

June 7, 1960

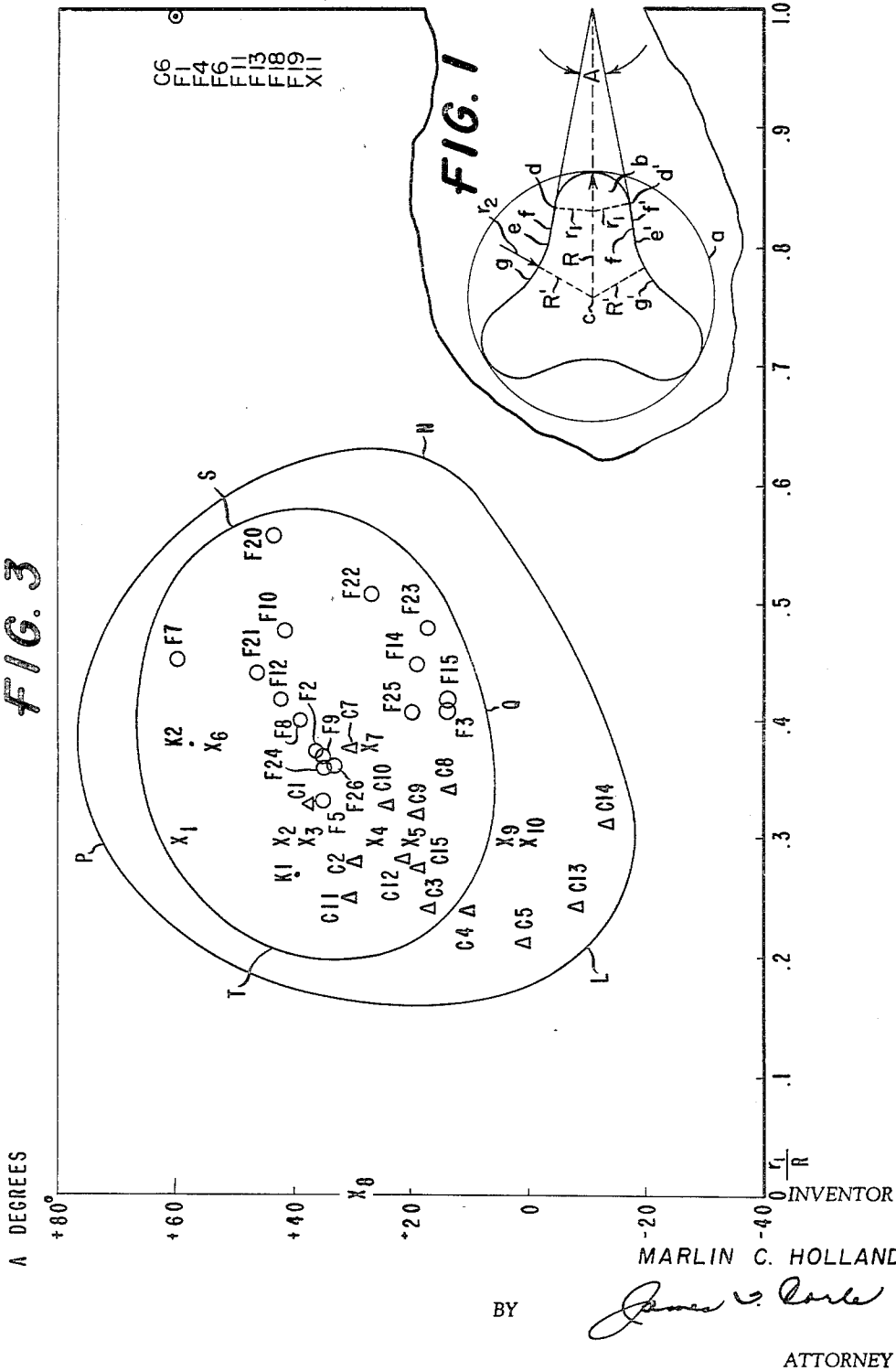
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2,939,201

TRILOBAL TEXTILE FILAMENT

Filed June 24, 1959

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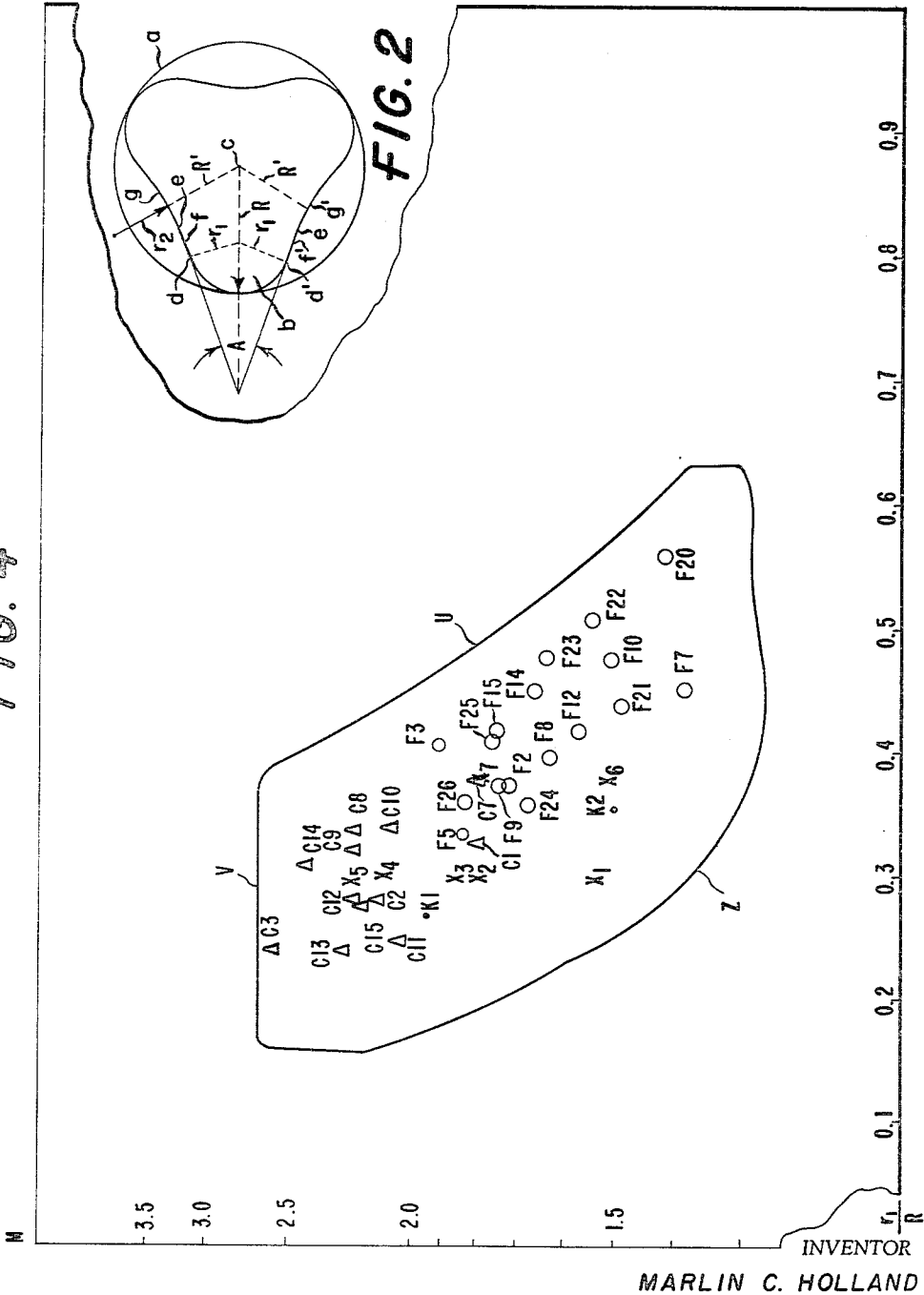
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FIG. 4



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TRILOBAL TEXTILE FILAMENT

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Filed June 24, 1959, Ser. No. 822,514

19 Claims. (Cl. 28—82)

This invention relates to novel trilobal synthetic filaments and fibers having improved optical properties and improved resistance to soiling when incorporated in textile materials.

This application is a continuation-in-part of my co-pending application Serial No. 748,447, filed July 14, 1958, and now abandoned.

Various synthetic fibers have been used in the construction of floor coverings. The two most important examples in recent years have been rayon and nylon fibers employed in the face or pile. It has been customary to select a fiber which has a minimum surface area, i.e., fiber most nearly round in cross-section, in order to provide minimum soiling of carpets. Various modifications of the cross-section of carpet fibers have been proposed but in this connection those cross-sections having relatively high degrees of modification have been chosen to provide the greatest improvement in stiffness. Fibers of even moderately high modification ratios tend to soil readily and tend to distort and collapse when bent around the sharp radii encountered in carpet use, leading to reduced bulk and compression resistance. Also, such fibers tend to fibrillate and break off in use. It has also been proposed to incorporate in the manufacture of the fiber various delusterants, such as titanium dioxide, in order to improve the resistance of the carpet to soiling. However, the use of delustered round fibers as well as fibers having a moderate to high modification ratio, as well as other odd shapes, has always resulted in an undesirable chalky appearance, lacking luster.

It is, therefore, an object of this invention to provide novel fibers and filaments particularly adapted for use in the construction of floor coverings having improved properties. A further object is to provide synthetic fibers and filaments of particular cross-section configuration that give higher resistance to soiling when used in carpets. Another object is to provide a synthetic carpet fiber which produces a carpet having improved dye brightness and covering power compared with carpets heretofore available. Another object is to provide woven and knitted fabrics exhibiting a unique luster highlight in addition to other desirable properties. A still further object is to provide textile materials having a combination of unique optical properties, improved resistance to soiling, and high covering power. Still another object is to provide new and improved floor covering fabrics. Other objects will appear hereinafter.

The objects of this invention are accomplished by providing novel filaments and fibers prepared from synthetic polymers which have a cross-sectional shape consisting of three essentially symmetrical lobes located about a central point. By maintaining the cross-sectional shape within certain parameters to be defined in detail later herein, the products prepared from such filaments and fibers not only exhibit outstanding and unique optical properties but also exhibit greatly improved resistance to soiling.

In general, each lobe of the filaments has a curved terminal portion generated by a radius, the origin of which

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is along the line of symmetry of the lobe. Each lobe has essentially straight side portions extending outwardly and tangent to the curved portion at each end. The arm angle is defined by extension of the sides. The tips of the three lobes define a circle having its center equidistant from their extremities. In accordance with this invention, the ratio of the tip radius to the radius of the circumscribed circle must be between about 0.16 and about 0.63, and the arm angle must be between about -17° and about $+77^\circ$. In addition, the modification ratio of the radius of the circumscribed circle to an inscribed circle must be between about 1.27 and about 2.6. However, it will be apparent from the detailed description which follows that only certain combinations of the aforementioned parameters in accordance with the teachings of this invention provide filaments having a combination of outstanding properties.

Throughout the specification and claims, the terms "filaments" and "fibers" will be used interchangeably in their usual and accepted sense. By the term "luster highlight" is meant the frequency of and the degree of concentration (in area) of the high intensity light reflected from a small area of a yarn or textile material relative to the average of the total amount of light reflected from a portion of the same yarn or textile material which includes the small area. By the term "soiling resistance" is meant the apparent resistance of a textile material to visible soiling which may be independent of the soiling which may actually occur. By the term "trilobal" is meant those cross-sectional shapes defined by the following equation:

$$(I) \quad \frac{1}{M} \frac{r^2}{R} = \frac{1 - \frac{r_1}{R} \frac{f}{R} \sec \frac{A}{2}}{\cos \frac{A}{2}} = \frac{\frac{r_1}{R} - \frac{r_2}{R} + \frac{f}{R} \tan \frac{A}{2}}{\sin \left(30 - \frac{A}{2} \right) \sin 60}$$

The significance of the symbols will be discussed later herein.

In general, the filaments of this invention may be prepared by extruding molten polymer or a solution of the polymer through an orifice which provides a trilobal shape. Spinning conditions must, of course, be varied, depending on the particular synthetic polymer being spun. Conditions should be controlled to give filaments which have a substantially uniform cross-sectional shape along their length. Although the shape of the filaments must remain within the limits previously described, slight variations in the parameters may occur along the length of the filament or from filament to filament in a bundle without adversely affecting their unique properties. In addition, the cross-sections may not be perfectly symmetrical. The denier of the filaments may vary within wide limits; however, deniers in the range from 1 to 35 are usually preferred. The optimum denier will be dictated by the end use of the textile material being prepared.

The present invention will be more fully understood by reference to the following detailed description and the accompanying drawings, in which:

Figures 1 and 2 are enlarged representations of cross-sections of filaments of this invention; and

Figures 3 and 4 are graphs showing the areas in which the critical parameters defining the cross-sections of the filaments of this invention appear.

In Figures 3 and 4, the filaments and models described in the examples which follow have been plotted as points. Triangles with the code letter C have been used to designate filaments utilized in preparing carpet samples such as those described in Example I. Circles with the code letter F denote filaments used in preparing woven fabric samples such as those described in Example II. Crosses denote the plastic models described in Example VIII.

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Shaded dots (identified as K1 and K2) denote the polypropylene yarn sample and polyamide hosiery sample described in Examples XIV and XV, respectively. A circle having a dot at its center, shown in Figure 3, denotes samples prepared from round filaments and fibers.

Although a multitude of different filaments having trilobal configurations are defined by Equation I which is set out at line 35 of column 2, only a very limited group of filaments exhibit the unique properties previously mentioned. All of the possible cross-sectional shapes of trilobal filaments can be described by the following five parameters, the relation of which is illustrated in Figures 1 and 2:

(1) The ratio of tip radius r_1 of the lobe to the radius R of a circle a having a center c circumscribed about the tips b of the lobes;

(2) The arm angle A formed by extending the essentially straight portions f and f' of each lobe;

(3) The ratio of the length $d-e$ of the essentially straight portion f to the radius R of the circumscribed circle;

(4) The ratio of the radius r_2 of the arc g to the radius R ; and

(5) The ratio of the radius R to the radius R' of a circle having center c inscribed within the cross-section, commonly referred to as the modification ratio M . As previously indicated, Equation I expresses the interrelation of these parameters. Although the equation is written in terms of five variables, it will be apparent that by specifying any three of the variables the remaining two are fixed. It will also be apparent that trilobal cross-sections may be defined by other suitable equations. For convenience, I have chosen to define my invention in terms of the tip radius ratio

$$\frac{r_1}{R}$$

the arm angle A , and the modification ratio M .

Referring again to Equation I, actual trilobal shapes are described only under the following conditions:

When $A < 60$

$$0 \leq \frac{r_1}{R} \leq 1$$

$$0 \leq \frac{f}{R} \leq \sin 60^\circ$$

$$-\infty \leq \frac{r_2}{R} \leq 0$$

$$1 \leq M \leq \infty$$

and

When $A > 60$

$$0 \leq \frac{r_1}{R} \leq 1$$

$$0 \leq \frac{f}{R} \leq 1$$

$$0 \leq \frac{r_2}{R} \leq \infty$$

$$1 \leq M \leq 2$$

However, as previously indicated, only a very specific group of the many possible shapes provide the outstanding optical and soiling properties.

Since a word definition of the parameters which define the special group of filaments of this invention would be quite lengthy and unduly complex, I have chosen to describe the filaments by reference to Figures 3 and 4 of the drawings. In view of the fact that three parameters are

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required to define the filaments, reference must be made to both of the aforementioned figures.

Referring now to Figure 3, the filaments must have an arm angle A and a tip radius ratio

$$\frac{r_1}{R}$$

within the area represented by the ovoid LNP.

Referring to Figure 4, the filaments must have a modification ratio M within the area represented by the figure VUZ.

Referring again to Figure 3, filaments which exhibit the greatest luster highlight are described within the area of the ovoid QST.

Referring to area LNP of Figure 3 and area VUZ of Figure 4, when preparing filaments and fibers for use in carpets, it is preferred that the arm angle A be between about -17° and about 40° , the tip radius ratio

$$\frac{r_1}{R}$$

between about 0.22 and about 0.37, and the modification ratio M between about 1.75 and about 2.6. In preparing flat fabrics, it is preferred that the arm angle A be between about 7° and about 74° , the tip radius ratio

$$\frac{r_1}{R}$$

between about 0.275 and about 0.62, and the modification ratio M between about 1.33 and 2.0.

It will be noted that the areas shown on the graphs are not regular geometrical figures as might be expected. If a three-dimensional plot were made incorporating the points on the graph using the modification ratio as the vertical dimension, it would appear as a volume having a peak at a modification ratio of about 2.6 and then sloping off as indicated in Figure 4.

It is indeed surprising that the filaments of the present invention exhibit a unique luster highlight since sparkle and glitter have heretofore been thought to be attributable to the presence of relatively large, flat surface areas along the fiber axis. In addition, it has been generally accepted that in order to obtain optimum resistance to soiling, the surface of the fibers should be free from notches, unevenness, or grooves. Contrary to the teachings of the prior art and previous theories, only those filaments and fibers having the limited parameters described in Figures 3 and 4 of the accompanying drawings exhibit a combination of the unique luster highlight and greatly improved soiling resistance.

In addition to the luster highlight and soiling resistance, the filaments of this invention exhibit high covering power and color clarity. Surprisingly, these features may all be obtained without the addition of delusterants, the incorporation of which has heretofore been considered necessary in order to obtain good covering power. However, depending on the end use of the products, it may be desirable to include delusterants, such as titanium dioxide, in amounts up to about 2%. When delusterants are included, the unique luster highlight, although somewhat subdued, is still present.

As previously indicated, spinning conditions as well as the type of spinneret used in preparing the novel filaments of this invention will vary, depending on the type of polymer being spun. For example, in melt spinning polymers such as polyesters and polyamides, a spinneret of the type shown in Figure XI of the copending application of Lehmicke, U.S. application Serial No. 517,434, filed June 23, 1955, may be advantageously used. Certain adjustments in the dimensions of the orifices, the viscosity of the polymer, the melt temperature, and the quenching conditions may be made in order to produce filaments having parameters within the scope of this invention as will be more fully described in the following examples which are intended to further illustrate this invention and

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in which parts and percentages are by weight unless otherwise indicated. The various tests used to illustrate the improved properties of the filaments of this invention are described in detail in the examples.

EXAMPLE I

Polyhexamethylene adipamide was melt spun at a temperature of 291° C. into a multifilament yarn through a spinneret having 79 round holes. The melt contained 0.02% titanium dioxide by weight. Five additional samples of the same polymer were melt spun through a spinneret of the type described in the aforementioned copending application Serial No. 517,434 under slightly varying conditions to give yarns having cross-sectional configurations as indicated in Table 1. Tows of approximately 100,000 denier were prepared.

Table 1

Sample No.	Chimney Air Flow, ft. ³ /min.	Spun Denier	Angle A (°)	M	r ¹ / _R
C1-----	150	4,100	37	1.8	0.33
C2-----	200	4,100	29	2.1	0.28
C3-----	160	4,100	17	2.6	0.24
C4-----	105	3,745	10	3.0	0.24
C5-----	225	3,420	0	4.0	0.21
C6-----	305	4,130	-----	1.0	-----

The tows were then chopped into 3-inch, 15 denier

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wax from shoes was placed at each end of the sample testing area so that a person walking through the area would walk over the lead carpet before walking over the samples. The positions of the various carpet samples were rotated daily according to a random number table and each sample was turned 180° and cleaned with a commercial vacuum cleaner daily. After a predetermined number of "traffic cycles," the samples were removed from the floor and subjectively evaluated for soiling by four people. The samples were rated according to the following scale:

- (1) Perfect, no visible soiling,
- (2) Slight soiling as compared with control sample (unsoiled),
- (3) Moderate soiling as compared with control sample,
- (4) Severe increase in soiling as compared with control sample, and
- (5) Extremely bad soiling as compared to control sample.

- 20 The ratings obtained for each sample were averaged, and the average reported as the "soil rating."

B. *Luster highlight*.—The luster highlight rating was determined by averaging the subjective ratings of four persons. Ratings were made on a scale from 1 to 5 with a rating of 1 representing a high luster highlight and a rating of 5 no luster highlight. The data recorded in the table were the average of four evaluations of fresh carpet samples lying flat on a table and cut to a size of 9 by 11 inches.

Table 2

Sample No.	Luster High-light Rating	Soiling Rating		Yarn Denier ¹ (Total) ²	Pile Yarn Weight ³ (oz./yd.) ²	Carpet Thickness ⁴ (Inches)
		Green Dyed Carpet (8,000 Traffic Cycles)	Undyed Carpet (4,000 Traffic Cycles)			
C1-----	1.5	2.2	2.2	6,500	30	0.475
C2-----	2.6	2.5 ¹ (2.3)	2.6 ² (2.9)	6,500	30	0.494
C3-----	2.0	2.7	-----	6,500	28	0.480
C4-----	3.4	2.8	-----	6,600	30	0.478
C5-----	4.6	3.0	-----	6,800	31	0.475
C6-----	5.0	3.0 ¹ (2.8)	3.4 ² (3.6)	5,500	30	0.476

¹ Average for 18 carpets. Also average for woven, tufted, loop pile and cut pile fabrics containing yarns prepared by cotton, woolen and worsted systems, both green and brown dyed.

² Average for 22 carpets. Also average for woven, tufted, loop pile and cut pile fabrics containing yarns prepared by cotton, woolen and worsted systems.

³ Calculated from weight of all polyamide yarn removed from a 6 square inch carpet sample after sample was treated in boiling water.

⁴ Measured on an Instron Testing Machine at 0.1 p.s.i.

per filament staple fiber, spun into yarn, and three ends were plied together to give a yarn having a total denier as indicated in Table 2. Each of the yarns was tufted into a 12 oz./yd.² woven jute backing on a 3/16 inch gauge tufting machine. One-half of each carpet sample was dyed green. The other half was left undyed but was scoured at 212° F. A standard latex dispersion was applied to the backing of each carpet sample. The carpet samples were then evaluated for soiling and luster highlight with the results listed in Table 2. Sample numbers in Table 2 correspond to those set forth in Table 1. The methods used were as follows:

A. *Soiling*.—Carpet samples were cut to a size of 7.5 inches by 22 inches with the longest dimension in the tufting direction. The samples were then attached to the floor by double-faced tape two inches wide. An electric mat switch 24 by 24 inches was placed adjacent to the samples. A "traffic cycle" was recorded by an electric counter each time one person walked over the mat. A lead carpet 27 inches wide and 6 feet long for removing

Three samples of polyhexamethylene adipamide polymer containing 0.3% by weight titanium dioxide were melt spun into one round and two non-round continuous multifilament yarns. The melt spinning conditions were essentially the same except for the shape of the spinneret orifice. In the case of the non-round filaments, a spinneret of the type described in Example I was used. Each of the samples (70 denier, 34 filaments, having one-half Z-twist per inch) were woven into a plain weave fabric and were then tested for luster highlight, soiling resistance, percent transmitted light, percent reflected light, and seam slippage. Test procedures were as follows:

A. *Luster highlight index*.—The luster highlight index was determined by an "Optical Wrinkleometer" comprised of a light source, a traveling specimen holder, a photomultiplier tube, and a recorder system. The light source used was a 35 mm. Argus "300" slide projector mounted so that the angle of light incidence to the long

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axis of a yarn sample was 60°. The light source was operated at 115 volts from a constant voltage supply and was mounted so that when the light was focused on the specimen the lens cap of the projector was 15 inches from the point on the specimen being measured.

The traveling specimen holder was a mechanical lathe bed powered by a variable speed motor. A yarn holder, comprised of a wooden block on which the yarn was wound, was fastened on the bed with the long axis of the yarn oriented in the same direction as the movement of the bed with the plane of the yarn perpendicular to the bed. The yarn sample, 1.8 inches long, was traversed at a speed of 1.31 inches per minute.

The photomultiplier tube (No. 931A, gas filled) was mounted in the same horizontal plane as the light source. The angle of reflectance from the long axis of the yarn was 60°. Reflectance was measured from 13 yarns (0.226 inch across the yarns and 0.00284 inch along the long axis of the yarns). To accomplish this, a 50 mm. lens was mounted between the specimen and the photomultiplier tube. The yarn image was focused on a ground glass between the lens system and the photomultiplier tube, and the desired yarn area to be measured, as indicated above, was obtained by masking off a slit on the ground glass of $\frac{1}{100}$ inch by $\frac{51}{64}$ inch which regulated the light reaching the photomultiplier tube.

The electrical output of the photomultiplier tube was fed into a Leeds & Northrup Type "G" recorder with a 0-10 millivolt full scale span, with a back electromotive force voltage and voltage divider in the recorder system to give a full scale span of 22.24 to 40.89 millivolts on the recorder chart.

The light tracing on the recorder was converted to a "Luster Highlight Index" by multiplying peak frequency per given length of yarn and the average difference in the chart units between adjacent chart peaks. An index of 20 is exceptionally good. An index below about 10 is poor.

B. Percent transmitted light.—In determining the percent transmitted light, I_t , which is a measuring of white light transmitted by a fabric within the range of 1% to 20% transmission, a photoelectric cell, a light source and a sample were arranged in a wooden box, the inside surface of which was painted a flat-black. The amount of light transmitted through a circular area of each sample which was illuminated by diffuse light was measured. A 100-watt frosted incandescent lamp placed six inches from the sample was used to illuminate the sample. The sample was hung in a vertical plane free from externally applied tension and was held against a two inch diameter hole. A Weston Photoelectric Cell, Model 594-RR, was placed in the beam of transmitted light, about eighteen inches from the sample, and a Simpson Microammeter, Model 29 (0-50 microampere range), was used to measure the output of the cell. The instrument was calibrated by adjusting a variable transformer which was connected between the instrument and a constant voltage transformer to give a meter reading of 36.6 milliamperes when a neutral filter having a transmission of approximately 12.5% is substituted for the fabric sample. Light transmission in percent as recorded in Table 3 was calculated by dividing the average of four meter readings for four samples by three.

C. Seam slippage.—The seam slippage test measures the resistance to slippage of filling yarns on warp yarns, or warp yarns on filling yarns at sewn seams in woven fabrics.

This method is an adaptation of American Society for Testing Materials Method Designation D434-42. The Instron Tester (Instron Engineering Corp., Quincy, Mass.) has been substituted for the constant rate of traverse type of tester specified, and sewing thread of polyethylene terephthalate with equivalent diameter has been substituted for the #00 cotton thread specified. Reported values are the average resistance to slippage in

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pounds to produce a 0.25 inch elongation. Slippages of less than 0.25 inch are reported as not measurable. The following data were obtained for the three samples.

Table 3

	Samples		
	F1	F2	F3
Fabric Construction (ends and picks).....	122 x 73.....	113 x 73.....	112 x 78.
Fabric Weight (oz./yd. ²).....	1.96.....	1.84.....	1.89.
Luster Highlight Index.....	6.3.....	20.3.....	10.4.
Light Transmission, I_t (percent).....	11.7.....	10.6.....	12.0.
Light Reflectance, I_r (percent).....	50.....	63.....	
Seam Slippage.....	(warp <0.25 in.) fill— 24.4 lbs.	(warp <0.25 in.) fill— 48.8 lbs.	
Filament Configuration.....	round.....	trilobal.....	trilobal.
Angle A (°).....		36.4.....	14.0.
M.....	1.0.....	1.72.....	1.91.
r_1		0.375.....	0.41.
R			

EXAMPLE III

Two samples of the same polyhexamethylene adipamide were melt spun using the spinning conditions described in Example II except the multifilament yarn was a 30 denier, 10 filament yarn. Sample F4 was prepared from round filaments and Sample F5 was prepared from a tri-lobal filament with parameters given in Table 4. Both yarns were given a 30 turns per inch Z-twist in both warp and filling. A plain weave chiffon fabric was prepared from each. Table 4 illustrates the superior seam slippage and yarn distortion properties of the fabrics made from the tri-lobal cross section fiber in accordance with this invention compared with the same properties of the fabrics made from round cross section fiber. (Yarn distortion is a measure of the distortion, in inches, of warp or filling yarns in woven fabric after surface friction has been applied. The test used follows the tentative method of testing issued by the American Society for Testing Materials (D1336-54T). An effective weight of one pound was used on the upper friction drum as recommended in the "American Standard Minimum Requirements for Rayon and Acetate Fabrics, L22," American Standards Assoc.).

Table 4

	Samples	
	F4	F5
Filament Configuration.....	round.....	trilobal.
Angle A (°).....		34.7.
M.....	1.0.....	1.83.
r_1		0.34.
R		
Fabric Construction (ends and picks).....	111 x 87.....	109 x 90.
Fabric Weight (oz./yd. ²).....	0.89.....	0.93.
Seam Slippage.....	(warp 13.9 lbs. fill 7.2 lbs.)	(warp <0.25 in. fill 17.8 lbs.)
Yarn Distortion (inches).....	(warp 0.09 fill 0.05)	(warp 0.015 fill 0.013)

EXAMPLE IV

Six pins of continuous multifilament polyhexamethylene adipamide yarn, containing 0.3% by weight titanium dioxide, spun under conditions similar to those described in Example II and having configurations as set forth in Table 5 were rated subjectively by three people. Luster highlight ratings are based on the same scale as described in Example I, 1—high luster to 5—no apparent luster. The results were as follows:

Table 5

Sample No.	Yarn ¹	Angle A (°)	M	$\frac{r_1}{R}$	Lister Highlight Rating
F6	70-34	(round)	1.0	-----	4.7
F7	200-34	59.9	1.38	0.46	1.7
F2	70-34	35.4	1.72	0.38	1.6
F8	40-13	39.2	1.63	0.40	2.3
F9	30-10	35.6	1.75	0.37	2.7
F3	70-34	14.0	1.91	0.41	3.7

¹ First number refers to total denier, and second number refers to number of filaments.

EXAMPLE V

Two samples of polyhexamethylene adipamide multi-filament yarn having trilobal cross sections were spun using the spinning conditions set forth in Table 6. One end of each of the samples was bulked by feeding it through a jet with steam according to the process described in the copending application of Breen and Lauterbach, U.S. application Serial No. 698,103, filed November 22, 1957. Three ends of the treated yarn were fed to each needle of a standard tufting machine and were tufted into a jute backing to make a loop pile carpet as described in Example I. Each carpet sample was divided into two parts, one-half being dyed red and the other half left undyed. Soil resistance rating and luster highlight rating were accomplished as described in Example I. The data obtained is set out in the following table:

Table 6

	Samples	
	C7	C8
Angle A (°)	30	13
M	1.8	2.2
$\frac{r_1}{R}$	0.38	0.34
Melt Temperature	285° C.	291° C.
Chimney Air Flow (ft. ³ /min.)	275	150
Unbulk Yarn (denier-filaments-twist/in.)	1,160-68-0	1,020-68-0.5 Z
Bulked Yarn Denier	2,012	1,975
Pile Yarn Weight (oz./yd. ²)	21	19
Luster Highlight Rating	1.0	2.5
Soiling Rating—Red Dyed Carpets (8,000 Traffic Cycles)	1.9	2.3

EXAMPLE VI

Four samples of polyester filaments were prepared. Samples F10 and F11 were prepared from polymer, having a relative viscosity of 19.5 (10% solution of polymer in 10 parts of phenol and 7 parts of trichlorophenol), as described in Belgian Patent 549,179.

In preparing Sample F10 the polymer was melt spun at 296° C. through a stainless steel spinneret of the type described in Example I in which the arms of the openings were 4 mils wide and 7 mils long. The effective thickness of the spinneret at the holes was 12 mils. Upon leaving the spinneret, the extruded filaments were quenched in cross-flow air having a velocity of 65 ft./min. and a temperature of 70° F., and then wound up as a 50 filament yarn at a windup speed of 1500 yards per minute. The total denier of the spun yarn was 170. The spun yarn was then drawn at a temperature of 104°, using a one-quarter inch ceramic snubbing pin, a draw ratio of 2.5, and a windup speed of 604 yards per minute. The drawn yarn was found to have a total denier of 70, a tenacity of 3.0 grams per denier, and a break elongation of 25%. Sample F11 was prepared substantially as indicated above except a spinneret having round orifices was used.

Samples F12 and F13, having a relative viscosity of 25.5, were prepared as described in U.S. Patent 2,465,319

and melt spun at 296° C. through a stainless steel spinneret having symmetrical trilobal and round openings as previously described. Upon leaving the spinneret, the extruded filaments were quenched in cross-flow air having a velocity of 89 feet per minute and a temperature of 70° F., and then wound up as a 203 denier, 50 filament yarn at a windup speed of 1500 yards per minute. The spun yarn was then drawn at a temperature of 102° C. using a one-quarter inch diameter ceramic snubbing pin, a draw ratio of 2.9, and a windup speed of 750 yards per minute. The drawn yarn was found to have a total denier of 70, a tenacity of 4.0 grams per denier, and a break elongation of 25%.

The parameters of each of the four continuous filaments are given in Table 7, together with test data. Each sample of polyester yarn (50 filaments, 1.4 denier per filament) was used to make a plain weave taffeta fabric. In weaving, a twist of five Z turns per inch were used in the warp and zero twist in the filling. The loom construction was 100 ends and 80 picks. Each fabric was scoured at the boil in aqueous medium in relaxed condition and then dried. The fabrics were heat set for one minute at 390° F. The finished weight of each fabric was 2.2 ounces per square yard. The fabrics were tested for covering power, for soiling in accordance with the soiling test described below, and were rated subjectively for luster highlight as described in Example I. The results of the tests show much better cover, luster highlight, and soiling resistance for Samples F10 and F12 than for the control Samples F11 and F13.

Soiling test.—The relative soilability of the woven fabric was tested by tumbling in the presence of a standard dry soil composed of the following materials:

	Grams
Humus	35
Cement	15
Silica (60-200 mesh)	15
Clay (Kamec kaolin)	15
Sodium chloride	5
Carbon black	1.5
Iron oxide	0.25
Palmitic acid	1.6
Oleic acid	1.6
Coconut oil	3
Lanolin (anhydrous)	1
Kerosene	2
Lauryl alcohol	0.5

The dry soil was mixed with 150 ml. of water, treated on a ball mill, dried at 110° C., and was then broken up and put through a 200-mesh screen. The changes in reflectance after soiling and after washing expressed as percentage of the original reflectance were reported. The soiling-washing sequence was repeated twice. The reflectance measurements are the percent of the original reflectance, i.e., reflectance before soiling, retained after the washing following the second soiling.

Soiling was carried out by placing two samples in each of two jars of soil. The jars were tumbled with one hundred 0.25 inch stainless steel balls for forty-five minutes at 70° F. The reflectance of each sample was measured after soiling. The samples were then washed in a Launder-Ometer, manufactured by the Atlas Electric Devices Company, for twenty minutes in 200 ml. of distilled water at 100° F. with 0.25% of a detergent, made and sold by Procter and Gamble under the tradename "Tide," and fifty 0.25 inch stainless steel balls. After washing, the samples were rinsed in distilled water, air dried, and the reflectance again determined. Reflectance measurements were determined using a Photovolt Reflectometer, Model 610 (Photovolt Corporation). The instrument was calibrated using a white enamel working standard (Catalog #6162, Photovolt Corporation) having 70-75 percentage reflectance with a green tristimulus filter (Catalog #6130, Photovolt Corporation).

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Table 7

	Samples			
	F10 ¹	F11 ¹	F12 ²	F13 ²
Angle A (°).....	40.6		41.6	
M.....	1.50	1.0	1.57	1.0
r_1	0.47		0.42	
R				
Covering Power:				
I ₁ (Percent).....	6.07	7.37	4.50	7.53
I ₂ (Percent) ³	70.9	59.6	73.0	57.2
Soiling Test (Percent Reflectance retained, I ₁).....	69.6	61.4	69.9	62.4
Luster Highlight Rating.....	2.7	3.7	2.6	4.2

¹ Made from ethylene glycol, 98 mol percent dimethylterephthalate and 2 mol percent sodium 3,5-di-(carboxymethoxy) benzenesulfonate.

² Made from polyethylene terephthalate.

³ Light reflectance measured as described in U.S. Patent 2,828,528.

EXAMPLE VII

Two polyhexamethylene adipamide multifilament yarns (1020 denier, 68 filaments, 0.5 Z-twist/in.) were melt spun using essentially the same procedure as that described for Sample C7 of Example V. These yarns contained filaments having cross-sectional configurations defined by the parameters set out in Table 8 which follows:

Table 8

	Samples	
	C9	C10
Angle A (°).....	18.5	24.4
r_1		
R	0.32	0.33
M.....	2.2	2.04

Both yarns exhibited satisfactory luster highlight before bulking and could be bulked as described in Example V. These yarns are adaptable for tufting into carpets having good resistance to soiling.

EXAMPLE VIII

Several transparent polymethyl methacrylate cylinders of various cross-sectional shapes were machined to give enlarged fiber models having parameters listed in Table 9. A point source of light was moved in all positions with respect to an exposed slit perpendicular to the axis of and in front of each model. The reflected light was measured by exposing photographic paper, and the resulting exposed portions were integrated to give single numbers representing total light reflections from internal surfaces for each model. Models with a value of at least 50 typify samples which would have sufficient internally reflected light to exhibit a combination of good luster highlight and soil resistance, whereas those models with numbers substantially less than 50 confirm the unsatisfactory luster highlight of actual fiber samples tested. The models as well as the filaments described in the preceding examples are plotted on the graph in Figures 3 and 4.

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Table 9

Model	Angle A (°)	M	r_1 R	Total Light Reflection
X1.....	60	1.54	0.3	71
X2.....	42	1.8	0.3	80
X3.....	38	1.87	0.3	77
X4.....	26	2.1	0.3	87
X5.....	20	2.22	0.3	59
X6.....	54	1.52	0.375	50
X7.....	29	1.8	0.38	50
X8.....	29	3.56	0	19
X9.....	4	2.75	0.3	37
X10.....	0	2.9	0.3	16
X11.....	(round)	1.0		9

EXAMPLE IX

One sample of yarn, identified as Sample F14, was prepared from polyethylene terephthalate polymer having a relative viscosity of 25.5 (10% solution of polymer in 10 parts phenol and 7 parts of trichlorophenol), as described in U.S. Patent 2,465,319.

The polymer containing 0.3% TiO₂ was melt spun at 305° C. through a stainless steel spinneret having a diameter of 3 inches. This spinneret was used to spin two yarn bundles, each bundle consisting of 34 continuous filaments. The individual filaments were spun from a group of four holes, each of which had a diameter of 6 mils, with three of the holes arranged radially 120° apart about the fourth hole to produce one coalesced filament. The distance between the center hole and each of the three radial holes was 7 mils, center to center. The effective thickness of the spinneret at each hole was 8 mils.

Upon leaving the spinneret, each extruded filament, formed by coalescence of the polymer from each group of four holes, was quenched with cross-flow air having a velocity of approximately 20 ft./min. and a temperature of 70° F. The filaments were wound up as a 34-filament yarn at a windup speed of 600 yds./min.

The drawn yarn was found to have a total denier of 52.3, a tenacity of 4.3 grams per denier, a break elongation of 24.5%, and a boil-off shrinkage of 9.5%. Measurements made on yarn cross-sections showed that each filament had an average modification ratio (M) of 1.65, an average angle (A) of 18.4°, and an average ratio

$$\frac{r_1}{R}$$

of 0.45.

The F14 yarn described above was woven into a plain weave taffeta fabric. In weaving, a twist of 7 Z turns per inch were used in the warp and zero twist in the filling. The loom construction was 116 ends and 92 picks. The fabric was scoured at the boil in aqueous medium in a jig and then dried, followed by heat-setting for one minute at 390° F. The finished weight of the fabric was 1.78 ounces per square yard, having a construction of 141 ends and 102 picks. The fabric was rated subjectively for luster highlight by five people, using the same scale as described in Example I. The average of the five ratings was 2.1.

EXAMPLE X

Three samples of polyethylene terephthalate multifilament yarn were spun with the same spinneret described in Example IX, except that spinning conditions were adjusted to produce the cross-sectional parameters described in Table 10.

Table 10

Sample No.	Yarn (total denier-number filaments)	Angle A (°)	M	r_1 R	Fabric Details			Luster Highlight Rating
					Warp, Ends/In.	Fill, Picks/In.	Weight, Oz. Yd. ²	
F15.....	57-34	13.5	1.74	0.42	139	94	1.95	2.4
F16.....	71-34	-14.2	2.05	0.42	123	85	2.14	4.4
F17.....	50-20	-16.2	2.15	0.42	139	93	1.62	4.4

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These three yarns were woven into fabric and finished by the same procedure as that described in Example IX. Luster highlight ratings reported in Table 10 were based on the same scale as described in Example I, and the values reported were the average subjective ratings of five people. Samples F16 and F17 were rated as being much poorer than Sample F15 in luster highlight.

EXAMPLE XI

Seven samples of polyhexamethylene adipamide were melt spun from polymer containing 0.75% titanium dioxide by weight through spinnerets of the type described in the aforementioned copending application Serial No. 517,434 as trilobal filaments under slightly varying conditions to give yarns having cross-sections as indicated for Samples F20 through F26, inclusive, in Table 11. Two samples of round filaments (F18 and F19) were also spun and made into similar yarns to serve as controls. Each of these nine yarns contained 13 filaments and had a total denier of 40.

Each of the yarns was woven into a plain-weave fabric, the warp yarns of each fabric having a twist of $7\frac{1}{2}$ Z turns per inch and the filling yarns each having a twist of one-half Z turns per inch. All nine fabrics were finished by the method described in Example IX. These fabrics when rated subjectively by five people for luster highlight showed the trilobal fibers to be superior to comparable control fabrics having fibers of round cross-section based on the same scale as used in Example I. The fabric constructions and luster highlight ratings for all nine fabrics are given in Table 11.

Table 11

	Angle A (°)	M	$\frac{r_1}{R}$	Fabric Details			Luster High- light Rating
				Warp Ends/ In.	Fill Picks/ In.	Weight Oz./Yd. ²	
F18 ¹ -----	-----	1.0	-----	146	102	1.38	5.0
F19 ² -----	-----	1.0	-----	142	102	1.38	4.3
F20-----	43.0	1.42	0.55	151	103	1.45	2.7
F21-----	47.0	1.49	0.44	151	102	1.46	2.5
F22-----	27.0	1.54	0.51	147	101	1.42	2.1
F23-----	17.1	1.64	0.48	145	101	1.43	2.3
F24-----	39.5	1.68	0.36	148	101	1.41	2.3
F25-----	19.4	1.77	0.41	151	97	1.40	3.1
F26-----	33.2	1.84	0.36	153	97	1.43	2.9

¹ Round cross-section containing 2.0% TiO₂ by weight.

² Round cross-section containing 0.3% TiO₂ by weight.

EXAMPLE XII

Filaments of polyhexamethylene adipamide having a trilobal cross-section (angle $A=30^\circ$, $M=2.03$,

$$\left(\frac{r_1}{R}=0.25\right)$$

were melt spun into a multifilament yarn. The melt contained 0.02% titanium dioxide. The yarn (identified as Sample C11) was melt spun through a spinneret containing 68 holes, each hole being characterized by three slots lying at 120° to each other and joined at the center. The length of each rectangular slot was approximately 12 mils and the width 3 mils. The temperature of the melt adjacent to the spinneret was 296°C . The chimney air flow was 340 ft.³/min. at a temperature of 50°F . The yarn was spun at 429 yards per minute and was drawn approximately $4\times$, giving a final denier of about 1000. One end of the drawn yarn was bulked by the same process as that described in Example V. A tufted carpet was prepared from the bulked yarn and was tested for luster highlight and soil resistance. The luster highlight rating of the tufted carpet was 1.7. This carpet was rated for soiling as considerably better, i.e., it soiled much less, than a control carpet made of round fibers of the same denier and composition.

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EXAMPLE XIII

Four different samples of trilobal polyhexamethylene adipamide filaments were melt spun into yarns using the same type of spinneret as described in Example XII but adjusting the spinning conditions slightly to give the filament parameters listed in Table 12. The amount of titanium dioxide in each melt is also listed in Table 12. Each yarn was bulked and then made into a tufted carpet as described in Example XII. Each carpet was rated for luster highlight and the ratings are given in Table 12.

Table 12

Sample No.	Angle A (°)	M	$\frac{r_1}{R}$	TiO ₂ (Percent)	Luster High- light Rating
C12-----	20	2.13	0.28	0.02	2.2
C13-----	-9	2.24	0.24	0.02	3.6
C14-----	-14	2.41	0.31	0.02	3.7
C15-----	18	2.16	0.28	0.15	5.5

The carpets were rated for soil resistance as much better, i.e., less soiling, than the same control carpet of round filaments referred to in Example XII.

EXAMPLE XIV

A sample of polypropylene, having a melt index of 12 at 190°C . as measured by ASTM Test Method D-1238-52T, was melt spun into filaments (identified as Sample K1) having a trilobal cross-section (angle $A=39^\circ$, $M=1.95$,

$$\frac{r_1}{R}=0.25)$$

The polymer was melt spun into a multifilament yarn through a spinneret containing 20 holes, each hole being an equilateral triangle 9 mils long on each side. At each vertex of the triangle a square slot was cut, running 3 mils in length from the vertex and being 3 mils wide. The temperature of the melt at the spinneret was 200°C . The yarn windup speed was 65 yards per minute and the denier of the as-spun yarn was 2300. The yarn was drawn at approximately $6\times$ at 124°C . over a hot pin. The as-drawn yarn had a tenacity of 4.6 grams per denier, an elongation of 76%, and an initial modulus of 54 grams per denier. Each filament had a denier of 20. The drawn yarn was wound on a cone and in this form was compared with a sample of polypropylene yarn made of filaments having a round cross-section. The yarn of trilobal polypropylene filaments exhibited a unique luster highlight to the unaided eye, compared to the dull, flat appearance of the round filament yarn.

EXAMPLE XV

This example describes the preparation of full-fashioned ladies' hosiery using the trilobal filaments of this invention. The hosiery were knit on a 60-gauge, 4-position Reiner full-fashioned hosiery machine (Robert Reiner, Inc., Weehawken, N.J.), using for the leg fabric continuous filament yarn (15 denier, 2 filament, $1/4$ Z twist) of polyhexamethylene adipamide containing 0.3% titanium dioxide by weight, each filament having a trilobal cross-section wherein the angle $A=57^\circ$, $M=1.50$, and

$$\frac{r_1}{R}=0.38$$

(identified as Sample K2). Standard 40-13- $1/2$ Z nylon yarn of the same composition having round filaments was used for the welt fabric and 30-10- $1/2$ Z round nylon for the splicing. The hosiery were seamed, preboarded five minutes at 27 p.s.i. steam, scoured in an aqueous bath containing 2% sodium lauryl sulfate and 2% NaOH, dyed a gold shade, finished with a standard resin emulsion hosiery finish, and postboarded dry at 200°F . using conventional procedures. The resultant gold-colored

hosiery were extremely brilliant, exhibiting a high level of luster highlight. Hosiery prepared with conventional 15-2-3/4 Z nylon yarn of round filaments in the leg fabric using the same procedure and dyes as above did not exhibit any of these luster highlights but, by comparison, appeared extremely dull and had low color clarity. The luster highlight in the sample of trilobal filaments and the difference between this and the dull flatness in the sample of round filaments were readily apparent with the hosiery laying flat on a surface or while being worn.

Although the above hosiery were seam-type hosiery equally attractive women's hosiery exhibiting unique luster highlight were prepared with trilobal filament yarns in seamless hosiery. In other hosiery samples the welt yarns and splicing yarns were also made of trilobal cross-section filaments to produce hosiery in which all sections of the hosiery exhibited luster highlight. The trilobal filament hosiery may be dyed to any and all shades that round filament hosiery are dyed.

The foregoing examples clearly illustrate the fact that the cross-sectional shape of the fiber or filament is critical in producing yarns and woven, knitted, and non-woven fabrics which have a combination of luster highlight, soil resistance, and other desirable physical properties.

The staple fiber or continuous filaments of the present invention may be prepared from a variety of synthetic polymers. Among the most important polymers are the polyamides such as polyhexamethylene adipamide, polyhexamethylene sebacamide, polycaprolactam, polyxylylene azelamide, polyoctamethylene oxalamide, polypyrrolidone, polymetaphenylene isophthalamide, polymetaphenylene adipamide; copolyamides, and irradiation grafted polyamides; and the polyesters and copolyesters such as the condensation products of ethylene glycol with terephthalic acid, ethylene glycol with a 98/2 mixture of terephthalic/5-(sodium sulfo)-isophthalic acids, ethylene glycol with a 90/10 mixture of terephthalic and isophthalic acids, polyesters derived from 2,2-bis(4-hydroxyphenyl) propane, and trans-p-hexahydroxylylene glycol with terephthalic acid; acrylonitrile polymers and copolymers such as polyacrylonitrile, copolymers of acrylonitrile with vinyl pyridine, vinylidene chloride, vinyl chloride, or methyl acrylate; vinyl chloride polymers and copolymers, vinylidene chloride polymers and copolymers; polyurethanes, e.g., those described in French Patent 1,172,566, polyesteramides, polyethylenes, polypropylenes, polycarbonates such as those derived from 2,2-bis(4-hydroxyphenyl) propane, fluorinated ethylene polymers and copolymers such as polymers of tetrafluoroethylene, hexafluoropropene, and monochlorotrifluoroethylene; composite filaments such as, for example, a sheath of polyamides around a core of polyester as described in the application of Breen, Serial No. 621,443, filed November 9, 1956, now abandoned, of which Serial No. 771,676, filed November 3, 1958, is a continuation-in-part, and two acrylonitrile polymers differing in ionizable group content spun as a sheath and core as described in the application of Taylor, Serial No. 640,722, filed February 18, 1957, now abandoned, of which Serial No. 771,677, filed November 3, 1958 is a continuation-in-part; cellulose acetate, regenerated cellulose, and the like. The fibers and filaments may be crimped or uncrimped, drawn or undrawn, and/or bulked or unbulk. Mixtures of the above fibers as well as blends containing a major proportion of the synthetic fibers of this invention with a minor proportion of natural fibers may be used to prepare fabrics.

The filaments of this invention are particularly useful in bulked form. Bulking may be conveniently achieved by a number of methods. For example, a particularly desirable bulking process is described in the copending application of Breen and Lauterbach, Serial No. 698,103, filed November 22, 1957. The novel filaments of this invention are peculiarly adaptable to being processed by the bulking process of the just mentioned application.

The trilobal filaments of this invention may also be treated according to the process described in the copending application of Breen and Sussman, Serial No. 810,671, filed May 4, 1959, to provide desirable products.

Obviously, slight variations in the configuration of the filaments of this invention may be present without impairing their desirable properties, e.g., the sides of the lobes of the filament need not be absolutely straight nor must the curved terminal portion be perfectly circular. The sides may curve slightly inwardly or outwardly. Other slight distortions may be introduced in the filament when it is spun or during the processing operations, such as drawing, crimping, twisting, dyeing, or bulking.

The chief advantage of this invention is that it provides fibers, filaments, yarns and fabrics with an unusual combination of pleasing optical properties and high soiling resistance. In particular, the optical properties exhibited by the critical fiber cross-section parameters include both a unique luster highlight visible to the naked eye as well as accompanying improvement in the optical cover and mechanical bulk of yarns and fabrics constructed from these special fibers.

Other property improvements are provided by the products of this invention. Dyed and/or printed fabrics exhibit improved clarity of color and print definition. In addition, the woven fabrics of this invention possess less seam slippage and less yarn distortion than those made from filaments of round cross-section. The improved fabrics also exhibit a greater coefficient of friction, resulting in better fabric tactile properties. The improved soiling resistance of the woven, knitted, and non-woven fabrics of this invention includes resistance to soiling by either dry or oily soils. The higher denier pile fabrics exhibit better mechanical bulk both before being used as well as after being in use when compared with control fabrics having round fibers and fibers having moderate to high modification ratios. In addition, the fibers of the present invention have improved dye wash fastness over fibers having higher modification ratios. The novel fibers of this invention have a higher rate of dyeing and a greater stiffness than round fibers due to their more efficient cross-sectional shape. Also, they do not collapse as do those fibers of higher modification ratio. Another advantage is that knitted fabrics prepared from the bulked trilobal filament yarns exhibit less "pickiness" than do comparable fabrics knitted from bulked round filament yarns.

The novel fibers and filaments of this invention may be employed to produce a wide variety of different types of fabrics, including both apparel and industrial textile products. Specific examples of these products include shirtings, suitings, dress and blouse fabrics, hosiery, sheeting, lingerie, taffetas, georgettes, sand-crepes, tissue-failles, foulards, broadcloths, batistes, rainwear, surah, tricot, tulles, circular knitted goods, satins, chiffons, sheers, wash-wear fabrics, crepes, casement fabrics, upholstery, filter cloths, ducks, beltings, webbing, braids, cordage and twine, fiber-reinforced laminates, tire cord, coated fabrics, stuffing materials, floor coverings, and tiles. The products of this invention are particularly useful in preparing various types of carpeting, e.g., tufted, chenille, Smyrna, Wilton, Saxony, Brussels, velvet, Axminster, orientals, knitted, pleated, and the like, due to their improved soil resistance, unique luster highlight, dye brightness, and bulking power.

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. A textile filament prepared from a synthetic poly-

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mer having an essentially trilobal cross-section along its length, said cross-section a tip radius ratio

$$\frac{r_1}{R}$$

and an arm angle A within the range represented by the area LNP on Figure 3 of the drawing and a modification ratio M within the range represented by the area VUZ on Figure 4 of the drawing, the lobes of said cross section being substantially equi-spaced and having an essentially symmetrical configuration.

2. The filament of claim 1 wherein said polymer is a polyester.

3. The filament of claim 2 wherein said polymer is comprised of polyethylene terephthalate.

4. The filament of claim 2 wherein said polyester contains a major proportion of terephthalate radicals and up to 2 mol percent of 5-(sodium sulfo)-isophthalate radicals.

5. The filament of claim 1 wherein said polymer is polypropylene.

6. The filament of claim 1 wherein said polymer is a polyamide.

7. The filament of claim 6 wherein said polyamide is polyhexamethylene adipamide.

8. The filament of claim 1 wherein the tip radius ratio

$$\frac{r_1}{R}$$

and the arm angle A are within the ranges represented by the area QST on Figure 3 of the drawing.

9. The filament of claim 8 wherein the arm angle A is between about 7° and 60°.

10. The filament of claim 8 in staple fiber form.

11. Textile yarn having improved optical properties and improved resistance to soiling comprised of filaments prepared from a synthetic polymer having an essentially uniform trilobal cross-section along their length, said cross-section having a tip radius ratio

$$\frac{r_1}{R}$$

and an arm angle A within the range represented by the area LNP on Figure 3 of the drawing and a modification ratio M within the range represented by the area VUZ on Figure 4 of the drawing, the lobes of said cross section being substantially equi-spaced and having an essentially symmetrical configuration.

12. The yarn of claim 11 comprised of filaments wherein the arm angle A is between about 7° and 60°.

13. The yarn of claim 12 wherein the tip radius ratio

$$\frac{r_1}{R}$$

is within the range represented by the area QST on Figure 3 of the drawing.

14. A knitted textile fabric prepared from the yarn of claim 13.

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15. The yarn of claim 11 wherein said filaments are continuous filaments.

16. A textile fabric having improved luster highlight and improved covering power comprised of filaments prepared from a synthetic polymer having an essentially uniform trilobal cross-section along its length, said cross-section having a tip radius ratio

$$\frac{r_1}{R}$$

and an arm angle A within the range represented by the area LNP on Figure 3 of the drawing and a modification ratio M within the range represented by the area VUZ on Figure 4 of the drawing, the lobes of said cross section being substantially equi-spaced and having an essentially symmetrical configuration.

17. The fabric of claim 16 wherein said tip radius ratio

$$\frac{r_1}{R}$$

is between about 0.275 and 0.62, said arm angle A is between about 7° and 74°, and said modification ratio M is between about 1.33 and 2.0.

18. A floor covering material having improved optical properties and improved resistance to soiling comprised of textile filaments prepared from a synthetic polymer having an essentially uniform trilobal cross-section along its length, said cross section having a tip radius ratio

$$\frac{r_1}{R}$$

and an arm angle A within the range represented by the area LNP on Figure 3 of the drawing and a modification ratio M within the range represented by the area VUZ on Figure 4 of the drawing, the lobes of said cross section being substantially equi-spaced and having an essentially symmetrical configuration.

19. The material of claim 18 wherein said tip radius ratio

$$\frac{r_1}{R}$$

is between about 0.22 and 0.37, said arm angle A is between about -17° and 40°, and said modification ratio M is between about 1.75 and 2.6.

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UNITED STATES PATENT OFFICE
Certificate of Correction

Patent No. 2,939,201

June 7, 1960

Marlin C. Holland

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 10, after "ratio" insert —, i.e., the ratio—; lines 32 to 36, the left-hand portion of Equation (I) should appear as shown below instead of as in the patent:

$$\frac{\frac{1}{M} - \frac{r_2}{R}}{\cos \frac{A}{2}}$$

column 5, Table 1, the heading to column 6 thereof should appear as shown below instead of as in the patent:

$$\frac{r_1}{R}$$

column 6, Table 2, columns 3 and 4 thereof and opposite Sample No. "C2", for "2.5¹(2.3)" and "2.6²(2.9)" read —2.5 (2.3)¹— and —2.6 (2.9)²—; same column 6, same Table 2, same columns 3 and 4 thereof and opposite Sample No. "C6" for "3.0¹(2.8)" and "3.4²(3.5)" read —3.0 (2.8)¹— and —3.4 (3.5)²—; column 7, line 15, for "mountd" read —mounted—; line 40, for "measuring" read —measure—; column 8, Table 4, first column thereof, fourth item, for

$$\frac{r^1}{R} \quad \text{read} \quad \frac{r_1}{R}$$

column 13, lines 54 to 56, strike out the opening parenthesis; column 14, Table 12, heading to the fourth column thereof should appear as shown below instead of as in the patent:

$$\frac{r_1}{R}$$

column 17, line 2, after "cross-section" insert —having—.

Signed and sealed this 22nd day of November 1960.

[SEAL]

Attest:

KARL H. AXLINE,
Attesting Officer.

ROBERT C. WATSON,
Commissioner of Patents.