Aug. 10, 1965 S. B. MAEROV ETAL 3,199,281
COMPOSITE POLYESTER YARN OF DIFFERENTIALLY SHRINKABLE CONTINUOUS FILAMENTS
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FIG. 1

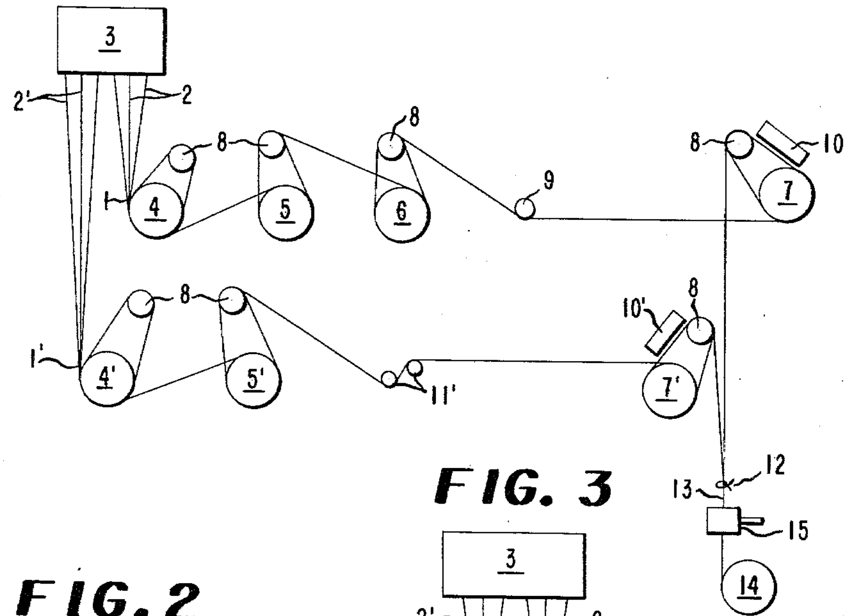

FIG. 2

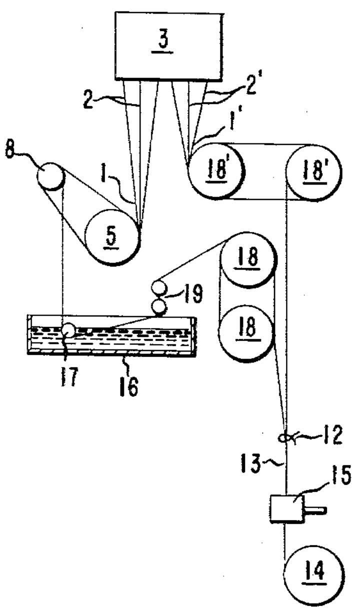

FIG. 3

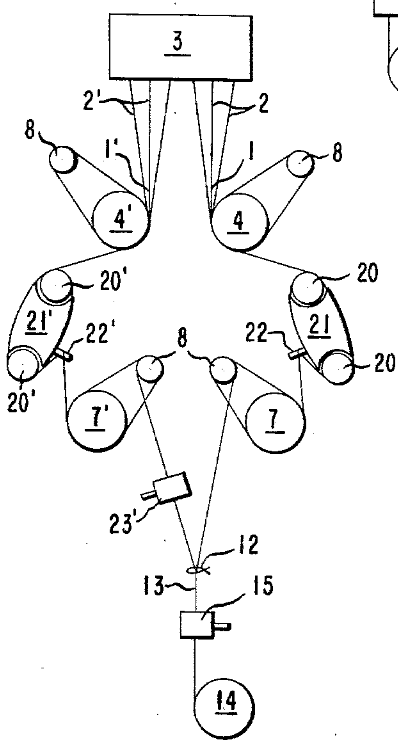

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FIG. 4

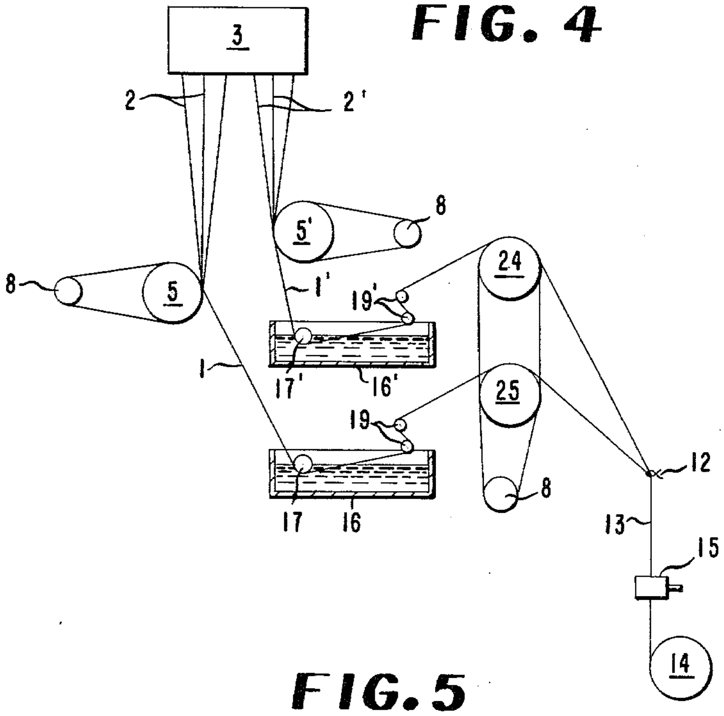


FIG. 5

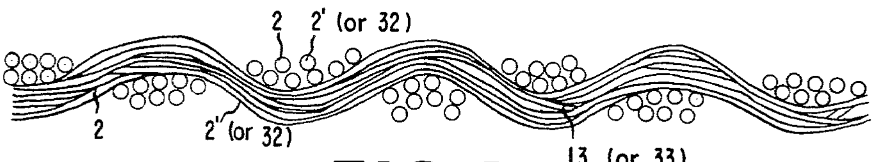


FIG. 6

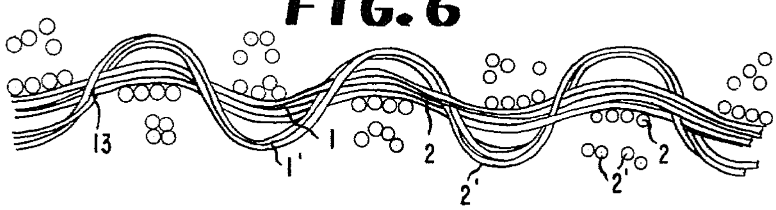
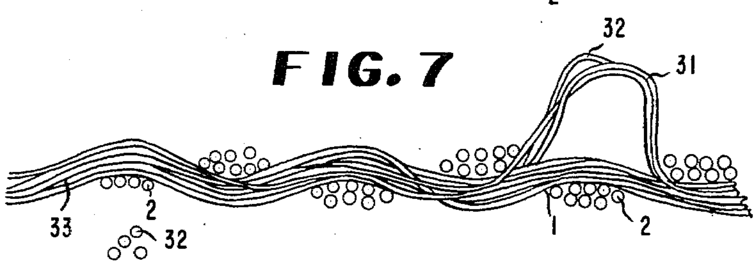


FIG. 7



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United States Patent Office

3,199,281

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3,199,281

COMPOSITE POLYESTER YARN OF DIFFERENTIALLY SHRINKABLE CONTINUOUS FILAMENTS

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Filed Sept. 27, 1961, Ser. No. 141,945
8 Claims. (Cl. 57—140)

This is a continuation-in-part of our copending application Serial No. 53,224, filed August 31, 1960, and now abandoned.

This invention relates to novel composite polyester yarns, and to fabrics prepared from such yarns, which can be caused at any desired time to become permanently bulky. More particularly, the invention relates to such composite polyester yarns which exhibit a soft, supple hand when woven into fabrics and converted to the bulky form. The invention is also directed to a novel process for making the bulkable composite polyester yarns.

It is well known that yarns formed from staple fibers, and particularly from the natural fibers such as cotton and especially wool, are more voluminous or bulky in character than are continuous filament yarns. The bulkiness of the staple yarns leads to fabrics which have high covering power. In the case of the natural fibers, the fabrics are also characterized by a soft, supple hand, especially when the yarns are not highly twisted and dense fabric constructions are avoided. Various attempts have been made to produce a bulky continuous filament yarn in order to combine the desirable aesthetic properties of staple yarns with the advantages of continuous filament yarn, such as strength and ease of processing. This has been accomplished in various ways by producing continuous filament yarns in which the various filaments contained in a short segment of yarn have different lengths when straightened out. In one previously described method, two yarns which have different amounts of residual shrinkage are associated and the resulting yarn, or the fabric produced from it, is subjected to conditions effective in bringing about shrinkage. As the component having the greater residual shrinkage shortens to its final length, the other component disposes itself outwardly from the more shrinkable component, such as by forming loops protruding from the axis of the yarn bundle. Usually it is desired to convert the yarns into fabric form before causing them to become bulky, since bulky yarns have a tendency to snag when they contact each other or various parts of the yarn processing equipment, as well as a tendency to be pulled out smooth by excessive tensions.

Yarns composed of the linear condensation polyesters have achieved high commercial success in recent years, owing in part to their usefulness for garments which are suitable for wear with little or no ironing after washing, as well as to their high strength and other characteristics. Since continuous filament yarns composed of the linear condensation polyesters characteristically lead to fabrics having a smooth, cool, slick hand, attempts have been made to prepare bulkier fabrics by making composite polyester yarns exhibiting differential shrinkage when heated. Such attempts, however, have not resulted in fabrics exhibiting the desired characteristics of fabrics prepared from staple yarns; rather, the fabrics have been found to have an unattractive, buckled appearance and to be harsh to the touch. The fabrics are thus generally unsuitable for use in wearing apparel, and there is little or no market for such composite continuous filament polyester yarns.

It is therefore an object of this invention to provide an improved composite continuous filament linear condensation polyester yarn which can be caused to become permanently bulky by a simple treatment which can be applied to the yarn either before or after the yarn is woven or knitted into fabric, as desired. Another object is to provide such a composite polyester yarn which, when bulked in fabric form, affords attractive fabrics having a soft, supple hand. A further object is to provide composite polyester yarns suitable for preparing fabrics having these characteristics and possessing also the characteristics of resilience and crease recovery requisite for garments suitable for wear with little or no ironing after washing. A still further object is to provide such composite polyester yarns having uniform dyeability characteristics. An additional object is to provide a process for preparing such composite polyester yarns. Other objects will become apparent from the following description and claims.

It has now been found that, in composite polyester yarns comprising differentially shrinkable components, the ability of the less shrinkable component to resist shrinkage under the influence of small restraining forces is the determining factor in preventing the occurrence of buckling in the finished fabric. In accordance with the invention, therefore, the product comprises a composite linear condensation polyester yarn comprising a plurality of filaments of at least two species, the first filament species being characterized by a zero load residual shrinkage in the range of 0.0% to about 20% and a residual shrinkage at 0.05 grams per denier (g.p.d.) load at least about 1.2% less than the zero load residual shrinkage, and a second filament species being characterized by a zero load residual shrinkage at least 2% higher than the zero load residual shrinkage of the first filament species. Yarn so characterized, after being woven or knitted into fabric, boiled off or scoured, and then ironed or heat set, surprisingly yields bulky fabrics which have a soft, supple, staple-like hand and an attractive appearance. In contrast, fabrics produced from differentially shrinkable composite polyester yarns in which the less shrinkable component has a zero load residual shrinkage only slightly greater than the residual shrinkage at 0.05 g.p.d., up to about 1.2%, are buckled or puckered and have a harsh hand.

In a preferred embodiment of the invention, where the composite polyester yarns are intended for use in dyed fabrics, and where uniform dyeability characteristics are desired, the filament species making up the composite yarn have substantially equivalent tenacities.

By "residual shrinkage" as used herein and in the appended claims is meant the capability remaining or existing in the filament or yarn for linear contraction under the specified tension in water at 100° C. for an exposure time of 5 minutes. When the tension is not specified, residual shrinkage under zero tension is implied. The term "shrinkability" is also used synonymously with "residual shrinkage" as an attribute of a filament or yarn. When used alone, the term "shrinkage" refers to the actual step of carrying out linear contraction of a filament or yarn, or the observation of the amount of linear contraction, the shrinkage being carried out under zero tension in water at 100° C. for 5 minutes except where otherwise specified. Filaments or yarns which exhibit no change in length when heated are regarded herein as the limiting case in which the shrinkage is zero (0.0%). In some cases, the filaments or yarns may be stretched when they are heated while held under tension; in such cases, the length change is regarded as shrinkage of negative value and the residual shrinkage under the specified load of the yarn prior to heating is correspondingly assigned the appropriate negative value.

For the purpose of the invention, satisfactory determinations of shrinkage values are made as follows. To measure shrinkage of the yarn at zero load, a length of the yarn is cut and two knots are tied in the yarn about 8 to 15 centimeters apart. Clamps are placed over the knots, and additional weights are hung on the yarn to make a total load of 0.05 g.p.d. so that any kinks in the yarn will be pulled out and the yarn will hang straight. The length of the yarn between the knots is measured to the nearest 0.01 centimeter with a cathetometer. The addition weights are then removed and the sample is hung by both clamps in 100° C. water with the yarn forming a free loop immersed in the water, for 2 to 5 minutes. The sample is then removed from the water and, after the yarn has cooled, the additional weights are again added to make the yarn hang straight and the length of the yarn between the knots is again measured. The shrinkage is calculated in accordance with the formula

$$\text{Shrinkage}=\frac{(\text{Original Length}-\text{Final Length})\times 100\%}{\text{Original Length}}$$

To measure shrinkage of the yarn under a load of 0.05 g.p.d., the denier of the yarn sample is determined and an 8 to 15 centimeter sample is prepared and measured to the nearest 0.01 centimeter as before. The weights are then adjusted so as to provide a total load on the yarn of 0.05 g.p.d., when corrected for the buoyancy of water, and the sample is placed in water at 100° C. for 2 to 5 minutes, making sure that the sample and weight hang free in the water and are completely covered by the water. The final length of the sample is measured before removing it from the water and the percentage shrinkage is calculated in accordance with the above formula.

The symbol "$\Delta S_{0.05}$" is employed herein to represent the difference between the zero load residual shrinkage and the residual shrinkage under a load of 0.05 g.p.d. The value of $\Delta S_{0.05}$ for a given yarn is determined by measuring the values for zero load residual shrinkage and residual shrinkage at 0.05 g.p.d. load in the manner described above and substituting them in the equation

$$\Delta S_{0.05}=\text{Shrinkage at Zero Load} - \text{Shrinkage at a Load of 0.05 g.p.d.}$$

In accordance with the present invention the less shrinkable component is characterized by a $\Delta S_{0.05}$ value of at least 1.2%. The $\Delta S_{0.05}$ value of the more shrinkable component of the yarn is not a critical factor in determining the utility of the composite yarn, and $\Delta S_{0.05}$ values for the more shrinkable component are accordingly not reported herein.

The present invention also comprehends a novel continuous process for preparing the composite yarns. In accordance with the invention, a linear condensation polyester is extruded into a plurality of filaments which are wound up together as a yarn bundle, a first part of the filaments being attenuated after extrusion such that each filament has a zero load residual shrinkage in the range 0.0% to about 20% and a residual shrinkage at 0.05 g.p.d. load at least about 1.2% less than the zero load residual shrinkage, and a second part of the filaments being attenuated after extrusion to the same final length as the first but in a manner such that each filament has a zero load residual shrinkage at least 2% higher than the residual shrinkage of the first part of the filaments. By the term "attenuation" of a filament is meant reduction in its denier, not only during the spinning step as the extruded molten polyester is pulled away from the spinneret and quenched to a solid filament, but also in any stretching steps which may be applied to the filament subsequently. If desired, two or more spinneret packs may be used to supply the filaments which are brought together to form the composite yarn. In practice, however, it is generally preferred to divide the filaments extruded from a single spinneret pack into parts and recombine them to form the composite yarn after processing each part of the filaments separately as described above. If desired, the coherency or retentiveness of the composite yarn may be improved by false-twisting it or by imparting a low twist to the yarn after its component parts are brought together. Alternately, the yarn may be "interlaced" by passing it under positive tension through a zone of controlled fluid turbulence formed by two or more fluid vortices, at least one of which has an axis which is at least momentarily substantially parallel to the axis of the yarn, to open the yarn bundle and intermingle the filaments so that the yarn bundle is consolidated into a compact unitary strand which maintains its unity even at zero twist.

The novel product of the invention as well as the process in its various embodiments will be better understood by reference to the accompanying figures, in which

FIGURE 1 is a diagrammatical sketch or flow sheet of one embodiment of the process, in which the filaments are stretched under different conditions after they have been spun;

FIGURE 2 illustrates another process embodiment of the invention, in which part of the extruded filaments are forwarded from the spinneret at high speed, without subsequent stretching, while the remainder of the filaments are forwarded from the spinneret at lower speeds and subsequently drawn;

FIGURE 3 shows a process embodiment of the invention in which all of the filaments are drawn and part of the filaments are relaxed after drawing, the remainder not being relaxed;

FIGURE 4 shows still another process embodiment of the invention, in which part of the filaments are drawn under one set of conditions while the remainder are drawn under a different set of conditions;

FIGURE 5 is an enlarged view of a cross section of a fabric before boil-off, said fabric being woven from a composite linear condensation polyester yarn wherein the component filaments have different amounts of residual shrinkage;

FIGURE 6 is an enlarged view of a cross section, after boil-off and heat setting, of a fabric having the original appearance shown in FIGURE 5, illustrating the uniform bulking effect achieved when the fabric of FIGURE 5 is woven of the composite linear condensation polyester yarn of the invention, wherein the component filaments having the lesser shrinkability have a high $\Delta S_{0.05}$ value (above 1.2%); and

FIGURE 7 is an enlarged view of a cross section, after boil-off and heat setting, of a fabric having the original appearance shown in FIGURE 5, illustrating the irregular structure of the boiled-off fabric when the fabric of FIGURE 5 is woven of a composite linear condensation polyester yarn wherein the component filaments having the lesser shrinkability have a $\Delta S_{0.05}$ value below 1.2%.

Turning now to FIGURE 1, one preferred embodiment of the process of the present invention comprises stretching the spun filaments under different conditions. Filament bundles **1** and **1'**, comprised of individual filaments **2** and **2'**, are obtained by separating into two groups the filaments extruded from spinneret pack **3**, which may be any conventional spinneret pack suitable for spinning molten condensation polyesters. The filament bundles pass around forwarding rolls **4** and **4'**, respectively, which exert tension on the extruded filaments and determine the forwarding speeds F and F', respectively (also designated as the spinning speeds). Filament bundle **1** is then forwarded in turn to rolls **5**, **6**, and **7**, while filament bundle **1'** is forwarded to rolls **5'** and **7'**. Each of the rolls may have a separator roll **8** positioned on an axis slightly skew from the plane of the axis of the roll with which it is associated, to ensure separation of wraps of the filament bundle around the roll. In passing a yarn from a roll and its associated separator roll to the next element in the apparatus, the last wrap may terminate either on the roll or the separator roll, whichever is most convenient. Rolls 5 and 5' are feed rolls rotating at the same speed as forwarding rolls 4 and 4', respectively, while roll 6 operates at higher speed than roll 5 and roll 7 rotates at higher speed than roll 6. Similarly, roll 7' rotates at higher speed than roll 5'.

In the treatment of filament bundle 1, roll 5 is heated to a temperature in the range 130° to 180° C. so that the filament bundle is superstretched by factor s of its spun length without undergoing orientation while being passed from rolls 5 to 6. Such a superstretching process, in which the filaments are attenuated under conditions which appear to approximate plastic flow, is disclosed by Pace in his U.S. Patent 2,578,899. The factor s may vary over a wide range but is usually in the range of about 1.05 to 6. Roll 6 is maintained at a temperature in the range of room temperature to 120° C. and the filament bundle contacts snubbing means 9, such as a draw pin around which the bundle is passed, between rolls 6 and 7 so that filament bundle 1 is drawn by a factor d of its length after the superstretching step. The drawing step differs from the superstretching step in that, in the drawing step, the filaments are attenuated in such a manner that they undergo orientation. Optionally, the filament bundle 1 may be passed over hot plate 10 between draw roll 7 and its separator roll to modify the residual shrinkage and other properties of the yarn; alternately, the draw roll may be heated to serve the same purpose, or the yarn may be passed over a hot plate after leaving the draw roll. The factor d is usually in the range of about 3 to 5. As is well known in the prior art, the properties of the drawn yarn are dependent not only on the draw ratio but also to some extent upon the temperature of drawing, the spinning orientation imparted to the yarn, and other factors.

In accordance with the invention, while filament bundle 1 is being stretched in the manner described above, filament bundle 1' is being stretched to the same final length but under different conditions. Upon leaving the forwarding roll 4', filament bundle 1' passes to feed roll 5' heated to a temperature in the range 100° to 190° and then undergoes superstretching while being passed to roll 7'. The superstretching step may be carried out without snubbing means and hence without orientation of the filaments; or a modified superstretching process may be used in which a moderate amount of orientation is introduced into the yarn by contacting the filament bundle between rolls 5' and 7' with means 11' for providing a moderate degree of snubbing, such as a pair of snub pins between which the filament bundle is passed, as shown in FIGURE 1. After undergoing stretching, filament bundle 1' may be heated to reduce its residual shrinkage. This may be done by passing the filament bundle over hot plate 10' between draw roll 7' and its separator roll; or alternately by heating roll 7' or by passing the yarn over a hot plate after it leaves the draw roll. The temperature in the final heating step of filament bundle 1' is maintained sufficiently high that the residual shrinkage of filament bundle 1' is at least 2% less than that of filament bundle 1. If desired, in instances where filament bundle 1' is heated after leaving roll 7', the filament bundle may be allowed to relax by a factor r' of its superstretched length; similarly, if desired, relaxation by a factor r of the drawn length of filament bundle 1 may be permitted when the filament bundle is heated after leaving roll 7. By processing filament bundle 1' in the manner indicated, the $\Delta S_{0.05}$ value of the filament bundle is maintained above about 1.2%.

After the filament bundles have been attenuated as described, they are brought together by means of guide 12 to form a composite yarn 13 which is wound up on package 14. If desired, means 15 for increasing the coherency of the yarn, such as false-twisting or interlacing means, may be employed between the guide 12 and package 14, or at some other convenient location.

In accordance with the invention, the composite yarn 13 is provided as a non-bulky continuous filament yarn by maintaining filament bundles 1 and 1' at the same speed as they are brought together at guide 12 and wound on package 14. This is accomplished by carrying out the respective attenuation processes for filament bundles 1 and 1' in accordance with the generalized relationship

$$\text{windup speed} = Fsdr = F's'd'r \qquad (6)$$

where d' is analogous to d and represents the factor by which filament bundle 1' may be drawn in any drawing step (separate from the superstretching step) which may be applied. In the process embodiment just described $d'=1$, of course; and in a typical example of the process embodiment $F=F'$ and $r=r'=1$, reducing the relationship to the equality $sd=s'$.

Another preferred process embodiment of the invention is shown in FIGURE 2. Filament bundles 1 and 1' comprised of individual filaments 2 and 2' are extruded from spinneret pack 3. The spun filament bundle 1 is passed around feed roll 5 and its associated separator roll 8, into liquid bath 16 maintained at a temperature in the range 75–150° C., under draw pin 17 in contact with the bath, and around a pair of draw rolls 18. If desired, guides 19 may be provided above the surface of the bath between draw pin 17 and draw rolls 18 to aid in removing water from the yarn through centrifugal action. Spun filament bundle 1', however, is fully attenuated in the spinning step alone, being passed around rolls 18' and thence directly brought together with filament bundle 1 at guide 12 to form composite yarn 13 wound upon package 14. In this embodiment of the process, $d'=1$, $s=s'=1$, and $r=r'=1$ in the generalized relationship given above, reducing the relationship to $Fd=F'$. In practice, the peripheral speed F' of rolls 18' is selected high enough to yield a spun yarn having a residual shrinkage of not more than about 20%. The minimum speed effective for this purpose will vary since the specific polyester composition, the polymer viscosity, and the denier of the spun filaments also have some effect on the residual shrinkage of the yarn; however, in general, the required forwarding speed of rolls 18' is at least about 3,000 yards per minute. By attenuating filament bundle 1' in this way its $\Delta S_{0.05}$ value is maintained considerably above the critical limit of 1.2%. After selecting the spinning speed F' for filament bundle 1', a draw ratio d for filament bundle 1 is selected, which also fixes the spinning speed F of filament bundle 1. The draw ratio is selected such that the residual shrinkage of filament bundle 1 is at least 2% higher than the residual shrinkage of filament bundle 1'. If desired, draw rolls 18 may be heated to modify the residual shrinkage and other properties of filament bundle 1. Where rolls 18 and 18' are to be maintained at the same temperature, one pair of rolls may be eliminated by passing filament bundles 1 and 1' around the same pair of rolls, since the final speeds of the bundles before they are brought together are the same.

In a variation of the process just described with reference to FIGURE 2, filament bundle 1' is spun as before, but rolls 18' are maintained at a temperature in the range 100° to 180° C., so that the filament bundle 1' undergoes heat setting at constant length. In this way, the residual shrinkage of the filament bundle 1' is markedly reduced. Owing to this, the minimum spinning speed of filament bundle 1' (peripheral speed of rolls 18') may be reduced to much lower levels, if desired. Although the minimum spinning speed of filament bundle 1' is no longer critical, speeds as low as 2500 yards per minute are considered practicable. Of course, the spinning speed of filament bundle 1 is necessarily reduced also if the same draw ratio d is employed. A more important advantage for this aspect of the invention, however, is that the residual shrinkage of filament bundle 1′ may be reduced to quite low levels, approaching zero residual shrinkage.

In the embodiment of the invention shown in FIGURE 3, all of the filaments are drawn, but part of the filaments are subsequently relaxed while the remainder are not relaxed. After extrusion, filament bundle 1 is passed around forwarding roll 4 and its associated separator roll, around a pair of rolls 20 between which is situated a heating block 21 curved on each side and maintained at a temperature in the range 75° to 115° C., around draw pin 22 mounted at one end of the heating block, and thence to draw roll 7. Filament bundle 1′ is similarly passed from forwarding roll 4′ around feed rolls 20′ and heating block 21′ to draw pin 22′ and draw roll 7′. However, between draw roll 7′ and guide 12 where filament bundles 1 and 1′ are brought together, filament 1′ is passed through a relaxing jet 23′ wherein it is exposed to hot gas or liquid. Instead of the relaxing jet, a hot plate or other relaxing means may be employed. Composite yarn 13 formed from filament bundles 1 and 1′ is then wound on package 14, first being passed if desired through interlacing jet 15 or other means for increasing the coherency of the yarn. In this process embodiment, $s=s'=1$ and usually $r=1$, so that $Fd=F'd'r'$. Of course, the drawing and relaxing conditions for filament bundle 1′ must be adjusted such that the $\Delta S_{0.05}$ value of the filaments is greater than about 1.2%. This is readily accomplished; in a typical example $F=182$ y.p.m., $F'=262$ y.p.m., $d=3.3$, $d'=2.75$, and $r'=0.833$, the temperatures of the heated blocks being 100° C. for both filament bundles, and air at 40 p.s.i.g. and 320° C. being used in the relaxing jet. The residual shrinkage of filament bundle 1′ is lower than that of filament bundle 1 when the yarn is made in this way, and the level of residual shrinkage as well as the $\Delta S_{0.05}$ level of filament bundle 1 are readily adjusted by varying the process conditions.

In a variation of the process just described with reference to FIGURE 3, draw pin 22′ is omitted. This allows for increased relaxation, resulting in higher $\Delta S_{0.05}$ values for filament bundle 1′.

In still other variations of the process shown in FIGURE 3, feed rolls 20′, heating block 21′, draw pin 22′, and relaxing jet 23′ may all be omitted; while draw roll 7′ is heated or the yarn is heated just before reaching the roll by passing it through a jet tube wherein it is exposed to hot gas or liquid. The residual shrinkage of filament bundle 1′ is thereby kept lower than that of filament bundle 1 and the $\Delta S_{0.05}$ value of filament bundle 1′ is maintained at a high level. In these process variations the factors s, s', r, and r' are all equal to unity, so that $Fd=F'd'$.

Still another embodiment of the process of the invention is illustrated in FIGURE 4. As in FIGURE 2, the spun filament bundle 1 is passed around feed roll 5 and its associated separator roll 8, into liquid bath 16 maintained at a temperature in the range 75–150° C., under draw pin 17 in contact with the bath, and around guides 19, after which it is passed several times around the combination of heated roll 25 and its associated unheated separator roll 8. Spun filament bundle 1′ is passed around feed roll 5′ and its associated separator roll 8, under draw pin 17′ in contact with bath 16′, around guides 19′, and then several times around the pair of heated draw rolls 24 and 25. In the embodiment shown in FIGURE 4, roll 25 is used in common by filament bundles 1 and 1′, but the identity of the bundles is maintained until they are brought together at guide 12 to form composite yarn 13 wound upon package 14. The temperature of filament bundle 1′ at the draw rolls 24 and 25 is substantially higher than that of filament bundle 1, since the former is wrapped around two heated rolls, while the latter is wrapped around one heated and one unheated roll. The residual shrinkage of filament bundle 1′ is thereby kept lower than that of filament bundle 1 and the $\Delta S_{0.05}$ value of filament bundle 1′ is maintained at a high level. In this process embodiment $Fd=F'd'$, while $s=s'=1$ and $r=r'=1$.

Instead of using separate feed rolls 5 and 5′ in the process described above, a common feed roll may be used if the same forwarding speed is desired for both filament bundles, providing that the separate identity of the filament bundles is maintained. If different forwarding speeds are desired, a stepped feed roll having sections of different diameter may be employed. Similarly, other elements in the apparatus, such as the draw bath section, may be used in common where applicable providing that separate identity of the filament bundles is maintained until no longer required.

In the above discussion, the various process embodiments of the invention are described in terms of spinning the filaments and then subjecting them to the various superstretching, drawing, and relaxing treatments in a continuous manner, without interrupting the process to wind the filament bundles one or more times. Extrusion of the filament bundles preferably from the same spinneret, followed by continuous processing of the separated bundles and subsequent recombining of the bundles to form the composite yarn without intermediate winding operations is the preferred manner of carrying out the process. However, if desired, the process may be carried out in a sequence of individual operations with intermediate winding steps.

The novel character of the composite polyester yarn of the invention, as contrasted with other composite polyester yarns, is illustrated in FIGURES 5 through 7. The figures represent fabric cross sections taken parallel to the warp, with the filling seen in section. FIGURE 5 shows an enlarged view of a cross section of a fabric before boil-off, said fabric being woven from a composite linear condensation polyester yarn wherein the component filaments of the yarn have different amounts of residual shrinkage. As shown in the figure, the fabric has the appearance of a conventional fabric woven from synthetic continuous filament yarn. This appearance is characteristic of the fabric whether it is woven from the novel composite yarn 13 of the invention comprised of shrinkable filaments 2 together with filaments 2′ having a lesser residual shrinkage as well as a high $\Delta S_{0.05}$ value or woven from a composite linear condensation polyester yarn 33 (numeral indicated parenthetically in FIGURE 5) comprised of the same shrinkable filaments 2 together with filaments 32 (numeral indicated parenthetically in FIGURE 5) having the same low residual shrinkage as filaments 2′, but a $\Delta S_{0.05}$ value below 1.2%. Prior to boil-off, filaments 2 and 2′ (as well as filaments 2 and 32) are substantially identical in appearance.

FIGURE 6 illustrates the appearance of the cross section, after boil-off and heat setting at 196° C., of a fabric woven from the novel composite yarn 13 of the invention wherein the component filaments 2′ of lesser shrinkability have a high $\Delta S_{0.05}$ value, and having the original appearance shown in FIGURE 5. As shown in the figure, filament bundle 1 composed of individual filaments 2 and filament bundle 1′ composed of individual filaments 2′, are now identifiable, owing to the higher shrinkage of filament bundle 1. Owing primarily to the contraction of filament bundle 1, fabric shrinkage has occurred (reduced distance between filling ends in the figure). Filament bundle 1′, because of its lesser shrinkage, has disposed itself outwardly in loops, which are seen not only in the warp but in the filling in cross section (note filaments 2′ in cross section); such loops are 3-dimensional, of course, although indicated as being in the plane of the paper. It is to be noted that the loops formed by filament bundle 1′ are relatively uniform, occurring between each adjacent pair of cross-over points in both the warp and the filling. The boiled-off and heat-set fabric shown in section in FIGURE 6 is characterized by a soft, supple hand and a high degree of opacity and cover owing to its uniform bulkiness.

FIGURE 7 illustrates the appearance of the cross section, after boil-off and heat setting at 196° C., of a fabric having the original appearance shown in FIGURE 5, but woven from a composite linear condensation polyester yarn **33** wherein the component filaments **32** having the lesser shrinkability have a $\Delta S_{0.05}$ below 1.2%. Although shrinkable filaments **2** and filaments **32** of lesser shrinkability are substantially identical in appearance prior to boil-off and heat-setting, as shown in FIGURE 5, filament bundle **1** comprised of filaments **2** and filament bundle **31** comprised of filaments **32** are readily identifiable after boil-off since the latter has disposed itself outwardly in loops from the axis of the yarn bundle **33**. In contrast to the small uniform loops formed between each cross-over point by filament bundle **1'** shown in FIGURE 6, however, filament bundle **31** forms large loops between certain cross-over points without dissociating itself from filament bundle **1** between most of the cross-over points. As indicated in the figure, there is a tendency for all of the filaments to loop out at the same point, even when they are not twisted together. The boiled-off and heat-set fabric shown in section in FIGURE 7 is characterized by a harsh hand and has a "buckled" appearance owing to the presence of the loops.

It is believed that the formation of large, infrequent loops by filament bundle **31**, rather than small, uniform loops between each cross-over point, is attributable to the stiffness of filaments **32** even when heated, although this statement is not intended to be taken as limiting. In accordance with the invention, an inverse correlation has been observed between the $\Delta S_{0.05}$ value and the stiffness of the filaments, the critical $\Delta S_{0.05}$ value being about 1.2%.

When the novel composite polyester yarns of this invention are intended to be incorporated in fabrics which are subsequently dyed, it is important that the different species of filaments making up the composite yarn have matched dyeability characteristics. It would be expected that filaments having sufficient internal structural differences to give the shrinkage differences necessary for the yarns of this invention would inherently possess a difference in dyeability, and this is generally true. Surprisingly, however, it has been discovered that by choosing filament species having substantially equivalent tenacities, this dyeability difference can be eliminated.

Prior theories relating to the dyeability of synthetic polyester fibers have taught that degree of crystallinity is the major factor controlling dye uptake. Following these theories, it would have been expected that dyeing differences between fibers of different shrinkages could be eliminated by choosing fibers of the same degree of crystallinity. However, present experimental facts are incompatible with this viewpoint. Rather, it has been found, as a part of this invention, that the major factor controlling dye uptake is the degree of orientation of the molecules in the amorphous areas of the fiber. A convenient measure of "amorphous orientation" is fiber tenacity.

Furthermore, it has been discovered that in critical color shades with dispersed dyes commonly used for polyester fibers, a very uniformly dyed fabric is obtained if the high shrinkage filament species is one which accepts dyes a little more readily than the low shrinkage species. This phenomenon is thought to be due to the fact that upon exposure to the heat of the dye bath, or upon exposure to heat previous to dyeing, the high shrinking filament species retreats to the interior of the yarn bundle and thereby becomes less accessible to the dye bath. In any case, it has now been found that composite polyester yarns of uniform dyeability are obtained when the numerical value of the ratio of the tenacity of the high shrinkage component to that of the low shrinkage component is 0.90±0.20. In other words, the tenacity ratio

$$\frac{\text{high shrinkage species}}{\text{low shrinkage species}}$$

should fall in the range 0.70 to 1.10 in order for fabrics prepared from the composite yarns of this invention to give a smooth and uniform appearance after dyeing. composite polyester yarns made up of species having different shrinkage characteristics and having a tenacity ratio falling outside of the range 0.7 to 1.1 do not give uniformly dyed fabrics. Rather, dyed fabrics produced from such yarns exhibit a distinct moiré or heather effect. For white goods, of course, the tenacity ratio is unimportant.

The term "tenacity" as used herein refers to the tensile stress required to break a filament or yarn, expressed in terms of force per unit linear density, as grams per denier or grams per tex. The measurement of tenacity is well known in the textile art and many suitable methods are available for such determinations.

Once the relationship between tenacity and dyeability is recognized, the preparation of composite polyester yarns having differential shrinkage characteristics and equivalent dyeability may be carried out in any of a number of ways as will be illustrated in the specific examples presented herein. The uniform dyeability achieved by substantially matching the tenacities of the different filament species is not limited to one class of dyes. Any class of dyes suitable for dyeing polyester fibers may be used. Suitable dyes include dispersing dyes, cationic dyes, and anionic dyes. Dispersed dyes are generally used for unmodified polyesters whereas cationic dyes may be used for polyesters modified with sulfonate salt groups as disclosed in Belgian Patent 562,460, and anionic dyes may be used for polyesters modified with linking units containing tertiary amine groups and the like.

The novel yarn of the invention is composed of a synthetic fiber-forming linear condensation polyester. By "linear condensation polyester" is meant a linear polymer comprised of recurring structural units containing, as an integral part of the polymer chain, recurring carbonyloxy groups

$$(-\overset{\overset{\displaystyle O}{\|}}{C}-O-)$$

and having a relative viscosity of at least about 8 in a solution of 11 g. of the polymer in 100 cc. of a mixed solvent composed of 58.8 parts by weight of phenol and 41.2 parts by weight of trichlorophenol. Preferably, at least about 75% of the recurring structural units of the polyester are derived from a glycol containing 2 to 12 carbon atoms and a dicarboxylic acid selected from the group consisting of terephthalic acid and the naphthalic acids. The polyesters may be prepared by reacting the dicarboxylic acid or an ester-forming derivative thereof with an excess of a glycol, $G(OH)_2$, where —G— is a divalent organic radical containing from 2 to 12 carbon atoms and attached to the adjacent oxygen atoms by saturated carbon atoms, or an ester-forming derivative of the glycol. Following the preparation of the monomeric ester, polycondensation is carried out at elevated temperature and reduced pressure with elimination of excess glycol. Examples of suitable glycols include ethylene glycol, diethylene glycol, butylene glycol, decamethylene glycol, and cis- trans-p-hexahydroxylylene glycol. Mixtures of such glycols may suitably be used to form copolyesters, or small amounts, e.g., up to about 15 mol percent, of a higher glycol may be used, such as a polyethylene glycol. The acid component of the polyester preferably consists of at least 75% of terephthalic acid or a naphthalic acid, especially 2,6-naphthalic acid or 2,7-naphthalic acid. Similarly, copolyesters may be formed by replacing up to about 25 mol percent of the terephthalic naphthalic acid or derivative thereof with another dicarboxylic acid or ester-forming derivative thereof, such as adipic acid, dimethyl sebacate, isophthalic acid, hexahydroterephthalic acid, or sodium 3,5-dicarbomethoxybenzenesulfonate. The copolyester may also be formed by replacing part of the terephthalic or naphthalic acid or derivative thereof with a hydroxy acid or derivative thereof, such as p-(2-hydroxyethyl) benzoic acid or methyl p-(2-hydroxyethoxy) benzoate. Linear terephthalate or naphthalate polyesters and copolyesters are especially suitable for use in the present invention since they have high melting points and since the crystallinity and orientation of filaments formed from them may be readily controlled over a wide range. The different filament species of the composite yarn of this invention may be formed from the same polyester or from different polyesters. A preferred polyester is a copolyester containing 0.5 to 3.5 mol percent sodium 3,5-dicarbomethoxybenzenesulfonate, or an equivalent sulfonate salt-containing moiety, as described in Belgian Patent 562,460.

The following examples will serve to illustrate the invention further, although they are not intended to be limitative.

EXAMPLE 1

Polyethylene terephthalate having a relative viscosity of 25.5 and containing 0.3% TiO_2 is spun at 295° C. through a spinneret having 17 Y-shaped orifices formed by the intersection of 3 slots, each 0.007 inch in length and 0.004 inch in width. The yarn is wound up at a speed of 1206 y.p.m. and is found to have a spun denier of 110 (12.2 tex). The spun yarn is then used as a common supply for preparing yarns "A" and "B" as described below. In another experiment, polyethylene terephthalate having a relative viscosity of 15.0 and containing 0.3% TiO_2 is spun at 278° through a spinneret having 15 Y-shaped orifices formed by the intersection of 3 slots, each 0.007 in length and 0.004 inch in width. The yarn, which is designated below as yarn "C" is wound up at 1200 y.p.m. and is found to have a denier of 109 (12.1 tex). In still another experiment, a yarn designated below as yarn "D" is spun under the same conditions as yarn "C," except that the spun denier is 108 (12.0 tex).

Yarn "A" is drawn and relaxed in accordance with a modification of the process described with reference to filament bundle 1' of FIGURE 3. The yarn is passed from a feed roll around heated block 21' (5½ wraps), which is maintained at 88° C. The yarn is then passed directly to draw roll 7', without a draw pin being used in this instance. The speed of the yarn at the draw roll is 750 y.p.m. and the draw ratio is 3.77. The yarn is then passed through a relaxing jet ¼" in length supplied with air at 40 p.s.i.g. and 360° C., after which it is wound up at 634 y.p.m. The yarn is accordingly relaxed 15.3% between the draw roll and the windup. The drawn and relaxed yarn has a denier of 35 (3.9 tex), a tenacity of 4.0 g.p.d., an elongation of 30%, a boil-off shrinkage of 4.2%, a yield point of 0.8 g.p.d., an initial modulus of 61 g.p.d., and a $\Delta S_{0.05}$ value of 5.0%.

Yarn "B" is drawn in accordance with the process described with reference to filament bundle 1 of FIGURE 3. The yarn is passed from a feed roll around heated block 21 (7 wraps) maintained at 110° C., passed once around a ³⁄₁₆ inch draw pin, and thence to draw roll 7 which is operated at a peripheral speed of 634 y.p.m., after which the yarn is wound up at the same speed. The draw ratio is 3.20. The yarn has a denier of 35, a tenacity of 3.4 g.p.d., an elongation of 30%, a boil-off shrinkage of 14.5%, a yield point of 2.0 g.p.d., and an initial modulus of 89 g.p.d.

Yarn "C" is drawn in accordance with a modification of the process described with reference to filament bundle 1' of FIGURE 3. The yarn is passed from a feed roll around a heated block 21' (5 wraps) maintained at 90° C. The yarn is then passed directly to draw roll 7' operating at a peripheral speed of 150 y.p.m. after which the yarn is wound up at the same speed. No draw pin is used. The draw ratio is 3.494. The drawn yarn is passed from a roll operating at a peripheral speed of 180 y.p.m. into an oven containing steam at 100° C. and at atmospheric pressure and is passed out of the oven and wound up on a package operating at a peripheral speed of 149 y.p.m. The oven is 12 inches long and the allowed shrinkage in the oven is 17.2%. The yarn has a denier of 33 (3.7 tex), a tenacity of 3.0 g.p.d., ,an elongation of 30%, a boil-off shrinkage of 2.9%, a yield point of 1.0 g.p.d., an initial modulus of 69 g.p.d., and a $\Delta S_{0.05}$ value of 4.45%.

Yarn "D" is drawn by passing the yarn from a feed roll operating at a peripheral speed of 132 y.p.m. to a draw pin (1 wrap) 1.6 inches in diameter maintained at a temperature of 100° C. and thence to a draw roll operating at 454 y.p.m., after which it is wound at the same speed. The draw ratio is 3.451. The yarn has a denier of 31 (3.4 tex), a tenacity of 3.3 g.p.d., an elongation of 21%, a boil-off shrinkage of 9.2%, a yield point of 1.9 y.p.d., and an initial modulus of 104 g.p.d.

Yarns "A" and "B" are then combined through an interlacing jet to form a composite yarn having a tenacity ratio of 0.85. A 1 x 1 plain weave fabric containing 90 ends per inch in the warp (7Z twist) and 84 ends per inch in the filling 3Z twist) is then prepared from the yarn. Prior to boil off, the fabric has the smooth, slick hand characteristic of continuous filament synthetic fabrics. However, when the fabric is immersed in water at 100° C. for 5 minutes, dried, and ironed, the yarn comprising the fabric becomes quite bulky, and the hand of the fabric becomes warm and soft. The fabric has a weight of 2.2 oz./sq. yd. and a specific volume of 2.4 cc./g. The specific volume is determined by dividing the volume of the fabric by its weight; the volume of a fabric sample of known area being determined by multiplying the area by the thickness measured under a pressure of 3.4 p.s.i. in accordance with method D76–53 of the A.S.T.M. Standards on Textile Materials. The fabric has an attractive appearance with no trace of buckling.

Similarly, yarns "C" and "D" are combined through an interlacing jet to form a composite yarn having a tenacity ratio of 1.10. A 1 x 1 plain weave fabric containing 93 ends per inch in the warp (7Z twist) and 76 ends per inch in the filling (3Z twist) is prepared from the yarn. When the fabric is immersed in water at 100° C. for 5 minutes, dried, and ironed, the yarn comprising the fabric becomes quite bulky, and the hand of the fabric becomes warm and soft. The fabric has a weight of 1.8 oz./sq. yd. and a specific volume of 2.5 cc./g. The fabric has an attractive appearance with no trace of buckling.

Samples of the two fabrics are dyed at the boil to a medium blue shade with the dispersed dye 1-(p-ethylolanilino) 4,5-dihydroxy-8-nitroanthraquinone using 5 grams per liter of o-phenylphenol as a carrier. The resulting dyed fabrics are quite uniform in appearance, giving no evidence of heather or moiré effect.

Similar results are obtained by preparing composite yarns as described above, substituting polyethylene terephthalate/isophthalate (85/15) for polyethylene terephthalate in the preparation of yarns "C" and "D."

EXAMPLE 2

Polyethylene terephthalate having a relative viscosity of 30 and containing 2% TiO_2 is spun at 300° C. through a spinneret having 34 triangular orifices, each 0.012 inch on a side. The extruded filaments are separated into two bundles of 17 filaments each and processed continuously in accordance with the process shown in FIGURE 2. One bundle of spun filament is taken up by a feed roll operating at a peripheral speed of 890 y.p.m., passed under a draw pin immersed in a bath of water maintained at 90° C., and passed out of the bath via a pair of guides as shown in FIGURE 2 to a pair of draw rolls maintained at a temperature of 160° C. (contact time on rolls 0.063 second) and operating at a peripheral speed of 2800 y.p.m. The draw ratio is accordingly 3.146. The other filament bundle is passed directly from the spinneret to a pair of rolls maintained at a temperature of 160° C. (contact time on rolls 0.124 second) and operating at a peripheral speed of 2800 y.p.m. The two filament bundles are passed from the hot rolls to a guide where they are combined into a single composite yarn, passed through an interlacer, and wound up on a yarn package. At the end of the experiment, the filament bundles are collected separately to measure their separate yarn properties. The filament bundle drawn in the water bath is found to have a denier of 34 (3.8 tex), a tenacity of 3.7 g.p.d., an elongation of 26%, a yield point of 2.6 g.p.d., a boil-off shrinkage of 11.6%, and an initial modulus of 85 g.p.d. The filament bundle wound directly on the hot rolls has a denier of 32 (3.6 tex), a tenacity of 2.5 g.p.d., an elongation of 62%, a yield point of 0.9 g.p.d., a boil-off shrinkage of 3.8%, an initial modulus of 52 g.p.d., and a $\Delta S_{0.05}$ value of 2.8%. A 1 x 1 plain weave fabric containing 86 ends per inch in the warp (7Z twist) and 84 ends per inch in the filling (3Z twist) is then prepared from the composite yarn. The fabric is then immersed in water at 100° C. for 5 minutes, dried, and heat set at 200° C. for one minute. The resulting fabric exhibits a specific volume of 2.60 cc./g. and a weight of 1.98 oz./sq. yd. It has an attractive appearance with no evidence of buckling.

The experiment is repeated, using a spinneret containing 68 round holes, each 0.009 inch in diameter and separating the filaments into two bundles of 34 filaments each. The feed roll for the drawn yarn is operated at a peripheral speed of 930 y.p.m. and the hot draw rolls at 2780 y.p.m., the draw ratio being 2.989 and the contact time of the yarn on the heated roll 0.085 second. The hot rolls for the high-speed spun filament bundle are correspondingly operated at 2780 y.p.m. During most of the run the two filament bundles are combined as a composite yarn as indicated above, but individual samples of the filament bundles are also collected. The drawn yarn is found to have a denier of 76 (8.4 tex), a tenacity of 4.4 g.p.d., an elongation of 34%, a yield point of 3.5 g.p.d., a boil-off shrinkage of 10.5%, and an initial modulus of 61 g.p.d. The high-speed spun filament bundle is found to have a denier of 70 (7.8 tex), a tenacity of 2.5 g.p.d., an elongation of 114%, a yield point of 1.0 g.p.d., a boil-off shrinkage of 3.0%, an initial modulus of 34 g.p.d., and a $\Delta S_{0.05}$ value of 3.5%. A 1 x 1 plain weave fabric containing 68 ends per inch in the warp (7Z twist) and 64 ends per inch in the filling (3Z twist) is prepared from the composite yarn and boiled off, dried, and heat set at 200° C. for one minute. It exhibits a specific volume of 2.29 cc./g. and a weight of 3.6 oz./sq. yd. The fabric has an attractive appearance with no trace of buckling.

EXAMPLE 3

Polyethylene terephthalate/5-(sodium sulfo)isophthalate (99/1) containing 0.3% TiO_2 and having a relative viscosity of 26.5, prepared from ethylene glycol, dimethyl terephthalate, and 1 mol percent (base on the dimethyl terephthalate) of sodium 3,5-dicarbomethoxybenzenesulfonate, is spun at 295° C. through a spinneret having 34 round holes, each 0.009 inch in diameter. The extruded filaments are taken up by a roll (room temperature) operating at a peripheral speed of 3400 y.p.m. and are then wound up. The yarn has a denier of 35 (3.9 tex), a tenacity of 1.8 g.p.d., an elongation of 55%, a yield point of 1.1 g.p.d., a boil-off shrinkage of 3.7%, an initial modulus of 53 g.p.d., and a $\Delta S_{0.05}$ value of 2.6%. This yarn is identified as yarn "E" below.

In another spinning run, polyethylene terephthalate/5-(sodium sulfo)isophthalate (98/2) containing 0.3% TiO_2 and having a relative viscosity of 19 is spun at 295° C. through a spinneret having 27 round holes, each 0.009 inch in diameter, and the yarn is wound up at a speed of 1200 y.p.m. The yarn as spun is found to have a denier of 108 (12 tex). The spun yarn is then passed from a feed roll operating at a peripheral speed of 168 y.p.m. to a draw pin (2 wraps) 1.6 inches in diameter maintained at a temperature of 96° C. and thence to a draw roll operated at 454 y.p.m., finally being wound up. The draw ratio is 2.7. The yarn, identified as yarn "I," has a denier of 40 (4.4 tex), a tenacity of 3.6 g.p.d., an elongation of 25%, a yield point of 1.8 g.p.d., a boil-off shrinkage of 12.0%, and an initial modulus of 91 g.p.d.

Yarns "E" and "I" above are combined to form a composite yarn with a tenacity ratio of 2.0 which is twisted 5 turns per inch (Z) for the warp and 3 turns per inch (Z) for the filling of a 1 x 1 plain weave fabric containing 96 ends per inch in the warp and 90 in the filling. The fabric is boiled off, dried, and ironed. It has a soft, supple hand and exhibits a specific volume of 2.5 cc./g. and a weight of 2.09 oz./sq. yd. The fabric has an attractive appearance with no evidence of buckling.

A sample of the fabric is dyed at the boil with the dispersed dye 1-(p-ethylolanilino) 4,5-dihydroxy-8-nitro-anthraquinone in the presence of o-phenylphenol as a carrier, and it is found that the two species of filaments dye at a different rate. The dyed fabric possesses a distinct moiré because of this nonuniform dyeability.

EXAMPLE 4

A series of yarns of low residual shrinkage, identified hereinafter as yarns "F," "G," and "H" and a series of yarns of high residual shrinkage, identified hereinafter as yarns "J," "K," and "L" are prepared separately as follows:

Polymer used and spinning conditions.—Yarns "F" and "J" are prepared from polyethylene terephthalate/5-(sodium sulfo)isophthalate (98/2) containing 2% TiO_2. Polymer having a relative viscosity of 18.1 is used for yarn "F" and polymer having a relative viscosity of 19.5 is used for yarn "J." The yarns are spun separately at 296° C. from a spinneret containing 17 round holes, each 0.009 inch in diameter, and wound up at 1500 y.p.m.

Yarns "G," "H," "K," and "L" are prepared from polyethylene terephthalate containing 2% TiO_2 and having a relative viscosity of 25.5. Yarns "G" and "K" are spun separately at 296° C. from a spinneret containing 17 round holes, each 0.009 inch in diameter, and wound up at 1206 y.p.m. Yarns "H" and "L" are spun separately at 296° C. from a spinneret containing 17 triangular holes, each 0.012 inch on a side, and wound up at 1000 y.p.m. (yarn "H") and 1500 y.p.m. (yarn "L").

Superstretching the low residual shrinkage yarns.—Yarns "F," "G," and "H," each of which has an as-spun denier of 240 (26.6 tex), are superstretched in a single stage superstretching apparatus of the type described with reference to filament bundle 1′ of FIGURE 1. The yarns are passed around a feed roll maintained at 165° C. ±5°, between a pair of snub pins, over a hot plate maintained at 143° C. ±3°, around a draw roll, and are then wound on a yarn package. The stretch ratio is 6.048 in each case and the drawing speeds and hot plate contact times are as follows: "G," 750 y.p.m. and 0.178 second; "F" and "H," 454 and 0.294. The properties of the superstretched yarns are summarized in Table 1.

Drawing the high residual shrinkage yarns.—Yarns "J" and "K" have deniers as spun of 120 (13.3 tex), while yarn "L" has an as-spun denier of 109 (12.1 tex). Each of the yarns are passed from a feed roll to a draw pin (2 wraps) 1.6 inches in diameter maintained at 100° C. ±2° and then to a draw roll operated at 454 y.p.m., finally being wound up. The respective draw ratios are: "J," 2.769; "K," 3.353; and "L," 2.969. The properties of the drawn yarns are summarized in Table 1.

Fabric preparation.—Composite yarns are prepared by combining yarns "F" and "J," "G" and "K," and "H" and "L," respectively. The composite yarns are twisted 7 turns per inch (Z) for the warp and 3 turns per inch (Z) for the filling of 1 x 1 plain weave fabrics having the number of ends per inch in warp and filling indicated in Table 1. The properties of the fabrics after boil-off and ironing are also indicated in the table.

TABLE 1—YARN & FABRIC PROPERTIES

A. Yarn Properties	Yarns					
	"F"	"G"	"H"	"J"	"K"	"L"
Denier	39	41	40	43	37	39
Tex	4.3	4.6	4.4	4.8	4.1	4.3
Tenacity, g.p.d.	1.6	1.9	2.4	2.9	4.1	3.6
Elongation, percent	72	108	69	35	23	28
Yield point, g.p.d.	1.0	0.7	0.9	2.4	3.5	1.1
Boil-off shrinkage, percent	4.4	3.5	3.9	11.1	10.6	11.1
Initial modulus, g.p.d.	47	42	45	84	124	94
$\Delta S_{0.05}$ value, percent	3.0	2.7	3.0	------	------	------

B. Fabric Properties	Fabrics Prepared From Designated Composite Yarns		
	"F"—"J"	"G"—"K"	"H"—"L"
Ends per inch, warp/filling	90/72	80/60	78/84
Specific volume, cc./g.	2.31	2.88	2.52
Weight, oz./sq. yd.	2.17	2.03	2.32
Buckling exhibited by fabric	None	None	None

EXAMPLE 5

Polyethylene terephthalate having a relative viscosity of 15 and containing 0.3% TiO_2 is spun at 278° C. through a spinneret having 15 Y-shaped orifices formed by the intersection of 3 slots, each 0.007 inch in length and 0.004 inch in width. The yarn is wound up at a speed of 1200 yards per minute and is found to have a spun denier of 180 (12 tex). The spun yarn is then used as a common supply for preparing yarns "M" and "N" as described below.

Yarn "M" is passed from a feed roll (1 wrap) operating at a peripheral speed of 145 y.p.m. and maintained at 118° C. to a draw roll operated at a peripheral speed of 454 y.p.m., after which the yarn is wound up at the same speed. No draw pin is used in this experiment, and the yarn is not relaxed. The draw ratio is 3.140. The drawn yarn has a denier of 34 (3.8 tex), a tenacity of 1.7 g.p.d., an elongation of 43%, a boil-off shrinkage of 3.6%, a yield point of 0.9 g.p.d., an initial modulus of 58 g.p.d., and a $\Delta S_{0.05}$ value of 3.75%.

Yarn "N" is passed from a feed roll operating at a peripheral speed of 132 y.p.m. to a draw pin (1 wrap) 1.6 inch in diameter maintained at a temperature of 100° C. and thence to a draw roll operated at a peripheral speed of 454 y.p.m., after which the yarn is wound up at the same speed. The draw ratio is 3.451. The drawn yarn has a denier of 31 (3.4 tex), a tenacity of 3.3 g.p.d., an elongation of 21%, a boil-off shrinkage of 9.2%, a yield point of 1.9 g.p.d., and an initial modulus of 104 g.p.d.

Yarns "M" and "N" above are combined through an interlacing jet to form a composite yarn. A 1 x 1 plain weave fabric containing 93 ends per inch in the warp (7Z twist) and 76 ends per inch in the filling (3Z twist) is then prepared from the yarn. After the fabric is boiled off, dried, and ironed, the yarn comprising the fabric becomes bulky and the hand of the fabric becomes warm and soft. The fabric has a weight of 1.9 oz./sq. yd. and a specific volume of 2.76 cc./g. It has an attractive appearance with no trace of buckling.

EXAMPLE 6

Polyethylene terephthalate containing 0.3%, TiO_2 and having a relative viscosity of 25.5 is spun at 296° C. through a spinneret having 17 round holes, each 0.009 inch in diameter, and the yarn is wound up at a speed of

1206 y.p.m. The yarn as spun is found to have a denier of 120 (13.3 tex). The spun yarn is then passed from a feed roll operating at a peripheral speed of 149 y.p.m. to a draw pin (1 wrap) 1.6 inches in diameter maintained at a temperature of 100° C. and thence to a draw roll operated at 454 y.p.m., after which it is wound up at the same speed. The draw raito is 3.049. The yarn, identified as yarn "P," has a denier of 40 (4.4 tex), a tenacity of 3.9 g.p.d., and elongation of 26%, a yield point of 1.3 g.p.d., a boil-off shrinkage of 11.5%, and a modulus of 81 g.p.d. A portion of this yarn, identified below as yarn "Q," is then heated on a yarn package (heated at constant length) in an oven at 140° C. for 12 hours. Yarn "Q" is found to have a denier of 40, a tenacity of 3.9, an elongation of 26%, a yield point of 1.3, a boil-off shrinkage of 1.1%, an initial modulus of 81 g.p.d., and a $\Delta S_{0.05}$ value of 0.75%.

In another spinning run, yarn is spun in the same manner described above for yarn "P," except that the denier of the yarn as spun is 240 (26.7 tex). This yarn, designated below as yarn "R," is superstretched in a single stage superstretching apparatus of the type similar to that described with reference to filment bundle 1' of FIGURE 1. The yarn is passed around a feed roll (single wrap) maintained at 165° C., between a pair of snub pins (48° wrap angle), around a draw roll maintained at 140° C. and equipped with a separator roll (5 wraps), and is then wound on a yarn package. The drawing speed is 454 y.p.m. The stretch stretch ratio is 6.048, and the contact time of the yarn on the on hot draw roll is 0.294 second. Superstretched yarn "R" has denier of 35 (3.9 tex). a tenacity of 2.1 g.p.d., an elongation of 93%, a yield point of 0.8 g.p.d., a boil-off shrinkage of 2.6%, an initial modulus of 52 g.p.d., and a $\Delta S_{0.05}$ value of 3.5%.

Yarns "P" and "Q" are then piled together to form a composite yarn. A 1 x 1 plain fabric containing 90 ends per inch in the warp (7Z twist) and 72 ends per inch in the filling (3Z twist) is then prepared from the yarn. Prior to boil-off, the fabric has the smooth, slick hand characteristic of continuous filament synthetic fabrics. When the fabric is immersed in water at 100° C. for 5 minutes, dried, and ironed, the yarn comprising the fabric becomes bulky; however, the hand of the fabric becomes rather harsh, and the fabric has an unattractive appearance with severe buckling being exhibited. The specific volume of the fabric is 1.9 cc./g.

Yarns "P" and "R" are similarly plied together to form a composite yarn. A 1 x 1 plain weave fabric containing 90 ends per inch in the warp (7Z twist) and 30 ends per inch in the filling (3Z twist) is prepared from the yarn. Prior to boil-off, the appearance and hand of this fabric are similar to the appearance and hand of the fabric prepared from plied yarns "P" and "Q," above. When the fabric prepared from yarns "P" and "R" is immersed in water at 100° C. for 5 minutes, dried, and ironed, the yarn comprising the fabric becomes bulky, and the hand of the fabric becomes warn and soft. The fabric has an attractive appearance, with no trace of buckling being exhibited. The fabric has a specific volume of 2.3 cc./g.

EXAMPLE 7

Polyethylene terephthalate/5 - (sodium sulfo) isophthalate (98/2) containing 0.3% TiO_2 and having a relative viscosity of 19 is spun at 295° C. through a spinneret having 34 Y-shaped orifices formed by the intersection of 3 slots, each 0.007 inch in length and 0.004 inch in width. The extruded filaments are separated into two bundles of 17 filaments each and are proccessed continuously in accordance with the process shown in FIGURE 4, except that a common feed roll and drawing apparatus are used to process the two bundles, maintaining the separate identity of the filament bundles. The feed rolls is operated at a peripheral speed of 980 y.p.m. and an 0.5-inch draw pin partially immersed in 90° C. aqueous bath is employed. The filament bundles are passed under the draw pin and thence out of the bath via a pair of guides, after which one of the filament bundles, identified as filament bundle "0," is passed around a pair of draw rolls operating at a peripheral speed of 2750 y.p.m. and maintained at a temperature of 180°C.

The other filament bundle, identified as filament bundle "00" is passed directly to the second heated draw roll and thence around an associated separator roll. Filament bundle "0" is wrapped a total of ten times around the two heated draw rolls and filament bundle "00" is wrapped a total of six times around the second heated draw roll and its associated separator roll, after which the two filament bundles are passed to a guide where they are combined into a single composite yarn, passed through an interlacer, and wound up on a yarn package at 2750 y.p.m. The draw ratio is 2.8. At the end of the experiment, the filament bundles are collected separately to measure their individual properties. Filament bundle "00" is found to have a denier of 35 (3.9 tex), a tenacity of 2.7 g.p.d., an elongation of 30%, a yield point of 1.4 g.p.d., an initial modulus of 67 g.p.d., and a boil-off shrinkage of 13.2%. Filament bundle "0" is found to have a denier of 35 (3.9 tex), a tenacity of 3.1 g.p.d., an elongation of 25%, a yield point of 1.2 g.p.d., an initial modulus of 76 g.p.d., a boil-off shrinkage of 3.0%, and a $\Delta S_{0.05}$ value of 1.35%.

A 1 x 1 plain weave fabric containing 90 ends per inch in the warp (7Z twist) and 72 ends per inch in the filling (3Z twist) is then prepared from the composite yarn. When boiled off, dier, and ironed, the fabric has a soft, supple hand and exhibits a specific volume of 2.3 cc./g. and a weight of 1.84 oz./sq. yd. The fabric has an attractive appearance with no evidence of buckling.

EXAMPLE 8

Poly(p-hexahydroxylylene terephthalate), derived from dimethyl terephthalate and a mixture of 65% trans- and 35% cis- p-hexahydroxylylene glycol, is spun at 300°C. through a spinneret having 27 round holes, each 0.009 inch in diameter. The extruded filaments are taken up by a roll operaing at a peripheral speed of 600 y.p.m. The yarn is drawn over a 1.6" diameter pin maintained at 90° C at a speed of 500 y.p.m. The draw ratio is 2.5 The yarn is then passed into a 12" long atmospheric steam oven at 100 y.p.m. and wound up at 87 y.p.m. The yarn has a denier of 35, a tenacity of 2.8 g.p.d., an elongation of 30, a yield point of 1.0 g.p.d., a boil-off shrinkage of 4%, an initial modulus of 40 g.p.d., and a $\Delta S_{0.05}$ of 3.0%. This yarn is identified as yarn "S" below.

In another spinning run, the experiment is repeated except that the pin temperature is 105° C., the draw ratio is 2.6, and the steam relaxation step is omitted. The yarn, identified as yarn "T" below, has a denier 35, a tenacity of 3.0 g.p.d., an elongation of 20%, a yield point of 1.5, a boil-off shrinkage of 12%, and an initial modulus of 50 g.p.d.

Yarns "S" and "T" above are combined to form a composite yarn which is twisted 7 turns per inch (Z) for the warp and 3 turns per inch (Z) for the filling of a 1 x 1 plain weave fabric containing 93 ends per inch in the warp and 76 in the filling. After the fabric is boiled off, dried, and ironed, it has a soft, supple hand and exhibits a specific volume of 2.5 cc./g. and a weight of 2.0 oz./sq. yd. The fabric has an attractive appearance with no evidence of buckling.

A sample of the fabric, in which the components have a tenacity ratio of 1.07, is dyed with 1(p-ethylolanilino)-4,5-dihydroxy-8-nitroanthraquinone at the boil using o-phenylphenol as a carrier. The resulting dyed fabric is quite uniform in appearance, giving no evidence of heather or moiré effect.

EXAMPLE 9

Polyethylene terephthalate containing 0.1% TiO_2 and having a relative viscosity of 25.5 is spun at 295° C. through a spinneret having 14 round holes, each 0.009 inch in diameter. The yarn is wound up at a speed of 1400 y.p.m. and is found to have a spun denier of 238 (26.4 tex). The yarn is drawn in accordance with the process described with reference to filament bundle 1 of FIGURE 3. The yarn is passed from a feed roll around a heated block 21 (5 wraps) maintained at 99° C., passed once around a 0.25 inch draw pin, and then to draw roll 7 which is operated at a peripheral speed of 750 y.p.m., after which the yarn is wound up at the same speed. The draw ratio is 3.395. The drawn yarn has a denier of 70 (7.8 tex). A portion of the drawn yarn is then heat set on the package at 84° C. for 4 hours in an air oven. The heat-set yarn, identified below as yarn "U," has a tenacity of 4.2 g.p.d., an elongation of 29%, a boil-off shrinkage of 7.5%, a yield point of 1.4 g.p.d., and an initial modulus of 81 g.p.d. Another portion of the drawn yard is passed from a roll operating at a peripheral speed of 161 y.p.m. into an oven containing steam at 100° C. and at atmospheric pressure and is passed out of the oven and wound up on a package operating at a peripheral speed of 149 y.p.m. The oven is 12 inches long and the allowed shrinkage in the oven is 7%. The yarn is then heat set on the package at 180° C. for 3 hours. The steam-treated yarn, identified below as yarn "V," has a tenacity of 4.8 g.p.d., an elongation of 26%, a boil-off shrinkage of 0.0%, a yield point of 1.2 g.p.d., an initial modulus of 81 g.p.d., and a $\Delta S_{0.05}$ of 0.4%.

Yarns "U" and "V" above are combined to form a composite yarn which is twisted 7 turns per inch (Z) for the warp and 3 turns per inch (Z) for the filling of a 1 x 1 plain weave fabric containing 66 ends per inch in the warp and 56 in the filling. The fabric is then boiled off, dried, and ironed. The resulting fabric is puckered and buckled and has a harsh, undesirable hand. Its specific volume is 2.34 cc./g. and its weight is 3.2 oz./sq. yd.

EXAMPLE 10

Polyethylene terephthalate having a relative viscosity of 30 and containing 2% TiO_2 is spun at 300° C. through a spinneret having 27 round orifices, each 0.009 inch in diameter. The yarn is wound up at a speed of 1,500 y.p.m. and is found to have a spun denier of 120 (13.3 tex). The yarn is drawn and relaxed in accordance with a modification of the process described with reference to filament bundle 1' of FIGURE 3. The yarn is passed from a feed roll around heated block 21' (5½ wraps), which is maintained at 100° C., and thence over a draw pin to draw roll 7', the draw ratio being 3.024. The yarn is next passed over a hot plate maintained at 220° C. and then through a fluid twister comprising a circular yarn passageway with a jet of air at 90 p.s.i. supplied circumferentially to the passageway. The yarn is wound up at a speed 10% lower than that of the draw roll. The drawn and relaxed yarn has a denier of 40 (4.4 tex), a tenacity of 3.1 g.p.d., an elongation of 30.4%, a boil-off shrinkage of 4.6% (spontaneous crimping observed during boil-off), a yield point of 1.2 g.p.d., an initial modulus of 63 g.p.d., and a $\Delta S_{0.05}$ value of 3.2%. This yarn is designated as yarn "W."

Yarn "W" is combined through an interlacing jet with yarn "B" of Example 1 to form a composite yarn. A 1 x 1 plain weave fabric containing 90 ends per inch in the warp (7Z twist) and 84 ends per inch in the filling (3Z twist) is then prepared from the yarn. Prior to boil-off, the fabric has the smooth, slick hand characteristic of continuous filament synthetic fabrics. However, when the fabric is immersed in water at 100° C.

for 5 minutes, dried, and ironed, the yarn comprising the fabric becomes quite bulky and the hand of the fabric becomes warm and soft.

When a sample of the fabric is dyed with 1(p-ethylolanilino)4,5-dihydroxy-8-nitroanthraquinone in the presence of o-phenylphenol, a uniformly dyed fabric is produced which shows no evidence of heather. It is noted that the ratio of the tenacity of the high shrinkage component to that of the low shrinkage component is 1.10.

EXAMPLE 11

Polyethylene terephthalate/5-(sodium sulfo)-isophthalate (98/2) containing 0.3% TiO_2 and having a relative viscosity of 19 is spun at 295° C. through a spinneret having 50 Y-shaped orifices formed by the intersection of 3 slots, each 0.007 inch in length and 0.004 inch in width. The yarn is wound up at a speed of 1,200 y.p.m. The spun yarn is then passed from a feed roll operating at a peripheral speed of 168 y.p.m. to a draw pin (2 wraps) 1.6 inches in diameter maintained at a temperature of 96° C. and thence to a draw roll operated at 454 y.p.m., finally being wound up. The draw ratio is 2.7 and the denier of the drawn yarn is 70 (7.8 tex). A supply of the drawn yarn is passed from a feed roll at 1,000 y.p.m. through a jet tube wherein it is contacted with steam at 316° C. and 50 p.s.i. As the yarn emerges from the jet, it is impinged on a moving screen, passed between take-up rolls, and wound up at 530 y.p.m. This yarn, designated as yarn "X," is crimped and has a denier of 125 (13.9 tex), a tenacity of 1.2 g.p.d., an elongation of 86%, an initial modulus of 3.1 g.p.d., a yield point of 0.5 g.p.d., a boil-off shrinkage of 0.4%, and a $\Delta S_{0.05}$ value of 18.7%.

Yarn "X" is then combined with three strands of yarn "I" of Example 3 through an interlacing jet to form a composite yarn. A 1 x 1 plain weave fabric prepared from the composite yarn, when immersed in 100° C. water for 5 minutes, dried, and ironed, becomes quite bulky and the hand of the fabric becomes warm and soft.

EXAMPLE 12

A commercially available 34-filament yarn comprises polyethylene terephthalate having a relative viscosity of 29 and containing 0.3% TiO_2 which has been spun, drawn, and then false twisted and heat set as described in U.S. Patent 2,803,109 to N. J. Stoddard et al. The yarn has a denier of 70 (7.8 tex), a tenacity of 4.3 g.p.d., and elongation of 24.9%, a boil-off shrinkage of 6.4% (spontaneous crimping observed during boil-off), a yield point of 1.2 g.p.d., an initial modulus of 49.7 g.p.d., and a $\Delta S_{0.05}$ value of 4.8%. When this yarn is combined with yarn "B" of Example 1 through an interlacing jet to form a composite yarn and a 1 x 1 plain weave fabric is prepared, immersion of the fabric in water at 100° C. for 5 minutes followed by drying and ironing produces a bulky fabric with a warm, soft hand.

EXAMPLE 13

Polyethylene 2,6-naphthalate having a relative viscosity of 30 is spun at 316° S. through a spinneret having 34 round orifices, each 0.009 inch in diameter. The yarn is wound up at a speed of 1000 y.p.m. and is found to have a spun denier of 275 (30.6 tex). The spun yarn is then passed from a feed roll to draw pin (2 wraps) 1.6 inches in diameter maintained at a temperature of 154° C. and thence to a draw roll operated at 149 y.p.m., finally being wound up. The draw ratio is 2.5. The yarn, identified as yarn "AA," has a denier of 110 (12.2 tex), a tenacity of 2.4 g.p.d., an elongation of 12%, a yield point of 1.8 g.p.d., a boil-off shrinkage of 14%, and an initial modulus of 100 g.p.d.

In a separate spinning run, polyethylene 2,6-naphthalate having a relative viscosity of 30 is spun at 316° C. and wound up at a speed of 1000 y.p.m. to form yarn having a spun denier of 326 (36.2 tex). The yarn is then passed from a feed roll to a draw pin (2 wraps) 1.6 inches in diameter maintained at a temperature of 135° C. and thence over a hot plate maintained at 160° C. to a draw roll operating at 149 y.p.m. The draw ratio is 3.1. The drawn yarn has a denier of 105 (11.7 tex), a tenacity of 3 g.p.d., and an elongation of 23%. A supply of the drawn yarn is passed from a feed roll at 1000 y.p.m. through a jet tube wherein it is contacted with steam at 285° C. and 50 p.s.i. As the yarn emerges from the jet, it is impinged on a moving screen, passed between take-up rolls, and wound up at 875 y.p.m. This yarn, designated as yarn "BB," is crimped and has a denier of 120 (13.3 tex), a tenacity of 2.7 g.p.d., an elongation of 45%, an initial modulus of 15 g.p.d., a yield point of 1.0 g.p.d., a boil-off shrinkage of 1.0% and a $\Delta S_{0.05}$ value of 4.5%.

Yarn "AA" is then combined with yarn "BB" through an interlacing jet to form a composite yarn. A 1 x 1 plain weave fabric prepared from the composite yarn, when immersed in 100° C. water for 5 minutes, dried, and ironed, becomes quite bulky and the hand of the fabric becomes warm and soft.

A sample of the fabric is dyed with 1(p-ethylolanilino) 4,5-dihydroxy-8-nitroanthraquinone in the presence of o-phenylphenol at the boil. The resulting dyed fabric shows no evidence of heather, being quite uniform in appearance.

Similar results are obtained by repeating the above experiment, substituting polyethylene 2,7-naphthalate for polyethylene 2,6-naphthalate.

EXAMPLE 14

Polyethylene terephthalate/hexahydroterephthlate (90/10) having a relative viscosity of 21.3 is spun at 295° C. through a spinneret having 34 round orifices, each 0.009 inch in diameter. The yarn is wound up at a speed of 1200 y.p.m. and is found to have a spun denier of 254 (28.2 tex). The spun yarn is passed from a feed roll around a heated block (5½ wraps), which is maintained at 110° C., and thence to a draw roll which is operated at a peripheral speed of 454 y.p.m. The draw ratio is 3.9. The yarn, designated as yarn "CC," has a denier of 65 (7.2 tex), a tenacity of 4.0 g.p.d., an elongation of 23%, a boil-off shrinkage of 10.1%, a yield point of 2.3 g.p.d., and an initial modulus of 93 g.p.d.

A quantity of yarn "CC" is passed from a roll into an oven containing steam at 100° C. and at atmospheric pressure and is then passed out of the oven and wound up on a package. The oven is 12 inches long and the allowed shrinkage in the oven is 12%. The resulting yarn, designated as yarn "DD," has a boil-off shrinkage of 4.9% and a $\Delta S_{0.05}$ value of 3.8%.

Yarn "CC" is then combined with yarn "DD" through an interlacing jet to form a composite yarn. A 1 x 1 plain weave fabric prepared from the composite yarn, when immersed in 100° C. water for 5 minutes, dried, and ironed, becomes quite bulky and the hand of the fabric becomes warm and soft.

EXAMPLE 15

A series of composite yarns are prepared from polyethylene terephthalate to illustrate the relationship between tenacity ratio and dyeability. Each composite yarn is composed of two components having a differential shrinkage of at least 2%, and with different tenacity values as shown in the table. Each yarn is woven into a plain weave fabric, boiled off, and dyed with 1(p-ethylolanilino)4,5-dihydroxy-8-nitroanthraquinone at the boil using o-phenylphenol as a carrier. After a medium shade of blue is obtained, the dyed fabrics are rinsed, dried, and pressed, and examined for moiré. The results are given in the last column of the table where it is clearly shown that uniform dyeability is achieved when the tenacity ratio falls in the range 0.7 to 1.1.

Code	Tenacity		Tenacity Ratio	Fabric Dyeability
	High Shrinkage Component	Low Shrinkage Component		
15-1	1.9	3.8	0.50	Moire.
15-2	2.7	3.8	0.71	Uniform.
15-3	3.6	3.8	0.95	Do.
15-4	4.4	4.1	1.07	Do.
15-5	4.0	3.5	1.14	Slight Moire.
15-6	4.4	2.2	2.00	Moire.
15-7	4.7	1.5	3.12	Intense Moire.

It will be apparent that many widely different embodiments of this invention may be made without departing from the spirit and scope thereof, and therefore it is not intended to be limited except as indicated in the appended claims.

We claim:

1. A composite linear condensation polyester yarn comprising continuous filaments of at least two species, one of which is characterized by a zero load residual shrinkage in the range of from 0.0% to about 20%, and a residual shrinkage at 0.05 gram per denier load of at least about 1.2% less than the zero load residual shrinkage, and the other said species being characterized by a zero load residual shrinkage at least 2% higher than the zero load residual shrinkage of the first said species.

2. A fabric comprising the yarn of claim **1**.

3. The yarn of claim **1** wherein at least about 75% of the recurring structural units of the polyester are derived from a glycol containing 2 to 12 carbon atoms and a dicarboxylic acid selected from the group consisting of terephthalic acid and the naphthalic acids.

4. The yarn of claim **3** wherein the polyester is polyethylene terephthalate.

5. The yarn of claim **3** wherein the polyester is polyethylene 2,6-naphthalate.

6. The yarn of claim **3** wherein the polyester is polyethylene 2,7-naphthalate.

7. The yarn of claim **3** wherein 0.5 to 3.5 mol percent of the recurring structural units are derived from sodium 3,5-dicarbomethoxybenzenesulfonate.

8. The yarn of claim **1** in which the ratio of the tenacities of the said two species is between 0.70 and 1.10.

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