

July 17, 1962

H. H. HEBELER
TEXTILE PRODUCT

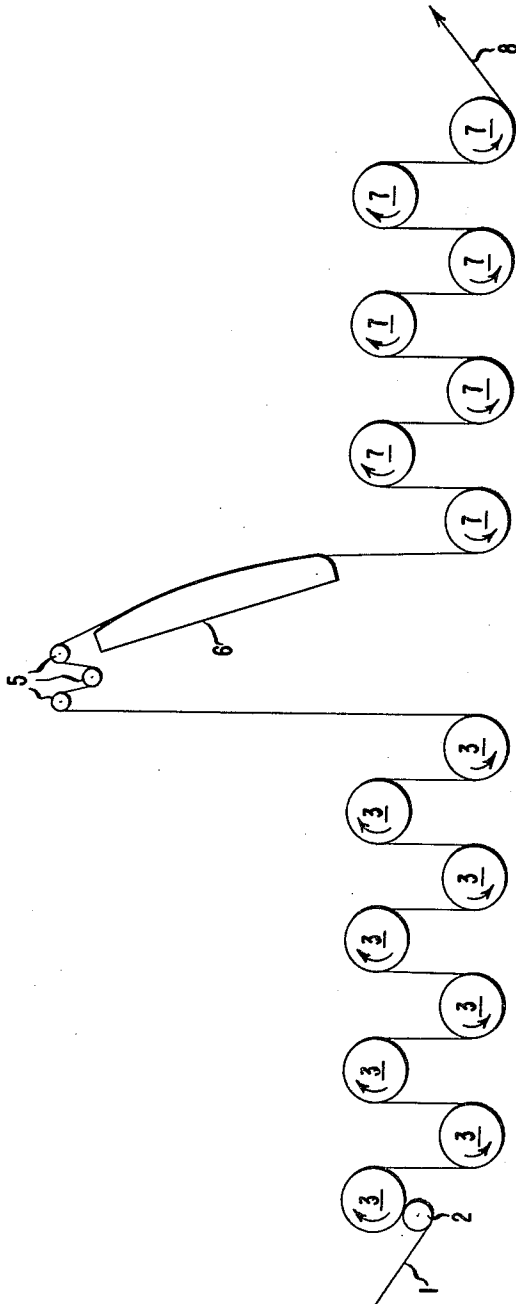
3,044,250

Filed June 28, 1957

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Fig. 1

TOW DRAWING MACHINE



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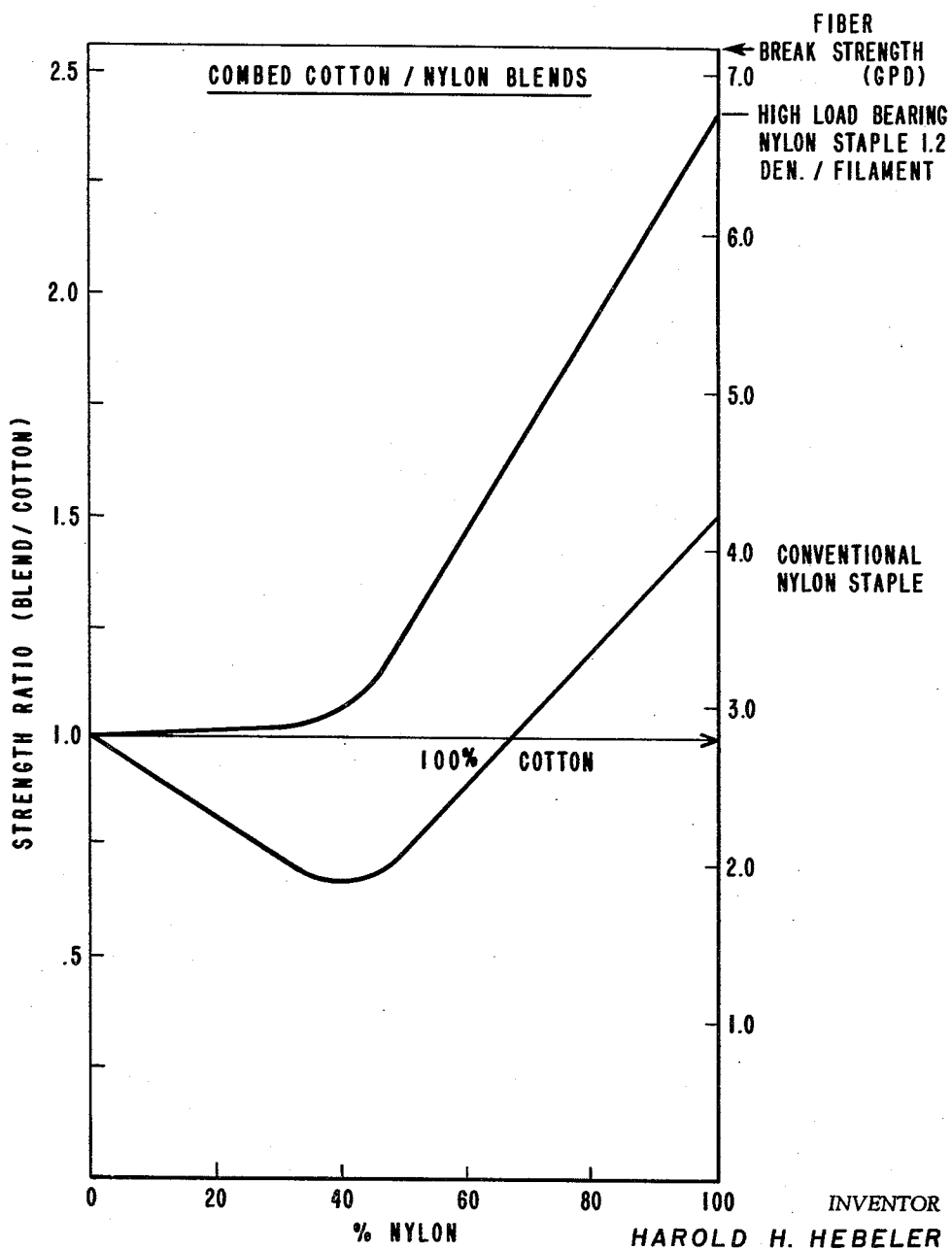
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Fig. 2

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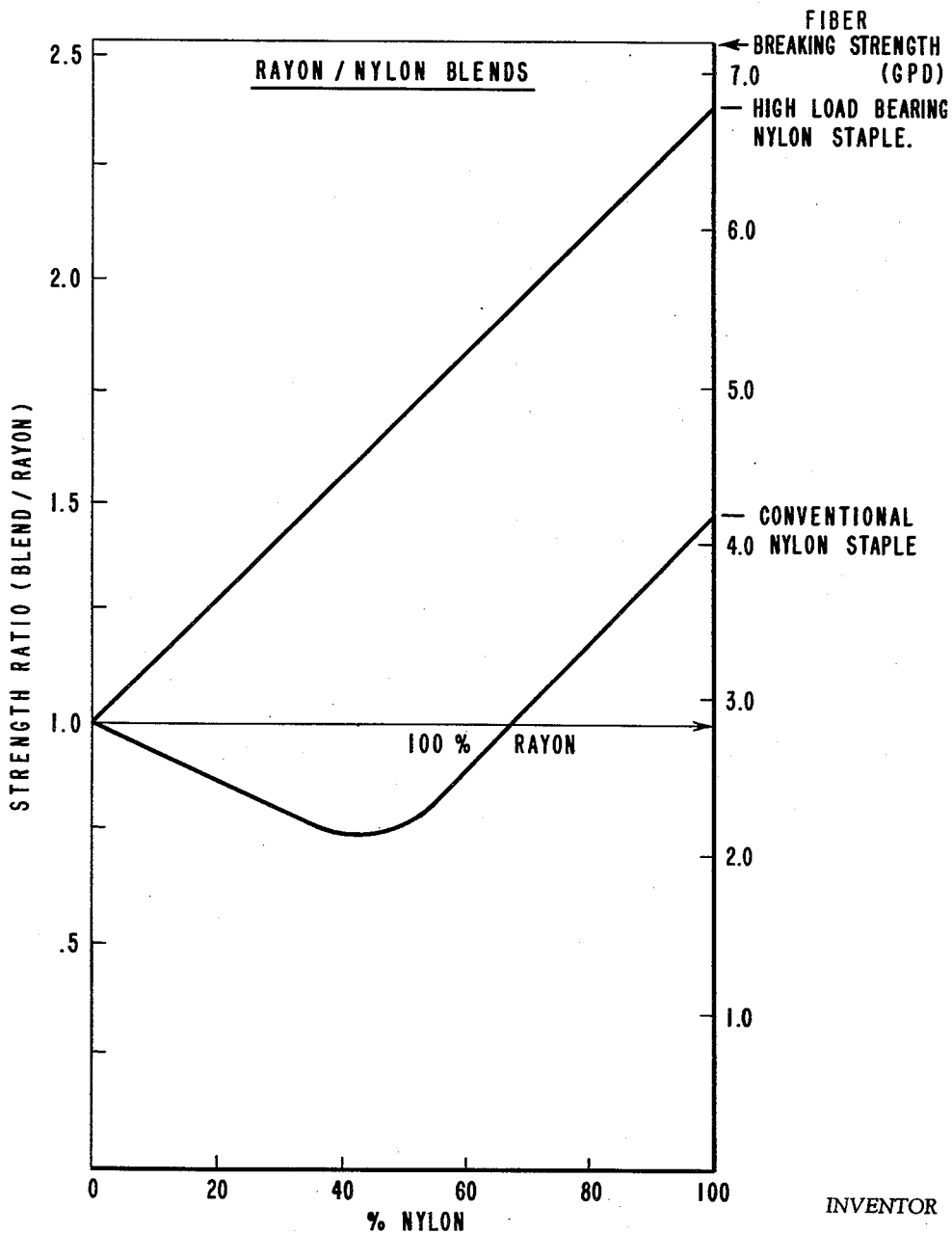
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Fig. 3



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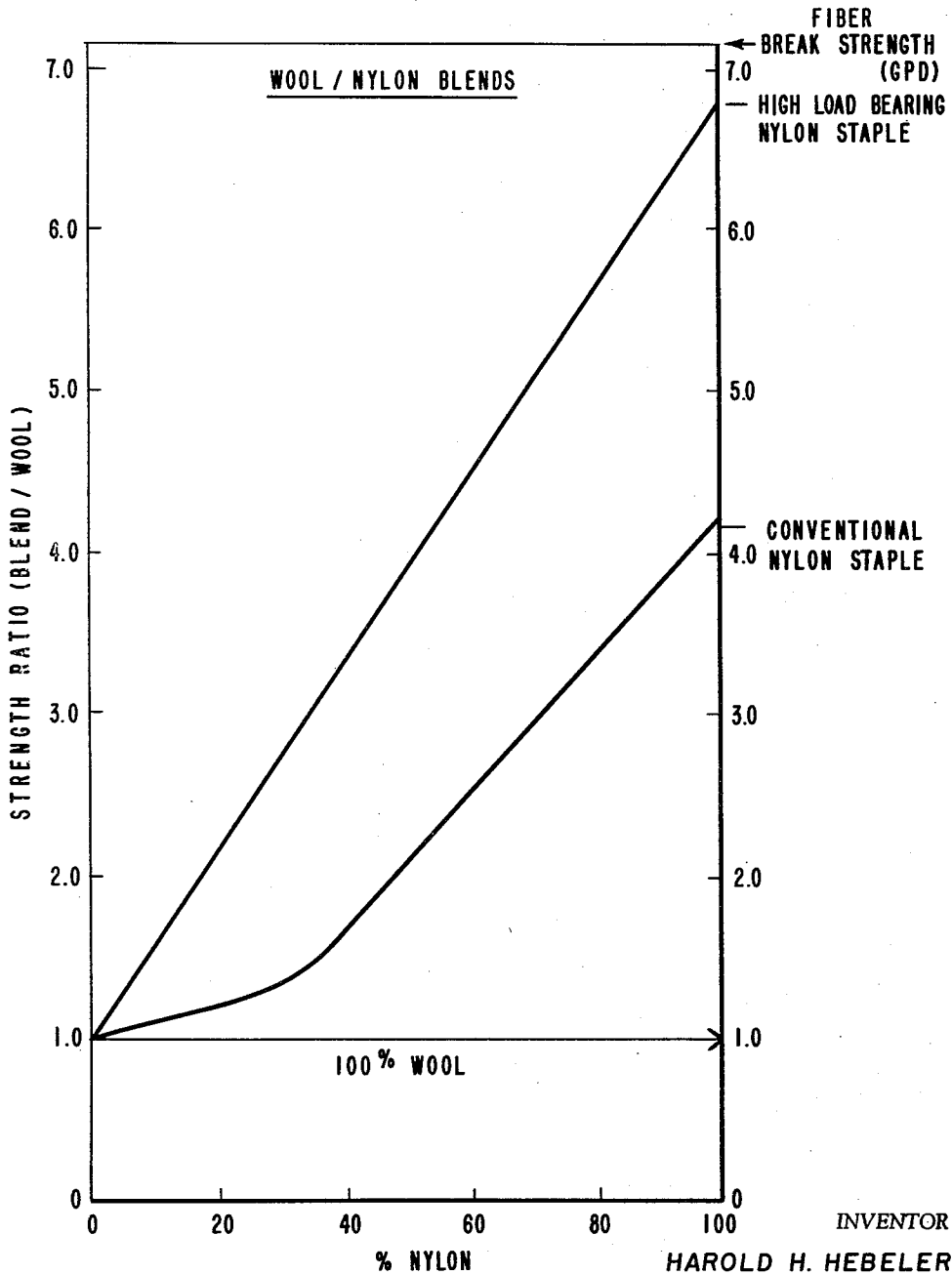
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Fig. 4



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3,044,250

TEXTILE PRODUCT

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Filed June 28, 1957, Ser. No. 668,718

2 Claims. (Cl. 57-140)

This invention relates to a new staple blend, and more particularly to a blend of synthetic and natural fibers having increased strength and abrasion resistance.

The use of two or more varieties of staple fibers to create blends, and yarns and fabrics prepared therefrom, are well known in the art. Such blends have been produced to provide new and attractive fabrics having improved physical and aesthetic properties. With the advent of the newer synthetic fiber materials, there appeared to be great promise of improving the strength of the well known and low cost natural fiber yarns by adding small amounts of the high tenacity new materials. For example, it was expected that cotton yarns having a strength of 1-2 grams per denier (g.p.d.) could advantageously be strengthened by blending nylon staple (tenacity 4-7 g.p.d.), with the cotton.

This advantage was not, in fact, realized and considerable research has been devoted to determine the cause. The subject is well treated in an article by A. Kemp and J. D. Owen, in Textile Institute Journal, Transaction, 46, 684-698 (1955). In this article, it is shown that blends of cotton and nylon are weaker than 100% cotton yarns, until about 80% nylon fiber is present. It was recognized that this behavior was due to the much greater elasticity of the nylon fiber; thus, at low loads, the cotton was the stress-bearing member. Due to its low break elongation (about 7%), the cotton ruptured before the nylon filaments bore any substantial proportion of the load, especially at low nylon compositions.

It has also been recognized in the art that the load-elongation (i.e., modulus) of many synthetic fibers can be increased by a hot-stretching operation. Such operations are common in the production of yarn for tire cord, for example. However, these treatments are unsuitable for improving staple fibers, in that the improvement is not stable to aging, when the filaments are free to retract (i.e., not wound upon a rigid package). This retraction results in a loss of the improved modulus, gained by hot stretching. In addition, such treatments are unstable to boil-off, a common treatment for textile fabrics, so that an excessive amount of shrinkage results in fabrics containing such fibers.

It is, therefore, a general object of this invention to provide a spun yarn which overcomes the above difficulties. A more specific object is to provide a blended staple yarn of certain high strength synthetic linear condensation polymers in combination with a high modulus cotton fiber or one derived from cotton or similar source of cellulose. Another object is the provision of a blended staple yarn having an increase in strength over that of the weaker component. Still another object is the provision of a yarn which has improved resistance to wear and abrasion. Another specific object of the invention is to provide a process for the production of linear condensation polymer fibers especially suitable for blending with cellulosic staple fibers. Other objects will appear as the description of the invention proceeds.

These and other objects are attained by treating the fibers of certain synthetic linear condensation polymers

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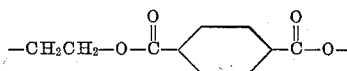
so that at the break elongation characteristic of the natural fiber with which it is blended, the synthetic fibers will have an equal or superior load-bearing capacity in comparison to that of the natural fiber. The synthetic linear condensation polymers which are particularly well adapted as part of the blend of the present invention are condensation polymers selected from the class consisting of polyhexamethylene adipamide, polycapraamide, and polyethylene terephthalate.

The synthetic condensation polymer fibers are treated to render them suitable in the present invention by (a) drawing them to the maximum operable draw ratio, and (b) subjecting them to a heat treatment under drawing tension for at least one second at the maximum operable temperature. This maximum temperature is usually about or close to the degradation point of the polymer.

The filaments so created are characterized by having both a high degree of crystallinity and a high degree of crystalline orientation. This characteristic renders them stable to slack aging so that the load-bearing properties are maintained at least until the fiber is incorporated into the fabric. Yarn spun from these filaments is also free from a high and objectionable boil-off shrinkage.

It is thus apparent that the condensation polymers suitable in the present invention are those which may be highly oriented by a drawing operation, and which then may be crystallized by a sufficiently severe heat treatment to retain the high orientation. Especially suitable polymers are the linear polyamides, such as polyhexamethylene adipamide (66 nylon) and polycapraamide (6 nylon); crystallizable polyamide copolymers are also suitable when 85% or more 66 nylon or 6 nylon component is present.

The high load-bearing synthetic polymer staple of this invention can also be prepared from filaments spun from linear terephthalate polyesters. Such polyesters are those in which the polymer-chain units are at least about 85% repeating units of the formula:



The high-modulus natural or naturally-derived staple fibers for which this invention is most useful are the cellulosic-based fibers such as cotton, viscose rayon, acetate rayon and other cellulosic derivatives. In addition fibers of lower modulus, such as for example the protein fibers (e.g., wool), and even for some synthetic fibers, such as fibers from polyacrylonitrile may be advantageously blended with the above specified high tenacity linear condensation polymers. Likewise blends of nylon and polyester fibers may be used with any one or blend of the natural fibers.

In the drawing, FIGURE 1 shows schematically one form of a tow drawing machine suitable for preparing the high load-bearing fiber of this invention. FIGURE 2 is a self-explanatory graph which shows the improvement in strength when the high load-bearing nylon staple of this invention is added to a combed cotton. FIGURE 3 likewise is a graph which shows a similar relation for rayon and nylon blends, while FIGURE 4 similarly graphs the strength relation for blends of nylon and wool. The curves for other blends of natural fibers such as wool with nylon and polyethylene terephthalate have the same general configuration.

In the operation of the apparatus shown in FIGURE 1, multiple ends of undrawn filaments from a bank of

spinning machines, from a creel or the like, are combined into a heavy denier tow (source of supply not shown) and enter the draw machine as a band of filaments at 1. The band of filaments is pressed against the first of a series of feed rolls 3, 3, 3, by means of pinch roll 2, thus preventing the tow from slipping. The feed rolls 3 are all driven at the same constant peripheral speed, and serve to meter the tow to the drawing pins 5. In the drawing zone, the tow passes in a zig-zag path about the three fixed stainless steel drawing pins 5, thus producing a snubbing effect, which localizes the draw point. The band of filaments then travels in contact with a heated plate 6 (heating means not shown) to the draw rolls, 7, 7, 7. The draw rolls, all operating at the same speed, rotate at a higher peripheral velocity than that of the feed rolls 3, 3, so that the yarn is thereby drawn. The relative peripheral speed of the two sets of rolls determines the draw ratio. The drawn tow leaves the machine at 8, and may pass thence to a crimping device, a cutting device, to storage or to a tow packaging device. It should be mentioned that hot plate 6 is relatively long, e.g., 9 feet and may suitably be heated electrically, or by hot oil, high pressure steam, or the like, as is conventional. It is desirable that the tow passing through this machine be spread out into a wide flat band of filaments of uniform but small thickness. When staple finishes are added to the tow prior to drawing, this usually takes place before the filaments reach pinch roll 2.

The apparatus of FIGURE 1 is merely illustrative of one suitable embodiment for towing-drawing; other designs may have especial advantages. For example, it may be desirable to use feed or draw rolls operating at different peripheral speeds, thus minimizing slippage. Greater or fewer draw pins, in a wide variety of known abrasion-resistant materials may be employed.

The process of this invention will be described in terms of its application to cotton-nylon blends, because of their great utility and importance in commerce. Application to other fiber blends will be discussed subsequently.

The break elongation of middlings cotton is about 7%, and the break strength is about 2.1 grams per denier. At this elongation, conventionally processed nylon from polyhexamethylene adipamide has a load-bearing capacity of about 0.5 to 1.0 g.p.d. For convenience and brevity in this specification, the load-bearing capacity of a filament at a given elongation will be referred to as T_{elong} ; for example, the load-bearing capacity (T_7) of the nylon fiber of this invention should be at least 2.0 grams per denier at 7% elongation, corresponding to the break elongation of cotton, which is about 7%, and has a strength of about 2 g.p.d.

EXAMPLE I

Conventionally spun nylon yarn from polyhexamethylene adipamide flake is combined into a bundle of about 16,700 filaments, to form a 63,000 denier rope. The rope (without addition of aqueous finishes) is drawn in a machine schematically shown in FIGURE 1. The machine is furnished with a 9 foot long hot plate, and the draw ratio, drawing speed, and the time of contact with the plate as well as the plate temperature are varied. The band of filaments is snubbed by a 420° wrap around three snubbing pins, preceding the heated plate. The temperature of the yarn during its passage over the hot plate is determined by means of a contact thermocouple. Average values are given in Table 1. The extent of heat treatment is calculated by multiplying the average yarn temperature by the time the yarn remains at that temperature. The product thus has the dimensions of degree-seconds.

Samples of yarn produced under these conditions are aged for nine days in relaxed condition at 78° F., 72% R.H., before determining their stress-strain characteristics. The preparation conditions for each sample are shown in Table 1.

Table 1
OPERATING CONDITIONS

Sample	Draw Ratio	Heat Treatment		Degree-sec.
		Sec.	Temp., ° C.	
A	3.01	2.0	30	60
B	3.01	0.15	190	29
C	3.01	1.8	180	320
D	3.01	12	175	2,100
E	3.01	30	170	5,100
F	3.62	2.0	30	60
G	3.62	0.15	180	27
H	3.62	1.8	175	320
I	3.62	12	170	2,000
J	3.62	30	180	5,400
K	3.62	45	170	7,700
L	3.62	60	160	9,600
M	3.87	2.0	30	60
N	3.87	0.15	180	27
O	4.07	2.0	30	60
P	4.07	12.0	170	2,000
Q	4.14	2.0	30	60
R	4.14	0.15	180	27
S	4.14	1.2	180	220
T	4.14	6	195	1,200
U	4.14	30	175	5,300
V	4.14	45	170	7,700
W	4.14	60	165	9,900

¹ Draw ratio too high to be operable; yarn broke down. No sample obtained.

The properties of the samples obtained under the conditions shown in Table 1 are listed in Table 2. The T_7 for each sample is determined from the stress-strain curve using a conventional Instron tester. Values are calculated on a gram per denier basis. Boil-off shrinkage is determined on a skein of the test yarn; the length of the skein is measured before and after the 60 minute boil-off treatment and the percent change (based on length before boil-off) is calculated.

The birefringence of the yarn is determined according to methods of Heyn, Textile Research Journal, 22, 513 (1952) and is a measure of crystalline orientation. The density is measured using density gradient tubes, according to the method of Boyer, Spencer and Wiley, Journal Polymer Science, 1, 249, (1946). The density is proportional to the degree of crystallinity of the fiber.

It is well known, of course, that nylon filaments consist of crystalline and amorphous regions. The density of the amorphous regions has been estimated to be about 1.069, while that of the crystalline regions has been estimated to be about 1.220 by use of infrared techniques. This is described by Starkweather and Moynihan in Journal Polymer Science, 22, 363 (1956). From these data, a value can be calculated which is proportional to the fraction of crystalline volume using the formula:

$$\frac{(\text{Avg. density of yarn}) - (\text{density of amorphous yarn}) \times 100}{(\text{density of 100\% crystalline yarn}) - (\text{density of 100\% amorphous yarn})} = \text{percent}$$

this gives a number which is proportional to the percent crystallinity.

An examination of the data in Table 2 shows that acceptable T_7 values are obtained when two criteria are met: (a) the density is higher than about 1.139, and (b) the birefringence is simultaneously above about 0.0590. Both of these parameters characterize the polyamide product of this invention, and are a minimum for acceptable cotton blending. It is obvious, of course, that at higher draw ratios, higher heating temperatures, and longer contact times, higher T_7 values and correspondingly greater strength contributions to the blended yarn are obtained.

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Table 2

TEST RESULTS

Sample	Tenacity, g.p.d. ¹	T ₇ , g.p.d. ²	Birefring- ence	Density	Shrinkage percent ³
A	3.7	0.98	0.0521	1.136	9.1
B	3.6	1.04	0.0528	1.135	9.0
C	3.9	1.35	0.0527	1.136	8.5
D	4.0	1.45	0.0564	1.141	5.1
E	3.9	1.47	0.0567	1.142	5.6
F	5.0	1.44	0.0573	1.137	8.1
G	5.3	1.54	0.0583	1.138	8.2
H	5.7	1.81	0.0584	1.138	7.0
I	5.9	2.19	0.0594	1.142	4.2
J	5.5	2.11	0.0586	1.140	5.2
K	5.8	2.18	0.0589	1.141	4.6
L	5.6	2.16	0.0602	1.143	4.4
M	6.0	1.61	0.0547	1.139	7.5
N	6.9	1.72	0.0568	1.139	8.1
P	7.3	2.68	0.0612	1.143	4.7
S	6.7	2.50	0.0602	1.140	5.6
T	7.3	2.68	0.0622	1.142	4.9
U	6.5	2.68	0.0606	1.141	6.0
V	6.5	2.61	0.0606	1.142	4.6
W	6.4	2.59	0.0594	1.142	4.9

¹ Tenacity after aging in relaxed condition, 9 days at 78° F., 72% R.H.

² Load at 7% elong., aged relaxed for 9 days.

³ Shrinkage determined by boiling a previously measured skein in water for 60 minutes.

It is apparent from an inspection of the data in Tables 1 and 2, that satisfactory results are obtained at draw ratios above about 4.0 with high plate temperatures, a heating time of at least 1 second and a yarn exposure of at least 200 degree-seconds. Better results are obtained, especially at lower draw ratios, when yarn is exposed to at least about 1000 degree-seconds. Higher values of T₇ and lower boil-off shrinkage are usually obtained at higher heat exposure.

It should be noted, however, that draw ratios causing excessive breakage and treating temperatures causing yarn discoloration should be avoided. For polyamide without added antioxidant, some slight discoloration becomes noticeable at exposures somewhat above about 5,000 degree-seconds which may be unacceptable for use in white fabrics.

As far as can be ascertained, high load-bearing nylon staple having the physical properties of the fiber of this invention has not been previously known. Some of the conditions exemplified in Table 1 are illustrative of those used in the current processing of nylon yarns. For example, the conventional drawing process in which yarn is drawn over a snubbing pin substantially as described by Babcock in U.S. Patent 2,289,232, is illustrated by samples A, F, and M, for draw ratios of 3.01 to 3.87. No heat, other than that produced by friction with the drawing pins, is supplied to the yarn. None of these samples have a T₇ above 2.0 grams per denier. A T₇ of at least 2.1 and preferably 2.5 g.p.d. is highly desirable. Sample M has the minimum density of 1.139 but it does not have the minimum birefringence of 0.0590. Higher orientation (via increased draw ratio) is not obtainable under these test conditions, as shown by test condition O, which was not operable at a draw ratio of 4.07. It is also worthy of note that these unacceptable yarns are further characterized by having a boil-off shrinkage above about 6.0%.

Conventional drawing techniques in which the yarn contacts a heated pin or plate during the drawing operation are characterized by samples B, G, N, and R. None of these samples (see Table 2) have an acceptable T₇ value, nor do they show birefringence or density above the prescribed minima. Test condition R shows that it is impossible to draw to higher ratios (4.14) at short heating times, since the yarn breaks down.

It should be recognized that the high load-bearing staple of this invention is not merely a product of higher tenacity obtained by routine increase in draw ratio and/or drawing temperature. This point is illustrated by samples M and N (Tables 1 and 2) which have a higher tenacity (due to higher draw ratio) than samples I

through L, but have unacceptable T₇ values. Samples I through L are acceptable.

EXAMPLE II

The process of Example I is repeated with filaments spun from vacuum-finished, low monomer (3 to 4%) 6-nylon (polymer from caprolactam). The draw ratio in this case is 4.00, and the filaments are held at a temperature of 165° C. for a period of 30 seconds under drawing tension. The yarn produced, following slack aging for a period of 9 days, had a tenacity of 6.3 g.p.d., a break elongation of 19.1%, and a T₇ of 2.3 g.p.d. The yarn sample had a density above 1.139, and a birefringence higher than 0.0590.

The increased strength of yarns prepared from the high load-bearing nylon staple of this invention in blends with combed cotton are shown in FIGURE 2, in comparison with conventionally prepared nylon staple. The graph shows that 70% or more conventional nylon staple must be added to combed cotton yarns to equal the strength of the original 100% cotton yarn. In contrast, the blended cotton-nylon yarn of this invention yields increased strengths when even small amounts of nylon are added.

The high load-bearing nylon staple of this invention is also advantageously used for blending with rayon staple yarns, as shown in FIGURE 3. In this case, the critical parameter is the break elongation of the rayon yarn, which is typically 14%. Thus, the nylon staple should have a high T₁₄ value. The nylon staple of this invention shows substantial improvement in this respect over conventional nylon staple; the curve in FIGURE 3 shows that initial additions of conventional nylon, up to about 50%, result in a strength decrease, and the original strength of the rayon is only attained when over about 65% of nylon is added thereto. In contrast, the nylon staple of this invention shows a strength increase with the initial additions.

The high load-bearing nylon staple of this invention may also be advantageously added to low modulus natural fibers such as wool, as shown in FIGURE 4. For equivalent compositions, the staple of this invention provides a stronger yarn than that when conventional nylon staple is used for wool-blending purposes.

A further measure of the improvement in strength and uniformity of yarns prepared from the blended fiber of this invention is obtained from the lea product (skein break), as shown in Table 3, for blends with cotton, rayon and wool. Lea products show consistent improvement in strength with increasing additions of the staple of this invention as compared to a decrease in strength or a lesser degree of improvement for conventionally prepared nylon staple.

Table 3

LEA PRODUCT VALUES FOR SPUN YARNS OF NYLON AND OTHER FIBERS
[Nylon, 1½", length, 3 den./filament]

Blending Fiber	Middlings Cotton		Rayon		Wool	
	T ₇ ¹	20/ls C ₂	T ₇	15/ls O	T ₇	8/ls C
Yarn Count.....						
Nylon Staple Type.....						
Lea Product, Nylon Added:						
0%.....	2,040	2,040	1,700	1,700	1,148	1,148
20%.....	2,150	1,730	2,200	1,580	2,240	1,480
30%.....	2,220	1,610	2,750	1,540	2,840	1,830
100%.....	4,300	3,000				

¹ High T₇ nylon staple.

² Conventional nylon staple.

In addition to improving the strength of cotton yarns made from blends containing the high load-bearing staple of this invention, there is a substantial improvement in abrasion resistance, as shown by the data in Table 4. High load-bearing 2.2 denier per filament, 1½ inch nylon staple was blended in the amount shown, with

1½ inch middlings cotton, and spun to 20/1s cotton-count yarn which was then knitted into fabric and subjected to a Stoll flat abrasion test, carried out in agreement with A.S.T.M. D-1175-55T. Fabrics were tested after boil-off.

Table 4

	Stoll flat abrasion ¹ cycles
Cotton, 1½" middlings-----	425
15% high T ₇ nylon added-----	1025
30% high T ₇ nylon added-----	1433
50% high T ₇ nylon added-----	1928

¹ Carried out in agreement with A.S.T.M. D-1175-55T.

The high load-bearing staple of this invention also has outstanding resistance to pilling, either as a blend in admixture with other staple fiber, or as a 100% nylon fabric. "Pilling" is a defect commonly observed when woven fabrics from high strength synthetic fibers are subjected to abrasion. The fibers on the surface become entangled into unsightly fibrous balls described as "pills."

What may be termed a "drawing-heat treating process," whereby the high load-bearing nylon staple of this invention is prepared, must be critically controlled. It is desirable to draw the nylon filaments in the absence of added moisture; that is, if antistatic finishes are applied to the yarn prior to drawing, they should be of the non-aqueous variety or, alternatively, the tow may be dried prior to subjecting to the drawing operations. If aqueous finishes are required, the heating step must also provide for sufficient time and heat capacity to flash off water in excess of that in equilibrium with the polymer at room temperature, as well as for subjecting the filaments to the required degree seconds of heat treatment. It is important to avoid exposing the treated filaments to moist conditions (i.e., to liquid water, steam, high humidity or high humidity-high temperature conditions) following the drawing-heat treating step.

It is obvious, that if an antistatic or other type staple finish is to be added to the tow, prior to heat treating and drawing, that such finish must be stable at the hot plate temperatures which the filaments will encounter.

As mentioned hereinabove, the maximum operable draw ratio should be used, subject only to the requirement that excessive filament breakage be avoided. The tow may suitably be heated by contact with a hot plate, wherein the shape is not critical, as long as good contact is obtained. It has been found that the yarn reaches plate temperature in ½ to 1 second; during the balance of the plate contact time, the filaments have been found to be substantially at plate temperature. An alternative which may sometimes be preferable is to use radiant heat, or to use an oven supplied with heated air. Combinations of these are often useful, since the hot plate heats the tow rapidly, while the oven provides a very uniform heat treatment and avoids yarn friction and formation of carbonized deposits of yarn finish on heated contact surfaces.

The 66 nylon tow may be heated to temperatures of 140 to 225° C., and preferably to 165 to 200° C. The time at this temperature may vary from 1 second to 40 seconds, shorter times requiring higher temperature, as disclosed hereinbefore. Very satisfactory results are obtained when the yarn is heated by contact with the plate at 195° C., followed by an oven at 185° C., for a period of 20 seconds. Under these conditions, the yarn is subjected to about 3800 degree-seconds, which is a very suitable exposure; a draw ratio of 3.7 may be used for 2.2 denier filaments. As a guide, draw ratios, satisfactory for different filament deniers, are listed:

1.2 den-----	3.2×draw
2.2 den-----	3.7×draw
4.3 den-----	4.5×draw
10 den-----	5×draw

The heat-treatment ranges apply to a wide range of deniers (e.g., from 1.2 to 15 denier and over per filament). It may prove desirable to increase the treating temperatures by about 5° C. for filaments of 10 to 15 denier, but treating times should not be altered. In general, the heat exposure under drawing tension should be about 1000 to 6000 degree-seconds, with 2000 to 5000 degree-seconds preferred.

Following the heat treating step, it is desirable to let the filaments cool somewhat before the drawing tension is released. Preferably the tow should cool to 90° C. or less.

After drawing, nylon intended for staple use is customarily crimped in some type of stuffer crimper (for example, that disclosed by Hitt in U.S. Patent 2,311,174). It has been found that this treatment leads to a certain amount of relaxation of the yarn, especially when done in the presence of moisture. This relaxation results in a significant loss in T₇, and hence is undesirable. For example, nylon is readily processed, without crimping to a T₇ of 2.5 g.p.d. Under the same processing conditions, but followed by a crimping step giving a crimp index of 10%, the T₇ is only 1.9 g.p.d.; with increased crimping to give a crimp index of 20.5% (normal for standard 3 denier/filament nylon staple), the T₇ falls to 1.57 g.p.d.

Crimp index is determined on individual filaments by (a) straightening a fiber to remove crimp without substantial elongation of the fiber, (b) measuring the straightened length, (c) allowing the fiber to retract freely and again measuring; the crimp index is calculated as follows:

$$\frac{\text{Length (a)} - \text{length (c)}}{\text{Length (a)}} \times 100\% = \text{crimp index}$$

Thus, for highest values of T₇, mechanical crimping is to be avoided. More satisfactory results are obtained by passing the tow directly to a suitable staple cutter. A suitable cutter is disclosed by Hull in U.S. Patent 2,694,447. The staple is thereafter preferably passed through an opener, such as for example the Davis Furber Synthetic Fiber Opener. The opened staple may then be packed into bales under customary baling pressure, whereby it acquires sufficient crimp so that it can be satisfactorily blended with cotton or processed on conventional cotton spinning equipment. Maximum retention of the high load-bearing properties of the staple of this invention is attained if the staple is cut and baled as soon as possible after the drawing operation.

The high load-bearing staple of this invention is suitable for stock blending, sliver blending, or for the preparation of 100% synthetic fiber spun yarns.

The high load-bearing staple of this invention can be prepared from polyethylene terephthalate filaments. The preparation is illustrated by the following example.

EXAMPLE III

Spun filaments of polyethylene terephthalate polymer (relative viscosity, 26.7) are combined into a tow of about 50,000 denier, 12,000 filaments, which is drawn on a machine arranged substantially as shown in FIGURE 1, with the exception that the snubbing pins and hot plate are eliminated. During the drawing operation, the tow is sprayed with water heated to 95° C. Following the drawing step on the machine of FIGURE 1, the tow passes through a heat treating oven, and from thence to a second set of drawing rolls, which maintain the yarn under suitable tension. By adjusting the peripheral speed of the second set of drawing rolls relative to the first set, the tow may be relaxed, held at constant length or stretched while it passes through said oven. The tow passes in an S-shaped path three times through the 8 foot oven. The tow is exposed for about 20 seconds to

190° C. circulating air in the oven. The yarn is stretched 1% while passing through the oven. This treatment is sufficient to remove most of the water added during drawing, but it is of more significance that it develops a high crystallinity in the yarn. Due to the much lower water sensitivity of polyethylene terephthalate filaments (as compared to nylon), it is unnecessary to maintain the tow in the dry state.

Following this processing, the tow is mechanically crimped, and cut to 1½ inch staple lengths. The staple is blended with Egyptian cotton, fiber properties and lea products (sample A) are shown in Table 5. Included also in Table 5 are similar results for a conventionally prepared polyethylene terephthalate staple (sample B); the preparation is similar to the high T₇ staple of this invention with the exception that tow is heat-treated in the heating oven while free to relax.

Table 5

PHYSICAL PROPERTIES OF "DACRON" /COTTON YARN BLENDS

Sample.....	A High T ₇ "Dacron"	Egyptian Cotton	B Conven- tional "Dacron"
Tenacity (g.p.d.).....	5.3	3-4	3.8
T ₇ (g.p.d.).....	4.8	3-4	1.0
Boil-off shrinkage, percent.....	3	3	0
Lea Product, 65/35 blend ² :			
13/1 cc.....	4,930	3,800 ³	2,940
47/1 cc.....	3,670	3,500 ³	2,060

¹ "Dacron" is the trademark designation for Du Pont polyester fiber produced from polyethylene terephthalate.

² Blend consists of 65 parts "Dacron," 35 parts cotton.

³ Lea count product for 100% cotton yarns.

In Table 5 it is seen that lea products for a blend of 65 parts of polyethylene terephthalate filaments and 35 parts of cotton filaments show substantial strength improvement when using the fiber of this invention.

EXAMPLE IV

Polyethylene terephthalate filaments are drawn as in Example III; and are then relaxed 3½% in the heat-treating oven at 130° C., followed by mechanical crimping and cutting to staple. These filaments are coded sample C. A second batch of staple, coded sample D, is prepared under similar conditions, except that the tow is subjected to a 2% stretch in the oven at 140° C., followed by a relaxed heat treatment at 140° C. The properties of the filaments are listed in Table VI.

Table 6

Sample.....	C	D
Tenacity, g.p.d.....	5.2	5.2
Break Elongation, percent.....	20	25
T ₇ , g.p.d.....	3.5	1.5

When blended with cotton in 65 parts to 35 parts (by wt.) cotton, the spun yarn from sample D has a 15% lower lea count product, thus showing that the T₇ value determines the blend strength, rather than the tenacity of the polyethylene terephthalate.

When the conditions for preparing sample C are repeated, except that the oven is held at a temperature of 220° C., similar results are obtained. The operability is somewhat better at 220° C.

Maximum values of T₇ may be obtained when the polyethylene terephthalate yarn is stretched about 1% in the oven, by suitable adjustment of the speed of the second set of draw rolls. This improvement is attained at some sacrifice in rate of dyeing, and hence is not preferred for

staple blends which must be dyed; for such blends, it is more desirable to relax about 4%, which represents a satisfactory compromise.

EXAMPLE V

When the test is repeated under the conditions of sample A, but using highly dyeable sulfonate-modified polyethylene terephthalate filaments, such as described by Griffing and Remington in U.S. patent application S.N. 622,811, the dye rate is sufficiently high so that oven temperatures of the order of 180° can be employed along with oven treatment at zero relaxation; under these conditions, high values of T₇ are obtained in conjunction with high dyeing rate.

The above examples are given by way of illustration since it will be apparent that variations may be made in the nature of the staple, time, temperature, drawing, etc., to obtain desired properties in the finished yarn or ultimate fabric. It is also to be understood that substitution of cotton staple by wool, or by other cellulosic fibers may be made where conditions permit.

Somewhat less beneficial results with polyethylene terephthalate filaments can be obtained when the drawing process is carried out without adding hot water, using the arrangement of FIGURE 1 found useful for nylon filaments. In addition, satisfactory results are obtained with dry drawing, followed by a heat treatment in an oven using superheated steam or air at 200° C.

The high load-bearing staple of this invention may contain conventional delusterants, dye modifiers, antistatic agents, antioxidants, heat stabilizers and the like. Suitable staple finishes may be added before, during or after the drawing and heat-treating step, subject to the requirements of heat-stability, and, for polyamides, freedom from hygroscopic effects tending to increase the fiber moisture content above the equilibrium value (e.g., about 4.1% at 76% R.H., 74° F.).

The present invention offers many advantages over the prior art. It permits the use of relatively cheap natural fibers or those derived from natural cellulosic materials with even small percentages of synthetic fibers to produce a yarn which may be fashioned into wearing apparel having improved wear and abrasion resistance. Another advantage is that apparel made from such blended fibers such as sweaters and socks have improved properties such as less pilling and stretching, softer hand, better shape retention, and greater comfort. It will be apparent, therefore, that the yarns herein disclosed offer a great economic improvement over the prior art.

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.

I claim:

1. An improved textile yarn consisting of blended staple cotton fibers and staple fibers of a high strength synthetic linear condensation polymer having both a high degree of crystallinity and crystalline orientation selected from the group consisting of polycaprolactam, polyhexamethylene adipamide and polyethylene terephthalate, the synthetic staple fibers in the yarn being characterized by being stable against slack-aging and having a load-bearing capacity at least equal to that of the cotton fibers at the break-elongation characteristic of the cotton fibers.

2. The product of claim 1 in which the synthetic polymer staple fibers are made from nylon characterized by a birefringence of at least 0.0590 and an average density above about 1.139.

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