United States Patent [19]

Pacofsky

[11] **3,748,844**

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[54] **POLYESTER YARN**

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[52] **U.S. Cl.** .... **57/140 R,** 57/157 R, 264/290 R

[51] **Int. Cl.** **D03g 3/02**

[58] **Field of Search** .... 57/34 B, 157 F, 157 S, 57/140 R, 140 BY, 157 R; 28/104, 72.12, 72.17; 264/290 R, 290 N, 210 F

[56] **References Cited**

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3,421,194	1/1969	Breen et al.	28/72.12
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3,452,130	6/1969	Pitzl	264/290 N
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[57] **ABSTRACT**

Improved multifilament polyester yarn has good processibility on knitting machines and provides good fabric bulk when used in combination with ordinary polyester yarn. The yarn is an assembly of low-shrinkage, continuous filaments of synthetic linear condensation polyester which are substantially free of crimp. The filaments are drawn and relaxed under conditions which provide a yarn having a sonic velocity value of 1.9 to 3.0 kilometers per second, an X-ray crystallinity value of 16 to 35 percent, and a single shrinkage-tension peak at a temperature below 100°C.

5 Claims, 2 Drawing Figures

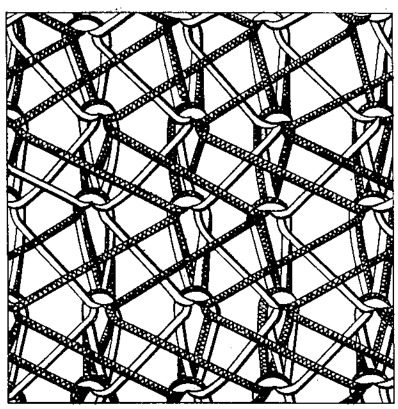

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FIG. 1

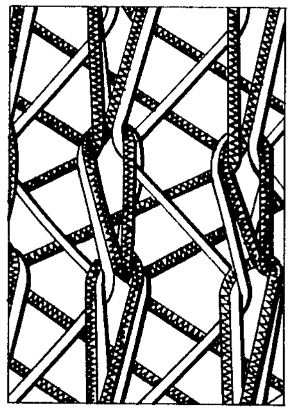
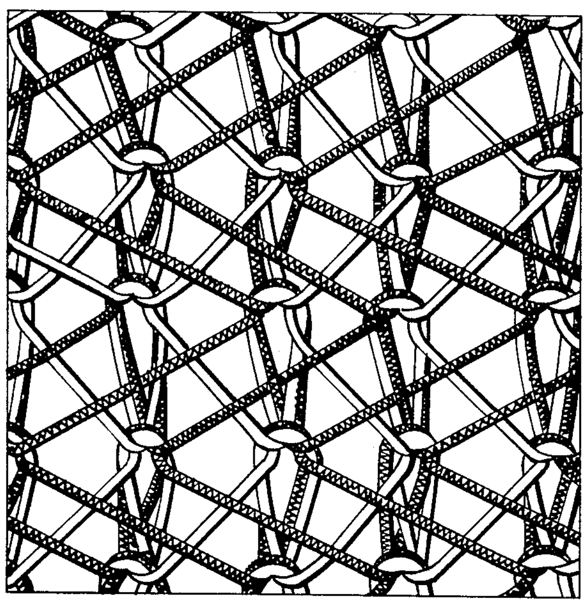


FIG. 2



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POLYESTER YARN

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a novel textile yarn. More specifically, it is concerned with a new synthetic polyester textile yarn particularly suited for the manufacture of improved knitwear.

2. Description of the Prior Arts

Synthetic polyester fibers, such as those described by Whinfield & Dickson in U.S. Pat. No. 2,465,319, have become important articles of commerce. Early fabrics prepared from melt spun polyesters were characterized by a "slick" handle and by lack of bulk, and many methods to improve the tactile aesthetics and bulk of polyester fabrics have been developed. These include many mechanical crimping treatments, such as the one described by Arnold in U.S. Pat. No. 3,335,477, which are usually followed by cutting the crimped filaments into staple fibers that are processed into yarn in a manner similar to that used for natural fibers. Many procedures have also been proposed for the improvement of continuous filament yarn. For example, Breen U.S. Pat. Nos. 2,783,609 and 2,852,906 describe a textured yarn which is characterized by filament convolutions and which provides fabrics with improved bulk and tactile aesthetics. Steam or hot air can be used in a jet bulking apparatus to provide, under proper conditions, a stable crimped yarn which does not require twist to hold the filament convolutions in place. A yarn with a highly desirable stable crimp having a random, three-dimensional, curvilinear, extensible configuration is described by Breen et al. in U.S. Pat. No. 3,186,155 and an improved process for preparing such yarns is described by Scott in U.S. Pat. No. 3,143,784. Bulk has also been obtained by using yarns which are composed of filaments exhibiting differential shrinkage characteristics, as described by Maerov & McCord in U.S. Pat. No. 3,199,281 and by Waltz in U.S. Pat. No. 2,979,883. Such yarns are "postbulkable" in the sense that a non-bulked yarn may be woven into fabric and then bulked later by a heat treatment which activates the differential shrinkage characteristics. Another method of producing a post-bulkable yarn of this general type is described by Jamieson & Reese in U.S. Pat. No. 2,980,492, where the differential shrinkage characteristic is obtained by combining filaments of different denier. More recently, U.S. Pat. No. 3,454,460 to Bosely has described a highly desirable postbulkable yarn composed of bicomponent filaments capable of developing a helical crimp. Other methods of improving bulk and handle of polyester fabrics have included the use of a novel spontaneously elongatable polyester filament, as described by Kitson & Reese in U.S. Pat. No. 2,952,879, which may be combined with ordinary polyester filaments to obtain differential shrinkability.

Although desirable results have been achieved in improving the bulk and tactile aesthetics of fabrics of continuous filament polyester yarn by prior methods, further improvements are needed in specific end uses, such as knitwear, where pre-bulked continuous filament yarns give poor processibility and known postbulkable yarns are either excessively costly to prepare or do not provide the properties desired.

One method of improving warp knit fabrics, described by Kasey in U.S. Pat. No. 3,041,861, utilizes a low shrinkage yarn fed to the top (front) bar of a knitting machine in combination with a high shrinkage yarn fed to the bottom (back) bar of the machine. Subsequent heating of the fabric causes the two yarns to shrink different amounts, which results in improved fabric covering power. Bulk, however, is not significantly improved.

SUMMARY OF THE INVENTION

The present invention provides a novel continuous multifilament polyester yarn eminently suitable for use in the preparation of improved apparel, particularly knitwear. The yarn provided is prepared by an economical process, exhibits good processibility on knitting machines, and is capable of giving fabrics having excellent bulk and handle when used in combination with ordinary commercially available polyester yarns. The excellent processibility in knitting is in large measure due to the fact that the yarns are essentially crimpfree, and develop little or no crimp upon heating. In view of this lack of significant crimp, it is quite surprising that excellent bulk and tactile aesthetics are developed when fabrics containing these yarns are heated.

The improved multifilament yarn of the present invention is an assembly of low-shrinkage, continuous filaments which are substantially free of crimp. The yarn consists of synthetic linear condensation polyester and is characterized by having an orientation, as measured by sonic velocity, of 1.9 to 3.0 kilometers per second, an X-ray crystallinity value of 16 to 35 percent, and a single shrinkage-tension peak at a temperature lower than 100°C. The preferred yarns of the invention have a boil-off shrinkage of 1 to 10 percent and a sonic velocity value between 2.0 and 2.5 kilometers per second. The shrinkage-tension peak is determined for temperatures between 60° and 200°C. Preferably, this peak is at a temperature between 80° and 100°C. and the peak tension is less than about 0.06 gram per denier. Particularly good fabric bulk is obtained with yarns consisting essentially of ethylene terephthalate polyester, which may be modified slightly as illustrated in Example II for basic dyeability.

The novel yarn of the invention is prepared by a simple, low-cost manufacturing process characterized by a critical combination of spinning, drawing, and relaxing conditions not previously disclosed for polyester yarns. The process comprises melt-spinning a synthetic linear terephthalate polyester into filaments; quenching the filaments and combining them into a multifilament strand; drawing the multifilament strand at a temperature above 85°C. between feed rolls and draw rolls; heating the drawn strand in a substantially tensionless state in a plasticizing medium to cause it to shrink in the longitudinal direction; and then cooling and winding the strand. The process is characterized by the use of a low draw ratio within the range of about 2:1 to 3:1 to provide a drawn multifilament strand having a sonic velocity value within the range of 1.9–3.0 km./sec., and by the control of temperatures in and following the drawing process at a level to produce a boil-off shrinkage in the drawn yarn within the range of 7–20 percent, and further by control of the exposure time and temperature of the plasticizing medium in the shrinkage step to allow a shrinkage of 7–20 percent to occur without the formation of crimp to provide filaments having a crystallinity value that does not exceed 35 percent. In a preferred embodiment of the invention, the shrinkage step is carried out in a low-turbulence, heated gas stream, preferably air or steam, within a jet enclosure.

A suitable maximum machine draw ratio for the drawing step may be calculated from the expression D.R. $<4.5/(1 + 0.0006V_s)$ where V_s is spinning speed (i.e., feed roll speed) in yards per minute.

Why the critical combination of structural characteristics outlined above for the yarn of the invention should produce unexpectedly good bulk and handle is not fully understood. Although the surprising improvement in bulk cannot be explained, it is nevertheless an observable and demonstrable fact with yarns having the critical combination of structural characteristics described above.

The above-stated structural characteristics are necessary for the development of useful fabric bulk without sacrificing utility. Thus, it is necessary that the orientation and crystallinity levels be restricted to the limits defined in order that the yarns respond properly to fabric finishing conditions. If the orientation is too high, i.e., if the measured sonic velocity values are above 3.0 kilometers per second, then the fiber bending modulus appears to be too high for the present purpose because the fibers are unable to bend within the short lengths available in the fabric. Under such conditions, improved bulk is not obtained, as is shown in the examples when a conventional, high orientation yarn is used. On the other hand, yarns of very low orientation tend to become brittle when crystallized, so that fabrics prepared from such yarns, i.e., yarns having a sonic velocity below about 1.9 kilometers per second, would be relatively useless in ordinary commercial usage. With regard to crystallinity, yarns having a crystallinity value above about 35 percent are too crystalline to develop the desired bulk by ordinary fabric finishing treatments; and yarns having a crystallinity below about 16 percent would be so amorphous as to shrink excessively upon heating, which would lead to unacceptable commercial fabrics. A unique feature of the yarns of the present invention is the presence of a low-temperature peak (below 100°C.) in the tension-temperature spectrum. While the role of this feature is not fully understood, it is found in all yarns of the invention. It is possible that the reversal of tension at a relatively low temperature, as indicated by the peak, causes the individual fibers to move relative to each other and to "bloom" within the dimensions of a knit stitch, whereas filaments of yarns not showing this low-temperature peak appear to shrink in unison. As is known in the art, warp knit fabrics from yarns of the latter type show moderate changes in cover but no significant changes in bulk. The yarns of the invention are also characterized by the absence of crimp or twist, which contributes to better handling and knittability as well as improved fabric unifomity.

It should be noted that the yarns of the invention are "low-shrinkage" yarns in the sense that the normally measured boil-off shrinkage falls in the range of 1 to 10 percent.

The yarns of this invention are useful in many types of fabrics, but offer an outstanding improvement in properties in warp knit fabrics. Unusually good results are obtained, as illustrated more fully in the examples, in warp knit fabrics using bar-on-bar construction when the yarns of the invention are used in combination with conventional commercial yarns. In such fabrics, best results are obtained with the yarn of this invention on the top (front) bar. In addition to bar-on-bar constructions, excellent results may also be obtained by combining the yarns of the invention with ordinary commercial yarns by twisting or by intermingling filaments to form a unitary yarn for fabric preparation.

It is emphasized that the yarns of the invention are free of significant crimp and that fabric bulk is observed only after the fabric has been constructed and heated to a temperature of about 100°C. or above. Such heating takes place during normal fabric finishing procedures, as when the fabric is scoured, dyed, or heat-set on a tenter frame.

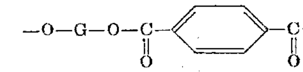
In addition to improved bulk and handle, fabrics prepared from the yarns of the invention possess excellent dyeability characteristics and show better color yield, improved color clarity and better print definition in comparison with both ordinary and set-textured polyester yarns.

DESCRIPTION OF THE DRAWINGS

FIGS. 1 and 2 are front and back views, respectively, of a warp-knit tricot fabric having a 2–3, 1–0 stitch on the front bar and a 1–0, 1–2 stitch on the back bar. In both figures, the front bar yarn is shown darker than the back bar yarn.

Discussion of Product Characterization and Tests

The novel yarns of the present invention are composed of a synthetic linear condensation terephthalate polyester of the type described in U.S. Pat. Nos. 2,465,319 and 2,901,466. Preferably, the yarn is composed of a glycol terephthalate polyester which is a linear polyester in which at least about 85 percent of the recurring structural units are glycol terephthalate units,



where G is a glycol residue. Included are copolyesters in which up to 15 percent of the terephthalate is replaced by a dicarboxylate of a hydrocarbon free from ethylenic unsaturation, or by a metallic salt of sulfoisophthalic acid. Typical copolyesters are formed by replacing up to about 15 mol percent of the terephthalic acid or derivative thereof with another dicarboxylic acid or ester-forming derivative thereof, such as adipic acid, dimethylsebacate, isophthalic acid, hexahydroterephthalic acid, or sodium 3,5-dicarbomethoxybenzene-sulfonate. Preferred glycols are ethylene glycol and hexahydro-p-xylylene glycol. Glycol terephthalate linear polyesters can readily be prepared in the oriented, relatively amorphous or noncrystalline form useful in preparing the yarns of the invention.

The yarns of this invention are composed of polymer of fiber-forming molecular weight, and have an intrinsic viscosity of at least about 0.3. Intrinsic viscosity is defined by the expression:

limit of the fraction ln η_r/C as C approaches 0 wherein η_r is the viscosity of a dilute solution of the polymer in a solvent divided by the viscosity of the solvent per se measured in the same units at the same temperature; and C is the concentration in grams of the polymer per 100 milliliters of solution. A convenient solvent for use in the measurement of intrinsic viscosity of polyethylene terephthalate is a mixture of trifluoroacetic acid and methylene chloride in a volume ratio of 1:3.

In the examples, degree of polymerization is also indicated by "RV" which is the relative viscosity of a polymer solution at a nominal concentration of 10 percent. The term "RV" refers to the ratio of the viscosity of a 10 percent solution (2.15 grams polymer in 200 milliliters solvent) of the polymer in a solvent to the viscosity of the solvent per se measured in the same units at 25°C. The solvent used for the measurement of relative viscosity in the examples is Fomal, a mixture of ten parts phenol and seven parts 2,4,6-trichlorophenol (parts by weight). A relative viscosity of 25 corresponds roughly to an intrinsic viscosity of 0.64, and a relative viscosity of 30 corresponds roughly to an intrinsic viscosity of 0.70.

The yarns of this invention are composed of filaments having a molecular orientation such that the measured values of sonic velocity fall between 1.9 and 3.0 kilometers per second, and preferably between 2.0 and 2.5 km./sec. The term "sonic velocity" is a polymer structural parameter related to molecular orientation along the fiber axis with higher values of sonic velocity indicating a higher degree of orientation. Sonic velocity (C) is related to the modulus of elasticity (E) by the formula $E = 11.3\ C^2$ where E is in grams per denier and C is in kilometers per second. Sonic velocity relationships and test procedures are described by Charch & Moseley in the *Textile Research Journal*, Volume 29, page 525 (July, 1959). Briefly, sonic velocity, in kilometers per second, is measured by passing a sound wave having a frequency of about 10,000 cycles per second through the polymer structure for a known distance using apparatus known in the art. The sonic velocity values reported in the examples, unless otherwise specified, were measured with the yarns held under a tension of 0.5–0.7 grams per denier (sufficient to insure detector-specimen contact without stretching the specimen) at 72°F. and 65 percent relative humidity using a "dynamic modulus tester" Model PPM—5, manufactured by the H. M. Morgan Company, 90 Sherman Street, Cambridge, Massachusetts.

Sonic velocity is used as a measure of orientation in preference to birefringence because birefringence is difficult to measure with precision in the range of concern (generally greater than 0.10), and is difficult to measure for filaments of non-round cross-section. Also, because birefringence measurements are made on very short segments of a filament, an excessive number of measurements is required to give a reasonable, average birefringence value unless highly uniform filaments are under observation.

The crystallinity of the terephthalate polyester making up the filaments of the present invention can be obtained by X-ray diffraction techniques. X-ray crystallinity, as reported in the examples, is as follows: a bundle of parallel filaments of 0.020 inch (0.05 cm.) thickness is mounted with the fiber axis perpendicular to a beam of nickel-filtered Cu X-rays generated at 50 kilovolts and 20 milliamperes and collimated through 0.020 inch (0.05 cm.) pin holes. The diffraction pattern is photographed in Ilford G X-ray film at a sample-to-form distance of 5 centimeters using an exposure time sufficient to give an optical density on the developed film of about 1.0 at the 010 diffraction maximum. The exposed film is developed for 3 minutes at 68°C. in Du Pont X-Ray Developer prepared as recommended by the manufacturer. The film is rinsed 30 seconds in 3 percent acetic acid stop bath, fixed for 6 minutes in Du Pont X-Ray Fixer and Hardener, rinsed for at least ont hour in running water and dried at room temperature. The optical density of the film is scanned along the equator using a Knorr-Alpers micorphotometer (Leeds & Northrop Model 6700 PI, A2 assembly), set at a plate travel rate of 5 millimeters per minute and a chart speed of 2 inches per minute (5.08 cm. per minute). As is well known, the resulting curve exhibits 3 peaks, corresponding to the scattering from the 010, 110, and 100 diffraction plates, which represent the principal scattering from glycol-terephthalate linear polyester crystallites. To estimate the crystallinity of the sample, a straight line is drawn underneath the 010 peak and tangent to the curve on either side of the 010 peak. A perpendicular line is then dropped from the highest point of the 010 peak to the 100 percent transmission axis. The height of the point of intersection between this perpendicular line and the line tangent to the curve is then designated as I_a, representing the intensity (log. 1/transmission) of the amorphous background. The height of the highest point of the 010 peak itself is designated as I_t. Crystallinity is then calculated from the following formula:

$$\text{percent crystallinity} = (I_t - I_a)/I_t \times 100 \text{ percent}$$

The yarns of this invention are composed of filaments having an X-ray crystallinity between 16 and 35 percent measured by the above procedure.

An alternative method of measuring X-ray crystallinity which gives results in conformance with those given by the above method utilizes a Norelco X-ray diffraction unit (North American Philips Co., Inc., New York) fitted with a wide-angle diffractometer and a scintillation counter. A high-intensity copper-target tube is used at a voltage of 40 kilovolts and a beam current of 40 milliamperes. The X-ray beam is collimated with 0.5° divergence slits, 0.006 inch receiving slits and 0.5° scatter slits. A nickel filter is placed before the receiving slit to provide monochromatic radiation, and pulse-height discrimination is also used according to the manufacturer's directions. A parallel array of fibers is mounted in the reflecting mode, and equatorial scattering is recorded at a scanning rate of 1° per minute (in 2θ units) and recorded as intensity (counts per second) vs. the scattering angle, 2θ. The resulting curve is equivalent to the densitometer curve obtained in the first-described method (above), counts-per-second being proportional to (log. 1/transmission), and the fiber crystallinity is calculated from the curve by the same procedure.

The term "shrinkage tension" refers to the retractive force exhibited by a yarn when heated. The shrinkage tension of terephthalate polyester filaments usually changes appreciably with the temperature to which the filaments are heated. In the temperature range 60°–200° C., the yarns of the present invention show a single peak in the tension-temperature spectrum, and this peak appears at a temperature below 100°c. The value of the peak shrinkage tension is less than about 0.06 gpd for the preferred yarns of the invention. Shrinkage tension is measured by mounting a looped specimen of yarn between Invar hooks in a small oven provided with a means of heating and a means of indicating temperature. One hook is attached to a strain gauge and the other is fixed at a distance which gives a taut loop (minimum measurable tension). Heat is applied to the oven to raise the temperature at a rate of about 30°C. per minute. The temperature and the tension are measured simultaneously and plotted on a graph of tension versus temperature to provide a convenient read-out of the temperature of peak tension. Measurements of this type are described by Weidner in *Chemiefasern* 10, 751 (1968).

The yarns of this invention are composed of continuous filaments essentially free from individual filament twist. In the case of non-round filaments, filament twist is easily observed by examination under a microscope. The methods for observing twist in round filaments involve microscopic examination of filaments illuminatee by plane-polarized light. For round filaments containing significant quantities of TiO_2, filament twist may be observed by using the techniques described by Astle-Fletcher, *Journal of the Textile Institute*, Vol. 48, T-12-8-132 (1957) and by Woods, *Journal of the Textile Institute*, Vol. 55, T-243-250 (1964).

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following examples illustrate specific embodiments of the invention. They are not intended to limit it in any manner.

EXAMPLE I

Polyethylene terephthalate continuous filament yarns consisting of filaments having a trilobal cross-section and spun from polymer containing 2 weight percent TiO_2 and having a relative viscosity of 29.0–29.7 are prepared by conventional, coupled, melt spinning and drawing procedures using a spinning speed (feed roll speed) of 1485 ypm (1358 mpm), and single-stage drawn in a steam jet similar to that described by Pitzl in U.S. Pat. No. 3,452,132 using steam at a temperature of 160°C. and a pressure of 50 psig. (3.4 atm.). The draw rolls, heated to the temperatures shown in Table I, rotate with a peripheral speed of 3000 ypm (2743 mpm) to impart a draw ratio of 2.02. Moving from the draw rolls, the yarn passes through a second (relaxing) jet having a design similar to that shown in FIGS. 1 and 2 of U.S. Pat. No. 3,261,071 to Clendening where the yarn is treated at reduced tension with air supplied at a temperature of 220°C. and a pressure of 55 psig. Tension in this second jet is maintained at a very low level by passing the yarn leaving the jet over snubbing pins before forwarding it to a windup. Windup speeds are shown in Table I. Several test yarns (coded B, C, and D) are prepared by this general process using the specific conditions listed in Table I. Examination of the test yarns reveals that they are free of significant crimp and give no indication of individual filament twist.

For comparison, a conventional yarn (A) is melt spun in the same fashion as above but drawn in an aqueous bath of the general type described by Dusenbury in U.S. Pat. No. 3,091,805 using a temperature of 91°–92°C. and a draw ratio of 2.4, with the draw roll heated to 115°C. No hot relaxing jet is used.

A second conventional yarn (E) is a commercially available dull (2% TiO_2) polyethylene terephthalate 27-filament yarn having a total denier of 40, a tenacity of 4.27 gpd, a break elongation of 27.6 percent, and a boil-off shrinkage of 8 percent. This yarn is characterized by a sonic velocity of 3.81 km./sec., an X-ray crystallinity of 28 percent, and a shrinkage-tension peak at 155°C.

The above-described test and comparison yarns are used to knit tricot fabrics in yarn combinations shown in Table II. Greige fabric construction parameters are adjusted to give the same finished fabric construction for all samples. The fabrics are finished by subjecting them to a relaxed scour, in which they are heated from room temperature to the boil and then held 20–30 minutes at the boil, using an aqueous solution of 0.5 gm./liter of a suitable wetting agent such as Duponol RA (sodium salt of a modified alcohol sulfate) or Alkanol HCS and 0.5 gm./liter tetrasodium pyrophosphate. After rinsing, the fabric is heat-set on a pin tenter for 60 seconds at 190°C. under sufficient tension to provide 48 × 48 wales and courses per inch (19 × 19 per cm.). Properties of the finished fabrics are listed in Table II.

TABLE Ia.—PROCESS CONDITIONS

Yarn code	Polymer RV	Spin temp., °C.	Draw ratio	Draw roll		Drawn yarn B.O.S., percent*	Relaxer jet over-feed, percent	Windup speed	
				Temp., °C.	Residence time, sec.			Y.P.M.	(M.p.m.)
A	29.4	297-8	2.37	115	0.35	(N.A.)		2,995	(2,738)
B	29.0	297-8	2.02	99	0.43	18.6	15.8	2,590	(2,368)
C	29.7	295-6	2.02	98.5	0.43	17.5	9.5	2,740	(2,505)
D	29.0	297-8	2.02	112	0.43	7.8	3.1	2,910	(2,661)
E (A commercial P.E.T. yarn).									

*Percent shrinkage in boiling water.

TABLE Ib.—YARN PROPERTIES

Yarn code	Den./fil.	SV, km./sec.	X-ray cryst.	Shrinkage tension peak		Boil-off shrinkage, percent
				Temp., °C.	Tension, g.p.d.	
A	40/27	3.09	35	126	0.243	8.6
B	40/14	2.19	29	92	0.022	0.7
C	39/14	2.39	33	91	0.056	7.1
D	40/14	2.36	30	91	0.036	3.3
E	40/27	3.81	28	155	0.293	8.0

TABLE II

Fabric No.	46	47	141-1	48	39	50	10
Yarn:							
Front (top) bar	E	A	A	B	C	D	[a]X_1
Back (bottom) bar	E	A	E	A	A	A	[b]X_2
Stitch:							
Front bar	2-3, 1-0	2-3, 1.0	2-3, 1-0	2-3, 1-0	2-3, 1-0	2-3, 1-0	2-3, 1-0
Back bar	1-0, 1-2	1-0, 1-2	1-0, 1-2	1-0, 1 2	1 0, 1-2	1-0, 1-2	1-0, 1-2
Runners (in.):							
Front bar	64.4	62.7	62	61.9	63.7	61.9	65.8
Back bar	47	45.8	44	46.5	45.5	46.5	48
Ratio, front/back	1.37/1	1.37/1	1.41/1	1.33/1	1.40/1	1.33/1	1.37/1
Fabric inches per rack	9	8	8	8	8	8	10
Finished count (w.p.i. x c.p.i.)	46 x 52	48 x 48	47.5 x 50	46 x 48	48 x 48	48 x 48	46 x 50

TABLE II—Continued

Fabric No.	46	47	141-1	48	39	50	10
Weight:							
Oz./sq. yd.	2.7	2.8	2.7	2.6	2.7	2.8	2.8
Gms./sq. m.	(92)	(95)	(92)	(88)	(92)	(95)	(95
Bulk (cc./gm.):							
At 3 gm./cm.² loading	3.3	3.6	3.58	5.8	5.0	4.8	3.8
At 40 gm./cm.² loading	3.0	3.2	3.14	4.6	4.1	4.1	3.3
At 239 gm./cm.² loading	2.7	2.8	2.81	3.4	3.2	3.1	2.8

[a] 4–6% BOS. [b] 14% BOS.

A further comparison illustrating the improvement over mixed shrinkage knits of the type described by Kasey in U.S. Pat. No. 3,041,861, is provided by fabric 10. Fabric 10 is knit with a 4–6 percent boil-off-shrinkage yarn on the front bar and a 14 percent boil-off-shrinkage yarn on the back bar. Preparation of these yarns, X_1 and X_2, is described subsequently (Example VI). The measured bulk of fabric **10,** as shown in Table II, is not significantly greater than that of fabrics 46, 47 and 141-1 which are knit from yarns having little or no shrinkage differential.

Fabric bulk is obtained by measuring the fabric thickness and dividing this thickness (in cm.) by the area density (gm./cm.²) to obtain bulk in cm.³/gm. The thickness is measured under loadings of 3, 40, and 239 gm./cm.² to obtain bulk properties corresponding to a range of tactile environments.

Inspection of the data in Table II clearly reveals that the tricot fabrics prepared with the test yarns of this invention, in combination with conventional yarns, exhibit a significant improvement in bulk. In addition, examination of the fabrics reveals that the fabrics prepared from the test yarns of the invention possess an attractive spun-like handle without the objectionable slickness of conventional synthetic fabrics.

EXAMPLE II

This example illustrates the preparation of a yarn of this invention from a basic dyeable copolymer of polyethylene terephthalate.

A copolymer of polyethylene terephthalate containing 2 mol. percent 5-(sodiumsulfo)-isophthalate in the molecule and having a relative viscosity of 20.5 is melt spun into a 14-filament yarn in which all filaments have a trilobal cross-section. Following the general procedure of Example I, the undrawn yarn passes over a feed roll moving with a surface speed of 1483 ypm (1356 mpm), through a steam draw-jet and then over draw rolls rotating at a surface speed of 3001 ypm (2744 mpm). Other specific process details are summarized in Table III. From the draw roll, the yarn is passed through a "relaxing" jet supplied with air at 55 psig. (3.7 atm.) and heated to a temperature of 250°C., from which it proceeds to a windup operating at 2767 ypm (2529 mpm). This is designated test yarn **1** in Table III.

A companion "conventional" yarn is prepared by spinning 30 RV polyethylene terephthalate homopolymer at a spinning speed of 806 ypm (737 mpm). The yarn passes through an aqueous bath maintained at a temperature of 92°C., where drawing occurs, and then on to draw rolls moving at a surface speed of 2998 ypm (**2740** mpm). Other process details are shown in Table III. The 40-denier/27-filament yarn is coded control yarn **2.**

The yarns produced as described above are examined and found to have the structural features listed in the Table.

Jersey tricot fabrics are knitted using the above-described test yarn 1 and "conventional" yarn 2 as specified in Table IV. These fabrics are finished by subjecting them to a relaxed scour, in which they are heated from room temperature to the boil and then held 30 minutes at the boil, using an aqueous solution of 0.5 gm./liter of a suitable wetting agent such as Duponol D (sodium lauryl sulfonate) and 0.5 gm./liter tetrasodium pyrophosphate. After rinsing and drying, the fabric is heat-set on a pin tenter for 60 seconds at 190°C. under sufficient tension to provide the wale and course counts specified in Table IV.

TABLE III

Yarn code	Polymer RV	Spin temp. (° C.)	Draw roll Temp. (° C.)	Draw roll Time (sec.)	Draw ratio	Windup (Y.p.m.)	Windup (M.p.m.)	Over-feed, percent	Den./fil.	SV(km./sec.)	X-ray cryst. percent)	Shrinkage tension, maximum (° C.)/tension (g.p.d.)	Percent yarn boil-off shrinkage
1	20.5	293	109	0.43	2.02	2,767	(2,529)	8.6	39/14	2.24	30	90/0.035	5.4
2	30	307	119	0.35	3.72	2,958	(2,703)	1.3	40/27	3.63	33	144/0.274	8.0

TABLE IV

Yarn (Table III):		
Front bar	1	2
Back bar	2	2
Stitch:		
Front bar	2–3, 1–0	2–3, 1–0
Back bar	1–0, 1–2	1–0, 1–2
Runners (in.):		
Front bar	62	62
Back bar	44	44
Ratio (front back)	1.41	1.41
Fabric in. per rack	8	8
Finished count (w.p.i.-c.p.i.)	48–54	50–54
Weight (oz./yd.²)	2.7	2.7
Bulk (cc./gm.):		
At 3 gm./cm.² loading	4.9	3.6
At 40 gm./cm.² loading	4.0	3.2
At 239 gm./cm.² loading	3.4	3.0

Inspection of the data in Table IV clearly indicatts that the test yarn of this invention imparts a significant improvement in bulk and further, subjective evaluation reveals that the tricot fabric of test yarn possesses a distinct spun-like handle in contrast to the slick filament-like character of the conventional synthetic filament yarn fabrics.

EXAMPLE III

This example illustrates the preparation of yarns of the present invention from copolymers prepared from terephthalic acid and an aliphatic dicarboxylic acid.

A copolymer of ethylene glycol, terephthalatic acid and sebacic acid in which the sebacic acid residues comprise 10 mol. percent of the acid units in the polymer, and which has a relative viscosity of 30.1, is melt spun at 298°C. to give a 27-filament yarn in which the filaments have a trilobal cross-section. This yarn is drawn in a steam jet, as described in Example I, which is supplied with steam at a temperature 160°C. and a pressure of 50 psig (3.4 atm.), and then passed over draw rolls operating at a surface speed of 3000 ypm (2743 mpm). The drawn yarn passes through a relaxing jet supplied with air at 55 psig. (3.7 atm.) which is heated to a temperature of 404°C. and then to a windup operating at 2950 ypm (2697 mpm). The yarn is designated test yarn 3, Table V.

For comparison, a "control" yarn (4) is prepared as above, with the draw yarn bypassing the relaxing jet and proceeding directly to the windup. Process details are shown in the table.

Jersey tricot fabrics are knit utilizing the test copolymer yarns (3) and "control" copolymer yarns (4) in the front bar with the conventional 40–27 yarn described in Table III as a common back bar yarn as specified in Table VI. These fabrics are scoured for 30 minutes at the boil in an aqueous solution of 0.5 gm./liter Duponol D and 0.5 gm./liter tetrasodium pyrophosphate, rinsed, centrifuged and dried. The dried fabric is heat-set on a pin tenter frame for 60 seconds at 190°C. to the wale and course counts given in Table VI. Fabric bulk data measured under the three compressive loadings of 3, 40, and 239 gm./cm.² clearly show the bulk improvement imparted by the copolymer test yarns of the invention relative to that imparted by the appropriate control yarns. A soft spun-like handle is also readily apparent for the test yarn items in contrast to the slick filament-like handle of the control tricots.

that used in Example I) which is supplied with steam at a temperature of 160°C. and a pressure of 50 psig. (3.4 atm.). The yarn proceeds from the jet to and around draw rolls heated to 101°C. and operating at a peripheral speed of 3005 ypm. (2747 mpm). The draw ratio is 2.09 X, and the residence time on the hot draw roll is 0.43 second. The drawn 38 denier yarn is wound up at 3010 ypm. (2752 mpm). A skein of this yarn is then allowed to relax for 10 minutes in water at a temperature of 66°C. A shrinkage of 5.0 percent is noted. After drying, the shrinkage tension of the yarn as a function of temperature is measured and the yarn is found to have a shrinkage tension peak at 95°C., and maximum shrinkage tension of 0.027 gpd. X-ray measurements indicate 23 percent crystallinity and sonic velocity measurements give a value of 2.52 kilometers/sec. measured under a tension of 0.7 grams per denier. The yarn is substantially free of crimp, and examination under a microscope between crossed polarizers gives no indication of individual filament twist.

Jersey tricot fabric is knitted using the above described yarn, designated test yarn 7, as a front bar yarn in combination with a back bar of conventional yarn 2 (Table III). This tricot fabric is finished according to the procedure specified in Example III and compared to a control tritot fabric (cf., Table IV) having front and back bar yarns of the conventional yarn 2 which is similarly finished. Fabric data given in Table VII shows that the tricot fabric containing yarn of this invention has appreciably greater bulk. Upon subjective evaluation of the fabrics, the preferred spun-like handle of the test yarn tricot is clearly evident.

TABLE V

Description	Yarn code	Spin speed Y.p.m.	Spin speed (M.p.m.)	Draw ratio	Draw roll temp. (° C.)	Relaxer jet air Temp. (° C.)	Relaxer jet air P.s.i.	Windup Y.p.m.	Windup (M.p.m.)	Den.	SV, km./sec.	X-ray cryst., percent	Shrinkage ten. peak ° C.	Shrinkage ten. peak Tension (g.p.d.)	Shrinkage, percent
2G–T/10 (90/10)	3	1,433	(1,310)	2.09	94	404	55	2,950	(2,696)	68.0	1.93	32	64	0.031	6.2
2G–T/10 (90/10)	4	742	(678)	4.05	145	------	------	2,960	(2,707)	70.0	2.91	50	150	0.142	9.5

TABLE VI

Yarns:		
Front bar (Table V)	3	4
Back bar (Table III)	2	2
Stitch:		
Front bar	2–3, 1–0	2–3, 1–0
Back bar	1–0, 1–2	1–0, 1–2
Runners (in.):		
Front bar	65	64
Back bar	44	43
Ratio (front back)	1.47	1.49
Fabric in. per rack	8	8
Finished count (w.p.i.–c.p.i.)	48–50	47–59
Weight (oz./yd.²)	4.1	4.0
Bulk (cc./gm.):		
At 3 gm./cm.² loading	4.4	3.6
At 40 gm./cm.² loading	3.8	2.9
At 239 gm./cm.² loading	3.2	2.6

TABLE VII

Yarns		
Front Bar	7	2
Back Bar (Table III)	2	2
Stitch		
Front Bar	2–3, 1–0	2–3, 1–0
Back Bar	1–0, 1–2	1–0, 1–2
Runners (in.)		
Front Bar	62	62
Back Bar	44	44
Ratio (Front/Back)	1.41	1.41
Fabric in. per rack	8	8
Finished Count (wpi - cpi)	47–53	50–54
Weight (Oz./Yd.²)	2.48	2.71
Bulk (cc./gm.)		
at 3 gm./cm.² loading	5.9	3.6
at 40 gm./cm.² loading	4.7	3.2
at 239 gm./cm.² loading	3.7	3.0

EXAMPLE IV

This example illustrates an alternative method of preparing a polyester yarn of the present invention.

Polyethylene terephthalate having a relative viscosity of 30.2 and containing 2 weight percent TiO_2 is melt spun at 294°C. into a yarn composed of 14 trilobal cross-section filaments. The quenched filaments are passed around a feed roll moving at 1434 ypm. (1311 mpm) and then through a steam draw jet (similar to

EXAMPLE V

Poly(cyclohexane-1,4-dimethylene terephthalate) having a relative viscosity of 34.9 and TiO_2 content of 0.28 weight percent is melt spun at 310°C. into a yarn composed of 34 filaments. The quenched filaments are passed around a feed roll moving at 1000 ypm (914 mpm) and then through an aqueous draw bath which is maintained at 90°C. The yarn proceeds from the draw bath to and around unheated draw rolls operating at a peripheral speed of 2750 ypm (2514 mpm) and is wound up at 2666 ypm (2437 mpm). The yarn has a boil-off shrinkage of 40.6 percent.

A skein prepared from this yarn is relaxed 10 minutes in 80°C. water during which time it shrinks 11.4 percent. The skein is dried and backwound. The 71-denier yarn has a crystallinity of 18 percent, a sonic velocity of 2.24 km./sec., a peak shrinkage tension of 0.035 gpd at 80°C. and exhibits a boil-off shrinkage of 5.6 percent. The yarn is designated test yarn 8.

A tricot fabric is prepared with the above-described yarn as a front bar yarn in combination with the conventional yarn 2 (Table III) in the back bar. The fabric is relax scoured, dried, and heat-set as described in Example III. Fabric properties are given in Table VIII. The test yarn is found to impart an appreciable amount of bulk, as well as improved tactile aesthetics, to the tricot fabric.

Measurement of the X-ray crystallinity of fibers of poly(cyclohexane1,4-dimethylene terephthalate) requires a modification of the previously described procedures because the polymer contains a mixture of cis- and transisomers of the glycol with the two crystal dimensions being slightly different. In the modified procedure, found suitable for crystallinities in the range 16–35 percent, the intensity vs. scattering angle (2θ) curve is prepared as usual, points on the curve located at 2θ valus of 18.5° and 26.7°, and a line drawn between these two points. A vertical line is drawn from the baseline to the intensity curve at a 2θ value of 22.3° (the approximate location of the 100 diffraction). This vertical line intersects the intensity curve at point I_s and the first-drawn line at point I_b. Percent crystallinity is calculated from the expression:

$$\text{Percent crystallinity} = (I_s - I_b)/I_s \times 100.$$

TABLE VIII

Yarn Code	
Front Bar	8
Back Bar (Table III)	2
Stitch	
Front Bar	2–3, 1–0
Back Bar	1–0, 1–2
Runners(in.)	
Front Bar	64
Back Bar	44
Ratio (Front/Back)	1.45
Fabric in. per rack	8
Finished Count	
(wales/in.-courses/in.)	40–55
Weight (Oz./Yd.^{2})	3.53
Bulk (cc./gm.)	
at 3 gm./cm.^{2} loading	4.3
at 40 gm./cm.^{2} loadinG	3.6
at 239 gm./cm.^{2} loading	3.0

EXAMPLE VI

For comparison with the excellent improvement in bulk shown by the yarns of this invention in Example I, a typical prior art fabric, as illustrated by Kasey in U.S. Pat. No. 3,041,861, is prepared from conventional polyester yarns. In accordance with the teachings of the patent, a warp knit bar-on-bar fabric is prepared from two yarns possessing a large difference in shrinkability. This fabric is then compared directly with a fabric knit from a single yarn (i.e., all the same shrinkage) under similar conditions. The yarns are prepared as follows: polyethylene terephthalate having an RV of 30 and containing 2.0 weight percent TiO_2 is spun at about 308°C. through a spinneret having 54 Y-shaped orifices. The trilobal filaments are quenched with a cross-flow stream of air at 125 cfm and 70°F., then passed around a feed-roll assembly (four wraps) maintained at 933 ypm (852 mPm), through an aqueous finish bath at 92°C. and onto a set of draw rolls (13 ½ wraps) running at a surface speed of 2998 ypm (2741 mpm), and then to a dual windup at 2900 ypm (2862 mpm) to maintain a threadline tension of 15 grams. The draw ratio is 3.2:1 and the draw rolls are held at 140°C. Two ends of 40-denier 27-filament yarn, coded **x1**, are obtained having representative properties of 4.0 gpd tenacity, 24 percent break elongation, 129 gpd initial modulus and a boil-off shrinkage (BOS) of 4–6 percent. Representative samples of these yarns have an SV of 3.22, an X-ray crystallinity of 45 percent and a shrinkage tension peak at 180°C.

A "high shrinkage" 40–27 polyethylene terephthalate yarn is prepared using the above procedure with the exception that the draw rolls are maintained at a temperat0re of 94°C. Representative properties of this yarn, coded **X2**, are 3.7 gpd tenacity, 30 percent break elongation, 145 gpd initial modulus, a boil-off shrinkage of about 14 percent, an SV of 3.92 km./sec., an X-ray crystallinity of 16 percent, and a shrinkage tension peak at 134° C.

The normal shrinkage 40–27 polyethylene terephthalate yarn described in Example I as yarn A is used in both bars to make a tricot control fabric (Fabric No. 47, Table II).

In this comparison experiment, the yarns are prepared for knitting by backwinding onto cones and then transferring the yarns to 7 inch (18 cm.) section beams for knitting on a 28 gauge tricot machine. Knitting and fabric details are summarized in Table IX. The knitting conditions of the fabric containing the low-shrinkage/-high-shrinkage yarn combination are adjusted to give a greige fabric which achieves the desired fabric weight under low tension finishing conditions. Finishing conditions, i.e., relaxed scour followed by heat setting at dry width, are such that maximum available bulk can be developed. It is found that under these optimum conditions only a marginal improvement in fabric bulk is obtained with the mixed-shrinkage fabric over the second fabric prepared from yarns having no difference in shrinkage.

TABLE IX

Comparison Fabrics

Fabric	Mixed Shrinkage	Normal
Yarn		
Front (top) bar	X1	X3
Back (bottom) bar	X2	X3
Stitch		
Front bar	2–3, 1–0	2–3, 1–0
Back bar	1–0, 1–2	1–0, 1–2
Runners		
Front bar	65.75 in.	62.7 in.
Back bar	48 in.	45.8 in.
Ratio	1.37/1	1.37/1
Fabric in. per rack	10 in.	8 in.
Finished count (wpi × cpi)	43 × 54	48 × 48
Fabric wt. (oz./yd.^{2})	2.7	2.8
Bulk (cc./gm.)		
at 3 gm./cm.^{2} loading	3.9	3.6
at 40 gm./cm.^{2} loading	3.3	3.2
at 239 gm./cm. ^{2} loading	2.9	2.8

The comparison experiment described above demonstrates that appreciable improvement in bulk is not obtained when two conventional prior art yarns with boil-off shrinkages differing by as much as 10 percent are combined in one tricot fabric. In contrast, as illustrated in the previous examples, the yarns of the present invention used in combinations with ordinary commercial polyester yarns provide a marked improvement in bulk as well as an improvement in tactile aesthetics. Furthermore, since the yarns of the invention are free of significant crimp, they offer outstanding processibility in knitting operations whereas prebulked yarns are difficult to knit. Although the advantages of the yarns of the invention are realized primarily in warp knit fabrics, such as tricot, it is appreciated that the yarns are also useful in preparing weft knits such as full-fashioned and circular knits and also woven fabrics such as taffeta, twill, oxford, satin, and basket Weaves. Warp knit fabrics are particularly useful in men's shirts, women's dresswear, uniforms, blouses and intimate apparel.

EXAMPLE VII

Polyethylene terephthalate containing 2 weight percent TiO_2 is melt spun to give a 14-filament strand in which all filaments have a trilobal cross section. The quenched strand is passed over a feed roll operating at a surface speed of 1271 yards per minute (1162 meters per minute), then through a jet enclosure supplied With steam at a temperature of 190°C. at a pressure of 50 psig. (3.4 atm.), and then around draw rolls operating at a surface speed of 3060 ypm (2798 mpm). The draw ratio is 2.4:1. The draw rolls are enclosed in a box heated with circulating air maintained at a temperature of 92°–93°C. The drawn yarn proceeding from the enclosed draw rolls passes through a "relaxing" (shrinkage) jet enclosure supplied with air at a pressure of 55 psig (3.7 atm.) and a temperature of 290°C., then around a change-of-direction roll to a driven "letdown" roll assembly running at a surface speed of 2600 ypm (2377 mpm), and then to a windup operating at 2643 ypm (2417 mpm). The percent overfeed to the relaxing jet, based on letdown roll speed, is 17.3 percent. The percent net overfeed, based on windup speed, is 15.5 percent.

A sample of drawn yarn prepared by going directly from the draw rolls to windup, by-passing the relaxer jet and letdown roll, has the properties listed in Table X.

TABLE X

DRAWN YARN PROPERTIES

Denier	35.7
Tenacity (gpd)	3.05
Elongation (%)	73.1
Modulus (gpd)	100.2
Boil-off Shrinkage (%)	17.2
Sonic Velocity (Km./sec.)	2.68

The relaxed yarn which is wound up in the above-described process has the properties listed in Table XI.

TABLE XI

RELAXED YARN PROPERTIES

Denier	42.8
Tenacity (gpd)	2.44
Elongation (%)	100.8
Modulus (gpd)	50.2
Boil-off Shrinkage (%)	4.9
Sonic Velocity (Km./sec.)	2.17
Shrinkage Tension Peak (°C.)	82
Maximum Shrinkage Tension (gpd)	0.026
X-Ray Crystallinity (%)	25

Using single-end warping facilities, test yarn (VII–1) prepared by the process described above is knit into a tricot fabric as the front-bar yarn along with a commercial polyester yarn (T–57) similar to Yarn E in Table *Ib* in the back bar. The greige knit fabric is given a finishing treatment similar to that described for knit fabric in Example I. Fabric construction parameters and finished fabric properties are summarized in Table XII along with similar parameters and properties for a comparison fabric knit with the conventional yarn in both the front bar and back bar. The improved bulk and spunlike handle of the test fabric are readily apparent.

TABLE XII

TRICOT FABRIC PROPERTIES

YARNS		
Front Bar	Test VII-1	T-57
Back Bar	T-57	T-57
STITCH		
Front Bar	2–3, 1–0	2–3, 1–0
Back Bar	1–0, 1–2	1–0, 1–2
RUNNERS (INS.)		
Front Bar	62	62
Back Bar	44	44
Ratio Front/Back	1.41	1.41
Fabric in. per rack	8"	8"
Weight (oz./yd.^{2})	2.87	2.80
Finished count (wpi × cpi)	41 × 63	41 × 65
BULK (cc/g)		
At 3 gm./cm.^{2} loading	4.77	3.35
At 40 gm./cm.^{2} loading	3.82	3.02
At 239 gm./cm.^{2} loading	3.12	2.77

EXAMPLE VIII

Following the general procedure of Example I, polyethylene terephthalate containing 2 weight percent of TiO_2 is melt-spun through a 14-hole spinneret to give a yarn in which all filaments have a trilobal cross section. The quenched, undrawn yarn passes over a feed roll rotating with a surface speed of 960 ypm (878 mpm), through a jet enclosure supplied with steam at a temperature of 190°C. and a pressure of 50 psig (3.4 atm.), and then over draw rolls operating at a surface seed of 3010 ypm (2752) mpm). The draw ratio is 3.14:1. The draw rolls are enclosed in a box heated with circulating air at a temperature of 78°C. which gives a drawn yarn with a boil-off shrinkage of 17 percent. As the drawn yarn proceeds from the draw rolls, it passes through a "relaxing" jet enclosure supplied with air at 55 psig. (3.7 atm.) and a temperature of 268°C., and is then passed around an idler roll to a driven "letdown" roll assembly rotating at a surface speed of 2593 ypm (2371 mpm). The relaxed yarn then proceeds to a windup rotating at a surface speed of 2631 ypm (2406 mpm). Threadline tension measurements made on the yarn immediately before it enters the relaxing jet give a value of 6.0 grams, and immediately following the relaxing jet, but before the letdown rolls, give a value of 0.2 grams. The tension on the yarn measured at a point immediately above the windup is 12 grams. A calculation of the percent overfeed to the relaxing jet gives a value of 16.2 percent overfeed based on letdown roll speed, and a value of 14.5 percent overfeed based on windup speed. The properties of the relaxed yarn are summarized in Table XIII.

TABLE XIII

PROPERTIES OF RELAXED YARN

Denier	41.0
Tenacity (gpd)	2.97
Elong. (%)	51.9
Modulus (gpd)	68.0

Boil-off Shrinkage	3.9
Shrinkage Tension Peak (°C.)	98
Maximum Shrinkage Tension (gpd)	0.057
Sonic Velocity (kl./sec.)	2.64
Crystallinity (%)	31

A single end of test yarn prepared by the above process is knitted into a tricot fabric using the test yarn on the front bar and a commercial (T—57) 40-denier 27-filament polyethylene terephthalate yarn on the back bar. The knitted greige fabric is then finished in a manner similar to that discussed in Example I. Measured properties are summarized in Table XIV. The Table also includes properties of a comparison fabric knitted with the T—57 yarn on both front and back bars. The improvement in bulk provided by the test fabric is evident from the data in the Table.

TABLE XIV

FABRIC PROPERTIES

Fabric	Test VIII	Comparison
Yarn		
Front Bar	Test	T-57
Back Bar	T-57	T-57
Finished Count (wpi × cpi)	46 × 60	52 × 56
Weight (oz./yd.²)	3.13	3.14
Bulk (cc/gm)		
at 3 gm./cm.² loading	3.89	2.47
at 40 gm./cm.² loading	3.24	2.24
at 239 gm./cm.² loading	2.76	1.98

I claim:

1. Improved multifilament polyester yarn having good processibility on knitting machines and providing fabric bulk when used in combination with ordinary polyester yarn, the improved yarn consisting of low-shrinkage, continuous filaments of synthetic linear condensation terephthalate polyester which are substantially free of crimp, and the yarn being characterized by a sonic velocity value of 1.9 to 3.0 kilometers per second, an X-ray crystallinity value of 16 to 35 percent and a shrinkage-tension peak at a temperature below 100°C. which is the only peak found between 60° and 200°C.

2. A yarn as defined in claim **1** wherein said sonic velocity value is between 2.0 and 2.5 kilometers per second.

3. A yarn as defined in claim **1** wherein said tension peak is at a temperature between 80°C. and 100°C.

4. A yarn as defined in claim **1** wherein the peak tension at said peak is less than about 0.06 grams per denier.

5. A yarn as defined in claim **1** composed of ethylene terephthalate polyester.

* * * * *