcloth fabrics, but the prior-art fabric had a fine surface pucker resembling a crepe. Fabric XV-c could have been heat-set at a narrower width to give a higher finished warp count and increased fabric elongation, but the fabric surface in this case would have been so badly puckered and deformed as to be totally unacceptable for textile uses.

TABLE 10

Item	Spin speed, y.p.m.	Spin temp., °C.	Draw ratio	Draw temp., °C.	Draw temp., °C.	Annual Den. (lbs./in. of fabric)	Skain shrinkage, percent	Crimp development, percent	Crimp elongation, percent	Loom const'n, #X/F	Finished const'n, #X/F	Percent recovery in 1 minute from max. stretch <sup>1</sup>	Percent elongation 16% emulsion load, lbs./in. fabric width	Stress at 16% emulsion load, lbs./in. fabric width	Stress at 50% of total stretch, lbs./in. of fabric width
XV-a	660	268	3.70	90	190	71/34	15	55	98	104X70	172X70	99.5	38.8	.99	1.40
XV-b	724	268	3.63	92	187	70/34	13	62	123	104X70	176X70	99.5	40.8	.76	1.30
XV-c						(Ward)				96X68	110X76	99.9	15.7	.....	.62
XV-d	468	280	4.7	93	170	68/24	12	55	106	104X70	164X84	99.7	30	1.34	1.34

<sup>1</sup> Maximum stretch is taken as that extension resulting from 2 lbs./in. load.  
<sup>2</sup> Estimated value.  
<sup>3</sup> Ward.  
<sup>4</sup> Full.

EXAMPLE XVI

This example illustrates the use of a cospun antistatic material in the practice of this invention. PPT polymer (93.2 parts) of 1.53 intrinsic viscosity, in the form of flake ground to pass a 1/8" mesh screen is blended with six parts of finely divided polyethylene glycol of 20,000 molecular weight and 0.8 part of a commercial polyphenol antioxidant by tumbling the three materials together. This physical mixture is designated PPT-A. Mixture PET-A, comprising 93.2% PET polymer of 26 relative viscosity, 6% of the same polyethylene glycol and 0.8% of the same antioxidant, is prepared in a parallel manner. In the data given hereinafter, PPT and PET indicate the foregoing polyester polymers free from those additives.

Using the process of Example XII, two 34-filament bicomponent yarns are prepared with a non-uniform ratio of components filament-to-filament, using the foregoing polymer compositions as the two components, and drawing to varying extents. These yarns are knitted on a 4 1/2" diameter circular knitting machine. The resulting fabrics are scoured in boiling water, dried and evaluated for bulk properties. These variable-ratio products and a similar product having no co-spun antistat are identified in Table 11 opposite "Fiber Composition" by the prefix "V-".

Two more products are prepared by the procedure of Example III to result in a 40/60 ratio of PPT component to PET component, in one instance employing PPT/PET-A and in the second instance using PPT-A/PET-A. The evaluation data obtained on these preparations are summarized in Table 11.

TABLE 11

Fiber composition	V-PPT-A/PET		V-PPT-A/PET-A		V-PPT/PET		PPT/PET-A	
	PET	PET-A	PET	PET-A	PET	PET-A	PET-A	PET-A
Draw ratio	2.8	3.9	4.1	4.9	4.1	4.9	4.2	4.2
Skain shrinkage (percent)	11	11	12	11	12	11	11	11
Crimp elongation (percent)	15	27	63	164	63	164	185	185
Crimp development (percent)	11	19	35	69	35	69	63	63
Tenacity (gms./den.)	2.3	3.1	3.4	4.3	3.4	4.3	4.0	4.0
Elongation (percent)	17	33	24	19	24	19	25	25
Initial Modulus (gms./den.)	19	36	21	62	21	62	44	44
Stretch (percent)	124	118	148	.....	148	.....	.....	.....
Recovery (percent)	94	94	97	.....	97	.....	.....	.....
Work (mg.-inches/den.)	4.0	4.1	4.7	.....	4.7	.....	.....	.....
Work Recovery (percent)	50	47	51	.....	51	.....	.....	.....
Bulk (cc./gm.)	6.4	6.0	6.4	.....	6.4	.....	.....	.....
Static propensity <sup>1</sup> :								
Initial Charge (kV)	3.7	4.4	.....	3.3	4.6	.....	.....	.....
Discharge:								
t <sub>1/2</sub> (sec.)	0.6	0.6	.....	2.0	0.5	.....	.....	.....
t <sub>100</sub> (sec.)	7	3	.....	33	24	.....	.....	.....

<sup>1</sup> Initial charge developed in 420 seconds at the center of a 3" x 6" (76 x 152 mm.) strip of fabric to the ends of which is impressed a potential of 5,000 volts.  
 Note.—Discharge, t<sub>1/2</sub>=time in seconds for the center portion of the fabric to drop to 1/2 of its charged potential after the two clamps are grounded. t<sub>100</sub>=time in seconds for the center portion of the fabric to drop to 500 volts after the clamps are grounded.

It is apparent from the data in Table 11 that the valuable properties of the filament of this invention are not impaired materially by the presence of a cospun antistat such as polyethylene glycol.

EXAMPLE XVII

This example illustrates thermal relaxing to modify shrinkage and crimp development of the yarn to produce attractive bulky low stretch woven and knitted fabrics. A 34-filament bicomponent yarn is prepared from PPT of 1.4 intrinsic viscosity and PET of 24 relative viscosity

by co-spinning at 293° C. from a pre-coalescing spinneret similar to that of Example III in conjunction with a meter plate as described in Example XII but having a 50/50 PPT/PET ratio. The filaments are withdrawn from the spinneret at 671 y.p.m. (612 m./min.), drawn to 382% of their spun length in an aqueous bath at 92.5° C., and annealed on rolls at 130° C. The bundle is led to a jet fed with 65 p.s.i. air at 203° C., where the yarn relaxes 17%, and wound up at 2130 y.p.m. (1945 m./min.). Yarn properties are: denier 64.7, tenacity 3.0 g.p.d., elongation 39.9%, crimp development (CD) 7.3%, skein shrinkage (SS) 3.7%.

Knitted and woven fabrics from these yarns have good bulk but low stretch and low width losses on finishing, reflecting the low CD and the low SS, respectively. Knitted tubing prepared from these yarns by the process of Example XII have the following properties: basis weight 4.7 og./sq. yd. (159 gms./m.<sup>2</sup>) bulk 6.8 cm.<sup>3</sup>/gm., stretch 87% (5 mg./den. stress), stretch recovery 87.5%, power 1.0 mg./den. (at ½ maximum extension).

#### EXAMPLE XVIII

This example illustrates thermal relaxing to modify the shrinkage and crimp development of the yarn to produce bulky, stretch, knitted and woven fabrics with intermediate stretch and stretch power and low width losses on finishing. The properties reflect the intermediate level of CD and the low level of SS in this yarn.

A 34-filament bicomponent yarn is prepared from PPT of 1.2 intrinsic viscosity and PET of 22 relative viscosity by co-spinning at 302° C. from a precoalescing spinneret similar to that of Example III, using a 50/50 PPT/PET ratio. The filaments are withdrawn from the spinneret at 535 y.p.m. (489 m./min.) then drawn to 480% of their spun length in an aqueous bath at 93° C., annealed on rolls at 130° C. and wound up. The yarn is subsequently removed from the package at 2800 y.p.m. (2560 m./min.) and fed into a jet employing air at 70 p.s.i.g. and 400° C., relaxed 11% and wound up at 2500 y.p.m. (2280 m./min.). Yarn properties are: Denier 148.4, tenacity 3.7 g.p.d., elongation 34.6%, CD 23.1%, SS 4.6%.

Knit tubing prepared as in Example XII had the following properties: basis weight 3.7 oz./yd.<sup>2</sup> (126 gms./m.<sup>2</sup>), bulk 8.7 cm.<sup>3</sup>/gm., stretch 96% (at 5 mg./den. stress), stretch recovery 92%, power 1.4 mg./den. (at ½ maximum extension).

#### EXAMPLE XIX

This example illustrates the utility of this yarn in the production of novel fabric textures.

A 34-filament yarn is prepared from PPT of 1.4 intrinsic viscosity and PET of 30 relative viscosity by co-spinning at 297° C. from a precoalescing spinneret similar to that employed in Example III, using 50/50 PPT/PET ratio. The filaments are withdrawn from the spinneret at 700 y.p.m. (639 m./min.), drawn to 370% of their spun length in an aqueous bath at 92° C., and annealed on rolls at 180° C. Yarn properties are: denier 70, tenacity 3.6 g.p.d., elongation 21.4%, CD 10%, SS 3.0%. This yarn is used to prepare a knitted fabric by the procedure of Example XII. When the fabric is boiled-off, severe surface distortions result, giving a novel, heavily creped appearance.

It will further be obvious that fiber deniers and crimp properties may be altered for specific end-uses, that polymer inherent (or intrinsic) viscosities may be varied (e.g., to control strength and pilling) and that other fiber and polymer modifications, such as have been taught in the art, may be employed in the practice of this invention without departing from the scope thereof.

It has been shown that this invention is useful in the production of composite filaments of high crimp development and superior crimping force with filaments find advantageous utility in many types of fabrics. It has also been shown that under appropriate processing conditions filaments with less than maximum crimp development may also be prepared, which filaments also have utility in important textile applications. Both types of filaments although distinctly different in crimp properties, offer advantages over other crimpable fibers known in the prior art in the uses for which they are intended.

Low crimp filaments made according to this invention are particularly useful in the form of staple fibers in which they possess many of the attributes of wool and can be used to produce bulky fabrics with wool-like tactile aesthetics either alone or in fiber blends with wool and other man-made fibers.

The inherent differences in characteristics of and textile processes leading to staple-spun yarns, as compared to continuous filament yarns, are reflected in differing requirements for the fibers which constitute those yarns. High-crimp filament yarns make attractive, bulky and aesthetically pleasing fabrics. Staple fibers with similar crimp properties are boardy, harsh and aesthetically undesirable in typical worsted yarn and fabric constructions. As will be illustrated, lower crimp frequency (CF) and crimp development in staple fibers lead to attractive, bulky, wool-like fabrics. CF is measured as crimps per extended inch after boil-off under 1.5 mg./den. load. These crimp properties may be lowered in a variety of ways, including reduction of molecular weight (hence orientation) of the inner, non-extended, component relative to the outer component; reduction of the ratio of the inner to the outer component in the fiber cross section; changes in the disposition or configuration of the two components in the fiber; reduction of processing temperatures, draw-ratio, or time of exposure to elevated temperatures during constant-length processing of the filaments; controlled or free relaxation of the fiber at elevated temperatures during processing; and by other methods which will be apparent to those skilled in the art.

Another required property of staple fibers which is relatively unimportant in filament yarns is the initial crimp as estimated by crimp index (CI). In this specification, CI is measured in a manner identical to that for CD except that the boil-off step is eliminated. Thus, CI is a measure of the crimp available during processing of the fiber to yarn. The amount of initial crimp has a pronounced influence on the efficiency of processing a staple fiber to a spun yarn. Excessive crimp in fiber intended for cotton-system or worsted-system processing leads to nonuniform carding and neppy, poor quality yarn. A preferred embodiment of this invention is a crimpable staple with  $CI < 8$ ,  $9 < CF < 15$ , and  $5 < CD < 15$ . Such fibers may be processed either as staple or as tow, the resulting yarns offering knitted and woven fabrics of good uniformity, high bulk and wool-like tactility.

While CI is an important parameter for controlling processibility and CF plays a major role in determining ultimate aesthetics, CD is a major determinant of fabric bulk. Maximum bulk is attained in fabrics when most of the crimp is developed in yarn or fabric, as opposed to staple or tow, form. Development of bulk in a yarn or fabric, depends upon the crimpability of the fiber at elevated temperatures under the restraints imposed by the yarn or fabric construction. It is characteristic of the fibers of this invention that while tensions up to 1 g.p.d. may reduce the initial crimp (CI) of the fiber, such tensions have little or no effect on the ultimate, or developable, crimp (CD). Thus, it is possible to start with a tow of, say, 10% CI, 8% CD, and to process that tow through a Pacific converter, pin drafting, roving and spinning to produce a yarn in which the fibers have CI of about 5% but a retained CD of 8%. Such fibers would be considered "crimpable" in this context even though originally CI exceeded CD. A convenient test of crimpability in this context may be carried out by measuring CI and CD as previously described but subjecting the fibers to a load of 1 g.p.d. for 30 minutes before measuring CI and then boiling off the fiber and measuring CD in the normal manner. The staple or tow fiber will be classified as crimpable if CD is greater than CI after this procedure.

It is also important that crimp frequency be stable to (i.e., resilient under but not appreciably changed by) the loads, temperatures and plasticizing agents the fibers may be subjected to in processing and ultimate use. In a crimp-frequency-stable fiber CF as measured in the test corresponds to that of the surface fibers (which largely determine tactility) after, for example, yarn or fabric boil-off (where loads encountered by the external fibers would be significantly lower than those encountered by internal

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fibers or in the test), heat setting, or dyeing. Such stability appears as a unique advantage of fibers of this invention, which rely on differences in crystalline conformation. Typical bicomponent fibers of the art, crimp to varying frequency depending on environmental conditions to which they are subjected.

While most of the immediately foregoing discussion and the following examples are related to woolen and worsted staple processing and fabrics, similar advantages can be attained in blends with cellulose and other fibers blended with suitably crimped and/or crimpable staples of this invention and processed on the cotton system, for example.

## EXAMPLE XX

This example illustrates the utility of the fibers of this invention in preparation of worsted fabrics of improved bulk and tactility.

A 98/2 mol-ratio copolymer of PPT and ethylene sodium sulfo-isophthalate of 0.63 intrinsic viscosity and a 98/2 mol-ratio copolymer of PET and ethylene sodium sulfo-isophthalate of 15.0 relative viscosity are spun in a 35/65 ratio to side-by-side round bicomponent fibers as in Example V, except that extrusion temperature is 290-295° C. and windup speed is 530 y.p.m. (485 m./min.). The filaments are drawn to 364% of their spun length in a bath of water at 83° C. and annealed at constant length at 180° C. for 28 seconds. Tow properties are: tenacity 2.2 g.p.d., elongation 21.1%, CI 3.6%, CD 13.5%, CF 9.6 crimps/extended inch (3.8 crimps/extended cm.) and SS 2.5%.

A 1/27 worsted count yarn is spun on the worsted system to comprise 55% of the fiber of this example (which has been cut to 3" (7.6 cm.) staple) and 45% 64-70s wool. The yarn is woven to a 2 x 2 twill and mill-finished in parallel with a similar fabric comprising 55/45 commercial polyester staple/wool. An improvement in bulk (ASTM bulk 2.30 vs. 2.08 cc./gm.) is observed for the bicomponent-fiber blend fabric, which in addition has a pleasant, more wool-like handle.

## EXAMPLE XXI

This example illustrates the effect of varying annealing conditions on crimp properties in the range preferred for staple. A 50/50-ratio bicomponent staple is prepared with a PET polymer of 20 relative viscosity as sheath and a PPT of 0.8 intrinsic viscosity as an eccentric core, using a spinneret such as described in FIG. 1 of the Breen U.S. Pat. 2,987,797, a spinning temperature of 267° C., and a windup speed of 1000 y.p.m. (915 m./min.) to yield a yarn denier of 1150, 120 filaments. Bobbins of the spun yarn are combined to form a 37,950-denier tow, which is drawn in water at 90° C. to 330% of its spun length and annealed on rolls at a series of temperatures, while stretching an additional 10% during a 30-second exposure. The results are summarized in Table 12.

TABLE 12

Item	Crimp properties, as measured at 1.5 mg./den. load				
	Anneal. temp. °C.	SS, percent	CI, percent	CD, percent	CF, c.p.i.
A.....	160	6	8	19	16
B.....	140	8	9	13	18
C.....	120	9	10	10	18
D.....	None	12	2	3	6

Bulky fabrics may be obtained from Item D by two different techniques as illustrated by the following test.

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Item D is processed on the worsted system (as 3.5-inch (8.9 cm.) staple) to 20/1 cotton-count 55/45 polyester/wool blend yarn with 14 t.p.i., then woven to a 2 x 2 twill fabric having a weight of 6.5 oz./sq. yd. (222 gms./sq. meter) after finishing. The fabric is divided and finished by two methods. Part 1 is scoured at the boil, dyed, lightly fulled and heat-set at 160° C. for 3 minutes. Part 2 is similarly finished except that the fabric is heat-set at 160° C. for 5 minutes, while being held at constant length and width, prior to the initial boil-off. This fabric annealing step approximates that of the annealing given Item A yarn.

Both parts of Item D fabric are bulky, but the bulk of Part 1 fabric is characteristic of that obtained by a mixed-shrinkage mechanism; it has a soft hand and a somewhat fuzzy surface. Part 2 fabric, on the other hand, comprises filaments of spiral crimp, and has a more resilient hand, more even surface and a desirable degree of stretchiness, which characteristics are attributable to the helical crimp of the bicomponent staple. These characteristics are enhanced rather than lost, as a result of taut annealing before boil-off.

## EXAMPLE XXII

A series of PPT/PET staples in which each component contains 2 mol percent ethylene sodium sulfoisophthalate in copolymerized form, is prepared by means taught in the preceding examples to have a range of crimp frequencies. They are blended in 70/30 ratio with wool, processed on the worsted system to 1/30 worsted count yarns with 14 t.p.i. and knitted on a 20-cut machine to tubing which is finished with a boiling scour, piece dyed and tumble-dried.

Results on tactility are summarized in Table 13, with, as comparison items, similar fabrics comprising wool and a bicomponent fiber more typical of those of the prior art.

TABLE 13

Fiber CF:	Tactility <sup>2</sup>
5 .....	Slick-lean.
9 .....	Wool-like.
11 .....	Do.
12 .....	Do.
14 .....	Do.
17 .....	Harsh, wool-like.
21 .....	Do.
9 (wool) .....	
52 <sup>1</sup> .....	Harsh.

<sup>1</sup>Fabric prepared in a similar manner from side-by-side bicomponent fiber comprising PET and a 85/15 copolymer of PET and poly(ethylene isophthalate) in a 50/50 cross-sectional ratio.

<sup>2</sup> Subjective evaluation.

## EXAMPLE XXIII

This example illustrates utility of a sheath-core bicomponent fiber comprising PET and poly(tetramethyl terephthalate) (PBT) in staple form.

A 50/50 PET/PBT bicomponent yarn is prepared with a 21 relative viscosity PET as sheath and a 0.95 intrinsic viscosity PBT as eccentric core using a process similar to that of Example XXI. Spinning temperature is 285-290° C., windup speed 500 y.p.m. (457 m./min.), yarn count 1250 denier, 120 filaments. Seventy-five bobbins are combined as a tow, which is drawn to 371% of its as-spun length in water at 90° C. It is annealed on rolls at 180° C. for 33 seconds while stretching an additional 10% of its drawn length. The resulting fiber exhibits SS 3%, CI 14%, CD 17%, and CF 14 c.p.i.

The tow is cut to 3.5 inch (8.9 cm.) staple and processed to 55/45 polyester/wool yarns with 20/1 cotton count and 18 t.p.i. Processibility is found to be satisfactory despite the rather high crimp. Crimp development and bulk of the boiled-off wool blend yarns are similar to those of Item A, Example XXI, or of Example XX.

## EXAMPLE XXIV

A series of 3 inch (7.6 cm.) staples is prepared in a manner paralleling that of Example XX, except that annealing and other processing conditions are varied to produce a range of CI. Table 14 summarizes the results of carding these staples. As will be seen, a CI of about 8 is borderline-to-satisfactory for this method of textile processing. CI of 5 or less is preferred. It has been found, however, that higher CI tow (about 9%) processes in a satisfactory manner on the Pacific Converter to yield low-nep-level yarns.

TABLE 14

Wt. ratio, PET/PPT	Cross section	Spinning		Drawing		Annealing		CI	Card web appearance
		Speed, y.p.m.	Temp. ° C.	Ratio	Temp. ° C.	Temp. ° C.	Time, sec.		
65/35	SBS	553	292	4.0	90	180	28	3.0	No neps.
80/20	SBS	585	292	3.8	80-85	180	28	3.9	Do.
85/35	Sh/C	585	293	4.0	80-85	180	28	5.5	Do.
65/35	SBS	675	291	4.3	80-85	180	28	7.5	Excessive neps.
65/35	Sh/C	562	293	3.6	85	180	40	7.9	No neps.
65/35	SBS	553	292	4.3	90	180	28	8.3	Excessive neps.

<sup>1</sup> Estimated values.

NOTE.—PET=copolymer of PET containing 2 mol percent of ethylene sodium sulfoisophthalate and having relative viscosity of 12.5; PPT=copolymer of PPT containing 2 mol percent of ethylene sodium sulfoisophthalate and having an intrinsic viscosity of 0.7; SBS=side-by-side; Sh/C=eccentric sheath-core.

## EXAMPLE XXV

A side-by-side bicomponent fiber comprising 65% of a 98/2 mol-ratio copolymer of PET and ethylene sodium sulfoisophthalate of 13.5 relative viscosity containing 0.25% tetraethyl silicate and 35% of a 98/2 mol-ratio copolymer of PPT and ethylene sodium sulfoisophthalate of 0.63 intrinsic viscosity is spun at 292° C. from a 120-hole spinneret. The filaments are quenched with room-temperature air and wound-up at 525 y.p.m. (480 m./min.) to give a spun denier of 12 dpf. Yarn from 75 packages of 1440 denier each, is drawn to 407% of its as-spun length in water of 85° C. to yield a nominal 3 d.p.f. tow, which is annealed at constant length by exposure to rolls heated to 180° C. for 28 seconds. It is mechanically crimped to 6-8 c.p.i. (2.4-3.4 c.p. cm.) and cut to 3-inch (7.6 cm.) staple. Properties are: tenacity 2.3 g.p.d., elongation 15%, CF 10 c.p.i., CD 12.5%, CI 3.7% and skein shrinkage 3.0%.

The staple is blended 50/50 with a commercially available, basic-dyeable polyester staple intended for use in pill-resistant fabrics and processed to 2/30 worsted count yarn with 12 t.p.i. Z-twist in the singles and 6 t.p.i. S-twist in the plied yarn. The yarn is knitted at 13 courses/inch (5.1 courses/cm.) on a 12-cut circular knitting machine. The resulting fabric is scoured and can be piece-dyed at the boil using a disperse dye formulation comprising 5 g./liter of a carrier consisting of equal parts of dimethyl terephthalate and benzanilide. Bulk is developed during scouring and dyeing. The finished fabric has excellent stitch clarity and good bulk, resilience and liveliness. Tactile aesthetics approach those of an all-wool counterpart. The test fabric has a weight of 8.63 oz./yd.<sup>2</sup> (292 gms./m.<sup>2</sup>) and bulk of 5.47 cc./g. under a standard 3 g./cm.<sup>2</sup> load and 4.37 cc./gm. under a load of 40 g./cm.<sup>2</sup>.

## EXAMPLE XXVI

This example illustrates the advantage of delaying the development of the major portion of the bicomponent crimp until the fiber is in yarn or fabric form.

Bicomponent staple is prepared substantially according to the procedure of Example XXV to have CI 3.7% and CD 25-30% (as measured under no boil-off load). Card sliver is prepared; it is used to prepare worsted yarns by each of three process sequences:

(A) The sliver is blended 70/30 with wool in pindrafting and spun to 1/30 worsted count yarn with 14 turns twist.

(B) The sliver is relaxed at 100° C. to develop the crimp, blended 70/30 with wool in pindrafting and spun to 1/30 worsted count yarn with 14 turns twist.

(C) Roving prepared as in sequence A is steamed to develop crimp and spun to 1/30 worsted count yarn with 14 turns twist.

Crimp properties measured on single filaments of the

various structures developed in this example are summarized in Table 16.

TABLE 16

Structure	CI, percent	CD, percent	CF, c.p.i. <sup>1</sup>	Comments
Card sliver A	5.4	28	10.5	
Roving A	6.5	27	11.1	
Worsted yarn A	4.5	25	11.6	Good bulk.
Card sliver B	28	28	11.5	
Roving B	9.5	32	14.2	
Worsted yarn B	11.2	23	12.6	Do.
Roving C	21	25	15	
Worsted yarn C	17.5	14	11.9	Low bulk.

<sup>1</sup> CD and CF are measured after boiling off or steaming of the fibers in the form indicated. No restraining load is used during this relaxation.

Upon relaxing, yarn A bulks to about twice the diameter of yarn C. The basis for this is seen in comparison of CI and OD for these yarns. Essentially all the developable crimp is already present in yarn C (17.5 CI vs. 14 CD), while the bulk of the crimp is yet to be developed in yarn A.

The bulk of yarn B is equivalent to that of yarn A after boil-off. This is explained by the fact that the crimp previously developed in sliver B is eliminated in pindrafting and is redevelopable in the yarn.

## EXAMPLE XXVII

This example illustrates properties obtained in bicomponent-fiber structures more representative of the art.

Side-by-side bicomponent staple comprising as one component PET of 20 relative viscosity and as the second a 85/15 copolymer of bis(hydroxyethyl) terephthalate and bis(hydroxyethyl) isophthalate of 40 relative viscosity. The polymers are spun at a block temperature of 298° C. and wound up at 989 y.p.m. The spun denier is 810, 60 filaments. A tow of 81,000 denier comprising such filaments is drawn to 400% of its spun length in a water bath at 90° C. and annealed on rolls for 33 seconds at a series of temperatures. Results are given in Table 17.

TABLE 17

Item	Anneal roll temp., ° C.	Crimp properties			
		SS, percent	CI, percent	CD, percent	CF (c.p.i.)
A	180	4.5	1.5	11.5	12
B	160	6	1.7	12.6	14
C	140	10	1.4	13.3	18
D	120	20	4.5	13.8	28
E	Off	24	6.2	16.9	36

Note that as annealing temperature is increased, CD decreases, in contrast to the results obtained with the bicomponent fibers of this invention.

Items A, C and E are processed to 55/45 wool-blend worsted yarns of 20/1 cotton count which are woven to 2 x 2 right-hand twill fabrics. The fabrics are finished in a standard manner for mill-finished worsteds. All fabrics are judged objectionably harsh, the harshness increasing with increasing crimp properties (A through E), although similar fabric made from fibers of this invention with crimp properties similar to Item A had a pleasing tactility (e.g. Example XX). Microscopic examination shows the surface of the fabrics to be covered by tightly coiled fibers. It is postulated that the fibers coil on high temperature treatment during fabric heat-setting. This is confirmed by relaxing a sample of item A tow at tenter-frame temperatures (150° C. or higher under essentially no restraint), whereupon the fiber develops more than 50 crimps per inch. Fibers of this invention maintain nearly their measured crimp frequency when subjected to fabric heat-setting conditions, as illustrated in Example XXVIII.

#### EXAMPLE XXVIII

This example further illustrates the unique stability of the helical crimp in bicomponent fibers of this invention when subjected to the plasticizing action of dye carriers. The importance of crimp frequency to aesthetics makes this characteristic a valuable contributor to the development of superior textile fibers.

Bicomponent staple is prepared in accordance with the procedure of Example XX. Crimp frequency before and after various treatments, as noted, are summarized in Table 18, as compared with fiber such as that illustrated by Example XXVII.

TABLE 18

Fiber	As Example XX	As Example XXVII	
		Sample A	Sample B
Crimp frequency (c.p.i.): Initial.....	12.5	13.8	13.8
After relaxed boil-off:			
(a) In water.....	13.6	18	-----
(b) In 5 g./l. Carrier A.....	11.5	23	-----
(c) In 6 g./l. Carrier B <sup>2</sup> .....	10.8	45	-----
After relaxed heat setting at 155° C. for 40 seconds.....	13-15	-----	32.7

<sup>1</sup> Equal weights mixture of dimethyl terephthalate and benzanilide.  
<sup>2</sup> Orthophenylphenol.

#### EXAMPLE XXIX

This example illustrates the use of controlled relaxation to modify the crimp characteristics of bicomponent fibers of this invention.

A side-by-side bicomponent fiber comprising 70% of a 12.3 relative viscosity copolymer of 98 mol-percent PET and 2 mol-percent poly(ethylene sodium sulfoisophthalate) and containing 0.25 wt.-percent tetraethyl silicate, and 30% poly(tetramethylene terephthalate) of 0.8 intrinsic viscosity is spun at 280° C. from a 120-hole spinneret. The filament bundles from forty bobbins are combined and drawn to 3.7 ratio in an aqueous draw bath at 85° C. After drawing, the tow bundle is relaxed by conveying at 80 ft./min. once around the first of 2 pairs of heated rolls (1st pair roll temp., 185° C., 2nd pair, 195° C.) in an enclosure (air temp. 195° C.), then 9 times around the second pair operating at a surface speed of 60 ft./min. During the relaxation step the filaments develop a relatively high frequency spiral crimp (about 14 crimps per inch) of low amplitude (CI=3%). On subsequent boil-off under 1.5 mg./den. load, CD is found to be 9%; CD' (after boil-off under no load) is found to be 18%; CF remains about 14 crimps/in. in either case.

By contrast, similar bicomponent filaments processed without the controlled relaxation step to have a CD of 9% are found after boil-off to have only 6 crimps/in. and a CD' (after boil-off under no load) of 32%. The higher frequency and lower CD' of the filaments prepared by

controlled relaxation can be used to produce staple fibers which confer better visual aesthetics and reduced stretchiness in fabrics made from skein-dyed yarns.

#### EXAMPLE XXX

A side-by-side trilobal bicomponent filament in which one component is a copolymer of ethylene terephthalate (98 mol percent) and ethylene sodium sulfoisophthalate (2 mol percent) having a relative viscosity of 12 and the other component is a copolymer of tetramethylene terephthalate (98 mol percent) and ethylene sodium sulfoisophthalate (2 mol percent) having a relative viscosity of 21 is extruded at 265° C. from a 60-hole pre-coalescence spinneret to produce a yarn having a denier of 1220. The volume ratio of the ethylene terephthalate copolymer component to the tetramethylene terephthalate copolymer component is 75/25. A tow is prepared by combining 45 ends of the above yarn and drawn at a ratio of 3.95 in a 95° C. water bath. The drawn tow is subjected to light mechanical crimping in a stuffer box crimper and then relaxed in a heated atmosphere at 135° C. for 5 min. to develop crimp. The crimp index after this treatment is 22%. The tow is then stretched at room temperature to 1.20 times its original crimped length to remove part of the crimp and then passed in the stretched state around heated rolls for 24 seconds at 160° C. The resulting filaments have a CI of 7%, a CF of 12 crimps/in., a CD' after boil-off under no load of 13% and a CD'' after boil-off under 1.0 mg./den. load of 9%.

In the practice of this invention, additives normally employed in the manufacture of synthetic filaments may be used and are substantially without adverse effect on properties of the bicomponent filaments of this invention. It is possible, for example, to add antistatic agents, delusterants, fluorescent brighteners, dyes, pigments, surface rougheners and the like to one or both components within reasonably wide limits without adversely influencing differential shrinkage, crimp, stretch or stretch-recovery appreciably. Addition of topical finishes may also be practiced.

This invention is applicable to the production of fiber of any cross-sectional shape. Those which have been employed and found satisfactory include, for example, round, oval, ribbon, double round and trilobal.

While the exemplified development of crimp by shrinking has exclusively involved treatment in hot or boiling water in the examples herein, it is to be recognized that operative alternatives exist which also would develop the crimp. Treatment with a transitory plasticizer, for example, can lower the glass transition temperature of a polymer sufficiently to accomplish the necessary shrinkage for crimping at a temperature substantially below the normal second-order transition temperature; it is conceivable that such a treatment could shrink the filament at room temperature. Further, polymers vary widely in glass transition temperature, and treatment at temperatures substantially above 100° C. may be necessary to shrink filaments made from high glass-transition-temperature components.

The novel filaments of this invention can be used in light-weight stretch fabrics since use in this type fabric highlights the novel combination of properties offered by these filaments. In addition, as described in Examples XII, XVII, XVIII and XX-XXVIII, the bulk afforded by many of the spontaneously crimpable filaments of this invention is useful in a variety of fabrics where bulk and tactility are emphasized rather than stretch and power. The filaments of this invention are also useful as replacement for elastomeric or twisted and heat-set filaments in yarn structures produced by the core spinning processes illustrated in U.S. Pats. 2,777,310 and 2,880,566, as examples.

The broad range of available fabric stretch, power, bulk, tactility and surface appearance available with the filaments of this invention admirably equip them for use in a wide range of end uses. Among the suitable end uses



are upholstery, slip covers, carpets, hosiery, half-hose or socks, support hose, ski pants, leotards, boxer shorts, swim wear, sweaters, undergarments where support or bulk is needed, lingerie, brassieres, girdles, blouses, shirts, men's or women's suitings (for better fit, wrinkle recovery), etc. Suitable fabric types include wovens, knits and warp-knits as well as nonwoven, or felt-like, fabrics, especially where bulk durability, tactile and visual aesthetics, high power of recovery from stretch and/or simplicity and economy of fabrication are desirable.

The preceding representative examples may be varied within the scope of the present total specification disclosure, as understood and practiced by one skilled in the art, to achieve essentially the same results.

The foregoing detailed description has been given for clearness of understanding only and no unnecessary limitations are to be understood therefrom. The invention is not limited to the exact details shown and described for obvious modifications will occur to those skilled in the art.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A helically crimpable composite filament comprising a laterally eccentric assembly of at least two synthetic polyesters, the first of said two polyesters being partly crystalline in which the chemical repeat-units of its crystalline region are in a nonextended stable conformation that does not exceed 90 percent of the length of the conformation of its fully extended chemical repeat-units and which assumes a position on the inside of crimp helices formed when the assembly crimps, the second of said two polyesters being partly crystalline in which the chemical repeat-units of the crystalline region are in a conformation more closely approaching the length of the conformation of its fully extended chemical repeat-units than the first defined polyester.

2. The helically crimpable composite filament of claim 1 wherein the chemical repeat-units of the crystalline region of the second polyester are in a conformation that is 95% or more of the length of the conformation of its fully extended chemical repeat-units.

3. The helically crimpable composite filament of claim 2 wherein the filament is a bicomponent filament.

4. The helically crimpable bicomponent filament of claim 3 in which the first polyester is selected from the group consisting of poly(trimethylene terephthalate), poly(tetramethylene terephthalate), poly(trimethylene dinitroterephthalate) and poly(trimethylene bibenzoate).

5. The helically crimpable bicomponent filament of claim 4 in which the first polyester is poly(trimethylene terephthalate) and the second polyester is poly(ethylene terephthalate).

6. The helically crimpable bicomponent filament of claim 5 wherein each polyester employed contains minor amounts of ethylene sodium sulfoisophthalate in copolymerized form.

7. The helically crimpable bicomponent filament of claim 4 in which the first polyester is poly(tetramethylene terephthalate) and the second polyester is poly(ethylene terephthalate).

8. The helically crimpable bicomponent filament of claim 7 wherein each polyester employed contains minor amounts of ethylene sodium sulfoisophthalate in copolymerized form.

9. The helically crimpable composite filament of claim 1 in the form of staple.

10. A helically crimped composite filament comprising a laterally eccentric assembly of at least two synthetic polyesters, the first of said two polyesters being partly crystalline in which the chemical repeat-units of its crystalline region are in a nonextended stable conformation that does not exceed 90 percent of the length of the conformation of its fully extended chemical repeat-units and is positioned on the inside of the helical crimps, the second of said two polyesters being partly crystalline in which the chemical repeat-units in the crystalline region are in a conformation more closely approaching the length of the conformation of its fully extended chemical repeat-units than the said first polyester.

11. The helically crimped composite filament of claim 10 wherein the chemical repeat-units of the crystalline region of the second polyester are in a conformation that is 95% or more of the length of the conformation of its fully extended chemical repeat-units.

12. The helically crimped composite filament of claim 11 wherein the filament is a bicomponent filament.

13. The helically crimped bicomponent filament of claim 12 in which the first polyester is selected from the group consisting of poly(trimethylene terephthalate), poly(tetramethylene terephthalate), poly(trimethylene dinitroterephthalate) and poly(trimethylene bibenzoate).

14. The helically crimped bicomponent filament of claim 12 in which the first polyester is poly(trimethylene terephthalate) and the second polyester is poly(ethylene terephthalate).

15. The helically crimped bicomponent filament of claim 14 wherein each polyester employed contains minor amounts of ethylene sodium sulfoisophthalate in copolymerized form.

16. The helically crimped bicomponent filament of claim 12 in which the first polyester is poly(tetramethylene terephthalate) and the second polyester is poly(ethylene terephthalate).

17. The helically crimped bicomponent filament of claim 16 wherein each polyester employed contains minor amounts of ethylene sodium sulfoisophthalate in copolymerized form.

18. The helically crimped composite filament of claim 10 in the form of staple.

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ROBERT F. BURNETT, Primary Examiner

L. KOECKERT, Assistant Examiner

U.S. Cl. X.R.

161—175, 177; 264—171



UNITED STATES PATENT OFFICE  
CERTIFICATE OF CORRECTION

Patent No. 3,671,379 Dated June 20, 1972

Inventor(s) EVAN FRANKLIN EVANS and NORWIN CALEY PIERCE

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 12, line 6, "The filaments are" should read  
-- The 34 filaments are --.

Column 12, line 32, Table 3, last column, the numbers  
22 and 27 should be reversed.

Signed and sealed this 19th day of December 1972.

(SEAL)  
Attest:

EDWARD M. FLETCHER, JR.  
Attesting Officer

ROBERT GOTTSCHALK  
Commissioner of Patents



US006306499B1

(12) **United States Patent**  
**Ochi et al.**

(10) **Patent No.:** **US 6,306,499 B1**  
(45) **Date of Patent:** **Oct. 23, 2001**

(54) **SOFT STRETCH YARNS AND THEIR METHOD OF PRODUCTION**

(75) Inventors: **Takashi Ochi; Katsuhiko Mochizuki; Yuhei Maeda**, all of Shizuoka (JP)

(73) Assignee: **Toray Industries, Inc.** (JP)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/589,233**

(22) Filed: **Jun. 7, 2000**

(30) **Foreign Application Priority Data**

Jun. 8, 1999 (JP) ..... 11-160548  
Aug. 25, 1999 (JP) ..... 11-238240

(51) Int. Cl.<sup>7</sup> ..... **D01F 6/00; D01F 8/00**

(52) U.S. Cl. .... **428/364; 428/395; 428/370; 428/373**

(58) Field of Search ..... **428/364, 370, 428/374, 395, 373**

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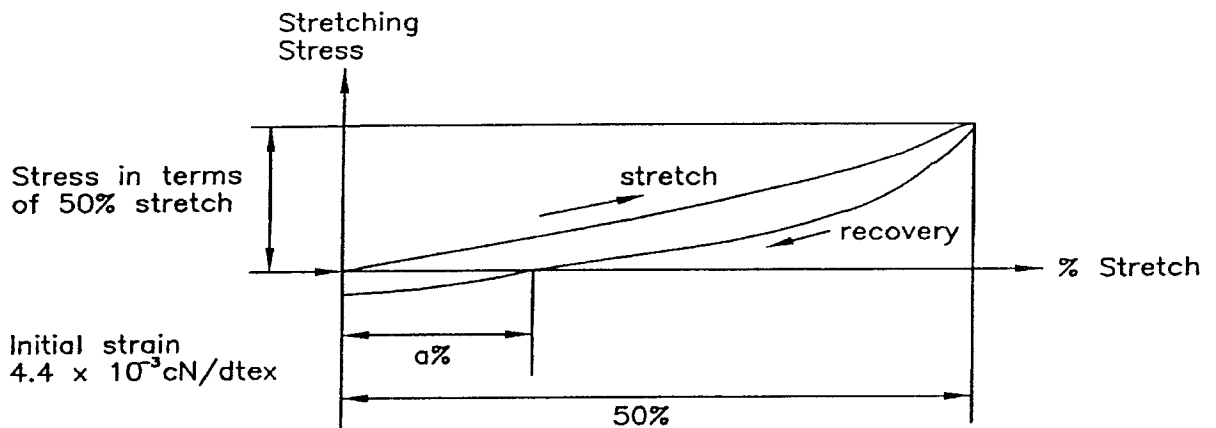
*Primary Examiner*—N. Edwards

(74) *Attorney, Agent, or Firm*—Schnader Harrison Segal & Lewis LLP

(57) **ABSTRACT**

A soft stretch yarn substantially comprising polyester fibers has a stress, at 50% yarn stretch, of no more than  $30 \times 10^{-3}$  cN/dtex and, at the same time, a percentage recovery of at least 60%. Preferably, the Uster unevenness is no more than 2.0% and the crimp diameter is no more than 250  $\mu\text{m}$ . This soft stretch yarn can be produced by spinning yarn of conjugate fibers comprising two types of polyester in which one component is PTT at a take-up velocity of at least 1200 m/min, drawing at a drawing temperature of 50 to 80° C. at a draw ratio such that the drawn yarn tensile elongation is 20 to 45%, and then heat setting.

**24 Claims, 7 Drawing Sheets**



**Stress-Strain hysteresis curve diagram**

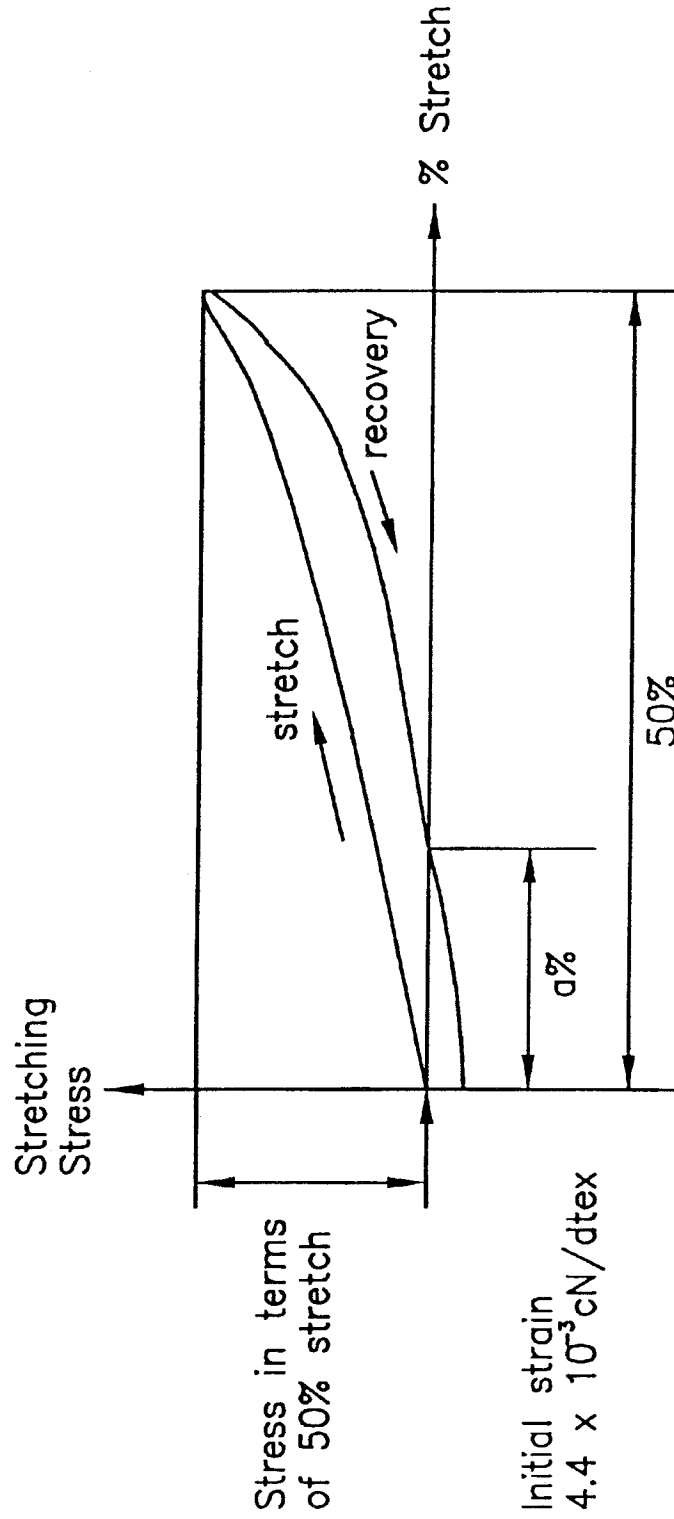


Fig. 1 Stress-Strain hysteresis curve diagram

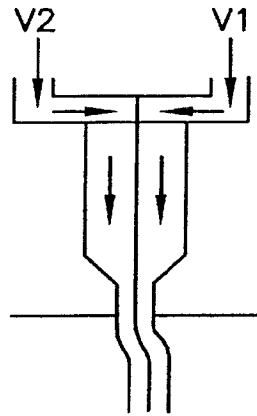


Fig. 2A

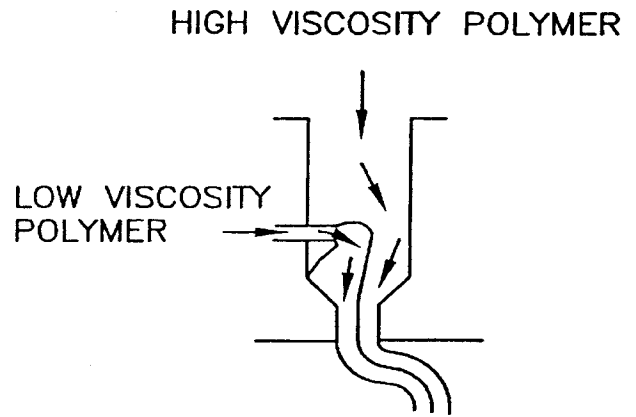


Fig. 2B

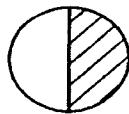


Fig. 3A

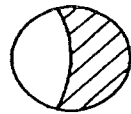


Fig. 3B

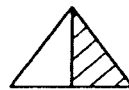


Fig. 3C

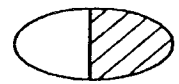


Fig. 3D

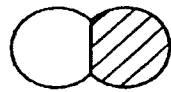


Fig. 3E

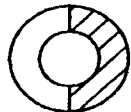


Fig. 3F



Fig. 3G

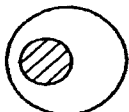


Fig. 3H



Fig. 3I



Fig. 3J

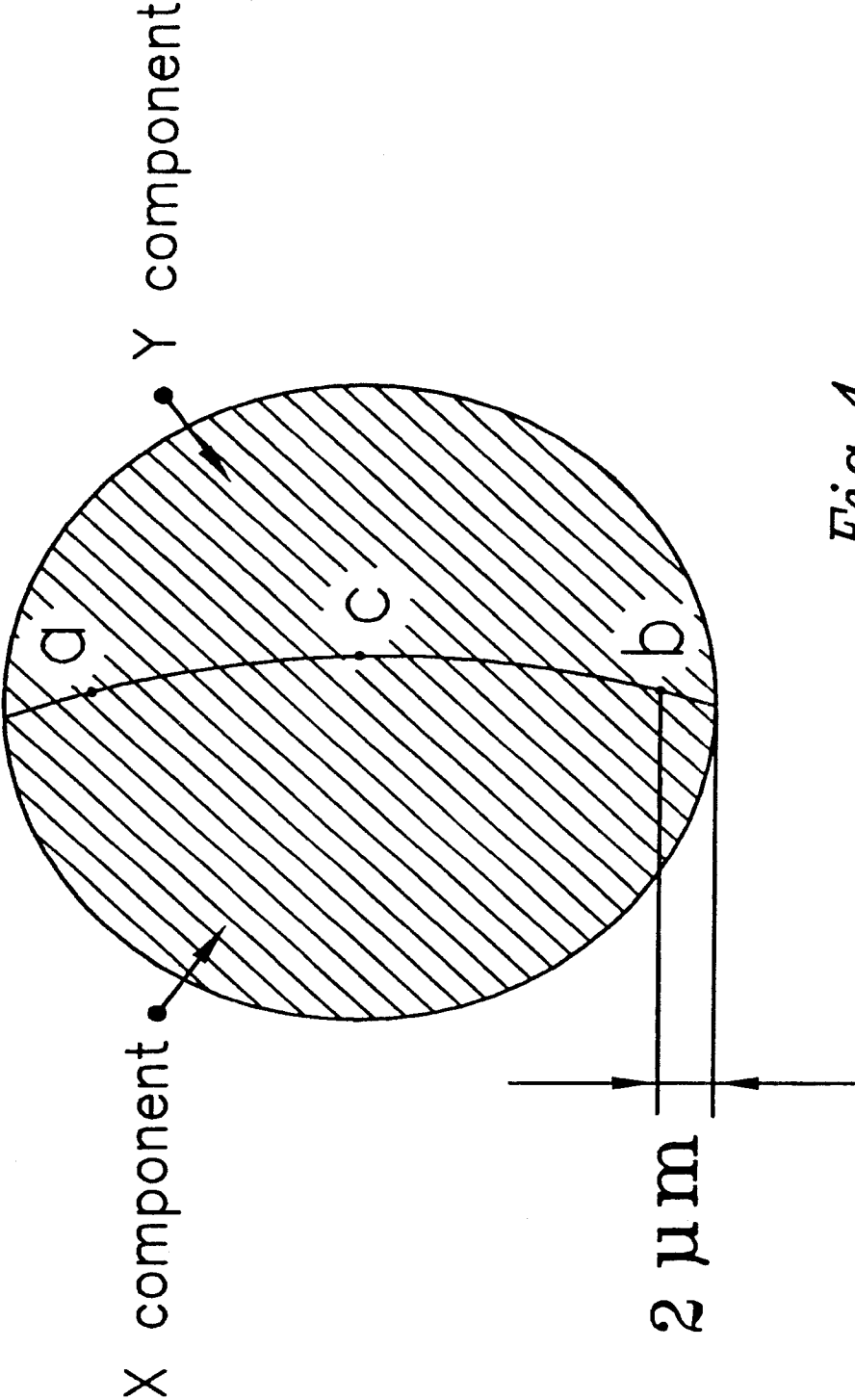


Fig. 4

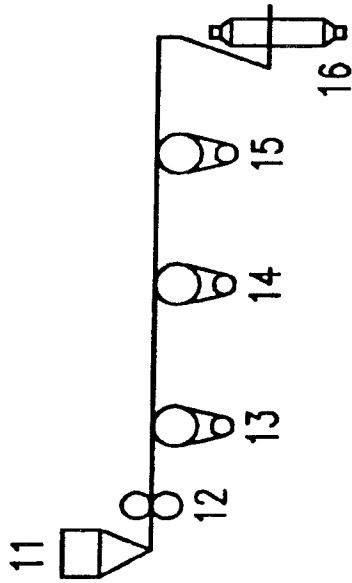


Fig. 6

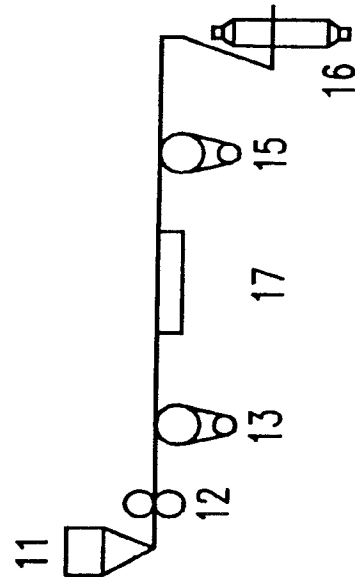


Fig. 7

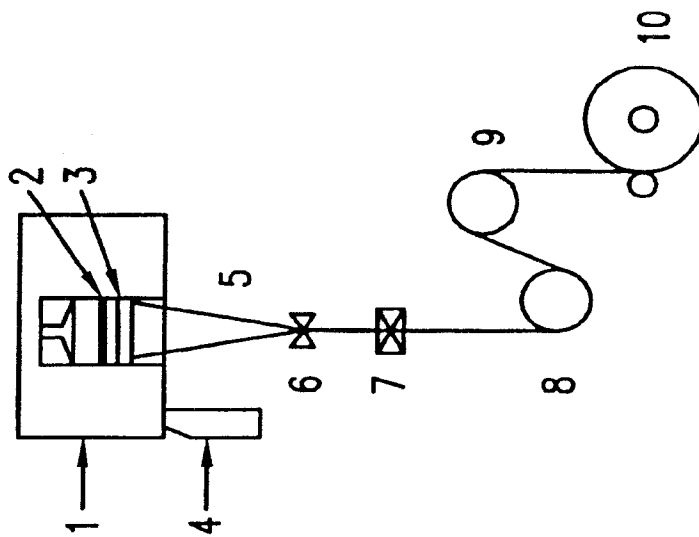


Fig. 5

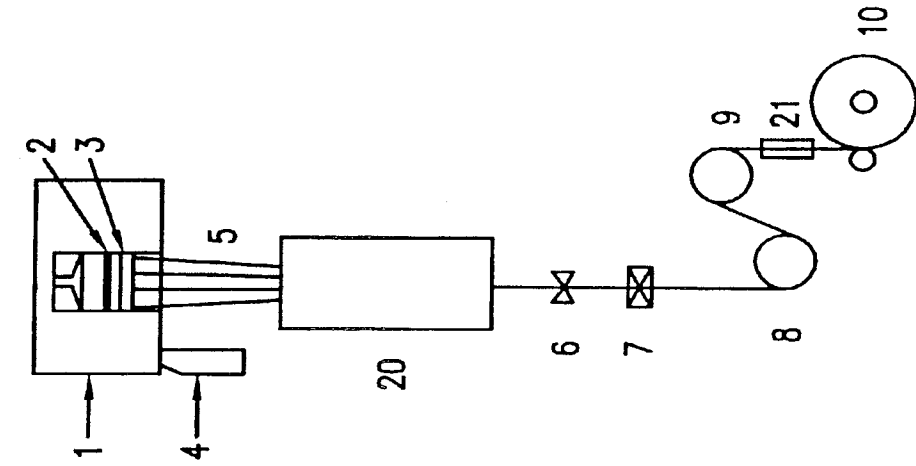


Fig. 9

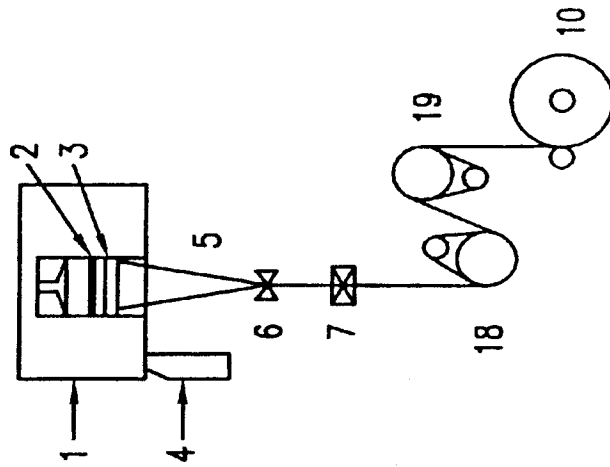
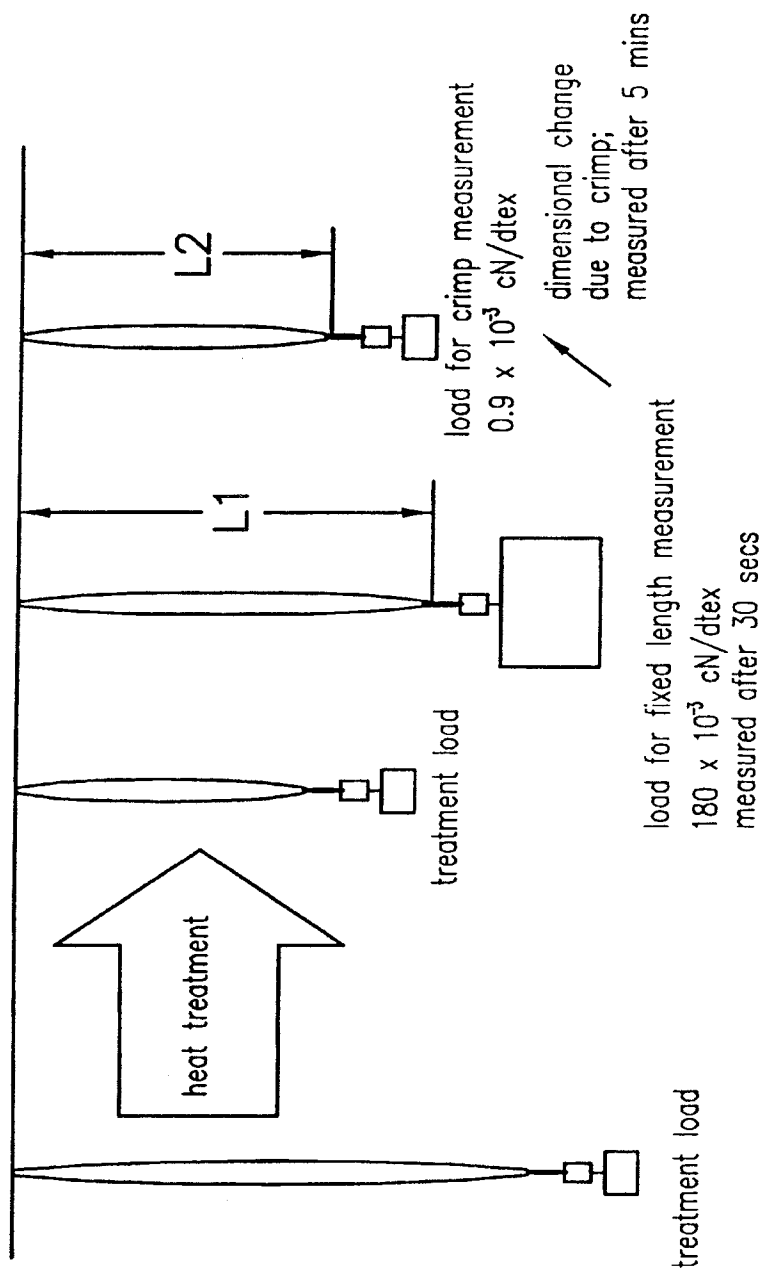


Fig. 8

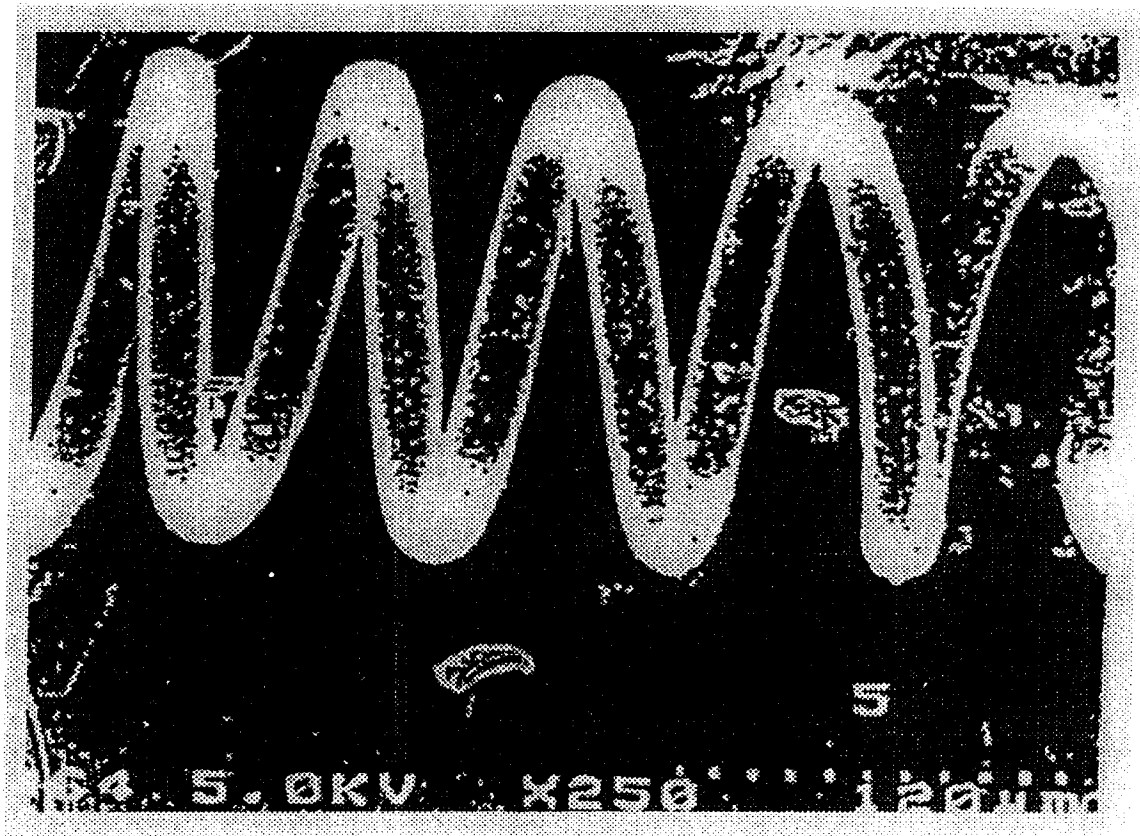


crimp stretch factor (%) =  $(L_1 - L_2) / L_1 \times 100(\%)$   
 heat treatment: 15 mins in boiling water +  
 15 mins dry heat at 180°C

Fig. 10



Fig. 11



## SOFT STRETCH YARNS AND THEIR METHOD OF PRODUCTION

### TECHNICAL FIELD

The present invention relates to soft stretch yarns which, by means of their outstanding crimpability, can confer soft stretchability on fabrics, and to the fabrics formed using said yarns.

#### 1. Prior Art

Synthetic fibre fabrics are outstanding in their durability, easy-care characteristics and the like when compared to natural fibre fabrics and semi-synthetic fibre fabrics, and are widely used. However, when compared to natural fibre fabrics and semi-synthetic fibre fabrics, they are inferior in terms of aesthetic appearance and handle, so various improvements have been made in the past. One approach has been to imitate natural or semi-synthetic fibres. On the other hand, in terms of appearance and handle, improvements have been actively pursued in recent years directed towards the synthetic fibres themselves, quite distinct from natural fibres and semi-synthetic fibres. Amongst these, considerable research has been conducted to broaden the areas where natural or semi-synthetic fibres are poor and synthetic fibres superior. One such major area is the characteristic known as stretch.

With regard to the conferring of stretchability, hitherto there has been employed for example the method of mixing polyurethane fibre into a woven fabric to impart stretchability. However, polyurethane fibre has problems such as the hardness of handle inherent in the polyurethane itself, and a lowering of the handle and drape of the fabric. Moreover, polyurethane is difficult to dye by the dyestuffs employed for polyester and, when used in combination with polyester fibre, not only is the dyeing process complex but also dyeing to a desired colour is difficult.

Hence, as a method which does not use either polyurethane fibre or false-twist textured yarn, polyester fibres employing side by side polymer conjugation have been variously proposed.

For example, in JP-44-2504 and in JP-A-4-308271, there are described side by side bicomponent fibres of polyethylene terephthalate (PET) with different intrinsic viscosities or intrinsic viscosities; and in JP-A-5-295634 there is described a side by side bicomponent fibre of homo PET and copolymer PET of higher shrinkage than the homo PET. When such polyester fibres with latent crimpability are used, it is indeed possible to obtain a certain degree of stretchability but there is the disadvantage that a high stress is generated when the fabric is stretched, that is to say there is a strong feeling of tightness and a hard fabric is formed. Moreover, with side by side bicomponent fibres of this kind, there is the problem that the capacity to manifest crimp in a constrained state within a woven material is low, or the crimp is readily permanently distorted by external forces. Side by side bicomponent fibre yarns do not utilize stretchability based on a substrate polymer such as a polyurethane fibre but, in order to provide the stretchability, utilize the crimp manifested as a result of the difference in shrinkage between the polymers in the conjugate fibre, with the polymer of higher shrinkage forming the inside of the crimp. Hence, it is thought that the aforesaid problems arise when, for example, heat treatment is carried out with the shrinkage of the polymer restricted as in the case when present in a woven fabric, and heat setting takes place in this state, so that the shrinkage capacity beyond this constrained state is lost.

Furthermore, side by side bicomponent fibre yarns employing polytrimethylene terephthalate (PTT) or polybu-

tylene terephthalate (PBT), which are polyesters with slight stretchability, are described in JP-43-19108, but in Example 15 of that publication it states that the power required for stretching is large. In fact, when estimated from the finished yarn counts of the heat treated fabric, in Example XV-d the stress generated at 30% stretch is rather high at  $60 \times 10^{-3}$  cN/dtex or more, and so there is a strong sense of tightness. In addition, when we conducted follow-up experiments, we found disadvantages in that the Uster unevenness (U%) was poor and dyeing unevenness when in the form of fabric was considerable.

#### 2. Objective of the Invention

The present invention aims to resolve the problems of a strong feeling of tightness and coarsening of the fabric, and the problems brought about by yarn unevenness, which are problems associated with conventional side by side bicomponent fibre yarns, and to provide soft stretch yarns which can give fabrics with more outstanding soft stretchability and more outstanding uniformity of dyeing than hitherto, together with the fabrics produced from said yarns.

### DISCLOSURE OF THE INVENTION

The present invention provides, according to one aspect, a yarn (Y) substantially comprising (and preferably consisting of) polyester fibres, which yarn (Y) is characterized in that, following heat treatment, the yarn has a stress at 50% yarn stretch of no more than  $30 \times 10^{-3}$  cN/dtex and, at the same time, a percentage recovery of at least 60%. Preferably, the Uster unevenness is no more than 2.0% and the diameter of the crimp is no more than 250  $\mu$ m. It is also preferable for the fibres to be conjugate, more preferably multi-segment (side by side) or a core sheath (ie. having an eccentric cross section) fibres having at least two components each of different respective polyesters.

According to a method aspect, the invention provides a method (A) of producing a yarn by spinning a yarn of conjugate fibres comprising two types of polyester in which, preferably, PTT is one component, at a take-up velocity of at least 1200 m/min, drawing at a drawing temperature of 50–80° C. and a draw ratio which gives a drawn fibre elongation of 20 to 45%, and then heat setting.

According to other method aspects, the invention provides respective methods (B) and (C) of providing a yarn, in which method (B) a yarn of a conjugate fibre comprising two types of polyester is spun from a spinneret and taken up at a take-up velocity of at least 4000 m/min by providing a non-contact heater between the spinneret and a godet roller and in which method (C) a yarn of a conjugate fibre comprising two types of polyester is spun at a take-up velocity of at least 5000 m/min.

Each of the above methods may be utilized to produce a yarn (Y) having the above characteristics and thereby allow a soft stretch yarn to be obtained which at least partially remove the abovementioned problems.

### BRIEF EXPLANATION OF THE DRAWINGS

Practical embodiments of the invention will now be described with reference to the accompanying drawings which:

FIG. 1 is a diagram showing the stress-strain hysteresis curve a yarn embodying the invention.

FIG. 2 shows, diagrammatically, spinnerets used for side by side bicomponent fibre spinning in a method embodying the invention.

FIG. 3 shows, diagrammatically, various fibre cross-sectional shapes of polyester fibres of yarns embodying the invention.

FIG. 4 is a diagram showing the method of calculating the radius of curvature of an interface between two components of a bi-component fibre present in a yarn embodying the invention.

FIG. 5 is a diagram showing a spinning/winding machine for use in a method embodying the invention.

FIG. 6 is a diagram showing a drawing machine for use in another method embodying the invention.

FIG. 7 is a diagram showing a drawing machine for use in yet another method embodying the invention.

FIGS. 8 and 9 are diagrams showing direct spin draw machines.

FIG. 10 is a diagram showing the crimp stretch factor measurement method for use in still further methods embodying the invention.

FIG. 11 is an electron micrograph showing one example of the soft stretch yarn crimp shape.

Explanation of the numerical codes:

- 1: spinning block
- 2: nonwoven filter
- 3: spinneret
- 4: cooling chimney
- 5: yarn
- 6: oiling guide
- 7: interlacer nozzle
- 8: 1st godet roller (1GD)
- 9: 2nd godet roller (2GD)
- 10: winder
- 11: undrawn yarn
- 12: feed roller (FR)
- 13: 1st hot roller (1HR)
- 14: 2nd hot roller (2HR)
- 15: cold roller
- 16: drawn yarn
- 17: hot plate
- 18: 1st hot nelson roller (1HNR)
- 19: 2nd hot nelson roller (2HNR)
- 20: non contact heater
- 21: steam setter

#### PRACTICAL EMBODIMENTS OF THE INVENTION

In a yarn embodying the present invention, in order to achieve soft stretchability, it is important that the resistance to yarn stretch be low and that the recovery from stretch be high, and these characteristics can be evaluated by means of the stress when the yarn is stretched 50% and the percentage recovery in the stress-strain hysteresis curve (FIG. 1). In practice, the hank-wound yarn is heat treated and crimp manifested, after which an initial tension of  $4.4 \times 10^{-3}$  cN/dtex (5 mgf/d) is applied to the yarn using an automatic tensile testing machine, then the yarn stretched 50% and the stress read off.

In the case of the soft stretch yarn of the present invention, it is important that the stress at 50% yarn stretch be no more than  $30 \times 10^{-3}$  cN/dtex and, in this way, it is possible to obtain good soft stretchability and there can be obtained soft fabrics with no feeling of tightness. On the other hand, with a conventional side by side bicomponent yarn, the stress at 50% yarn stretch is high, exceeding  $50 \times 10^{-3}$  cN/dtex, so only fabrics with a strong sense of tightness and a coarse feel

are obtained. The stress at 50% yarn stretch is preferably no more than  $10 \times 10^{-3}$  cN/dtex. Furthermore, in order to obtain sufficient stretchability, it is important that the recovery be at least 60%. Preferably, the recovery is at least 70%.

Again, when the crimp diameter of the soft stretch yarn following heat treatment is less than  $250 \mu\text{m}$ , soft stretchability is readily manifested and, furthermore, when fabric is produced, coarseness of the fabric surface is suppressed and it is possible to obtain a material of high quality, so this is preferred. The crimp diameter of the soft stretch yarn is more preferably no more than  $200 \mu\text{m}$ .

Furthermore, if the crimp phase between the individual filaments is uniform, a fine crepe is raised when formed into a fabric and it is possible to obtain fabric with an attractive surface. On the other hand, if there is a divergence in the crimp phase between the individual filaments, it is easier to form a fabric with a plain surface and it is possible to produce a fabric with good smoothness.

Moreover, where the crimp stretch factor ( $E_0$ ) after heat treatment substantially under no load is at least 45%, the stretchability is further enhanced and this is preferred. Here, the crimp stretch factor is an index denoting the degree of crimp, and the higher the value of the crimp stretch factor the higher the degree of crimp and the better the stretchability.  $E_0$  is more preferably at least 60%.  $E_0$  reflects the extent of crimping under no load. However, in the case where a side by side bicomponent fibre yarn is in the form of a high twist yarn or a fabric, sometimes there is constraint by the high twisting or a constraining force acts due to the weave structure, so that it is difficult for crimp to be manifested. Hence, the crimp stretch factor under load may also be important, and this property can be assessed from the crimp stretch factor ( $E_{3,5}$ ) when a load of  $3.5 \times 10^{-3}$  cN/dtex (4 mgf/d) is applied. In the case of the soft stretch yarn of the present invention,  $E_{3,5}$  is preferably at least 10%. On the other hand, with conventional polyethylene terephthalate type side by side bicomponent yarns,  $E_{3,5}$  is about 0.5%, and so in cases where a high twist yarn or a fabric is produced crimp is not readily manifested and there is poor stretchability.  $E_{3,5}$  is preferably at least 14%.

Furthermore, if the percentage crimp retention after repeatedly stretching 10 times is at least 85%, then the crimp does not readily show permanent deformation and the shape retentivity when the fabric is stretched is markedly raised, so this is preferred. The crimp retention after stretching 10 times is preferably at least 90% and more preferably at least 95%. On the other hand, with conventional polyethylene terephthalate type side by side bicomponent yarns, the crimp retention after stretching 10 times is less than 80% and the shape retentivity when the fabric is stretched is poor.

Again, in order that high twist or weaving constraints be surmounted and crimp still be manifested, the shrinkage stress may also be important, and it is preferred that the maximum value of the stress be at least 0.25 cN/dtex (0.28 gf/d). More preferably, the maximum value of the stress is at least 0.30 cN/dtex (0.34 gf/d). Moreover, the temperature at which the maximum shrinkage stress is shown is preferably at least  $110^\circ \text{C}$ .

In addition, if the initial modulus of the yarn is no more than 60 cN/dtex, the fabric is softer and so this is preferred. The initial modulus of the yarn is preferably no more than 50 cN/dtex.

Furthermore, if there is excessive fabric shrinkage in subsequent fabric processing stages, coarsening will occur, so it is preferred that the dry heat shrinkage of the soft stretch yarn be no more than 20%.

In the present invention, It is preferable that the Uster unevenness, which is a measure of the unevenness of the yarn denier (thickness unevenness), be no more than 2.0%. In this way, not only is it possible to avoid the occurrence of fabric dyeing unevenness, but also yarn shrinkage unevenness when in the form of fabric is suppressed and it is possible to obtain an attractive fabric surface. The Uster unevenness is more preferably no more than 1.2%.

Again, the strength of the soft stretch yarn is preferably at least 2.2 cN/dtex (2.5 gf/d) from the point of view of smooth passage of the soft stretch yarn through subsequent processing stages and the securing of adequate tear strength in the form of fabric. The strength is more preferably at least 3.0 cN/dtex (3.4 gf/d). Moreover, from the point of view of yarn handling, the elongation of the soft stretch yarn is preferably 20 to 45%.

It is especially preferred that the structure of a soft stretch yarn embodying the present invention is a conjugate fibres having at least two components, wherein, in cross-section, respective components are each disposed eccentrically relative to another component (and most preferably, where at least one component is PTT), that is to say either a side by side type multi-, especially bicomponent fibres or eccentrically disposed sheath core conjugate fibres. Hereinafter, such fibres are referred to as "eccentric conjugate fibres". With such fibres, the stress at 50% yarn stretch is readily lowered and, furthermore, the percentage recovery can readily be raised at the same time. Moreover, if two polyesters with a large difference in melt viscosity are employed, then the stretch characteristics, namely the recovery in terms of 50% yarn stretch and the crimp stretch factor, are enhanced, so this is preferred. Again, where PTT is on the inside of the crimp, the stretchability is further raised so this is preferred. Moreover, if PET is combined with PTT, the heat resistance is raised, so this is preferred. If low viscosity PTT is combined with high viscosity PTT, then the Young's modulus is lowered and better soft stretchability is obtained in the form of a fabric, so this is preferred. Again, if PBT is combined with PTT then the crimp retention factor is raised, permanent deformation of the crimp does not readily occur, and there is improved fabric shape retentivity in terms of stretch, so this is preferred.

As to the conjugate ratio of the polyesters but, from the point of view of the manifestation of crimp, from 3/7 to 7/3 is preferred. From 4/6 to 6/4 is more preferred, with 5/5 being still further preferred.

Herein, PET refers to a condensation polymer employing terephthalic acid as the acid component and ethylene glycol as the diol component; PTT refers to a condensation polymer employing terephthalic acid as the acid component and 1,3-propanediol as the diol component; and PBT denotes a condensation polymer employing terephthalic acid as the acid component and 1,4-butanediol as the diol component. Furthermore, within respective ranges not exceeding 15 mol%, a part of the diol component and/or part of the acid component may be replaced by other copolymerizable component(s). In the case where the copolymerized component is polyethylene glycol, this will be no more than 15 wt%. Again, there may also be added additives such as other polymers, delustrants, fire retardants, antistatic agents and pigments.

Now, if the difference in the melt viscosities of the conjugated polymers is too great, the spinnability may become markedly impaired because fibre bending just under the spinneret occurs. Hence, it may then be necessary to use an insert type complex spinneret (FIG. 2(b)) as described in

JP-A-11-43835. However, the yarn production properties may then be markedly lowered because of the different residence times of the polyesters in the pack or spinneret. Again, while it is also not impossible to use a spinneret of the kind shown in FIG. 3 of JP-43-19108 where the flow of two polyesters is merged and combined at the same time as extrusion, the conjugate form and the polyester flow rates will tend to be unstable, causing increased yarn unevenness, so this is preferably avoided. Hence, if, the melt viscosity ratio of the two types of polyester is actually decreased, then even by using a simple parallel type spinneret (FIG. 2(a)) it is possible to avoid the problem of reduced spinnability caused by fibre bending just under the spinneret as described in Sen'i Gakkai-shi {*Journal of the Society of Fibre Sciences and Technology, Japan*} Vol.54, p-173 (1998). Such a combination of melt viscosities has the advantage that it is possible to markedly improved the operational characteristics. The preferred melt viscosity ratio is 1.05:1 to 5.00:1, and more preferably 1.20:1 to 2.50:1. Here, the melt viscosity ratio is defined by the formula given below. The measurement conditions of melt viscosity are a temperature of 280° C. and a strain rate of 6080 sec<sup>-1</sup>, to match the polyester melt spinning conditions.

$$\text{Melt viscosity ratio} = V_1/V_2$$

$V_1$ : melt viscosity value of the polymer with the higher melt viscosity

$V_2$ : melt viscosity value of the polymer with the lower melt viscosity

Furthermore, where the melt viscosity of the lower viscosity polyester is 300–700 poise, the spinnability is enhanced, yarn unevenness and yarn breakage are reduced, and the soft stretchability is further enhanced, so this is preferred.

In a yarn embodying the present invention, the fibre cross-sectional shape is not restricted in any way and, for example, cross-sectional shapes of the kind shown in FIG. 3 can be considered. Of these, in terms of a balance between crimpability and handle, a semicircular side by side round cross-section can be selected, but where the aim is a dry handle then a triangular cross-section or where the aim is lightness of weight and thermal insulation a hollow side by side conjugate or other such suitable cross-sectional shape can be selected in accordance with the particular application.

Now, in a yarn embodying the present invention, where the interface in the side by side bicomponent fibre is linear in the filament cross section, the manifestation of crimp is facilitated and stretchability is enhanced. An index of the linearity of the interface is the radius of curvature  $R$  ( $\mu\text{m}$ ) of the circle which touches the three points a, b and c on the interface in the filament cross-section shown in FIG. 4, where a and b are points of depth  $2 \mu\text{m}$  in the direction of the centre from the filament surface and c is the point at the centre of the interface. It is preferred that  $R \geq 10 \times D^{0.5}$ . Here,  $D$  is the fineness of the filament (dtex).

A soft stretch yarn embodying the present invention can, for example, be produced as follows.

Initially, first and second preferred embodiments of the soft stretch yarn production method of the present invention are explained. Specifically, there is the method in which a conjugate fibre, preferably, an eccentric conjugate fibre comprising two type of polyester is spun at a take-up velocity of at least 1200 m/min, and drawn at a drawing temperature of 50–80° C. and preferably at a draw ratio which gives a drawn yarn elongation of 20–45%, followed by heat setting.

Here, with regard to the combination of the two types of polyester forming the conjugate fibre, if the melt viscosity

ratio is 1.05:1 to 5.00:1, then the spinnability is enhanced, and if at least one of the polyesters is PTT or PBT then soft stretchability is readily manifested, so this is preferred. More preferably, it is PTT. Again, in order to suppress yarn unevenness, the selection of the spinning temperature and the take-up velocity are important. Since the melting point of PTT is about 30–35° C. lower than that of PET, the spinning temperature is lower than the normal spinning temperature for PET and is preferably set at 250–280° C. In this way, thermal degradation of the PTT or an excessive fall in viscosity thereof can be suppressed, lowering of the yarn strength is prevented and yarn unevenness can be reduced. The spinning temperature is preferably 255 to 275° C. Moreover, by making the take-up velocity at least 1200 m/min, the cooling process during spinning is stabilized, yarn oscillation or trembling in the yarn solidification point can be considerably suppressed, and it is possible to markedly suppress yarn unevenness when compared with yarn spun at lower velocities. Again, there is also the advantage that the yarn strength can be raised. However, at a take-up velocity of about 3000 m/min, the stretch characteristics of the soft stretch yarn may be lowered, and this is preferably avoided. On the other hand, at take-up velocities of 5000 m/min or more, the stretch characteristics are actually raised, so employing high speed spinning is also preferred.

It is desirable that there be taken into consideration the fact that, at the time of drawing and heat setting, the glass transition temperature and melting point of PTT are lower, and the heat resistance inferior, when compared to PET. In particular, in order to suppress yarn unevenness, selection of the drawing temperature is important, and the drawing temperature is 50 to 80° C. In this way, excessive crystallization and thermal degradation of the yarn at the time of the preheating are prevented. Thus, yarn unevenness and also yarn breaks due to yarn oscillation or a change in the point of drawing on the roller or heated pin employed for the preheating are reduced, and the yarn strength is raised. The drawing temperature is more preferably 65 to 75° C. Furthermore, for the purposes of reducing the dry heat shrinkage of the drawn yarn, heat setting is carried out following the drawing. The shrinkage can be kept to less than 20% if the temperature is about 120–160° C. in the case where a hot roller is used as the heat setting means, and similarly if the temperature is about 110–180° C. in the case where a hot plate is used, so this is preferred. Again, when a hot plate is used as the heat setting means, the heat setting can be conducted in a state with the molecular chains under tension, so the yarn shrinkage stress can be raised, which is preferred. Furthermore, the draw ratio is important for the manifestation of the soft stretch properties of the present invention, and it is preferred that this be set such that the elongation of the drawn yarn is 20 to 45%. In this way, it is possible to suppress problems due to an excessively high draw ratio such as breaks in the drawing process, a lowering of the soft stretchability and the occurrence of breaks in the fabric forming process, and it is also possible to avoid troubles due to a low draw ratio such as a lowering of the stretchability and pilm barre in the fabric forming process. The draw ratio is more preferably set such that the drawn fibre elongation is 25–35%.

There can be used a two stage spinning and drawing method (the first preferred embodiment) in which the spun yarn is temporarily wound up, after which it is then drawn, or the direct spin draw method in which the spun fibre is drawn as it is without firstly being wound up (the second preferred embodiment). A more specific explanation of the two-stage spinning/drawing method is now provided with

reference to the drawings. With reference to FIG. 5, the molten polyesters in spinning block 1 are filtered using a filter such as nonwoven filter 2 and spun from spinneret 3. The spun yarn 5 is cooled by means of cooling equipment such as cooling chimney 4 and oiled via oiling device 6, after which entanglement is optionally conferred by means of an interlace nozzle such as air nozzle, and then take-up performed by means of first take-up roller (1GD) 8 and second take-up roller (2GD) 9, followed by wind-up by means of winder 10. Here, the peripheral velocity of 1GD 8 is the take-up velocity. Next, the wound undrawn yarn 11 is subjected to drawing and heat setting by means of a known drawing machine. For example, in FIG. 6, the undrawn yarn 11 is fed from feed roller (FR) 12, after which it is preheated by means of first hot roller (1HR) 13, and drawing carried out between 1HR 13 and second hot roller (2HR) 14. Furthermore, after heat setting at 2HR 14, the yarn passes via cold roller 15 and is wound up as drawn yarn 16. Again, in FIG. 7 there is shown an example where a hot plate 17 is used instead of 2HR 14 as the heat setting means. Now, the temperature of 1HR 13 is the drawing temperature, the temperature of 2HR 14 or of hot plate 17 is the heat setting temperature, and the velocity of cold roller 15 is the drawing velocity.

Next, a more specific explanation is given of the direct spin draw method with reference to the drawings.

Referring to FIG. 8, the molten polyesters are filtered using a filter such as nonwoven filter 2 and spun from spinneret 3. Furthermore, the spun yarn is cooled by means of a cooling device such as cooling chimney 4 and oiled using oiling means 6, after which entanglement is optionally conferred by means of an interlace nozzle such as air nozzle 7, and then the yarn taken up by means of first hot nelson roller (1HNR) 18 and, following preheating, drawing carried out between this and second hot nelson roller (2HNR) 19. After heat-setting at 2HNR 19, it is wound up by means of winder 10. Here, the peripheral velocity of 1HNR 18 is the take-up velocity, the temperature of 1HNR 18 is the drawing temperature and the temperature of 2HNR 19 is the heat setting temperature.

When the direct spin draw method is adopted in this way instead of the conventional two stage spinning and drawing method, there is the merit that the production process can be made more efficient and costs reduced. Moreover, the phase of the crimp in the soft stretch yarn tends to be more random and, in particular in the case where the yarn is employed without twisting, the shrinkage of the yarn in the fabric occurs randomly, with the result that there is the merit that a plain fabric with good smoothness is readily obtained.

Next, as a third embodiment of the method of producing soft stretch yarn of the present invention, a simplified direct spin draw method is explained with reference to FIG. 9. Here, a non contact heater 20 is provided on the spinning line between spinneret 3 and 1GD 8, and by taking up the aforesaid conjugate, preferably, eccentric conjugate fibres at a high take-up velocity of at least 4000 m/min, drawing automatically takes place due to the airdrag in non contact heater 20, after which heat setting is performed, preferably by means of a steam setter 21. At this time, since the yarn passes through the non contact heater in a non-constrained state, the drawing and heat setting take place randomly between the individual filaments, and the crimp phase difference in the soft stretch yarn can be made even more random than at the time of the aforesaid direct spin draw method with a hot roller, and so is preferred.

Next, as a fourth embodiment of the method of producing the soft stretch yarn of the present invention, a high velocity

spinning method is explained with reference to FIG. 5. In FIG. 5, by taking up the aforesaid conjugate fibres at a take-up velocity of 5000 m/min or above, drawing is automatically produced by the air drag between spinneret 3 and 1GD 8, and heat setting is carried out by the heat possessed by the yarn itself.

Now, if a twist of at least 100 turns/m is applied to the soft stretch yarn of the present invention, the phase of the crimp is readily made more uniform and stretchability is more readily manifested in the fabric state, so this is preferred. Again, generally speaking, when a side by side bicomponent yarn is produced as a high twist yarn, the crimpability is poor and the stretchability lowered, but in the case of the soft stretch yarn of the present invention  $E_{3.5}$  is very high compared to a conventional PET type side by side conjugate fibre, so adequate stretchability is manifested even in the form of a high twist yarn. Reference here to high twist means applying twist at a twist coefficient of at least 5000, and in the case of yarn of fineness 56 dtex, the number of twists will be at least 700 turns/m. The twist coefficient is defined as the product of the number of twists (turns/m) and the square root of the denier (dtex x 0.9).

The soft stretch yarn embodying the present invention can also be used twist-free, and in this case if there is a divergence in crimp phase between the individual filaments of the yarn, the woven material surface will be plain and, for example, it can be employed as a stretchable lining with excellent smoothness. Moreover, another merit is that the bulkiness is higher compared to the case where the crimp is uniformly arranged.

When a soft stretch yarn embodying the present invention is employed in a knitted material, it is possible to produce an outstanding stretchable knitted fabric with soft stretch properties not achievable in a conventional knitted fabric. In particular, with a knitted fabric, since the fabric shrinks in a state where the constraining forces are weak in the subsequent processing stages, the apparent shrinkage including that due to crimping is marked and the knitted loops are closed up, so in cases where a stretch yarn is used the fabric is readily coarsened. Hence, in a knitted fabric, the soft stretchability possessed by the yarn itself is a particularly important parameter, and by using the soft stretch yarn of the present invention it is possible to obtain soft stretch knitted fabrics unattainable hitherto. Again, if there is used a soft stretch yarn in which the crimp phase is uniformly arranged, a fine crimp is readily produced between the knitted loops and a fine crepe is formed, and so it is possible to obtain a highly attractive knitted fabric.

Moreover, if a soft stretch yarn embodying the present invention is employed in the form of a combined filament yarn along with a low shrink yarn comprising polyester or nylon of boiling water shrinkage no more than 10%, then not only is the sense of softness increased but also the bulkiness and resilience are enhanced, which is desirable. If, comparatively speaking, the low shrinkage yarn is present at the outer periphery of the soft stretch yarn, then it has a cushioning role and the sense of softness is further enhanced. Again, the yarn diameter as a multifilament is increased and so the sense of bulkiness is raised. For this purpose, it is advantageous if the boiling water shrinkage of the low shrink yarn be low. More preferably, the boiling water shrinkage is no more than 4% and still more preferably it is no more than 0%. Again, it is advantageous if the initial modulus of the low shrink yarn is also low, preferably no more than 50 cN/dtex. Furthermore, the finer the individual filament denier of the low shrinkage yarn the greater the sense of softness, so the single filament fineness is preferably no more than 2.5 dtex and more preferably no more than 1.0 dtex.

Again, if a soft stretch yarn embodying the present invention is used as a mixture along with natural fibres and/or semi-synthetic fibres, it is possible to confer stretchability without impairing the moisture absorption/release properties and the outstanding handle such as coolness to the touch and resilience possessed by the natural or semi-synthetic fibres. Mixture here refers to a combined yarn or to a combined weave or combined knit. In order to balance the characteristics possessed by the soft stretch yarn and the handle of the natural or semi-synthetic fibres, it is preferred that the total weight of natural fibres or semi-synthetic fibres be from 10 to 90% of the fabric weight.

Yarns embodying the present invention can be used advantageously for textile materials such as socks, shirts, blouses, cardigans, trousers, skirts, one-piece costumes, suits, sportswear, lingerie and linings.

#### EXAMPLES

Preferred embodiments of the present invention will now be described in more detail with reference to the following Examples, in which the following methods were employed as the methods of measurement.

##### A. Stress at 50% yarn strain, and the percentage recovery

Firstly, the yarn was wound in the form of a hank, and then a heat treatment carried out by immersion for 15 minutes in boiling water in a substantially load free state. Next, using an automatic tensile testing machine, an initial tension of  $4.4 \times 10^{-3}$  cN/dtex (5 mgf/d) was applied to this heat-treated yarn at an initial sample length of 50 mm, then the yarn stretched 50% at a rate of extension of 100%/min, after which it was immediately returned to 0% extension at the same rate, and the hysteresis curve measured (FIG. 1). The maximum attained stress, based on the initial tension, was taken as the stress at 50% stretch. The percentage recovery was calculated from FIG. 1, using the relation: percentage recovery (%) =  $[(50-a)/50] \times 100\%$ . Here, 'a' is the percentage extension at the point when the stress in the recovery process of the hysteresis curve reaches the initial tension.

##### B. Crimp stretch factor (FIG. 10)

$$\text{crimp stretch factor (\%)} = [(L_1 - L_2)/L_1] \times 100\%$$

$L_1$ : hank length with a load of  $180 \times 10^{-3}$  cN/dtex applied, after having subjected the fibre hank to 15 minutes treatment in boiling water and then 15 minutes dry heat treatment at  $180^\circ \text{C}$ .

$L_2$ : the hank length when, following measurement of  $L_1$ , the load applied is changed from  $180 \times 10^{-3}$  cN/dtex (0.2 gf/d) to  $0.9 \times 10^{-3}$  cN/dtex (1 mgf/d)

$E_0$ : crimp stretch factor after having been heat treated under substantially no load

$E_{3.5}$ : crimp stretch factor after having been heat treated under a load of  $3.5 \times 10^{-3}$  cN/dtex (4 mgf/d)

##### C. Percentage crimp retention

$E_1$  was measured with the load at the time of the heat treatment in the measurement of the crimp stretch factor made  $0.9 \times 10^{-3}$  cN/dtex (1 mgf/d). Furthermore, after applying a heavy load ( $180 \times 10^{-3}$  cN/dtex) and a light load ( $0.9 \times 10^{-3}$  cN/dtex) and repeating this nine times, so that stretching/recovery was performed a total of 10 times, the hank length  $L_{10}$  was measured with the light load applied.

The crimp stretch factor  $E_{10}$  (%) following the stretching was determined from the relationship given below, and the percentage crimp retention was determined from the ratio in terms of the initial crimp stretch factor.

$$\text{Percentage crimp retention (\%)} = [E_{10}/E_1] \times 100 (\%)$$

$$E_1^{10}(\%) = [(L_0 - L_{10})/L_0] \times 100 (\%)$$

#### D. Crimp diameter

Following the measurement of  $E_0$ , the yarn was sampled in a state with, as far as possible, no force applied, and then observation performed with a scanning electron microscope (FIG. 11). The diameters (outer diameters) of 100 randomly selected crimps were measured and the average value thereof taken as the crimp diameter.

#### E. Uster unevenness (U%)

This was measured using a Uster Tester 1 Model C, manufactured by the Zellweger Co., in the normal mode while supplying yarn at a rate of 200 m/min.

#### F. Shrinkage stress

This was measured using a thermal stress measurement instrument manufactured by Kanebo Engineering Co., at a heating rate of 150° C./min. Sample=10 cm×2 loop, with initial tension=fineness (decitex)×0.9×(1/50) gf.

#### G. Tensile strength and elongation

With the initial sample length=50 mm and the rate of extension=50 mm/min (100%/min), the stress-strain curve was determined under the conditions given in Japanese Industrial Standard (JIS) L1013. The extension divided by the initial sample length was taken as the tensile elongation.

#### H. Melt viscosity

Measurement was carried out under a nitrogen atmosphere, using a Capilograph 1B, manufactured by the Toyo Seiki Co. Measurement was carried out three times at a measurement temperature of 280° C. and a strain rate of 6080 sec<sup>-1</sup>, with the average value being taken as the melt viscosity.

#### I. Intrinsic viscosity

Measured in o-chlorophenol at 25° C.

#### J. Initial modulus

Measured in accordance with JIS L1013.

#### K. Boiling water shrinkage and dry shrinkage

$$\text{boiling water shrinkage } (\%) = [(L_0 - L_1)/L_1] \times 100\%$$

$L_0$ : original hank length when drawn yarn is wound in the form of a hank and an initial load of 0.18 cN/dtex (0.2 gf/d) applied

$L_1$ : hank length under an initial load of 0.18 cN/dtex (0.2 gf/d), after the hank used to measure  $L_0$  was treated for 15 minutes in boiling water in a substantially load free state, and then air dried

$$\text{dry heat shrinkage } (\%) = [(L_0 - L_2)/L_0] \times 100\%$$

$L_2$ : hank length under an initial load of 0.18 cN/dtex (0.2 gf/d), after the hank used to measure  $L_1$  was dry heat treated for 15 minutes at 180° C. in a substantially load free state, and then air dried

#### L. Evaluation of handle

The fabrics obtained in the examples and comparative examples were evaluated on a scale of 1 to 5 in terms of soft feel, bulkiness, resilience, stretchability, dyeing evenness and surface impression (attractiveness of the fabric surface). A grade of 3 or more was acceptable.

### Example 1

Titanium dioxide-free homo PTT of melt viscosity 400 poise and homo PET of melt viscosity 370 poise containing 0.03 wt% titanium dioxide were separately melted at 260° C. and 285° C. respectively, and then each filtered using stainless steel nonwoven filters of maximum pore diameter 15 μm, after which they were spun at a spinning temperature of 275° C. from a 12-hole parallel type spinneret (FIG. 2(a))

to form side by side bi-component fibre (FIG. 3(b)) of conjugate ratio 1:1. The melt viscosity ratio at this time was 1.08. At a take-up velocity of 1500 m/min, 168 dtex 12-filament undrawn yarn was wound up. Subsequently, using the drawing machine with hot rollers illustrated in FIG. 6, drawing was carried out with the temperature of the 1HR 13 at 70° C. and the temperature of the 2HR 14 at 130° C., at a draw ratio of 3.00. In both the spinning and drawing, yarn production was good and there were no yarn breaks. The properties of the yarn are given in Table 2, and outstanding crimpability was shown with the PTT at the inside of the crimp. Furthermore, the crimp diameter manifested in the heat treatment for measuring  $E_0$  was extremely small, at 200 μm, so an extremely high quality product was formed. Moreover, the yarn was sufficiently soft, with an initial modulus of 42 cN/dtex, and the shrinkage was sufficiently low, with a dry heat shrinkage of 11%. Again, the temperature at which the shrinkage stress maximum was shown was sufficiently high at 128° C. The radius of curvature of the interface of the two components was 80 μm

### Example 2

Using a polymer combination of titanium dioxide-free homo PTT of melt viscosity 700 poise and homo PET of melt viscosity 390 poise containing 0.03 wt% titanium dioxide, spinning was carried out in the same way as in Example 1, and 168 dtex, 12-filament undrawn yarn was wound up. The melt viscosity ratio at this time was 1.75 and a side by side bicomponent fibre was formed of shape as in FIG. 3(b). Subsequently, using the drawing machine with a hot plate illustrated in FIG. 7, drawing was carried out with the temperature of the 1HR 13 at 70° C. and the temperature of hot plate 17 at 165° C., at a draw ratio of 3.00. In both the spinning and drawing, yarn production was good and there were no yarn breaks. The properties of the yarn are given in Table 2, and outstanding crimpability was shown with the PTT at the inside of the crimp. Furthermore, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was extremely small, at 190 μm, so an extremely high quality product was formed. Moreover, the yarn was sufficiently soft, with an initial modulus of 44 cN/dtex, and the shrinkage was sufficiently low, with the dry heat shrinkage being 11%. Again, the temperature at which the shrinkage stress maximum was shown was sufficiently high at 145° C. The radius of curvature of the interface of the two components was 40 μm

### Example 3

Using a polymer combination of titanium dioxide-free homo PTT of melt viscosity 1900 poise and homo PET of melt viscosity 390 poise containing 0.03 wt% titanium dioxide, spinning was carried out in the same way as in Example 1 at a take-up velocity of 1350 m/min using the 12-hole insert type conjugate fibre spinneret (FIG. 2(b)) described in JP-A-9-157941, and 190 dtex, 12-filament undrawn yarn wound up. The melt viscosity ratio at this time was 4.87 and there was formed a side by side bicomponent fibre of shape as in FIG. 3(b). Subsequently, drawing was carried out in the same way as in Example 2, at a draw ratio of 3.40. In both the spinning and drawing, yarn production was good. The properties of the yarn are given in Table 2, and outstanding crimpability was shown with the PTT at the inside of the crimp. Furthermore, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was extremely small, at 190 μm, so an extremely high quality product was formed. Moreover, the yarn was sufficiently soft, with an



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initial modulus of 44 cN/dtex, and the shrinkage was sufficiently low, with the dry heat shrinkage being 11%. Again, the temperature at which the shrinkage stress maximum was shown was sufficiently high at 145° C. Now, while still within the permitted range, there was an increase in yarn breakage in the spinning and drawing compared to Examples 1 and 2. The radius of curvature of the interface of the two components was 25  $\mu\text{m}$

## Example 4

A polymer combination of titanium dioxide-free homo PTT of melt viscosity 1500 poise and titanium dioxide-free homo PTT of melt viscosity 400 poise was separately melted at 270° C. and 260° C. respectively, after which spinning was carried out in the same way as in Example 1 at a spinning temperature of 265° C. and a take-up velocity of 1350 m/min using a 12-hole insert type conjugate fibre spinneret (FIG. 2(b)) as described in JP-A-9-157941, and 132 dtex, 12-filament undrawn yarn wound up. The melt viscosity ratio at this time was 3.75 and there was formed a side by side bicomponent fibre of shape as in FIG. 3(b). Subsequently, drawing was carried out in the same way as in Example 2 with the temperature of the 1HR 13 at 65° C. and the temperature of the 2HR 14 at 130° C., at a draw ratio of 2.35. In both the spinning and drawing, yarn production was good. The properties of the yarn are given in Table 2, and outstanding crimpability was shown with the high viscosity PTT at the inside of the crimp. Furthermore, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was extremely small, at 190  $\mu\text{m}$ , so an extremely high quality product was formed. Moreover, it was sufficiently soft, with an initial modulus of 22 cN/dtex, and the shrinkage was sufficiently low, with the dry heat shrinkage being 12%. Again, the temperature at which the shrinkage stress maximum was shown was sufficiently high at 125° C. Now, while still within the permitted range, there was an increase in yarn breakage in the spinning and drawing compared to Examples 1 and 2. The radius of curvature of the interface of the two components was 60  $\mu\text{m}$

## Example 5

A polymer combination of titanium dioxide-free homo PTT of melt viscosity 700 poise (intrinsic viscosity 1.18) and homo PBT of melt viscosity 600 poise (intrinsic viscosity 0.82) containing 0.03 wt% titanium dioxide was spun in the same way as in Example 4, and 168 dtex, 12-filament undrawn yarn wound up. The melt viscosity ratio at this time was 1.17 and there was formed a side by side bicomponent fibre of shape as in FIG. 3(b). Subsequently, drawing was carried out using the drawing machine with a hot plate shown in FIG. 7, with the temperature of the 1HR 13 at 65° C. and the temperature of the hot plate 17 at 160° C., at a draw ratio of 3.00. The properties of the yarn are given in Table 2, and outstanding crimpability was shown with the PTT at the inside of the crimp. Furthermore, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was small, at 220  $\mu\text{m}$ , so a high quality product was formed. Moreover, the yarn was sufficiently soft, with an initial modulus of 34 cN/dtex, and the shrinkage was sufficiently low, with the dry heat shrinkage being 12%. Again, the temperature at which the shrinkage stress maximum was shown was sufficiently high at 153° C. The radius of curvature of the interface of the two components was 28  $\mu\text{m}$

## Example 6

Using a polymer combination of titanium dioxide-free homo PBT of melt viscosity 1150 poise and homo PTT of

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melt viscosity 300 poise containing 0.03 wt% titanium dioxide, spinning was carried out in the same way as in Example 4. The melt viscosity ratio at this time was 3.83 and there was formed a side by side bicomponent fibre of shape as in FIG. 3(b), of radius of curvature 46  $\mu\text{m}$ . Subsequently, drawing was carried out using the drawing machine with a hot plate shown in FIG. 7, with the temperature of the 1HR 13 at 65° C. and the temperature of the hot plate 17 at 160° C., at a draw ratio of 3.00. The properties of the yarn are given in Table 2, and outstanding crimpability was shown with the PBT at the inside of the crimp. The crimp diameter manifested by the heat treatment for measuring  $E_0$  was 290  $\mu\text{m}$ , so the quality was somewhat inferior to that of Example 1. Moreover, the yarn was sufficiently soft, with an initial modulus of 31 cN/dtex, and the shrinkage was sufficiently low, with the dry heat shrinkage being 11%. Again, the temperature at which the shrinkage stress maximum was shown was sufficiently high at 150° C. Now, while within the permitted range, there were increased yarn breaks in the spinning and drawing compared to Examples 1 and 2.

## Example 7

Melt spinning was carried out under the same conditions as in Example 2 except that the take-up velocity was made 3000 m/min and 77 dtex 12-filament undrawn yarn was produced. Using this undrawn yarn, drawing was carried out under the same conditions as in Example 2 except that the draw ratio was made 1.40. Yarn production was good in both the spinning and drawing and there were no yarn breaks. The properties of the yarn are given in Table 2, and outstanding crimpability was shown with the PTT at the inside of the crimp. Furthermore, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was low, at 220  $\mu\text{m}$ , so an extremely high quality product was formed.

## Example 8

Melt spinning was carried out under the same conditions as in Example 1 except that instead of the side by side bicomponent yarn there was produced an eccentrically disposed sheath core conjugate fibres (FIG. 3(h)) and the polymers and conjugate ratio were changed as follows. There was employed at this time, as the sheath polymer, 60 wt% PET of melt viscosity 400 poise containing 0.40 wt% titanium dioxide and, as the core polymer, 40 wt% titanium dioxide-free PTT of melt viscosity 700 poise. The undrawn yarn was drawn under the same conditions as in Example 1 except that the draw ratio was made 2.60 and the temperature of the 2HR 14 was made 140° C. Yarn production was good in both the spinning and drawing and there were no yarn breaks. The properties are given in Table 2 and outstanding crimpability was shown. Furthermore, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was low, at 240  $\mu\text{m}$ , and a high quality product was formed.

## Example 9

Melt spinning was carried out under identical conditions to those in Example 2, except that the fibre cross-sectional shape was a hollow section (FIG. 3(j)), and 168 dtex, 12 filament undrawn yarn was wound up. Using this undrawn yarn, drawing was carried out under the same conditions as in Example 2 except that the draw ratio was made 2.95. The properties are given in Table 1, and outstanding crimpability was shown with the PTT at the inside of the crimp. Furthermore, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was low, at 240  $\mu\text{m}$ , and a high quality product was formed.



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## Example 10

Spinning was carried out in the same way as in Example 1 except that the PTT in Example 1 was changed to titanium dioxide-free polybutylene terephthalate (below referred to as PBT) of melt viscosity 390 poise, and 168 dtex, 12 filament undrawn yarn was wound up. Drawing was carried out in the same way as in Example 1, at a draw ratio of 3.00, and soft stretch yarn obtained. The properties are given in Table 2 and good crimpability was shown. Now, the stress in terms of 50% stretch exceeded  $10 \times 10^{-3}$  cN/dtex and the recovery was less than 70%, so the softness and stretchability were somewhat inferior to those in Example 1. Furthermore, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was  $300 \mu\text{m}$ , and so the product quality too was somewhat inferior to Example 1. Moreover, the crimp phase was random compared to Example 1.

## Example 11

Spinning was carried out in the same way as in Example 2, except that the PTT in Example 2 was changed to titanium dioxide-free PBT of melt viscosity 1050 poise, and 190 dtex, 12 filament undrawn yarn was wound up. Drawing was carried out in the same way as in Example 1, at a draw ratio of 3.40, and soft stretch yarn obtained. The properties are given in Table 2 and good crimpability was shown. Now, the recovery in terms of 50% stretch was less than 70%, so the stretchability was somewhat inferior to that in Example 2. Furthermore, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was  $280 \mu\text{m}$ , and the product quality too was somewhat inferior to Example 1. Moreover, the crimp phase was random compared to Example 2. Furthermore, with the initial modulus at 55 cN/dtex, the softness was somewhat inferior to Example 2 but the dry heat shrinkage was sufficiently low at 12%. The temperature at which the maximum shrinkage stress was shown was sufficiently high, at  $128^\circ\text{C}$ . While still within the permitted range, there was an increase in yarn breaks during spinning and drawing when compared to Examples 1 and 2.

## Example 12

Spinning was carried out in the same way as in Example 1 except that the PTT in Example 1 was changed to titanium dioxide-free PBT of melt viscosity 390 poise, and the take-up velocity was made 6000 m/min. 62 dtex, 12 filament undrawn yarn was obtained. Drawing was carried out in the same way as in Example 1 except that the draw ratio was 1.10, and in this way soft stretch yarn was obtained. The properties are given in Table 2, and good crimpability was shown. However, the recovery in terms of 50% stretch was less than 70%, so the stretchability was somewhat inferior to that in Example 6. Furthermore, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was  $260 \mu\text{m}$ , and the product quality too was somewhat inferior to Example 1. Again, the crimp phase was random compared to Example 1.

## Example 13

Using the direct spin draw machine shown in FIG. 8, drawing was carried out in the same way as in Example 2 with the peripheral velocity of 1HNR 18=1500 m/min and temperature= $75^\circ\text{C}$ ., peripheral velocity of 2HNR 19=4500 m/min and temperature= $130^\circ\text{C}$ . 56 dtex, 12 filament soft stretch yarn was wound up. The properties are given in Table 2 and good crimpability was shown with the PTT on the inside of the crimp. Furthermore, the crimp diameter mani-

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fested by the heat treatment for measuring  $E_0$  was extremely low, at  $200 \mu\text{m}$ , and an extremely high quality product was formed. Moreover, the initial modulus was 42 cN/dtex, so the yarn was sufficiently soft, and the dry heat shrinkage was also sufficiently low at 10%. Again, the temperature at which the maximum shrinkage stress was shown was sufficiently high at  $128^\circ\text{C}$ .

## Example 14

Using the direct spin draw machine shown in FIG. 9, drawing was carried out in the same way as in Example 2 with the temperature of the non-contact heater  $20=190^\circ\text{C}$ ., the take-up velocity=5000 m/min, and a  $100^\circ\text{C}$ . steam heat treatment carried out between the 2GD 9 and winder 10. The properties of the soft stretch yarn obtained are given in Table 2 and good crimpability was shown with the PTT on the inside of the crimp. Furthermore, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was extremely low, at  $190 \mu\text{m}$ , and an extremely high quality product was formed. The crimp phase varied between individual filaments and there was a sense of high bulkiness compared to Example 2. Furthermore, the initial modulus was 43 cN/dtex so the yarn was sufficiently soft, and the dry heat shrinkage was also sufficiently low at 12%. Again, the temperature at which the maximum shrinkage stress was shown was sufficiently high at  $126^\circ\text{C}$ .

## Example 15

Melt spinning was carried out under the same conditions as in Example 2 except that the take-up velocity was changed to 7000 m/min. This yarn could be used in the wound state without drawing. The properties are given in Table 2 and excellent crimpability was shown. Again, the crimp diameter manifested by the heat treatment for measuring  $E_0$  was extremely low, at  $120 \mu\text{m}$ , and the crimp phase varied between individual filaments, so that there was a sense of bulkiness as compared with Example 2. Moreover, with a dry heat shrinkage of 5%, the yarn had sufficiently low shrinkage.

## Comparative Example 1

Spinning was carried out in the same way as in Example 2 using a polymer combination of titanium dioxide-free homo PTT of melt viscosity 850 poise and homo PET of melt viscosity 850 poise containing 0.03 wt% titanium dioxide, at a take-up velocity of 900 m/min and a spinning temperature of  $286^\circ\text{C}$ . 168 dtex, 12 filament undrawn yarn was obtained. Drawing and heat setting were carried out in the same way as in Example 2. The properties are given in Table 2 and, while a certain degree of crimpability was shown, since the spinning temperature was high and there was thermal degradation on the PTT side the spinning was unstable. Moreover, since the undrawn yarn take-up velocity was low, there was considerable yarn oscillation during the spinning process and considerable variation in the solidification point. Hence, the strength of the drawn yarn was markedly lowered and there was a deterioration in the Uster unevenness. Again, the stress in terms of 50% stretch exceeded  $50 \times 10^{-3}$  cN/dtex, so the softness and stretchability did not reach the levels in Example 2.

## Comparative Example 2

The polymer combination in Comparative Example 1 was spun in the same way as in Example 1 at a spinning temperature of  $280^\circ\text{C}$ . and a take-up velocity of 1500

m/min, and 146 dtex 12 filament undrawn yarn obtained. Drawing and heat setting were carried out in the same way as in Example 2 except that the draw ratio was 2.70 and the temperature of the 1HR 13 was 100° C. The properties are given in Table 2 and, while a certain degree of crimpability was shown, since the temperature of the 1HR 13 was high there was thermal degradation of the PTT and frequent yarn breakage occurred. Moreover, the strength of the drawn yarn obtained was low and there was a deterioration in the Uster unevenness. Again, the stress in terms of 50% stretch exceeded  $50 \times 10^{-3}$  cN/dtex, so the softness and stretchability did not reach the levels in Example 2.

## Comparative Example 3

Homo PET polymers containing 0.03 wt% of titanium dioxide and respectively having a melt viscosity of 130 poise (intrinsic viscosity 0.46) or 2650 poise (intrinsic viscosity 0.77) were separately melted at 275° C. and 290° C., and separately filtered using a stainless steel nonwoven filter of maximum pore diameter 20  $\mu$ m, after which they were spun at a spinning temperature of 290° C. from a 12-hole insert type spinneret (FIG. 2(b)) as described in JP-A-9-157941 to form side by side bi-component fibre (FIG. 3(a)) of conjugate ratio 1:1. The melt viscosity ratio at this time was 20.3. At a take-up velocity of 1500 m/min, 154 dtex 12-filament undrawn yarn was wound up. Subsequently, drawing was carried out with the temperature of the 1HR 13 at 90° C. and the temperature of hot plate 17 at 150° C., at a draw ratio of 2.80. In both the spinning and drawing, yarn production was poor and there were frequent yarn breaks. The properties of the yarn are given in Table 2,

but the stress in terms of 50% stretch exceeded  $50 \times 10^{-3}$  cN/dtex and it was not possible to produce the soft stretch yarn of the present invention. Again,  $E_{3.5} = 0.5\%$  and the crimpability in a constrained state was low. Furthermore, with the initial modulus being 75 cN/dtex, the yarn lacked softness.

## Comparative Example 4

Homo PET of melt viscosity 2000 poise containing 0.03 wt% titanium dioxide and copolymer PET of melt viscosity 2100 poise in which 10 mol% of isophthalic acid had been copolymerized as an acid component and which contained 0.03 wt% titanium dioxide were separately melted at 285° C. and 275° C. respectively, and then spinning carried out in the same way as in Example 1 at a spinning temperature of 285° C. and a take-up velocity of 1500 m/min. 154 dtex, 12 filament undrawn yarn was wound up. Subsequently, drawing was carried out in the same way as in Comparative Example 3 at a draw ratio of 2.75. In both the spinning and drawing, yarn production was good and there were no yarn breaks. The properties of the yarn are given in Table 2, but the stress in terms of 50% stretch exceeded  $50 \times 10^{-3}$  cN/dtex and it was not possible to produce the soft stretch yarn of the present invention. Again, with  $E_{3.5} = 0.4\%$ , the crimpability in a constrained state was low.

TABLE 1

	Process	Polymer Combination	Melt Viscosity Ratio	Spinning Temperature (° C.)	Take-up Velocity (m/min)	Drawing Temperature (° C.)	Heat Setting Temperature (° C.)
Ex. 1	2-stage	PTT/PET	1.08	275	1500	70	130
Ex. 2	2-stage	PTI/PET	1.75	275	1500	70	165
Ex. 3	2-stage	PTI/PET	4.87	275	1350	70	165
Ex. 4	2-stage	PTI/PTT	3.75	265	1350	65	130
Ex. 5	2-stage	PTT/PBT	1.17	265	1350	65	160
Ex. 6	2-stage	PBT/PTT	3.83	265	1350	65	160
Ex. 7	2-stage	PTI/PET	1.75	275	3000	70	165
Ex. 8	2-stage	PTI/PET	1.75	275	1500	70	140
Ex. 9	2-stage	PTT/PET	1.75	275	1500	70	165
Ex. 10	2-stage	PBT/PET	1.03	275	1500	70	130
Ex. 11	2-stage	PBT/PET	2.84	275	1500	70	130
Ex. 12	2-stage	PBT/PET	1.03	275	6000	70	130
Ex. 13	1-stage	PTI/PET	1.75	275	1500	75	130
Ex. 14	1-stage	PTT/PET	1.75	275	—	—	—
Ex. 15	1-stage	PTT/PET	1.75	275	7000	—	—
Comp. 1	2-stage	PTT/PET	1.00	286	900	70	165
Comp. 2	2-stage	PTT/PET	1.00	280	1500	100	165
Comp. 3	2-stage	PET/PET	20.3	290	1500	90	150
Comp. 4	2-stage	PET/PET	1.05	285	1500	90	150

TABLE 2

	Stress (cN/dtex)	Recovery (%)	F <sub>0</sub> (%)	F <sub>3.5</sub> (%)	Crimp Retention (%)	TS	U%	Flongation (%)	Strength
Ex. 1	$6.0 \times 10^{-3}$	71	45.0	12.2	92	0.31	0.9	28.0	3.6
Ex. 2	$5.5 \times 10^{-3}$	77	67.0	15.0	95	0.32	0.9	26.0	3.7
Ex. 3	$4.5 \times 10^{-3}$	81	75.0	15.8	96	0.34	0.9	27.8	3.9
Ex. 4	$4.0 \times 10^{-3}$	80	70.3	15.2	96	0.32	1.0	27.0	3.7

TABLE 2-continued

	Stress (cN/dtex)	Recovery (%)	E <sub>0</sub> (%)	E <sub>3,5</sub> (%)	Crimp Retention (%)	TS	U%	Elongation (%)	Strength
Ex. 5	6.0 × 10 <sup>-3</sup>	68	51.0	14.8	98	0.30	0.9	26.8	3.1
Ex. 6	3.6 × 10 <sup>-3</sup>	74	63.5	23.8	98	0.26	1.0	25.8	3.0
Ex. 7	7.5 × 10 <sup>-3</sup>	70	42.4	11.5	92	0.26	0.9	27.8	3.2
Ex. 8	8.5 × 10 <sup>-3</sup>	70	40.1	11.1	90	0.31	1.1	29.1	3.5
Ex. 9	9.5 × 10 <sup>-3</sup>	70	41.2	11.2	90	0.29	1.3	27.3	3.2
Ex. 10	10.5 × 10 <sup>-3</sup>	61	38.5	15.4	98	0.30	1.0	27.8	3.0
Ex. 11	5.8 × 10 <sup>-3</sup>	68	56.0	20.2	98	0.33	1.0	27.2	3.9
Ex. 12	5.2 × 10 <sup>-3</sup>	67	58.3	21.4	98	0.35	1.0	34.0	3.7
Ex. 13	6.0 × 10 <sup>-3</sup>	77	65.0	15.0	95	0.32	0.9	25.0	3.6
Ex. 14	5.5 × 10 <sup>-3</sup>	79	68.0	15.0	95	0.32	0.9	22.3	3.5
Ex. 15	5.1 × 10 <sup>-3</sup>	75	65.0	10.0	95	0.24	0.8	34.5	3.1
Comp. 1	>50 × 10 <sup>-3</sup>	62	44.2	9.4	86	0.34	3.2	28.2	2.1
Comp. 2	>50 × 10 <sup>-3</sup>	67	42.0	9.2	86	0.32	3.5	25.0	2.1
Comp. 3	>50 × 10 <sup>-3</sup>	65	48.3	0.5	65	0.21	1.5	20.1	3.1
Comp. 4	>50 × 10 <sup>-3</sup>	45	41.2	0.4	60	0.30	1.0	28.8	4.5

TS = maximum value of shrinkage stress (cN/dtex)  
strength = strength of soft stretch yarn (CN/dtex)

Example 16

Using the yarns obtained in Examples 1 to 15 and Comparative Examples 1 to 4, twisting was carried out at 700 turns/m and twist setting conducted by steam at 65° C. Then, using a 28 gauge circular knitter, knitted materials with an interlock structure were produced. These were subjected to relaxation scouring at 90° C. in accordance with normal procedure, after which presetting was carried out at 180° C. Furthermore, after a 10 wt% caustic treatment again in accordance with normal procedure, dyeing was conducted at 130° C.

The handle of the materials obtained were subjected to functional evaluation (Table 3). Where the soft stretch yarns of Examples 1 to 13 had been used, the softness and stretchability were excellent and, furthermore, the material surface was highly attractive. Moreover, in the case of Examples 1 to 4 and 7, 12 and 13, the crimp coil diameter was sufficiently low so knitted materials of outstanding attractiveness were produced. On the other hand, in the case of Comparative Examples 1 and 2, dyeing unevenness occurred and the fabrics were of poor quality. Moreover, in Comparative Examples 3 and 4, the handle was coarse.

TABLE 3

Yarn Used	Soft-ness	Bulki-ness	Re-silience	Stretch-ability	Dyeing Evenness	Surface Impression
Ex. 1	4	3	3	4	5	4
Ex. 2	4	3	3	5	5	5
Ex. 3	4	3	3	5	5	5
Ex. 4	4	3	3	5	4	5
Ex. 5	4	3	3	4	5	4
Ex. 6	5	3	3	5	4	4
Ex. 7	4	3	3	4	5	4
Ex. 8	4	3	3	4	4	4
Ex. 9	4	3	3	4	3	4
Ex. 10	3	3	3	3	4	3
Ex. 11	4	3	3	3	4	3
Ex. 12	4	3	3	3	4	3
Ex. 13	4	4	3	5	5	5
Ex. 14	4	4	3	5	5	5
Ex. 15	4	4	3	4	5	5
Comp. 1	2	3	3	2	1	2
Comp. 2	2	3	3	2	1	2
Comp. 3	1	2	3	2	3	2
Comp. 4	1	2	2	2	4	2

Example 17

Using the yarns obtained in Examples 1 to 15 and in Comparative Examples 3 and 4, twisting was carried out at 1500 turns/m and twist setting conducted by steam at 65° C. Then, in each case, a plain weave fabric was constructed using the same yarn for the warp and weft. The yarn densities at this time were warp=110 per inch and weft=91 per inch, and a torque balance was obtained by alternate placement of S-twist/Z-twist yarns. The cloth obtained was processed as follows. Firstly, relaxation scouring was conducted at 90° C., after which presetting was carried out with dry heat at 180° C. using a pin stenter. Furthermore, after a 15% caustic treatment in the usual way, dyeing was carried out at 130° C., once again by normal procedure.

The handle of the fabrics obtained was subjected to functional evaluation (Table 4). As predicted from the properties of the yarn, with the fabrics produced from the yarns in Examples 1 to 13 stretchability was manifested in each case, whereas the stretchability was poor in the case of Comparative Examples 3 and 4.

TABLE 4

Yarn Used	Soft-ness	Bulki-ness	Re-silience	Stretch-ability	Dyeing Evenness	Surface Impression
Ex. 1	4	3	3	4	5	4
Ex. 2	4	4	3	5	5	5
Ex. 3	4	3	3	5	5	5
Ex. 4	4	3	3	5	4	5
Ex. 5	4	3	3	4	5	4
Ex. 6	5	3	3	5	4	4
Ex. 7	4	3	3	4	5	4
Ex. 8	4	3	3	4	4	4
Ex. 9	4	3	3	4	3	4
Ex. 10	3	3	3	3	4	3
Ex. 11	4	3	3	3	4	3
Ex. 12	4	3	3	3	4	3
Ex. 13	4	5	3	5	5	5
Ex. 14	4	5	3	5	5	5
Ex. 15	4	4	3	4	5	5
Comp. 1	2	3	3	2	1	2
Comp. 2	2	3	3	2	1	2
Comp. 3	1	2	3	1	3	2
Comp. 4	1	2	2	1	4	2

Example 18

Using the soft stretch yarns obtained in Examples 13 and 14 as warp and weft without applying twist, plain weave

fabrics were produced. The yarn densities at this time were warp=110 per inch and weft=91 per inch. The cloths obtained was processed as follows. Firstly, relaxation scouring was conducted at 90° C., after which presetting was carried out with dry heat at 180° C. using a pin stenter. Dyeing was carried out at 130° C. by normal procedure.

The materials obtained had a plain surface and were very smooth. They were suitable as soft stretch linings.

Example 19

Using the soft stretch yarns obtained in Examples 1, 2, 8 and 9, and in Comparative Examples 3 and 4, combined filament yarns were produced along with low-shrink PET yarn under the conditions given in Table 5, and twist setting carried by steam at 65° C. Weaving, processing and evaluation were conducted in the same way as in Example 17.

The handle of the fabrics obtained was subjected to functional evaluation (Table 6). As predicted from the properties of the yarn, in the case of the fabrics produced from the yarns in the Examples a soft handle and excellent softness was shown, but where the yarns of Comparative Examples 3 and 4 were used there was a highly coarse feel.

TABLE 5

Code	Yarn Used	Product Type	Properties of the Other Yarn used in the Combined Filament Yarn		Twist in Combined	Yarn Density (warp x weft) (yarns per inch)
			Boiling Shrinkage (%)	YM (cN/dex)		
A	Example 1	55 dtex-24 fil	-1.0	35	400	101 x 90
B	Example 2	55 dtex-24 fil	-2.0	30	400	101 x 90
C	Example 2	55 dtex-24 fil	1.0	35	400	101 x 90
D	Example 2	55 dtex-24 fil	8.0	76	400	101 x 90
E	Example 2	75 dtex-144 fil	6.5	35	600	99 x 84
F	Example 2	55 dtex-12 fil	1.0	35	400	101 x 90
G	Example 8	75 dtex-144 fil	-1.0	34	800	99 x 84
H	Example 9	55 dtex-24 fil	1.0	32	400	101 x 90
I	Comp. Ex. 3	55 dtex-24 fil	1.0	35	400	101 x 90
J	Comp. Ex. 4	55 dtex-24 fil	1.0	35	400	101 x 90

YM: Young's modulus

TABLE 6

Code	Softness	Bulkiness	Resilience	Stretchability	Dyeing Evenness	Surface Impression
A	4	5	5	4	5	4
B	4	5	5	5	5	4
C	4	4	4	5	5	4
D	3	3	3	5	5	4
E	5	3	4	5	5	4
F	3	4	5	5	5	4
G	4	5	4	5	5	4
H	3	4	4	3	3	3
I	1	3	2	1	4	2
J	1	3	2	1	4	2

Example 20

A plain weave fabric was constructed using the untwisted soft stretch yarn obtained in Example 13 as the weft, and using the cuprammonium rayon "Cupra" produced by the Asahi Chemical Ind. Co. (83 dtex, 45 filament) as the warp. The yarn densities at this time were warp=110 per inch and weft=91 per inch. The fabric obtained was processed as follows. Firstly, relaxation scouring was carried out at 90°

C., after which presetting was performed with dry heat at 150° C. using a pin stenter. Furthermore, dyeing was carried out at 100° C.

The woven material obtained was soft and had good stretchability. Furthermore, a highly dry feel was apparent due to the marked coolness of touch characteristic of the cuprammonium rayon. Again, the moisture absorption/release properties and the smoothness of the material surface were good, and it was suitable as a stretch lining.

Example 21

Using the soft stretch yarn obtained in Example 2, this was subjected to twisting at 700 turns/m and twist setting carried out by means of steam at 65° C. Furthermore, with this as the weft and using the viscose rayon "Silma" manufactured by the Asahi Chemical Ind. Co. (83 dtex, 38 filament) as the warp, a plain weave fabric was constructed. The yarn densities at this time were warp=110 per inch and weft=91 per inch and a torque balance was obtained by alternate arrangement of S twist/Z twist yarns. The fabric obtained was processed as follows. Firstly, relaxation scouring was carried out at 90° C., after which presetting was performed with dry heat at 150° C. using a pin stenter.

Moreover, dyeing was carried out at 100° C. The woven material obtained was soft and had good stretchability. Furthermore, a springy sense of touch was obtained due to the excellent resilience characteristic of the viscose rayon and, moreover, a dry feel was apparent due to the high coolness of touch. In addition the moisture absorption/release was good.

Example 22

Using the soft stretch yarn obtained in Example 2, this was subjected to twisting at 550 turns/m and twist setting carried out by means of steam at 65° C. With this, there was mixed the cuprammonium rayon employed in Example 20, and a knitted material with an interlock structure constructed by means of 24 gauge circular knitting. Following normal procedure, this was subjected to relaxation scouring at 90° C., after which dyeing was carried out at 100° C.

The knitted material obtained was soft and had good stretchability. Furthermore, a very dry feel was apparent due to the high coolness of touch characteristic of the cuprammonium rayon. Moreover, the moisture absorption/release was good.

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## Example 23

A knitted material was constructed in the same way as in Example 22, except that instead of the cuprammonium rayon there was used the viscose rayon employed in Example 21.

The knitted material obtained was soft and had good stretchability. Furthermore, a springy sense of touch was obtained due to the excellent resilience which is characteristic of the viscose rayon and, moreover, a very dry feel was apparent due to the high coolness of touch. In addition, the moisture absorption/release was good.

## Effects of the Invention

By means of a yarn embodying the present invention, the conventional problems of a strong feeling of tightness and a coarsening of the fabric can be resolved, and it is possible to offer soft stretch yarns which can provide materials with more outstanding soft stretchability than hitherto, and the fabrics produced from said yarns.

What is claimed is:

1. A yarn comprising polyester fibres which yarn is characterized in that following heat treatment the yarn has a stress, at 50% yarn stretch, of no more than  $30 \times 10^{-3}$  cN/dtex and, at the same time, a percentage recovery of at least 60%.

2. A yarn according to claim 1 where the Uster unevenness is no more than 2.0%.

3. A yarn according to claim 1 where the diameter of the crimp is no more than 250  $\mu\text{m}$ .

4. A yarn according to claim 3 where the diameter of the crimp is no more than 200  $\mu\text{m}$ .

5. A yarn according to claim 1, having a strength of at least 2.2 cN/dtex and a shrinkage stress of at least 0.25 cN/dtex.

6. A yarn according to claim 1, having a crimp retention factor after stretching 10 times of at least 85%.

7. A yarn according to claim 6, where the crimp retention factor after stretching 10 times is at least 90%.

8. A yarn according to claim 7, where the crimp retention factor after stretching 10 times is at least 95%.

9. A yarn according to claim 1, which has conjugate fibres having at least two polyester components.

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10. A yarn according to claim 9, wherein the conjugated fibre components are disposed eccentrically relative to one another in the cross-section of the fibres.

11. A yarn according to claim 9, wherein the ratio of the respective melt viscosities of the polyesters is from 1:1 to 5:1.

12. A yarn according to claim 9, where at least one component of the conjugate fibres is PTT or PBT.

13. A yarn according to claim 12, where at least one component of the conjugate fibres is PTT.

14. A yarn according to claim 13 where the conjugate fibres comprise PTT and PET.

15. A yarn according to claim 1, having a crimp stretch factor ( $E_0$ ) when heat treated under no load of at least 45%.

16. A yarn according to claim 1, having a crimp stretch factor ( $E_{3.5}$ ) when heat treated under a  $3.5 \times 10^{-3}$  cN/dtex (4 mgf/d) load of at least 10%.

17. A combined yarn which is characterized in that the yarn has, in combination, a yarn component which is a yarn according to claim 1 and a yarn component which is a low shrinkage yarn of boiling water shrinkage no more than 10%.

18. A yarn according to claim 1 or a combined yarn according to claim 17, where a high twist coefficient of at least 5000 is applied:

twist coefficient = number of twists per 1 m (turns/m)  $\times$  square root of denier ( $\text{dtex} \times 0.9$ ).

19. A fabric which is characterized in that it is produced using at least a yarn according to claim 1.

20. A fabric which contains a yarn according to claim 1 at least as a component of a combined yarn.

21. A fabric which contains, as an entire yarn, a yarn according to claim 1.

22. A fabric according to claim 19 further comprising natural and/or semi-synthetic fibres.

23. A fabric according to claim 20, wherein the natural and/or semi-synthetic fibres are present as another component yarn in the combined yarn.

24. A fabric, which contains respective separate yarns according to of claim 1 and yarns of natural and/or semi-synthetic fibres.

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