

Feb. 19, 1963

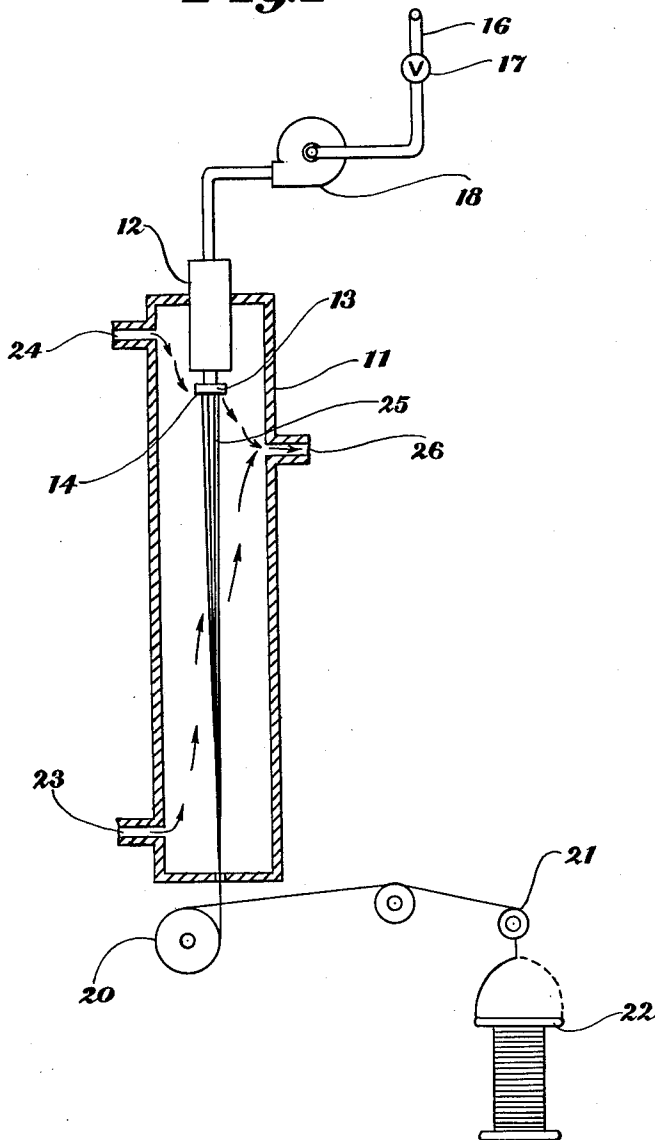
D. W. RAYNOLDS ET AL
APPARATUS FOR SPINNING SYNTHETIC FILAMENTS AND
FIBERS OF INCREASED BULK AND STIFFNESS

3,077,633

Filed May 15, 1958

5 Sheets-Sheet 1

Fig. 1



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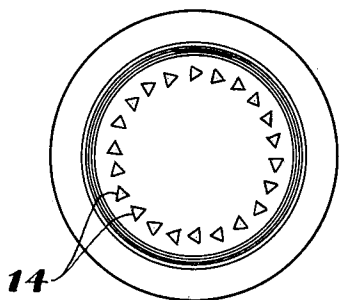
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5 Sheets-Sheet 2

Fig. 2



SECTION OF SPINNERETTE
SHOWING
ONE ORIFICE

Fig. 3

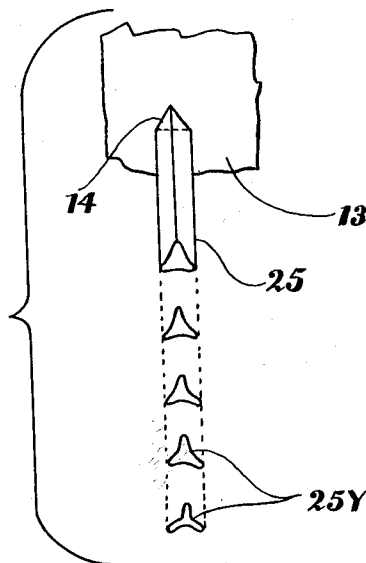
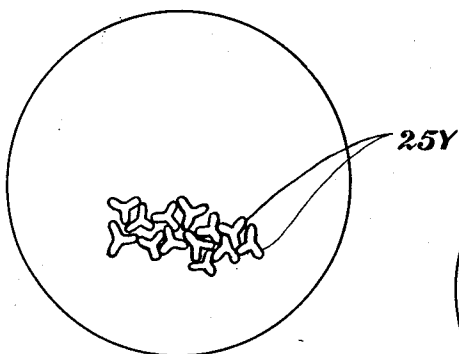
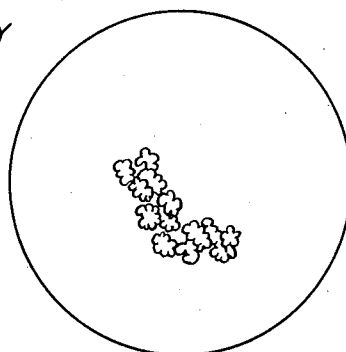


Fig. 4

Fig. 5
PRIOR ART



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5 Sheets-Sheet 3

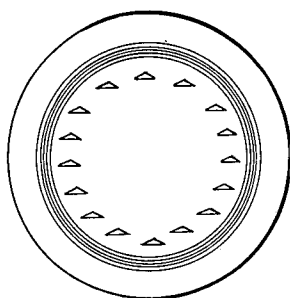


Fig. 6

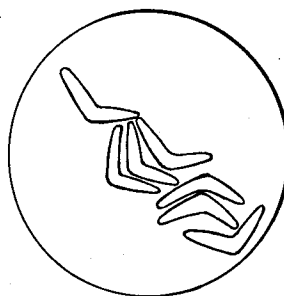


Fig. 7

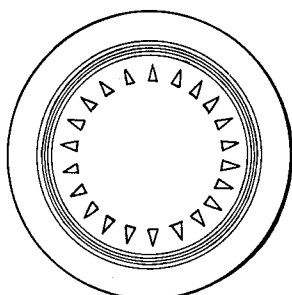


Fig. 8

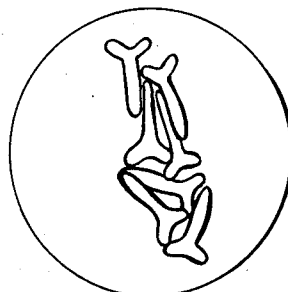


Fig. 9

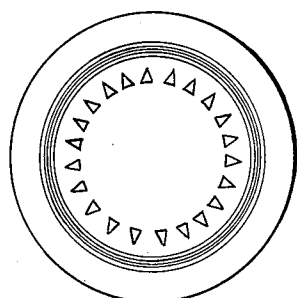


Fig. 10

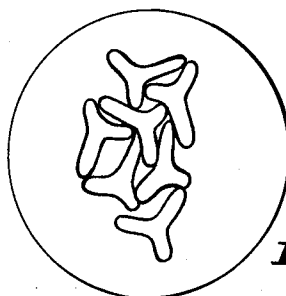


Fig. 11

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5 Sheets-Sheet 4

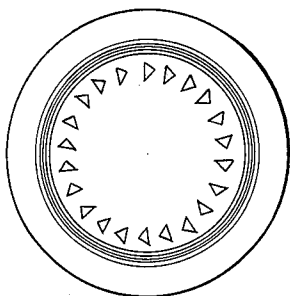


Fig. 12

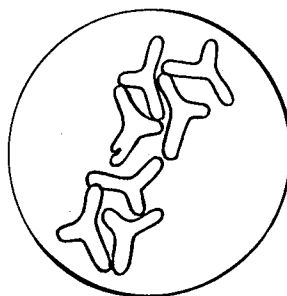


Fig. 13

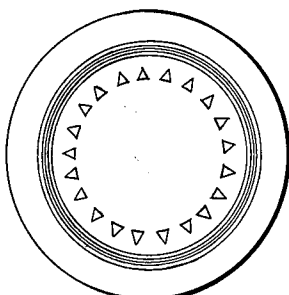


Fig. 14

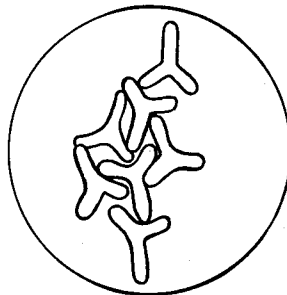


Fig. 15

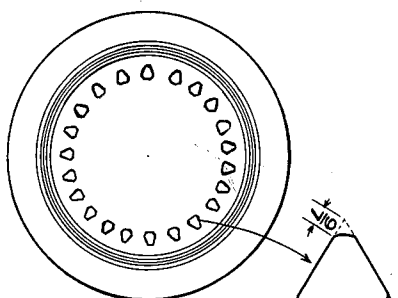


Fig. 16

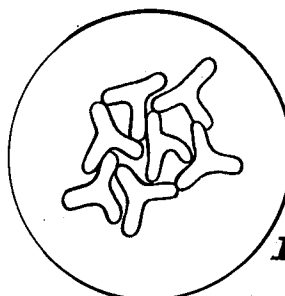


Fig. 17

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5 Sheets-Sheet 5

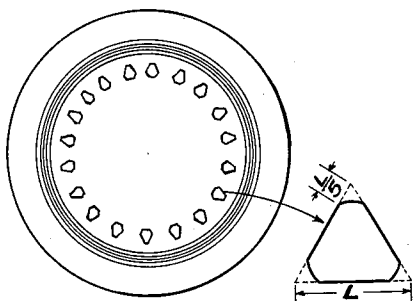


Fig. 18

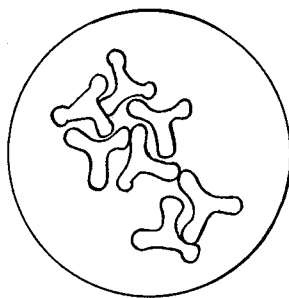


Fig. 19

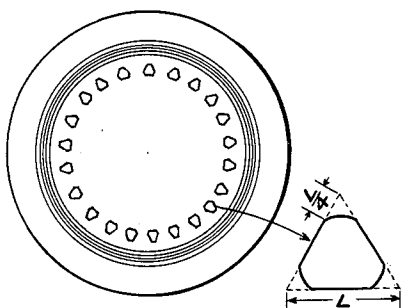


Fig. 20

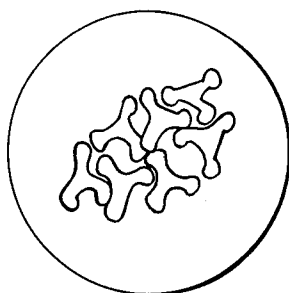


Fig. 21

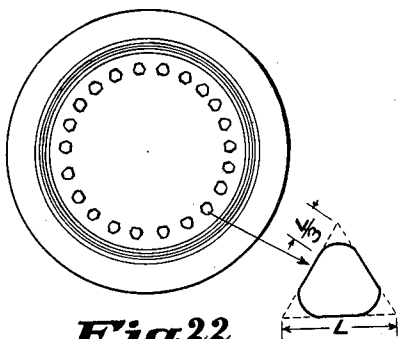


Fig. 22

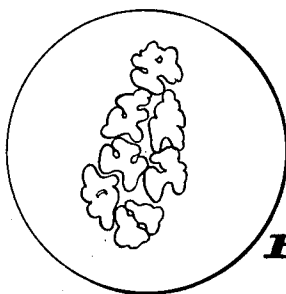


Fig. 23

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APPARATUS FOR SPINNING SYNTHETIC FILAMENTS AND FIBERS OF INCREASED BULK AND STIFFNESS

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Filed May 15, 1958, Ser. No. 735,607
6 Claims. (Cl. 18—8)

This invention relates to the preparation of synthetic filaments and fibers of predetermined cross-section and of predetermined bulk, stiffness, stretch, luster and covering power. More particularly, this invention relates to improved dry spinning apparatus for producing, from cellulose organic acid ester spinning solutions, filaments and fibers generally of Y-shaped or modified Y-shaped cross-sections having the aforementioned characteristics.

Heretofore, various processes and apparatus have been provided for the production of synthetic filaments and fibers of various cross-sections. Generally these well-known cross-sections fall within one or two classifications such as relatively narrow and rectangular cross-sections, or round or round-like cross-sections which include filaments of round and flat sides, clover-leaf configurations and other related variations produced by physically deforming the filament, after it has assumed its normal shape, as it issues from the spinning cabinet.

Typical methods and apparatus for dry spinning solutions into synthetic fibers are disclosed in U.S. Patents 2,000,047 and 2,000,048 of May 7, 1935, to H. G. Stone. These patents describe methods including the forcing of a heated cellulose ester spinning solution through a spinnerette having a plurality of separated round orifices and into a drying chamber containing an evaporation atmosphere maintained at a suitable drying temperature. By such controlled conditions, filaments can be consistently formed of approximately round or clover-leaf cross-section as contrasted to the filaments previously produced of elliptical shape.

Also, as shown in U.S. Patent 1,695,455 of December 18, 1928, by drawing the filaments from the round orifice spinnerette in a direction other than perpendicular to the horizontal face of the spinnerette, filaments having a more or less flattened cross-section are produced. It is also known that slight variations from the round cross-section can be caused by adjusting the particular evaporating conditions under which the filaments are dried in the spinning cabinet. A suitable selection of these conditions will permit the production, from spinnerettes having round orifices, of filaments with either a smooth or an unsymmetrical irregular surface.

In U.S. Patent 1,773,969 of August 26, 1930, the technique of the extrusion of filament forming solutions through circular orifices into evaporative atmospheres is also discussed. As described therein it is suggested that the outer layer of the stream of cellulosic material which is initially circular in cross-section as it issues through the spinnerette orifices, hardens or solidifies first forming a skin that is tougher and less fluid than the interior. After this initial hardening of the outer surface, the interior of the filament is precipitated or dried and thereby shrinks while the outer layer is being further hardened. The outer shell of the filament being tougher and more determined in shape than the interior, the contraction of the volume of the interior causes the outer film or layer to collapse and to assume a very irregular cross-section which is in the form of a figure of many indentations of varying sizes and shapes and which is often quite flat. Because of the irregularity of shape and flatness of the cross-section of such filaments, their covering power,

2

their bulk, stiffness and luster are quite irregular. This Patent 1,773,969 then describes the use of spinnerettes having orifices of compact or squat shape having indentations in the form of re-entrant angles. The re-entrant angles can be constituted by straight or curved boundary lines. However, the filaments produced by extruding cellulose ester filament forming solutions through such orifices have more or less cross-sections characterized by rounded surfaces.

As described in Hickey Patent 2,373,892 of April 17, 1945, I-beam type cross-section filaments or fibers having a high degree of resiliency and crush resistance may be produced by extruding a suitable cellulose ester solution through a spinnerette having rectangular orifices, the ratio of the length to the width of each rectangular orifice being between 1.35 and 1.65. Fibers made from such I-beam filaments are particularly useful for manufacturing carpet materials, as well as, for the manufacture of rugging and other pile fabrics. However, the ends of the I-beam are of a round shape and do not extend substantially above the flat section of the I-beam.

An object of this invention is the preparation of the desired filaments and fibers from spinnerette orifices of a simplified design that can be easily and accurately manufactured.

Yet another object of this invention is to provide spinnerettes having extrusion orifices of equilateral triangular shapes or of modified triangular shapes.

Other objects will appear hereinafter.

The features of the invention include employing equilateral triangular orifices, non-equilateral triangular orifices and modified equilateral triangular orifices to form cellulose ester spinning solutions into yarns of novel characteristics.

In accordance with one feature of the present invention these and other objects may be attained by forcing a suitable spinning solution through a spinnerette having a plurality of equilateral triangular shaped filament forming orifices therein and drying the resulting filaments in a spinning cabinet under carefully controlled conditions of temperature while subjecting the filaments to predetermined drafting. The temperature of the spinning solution and its rate of extrusion must also be controlled for optimum results.

Under the optimum conditions of solution temperature and composition, extrusion, drying and drafting, the wet filaments as they leave the equilateral triangular orifices temporarily assume a triangular cross-sectional shape. However, in accordance with a surprising feature of our invention, by careful control of the extrusion rate, the drafting rate and drying temperatures, there will be a change in the filament cross-sections from triangular to a Y-shaped cross-section. Under preferred ranges of operation, as suggested above, and as described in detail further on in this specification, the "legs" of the Y-shaped cross-section filament will be substantially equal in length and of substantially uniform shape. Also the angles between adjacent legs of the Y will be substantially equal.

In general the spinnerette having the equilateral triangular orifices may be employed with any suitable spinning cabinet such as, for example, one of the general kind described herein. The Y-shaped cross-section filaments can be prepared in accordance with our invention within a satisfactory range of spinning, drafting and solution conditions as is described hereinafter.

Another interesting feature of our invention is the discovery that filaments produced in accordance with our invention through equilateral triangular orifices have a more perfect Y-shaped cross-section than is obtainable when a spinnerette having Y-shaped cross-section orifices is employed.

As previously stated above, we have found that the Y-shaped cross-section filaments and fibers of our invention have greater bulk and stiffness than the filaments or fibers of the various round and round-like cross-sections heretofore known in this art.

This appears due to the intermeshing of the legs of the Y of the individual filaments in the filament bundle so that each is reinforced by the other and the filament bundle has a resultant stiffness greater than the normal cross-section fiber of equivalent denier because of the increased surface area. It is noted that a circle taking in the three tips of the legs of the Y will be greater in diameter than one taking in the lobes of the well-known clover-leaf type of cross-section. This larger "circle" is, therefore, the effective area of the Y-shaped cross-section and explains the increased bulkiness of our novel Y-type of filament and fiber.

While the filaments and fibers extruded from equilateral triangular spinnerette orifices, and further processed in accordance with our invention, are preferred for most purposes, we have also discovered that employing triangular spinnerette orifices having angles other than equilateral, the spinning conditions being substantially similar to those employed with spinnerettes having equilateral triangular orifices, also will give filaments and fibers having bulk and stiffness measurements greater than filaments and fibers extruded from round orifices, but less than those extruded through equilateral triangular orifices.

We have also found that control of the bulkiness and stiffness of such filaments and fibers can be achieved while employing similar spinning conditions by employing, in the spinnerette, orifices which are derived from equilateral triangles. This modified orifice perhaps can be best described as an equilateral triangle, the corners of which are filled in and rounded off, the remaining straight sides being of equal length.

The present invention will be further understood by reference to the following detailed description in which several examples of our invention are given and to the related drawings in which:

FIGURE 1 is a schematic elevational view, partly in section showing a spinnerette which has equilateral triangular orifices positioned in a suitable dry spinning cabinet which is equipped with suitable auxiliary apparatus;

FIGURE 2 is a view of the face of a spinnerette showing a plurality of filament forming orifices of equilateral triangular shape;

FIGURE 3 is a greatly enlarged representation of the spinning solution coming out of the triangular orifices of the spinnerette and forming first into triangular cross-section filaments and then changing into the Y-shaped cross-section filaments;

FIGURE 4 is a reproduction of an actual photomicrograph showing the cross-section of several Y-shaped filaments of the present invention;

FIGURE 5 is a reproduction of an actual photomicrograph showing in cross-section several regular or clover-leaf filaments made by a prior art method;

FIGURE 6 is a view of a spinnerette face showing a plurality of filament forming orifices of triangular shape, the angles of each orifice being 120°, 30° and 30°;

FIGURE 7 is a reproduction of an actual photomicrograph showing the cross-section of several modified Y-shaped filaments which were made in accordance with the invention when employing a spinnerette such as shown in FIG. 6;

FIGURE 8 is a view of a spinnerette face showing a plurality of triangular filament-forming orifices each having angles of 24°, 78° and 78°;

FIGURE 9 is a reproduction of an actual photomicrograph showing the cross-section of several modified Y-shaped filaments produced in accordance with the invention through a spinnerette such as shown in FIGURE 8;

FIGURE 10 is a view of a spinnerette face showing a

plurality of triangular filament-forming orifices each having angles of 78°, 60° and 42°;

FIGURE 11 is a reproduction of an actual photomicrograph showing the cross-section of several modified Y-shaped filaments produced in accordance with the invention through a spinnerette such as shown in FIG. 10;

FIG. 12 is a view of a spinnerette face showing a plurality of triangular filament orifices each having angles of 84°, 48° and 48°;

FIG. 13 is a reproduction of an actual photomicrograph showing the cross-section of several modified Y-shaped filaments produced in accordance with the invention through a spinnerette such as shown in FIG. 12;

FIG. 14 is a view of a spinnerette face showing a plurality of triangular filament orifices each having angles of 48°, 66° and 66°;

FIG. 15 is a reproduction of an actual photomicrograph showing the cross-section of several modified Y-shaped filaments produced in accordance with the invention through a spinnerette such as shown in FIG. 14;

FIGURES 16, 18, 20 and 22 are views of spinnerette faces each having a plurality of orifices of different polygonal shape. These orifices may be generally considered as being derived from an equilateral triangular orifice whose sides have been reduced respectively by removal of $\frac{1}{6}$, $\frac{1}{5}$, $\frac{1}{4}$ and $\frac{1}{3}$ of each side at each corner or, in other words, reduced respectively to $\frac{2}{3}$, $\frac{3}{5}$, $\frac{1}{2}$ and $\frac{1}{3}$ of the length. These sides are connected by arcs and the apices of the triangle are filled in above the arc.

FIGURES 17, 19, 21 and 23 are reproductions of actual photomicrographs showing the modified Y-shaped cross-section filaments produced in accordance with the invention respectively from the spinnerettes of FIGURES 16, 18, 20 and 22.

The details of the operation of our process will be first described in connection with the production of uniform Y-shaped cross-section filaments through spinnerettes having equilateral triangle orifices.

Referring to FIGURE 1 there is shown schematically a side elevation view, partly in section, of a spinning cabinet 11 and its associated apparatus by which the novel Y-shaped and modified Y-shaped synthetic filaments and fibers of the instant invention may be manufactured. Mounted at the top of the cabinet is a candle filter unit 12 to which is connected a spinnerette 13 which in accordance with our invention when making uniformly Y-shaped cross-section filaments has a plurality of orifices 14 therein which are of the shape of equilateral triangles. The face of this novel type of spinnerette with the equilateral triangular orifices 14 therein is shown in the greatly enlarged view of FIGURE 2. The candle filter may be uniformly heated by means of heating coils, not shown, which are positioned so as to surround candle filter 12 and through which coils may be circulated any appropriate heat exchange medium such as water maintained at the desired temperature.

Spinning solution of composition described hereinafter is supplied from conduit 16 through valve 17 to pump 18 which forces the solution at the desired rate to the candle filter unit 12, thence to spinnerette 13 through the equilateral triangular orifices 14 from which it is extruded initially in the form of equilateral triangular filaments 25.

The filaments 25 pass downwardly in the cabinet 11 while progressively losing solvent by evaporation until, in a substantially solidified condition, they leave the cabinet 11 and pass around godet roll 20, which is positioned below the lower end of the spinning cabinet 11. Godet roll 20 is driven at a uniform speed by means, not shown, to give the desired draft to the filaments 25. From godet roll 20 the filaments pass over the usual guide rolls, one of which is shown at 21, and are finally wound onto a bobbin 22 after an appropriate twist has been imparted thereto, by means not shown.

To facilitate removal of solvent from the filaments during their travel through the cabinet, heated air is supplied.

5

to the cabinet 11 by means of inlet conduits 23 and 24 positioned respectively adjacent the lower and upper ends thereof, the air passing through the cabinet and emerges through outlet conduit 26 positioned at a substantial distance below spinnerette 13, as illustrated.

The change of the cross-section of the filaments while in the cabinet from an initial triangular cross-section shape to the desired Y-cross section shape is illustrated in FIGURE 3. As shown at 25 the filaments have just been formed by the triangular orifices and are substantially of an equilateral triangular cross-section. Further on in the downward progress of the filaments under the controlled condition of drafting and drying they have changed to the desired Y-cross section filaments 25Y which are depicted greatly magnified in FIGURE 4.

Our process for producing uniform Y-shaped cross-section filaments is described in further detail in the following examples.

EXAMPLE 1

A spinning solution consisting of 26.5% cellulose acetate, 1.25% titanium dioxide, based on the weight of the cellulose acetate, 1.75% water and the remainder being the solvent, acetone was spun into Y-shaped cross-section filaments of 55 denier using the apparatus and its general operation as described above in connection with FIGURE 1. The spinnerette had 13 equilateral triangular orifices therein. The conditions of operation are shown in Table I where they are identified as No. 1.

No.	Denier per strand	Number of filaments per strand	Extrusion speed, meter/min.	Candle filter temp., °C.	Extrusion temp., °C.	Top air flow, cfm.	Bottom air flow, cfm.	Top air inlet temp., °C.	Bottom air inlet temp., °C.	Spinnerette orifice	Draft
1	55	13	500	65	62	500	500	70	85	0.067	1.10
2	75	19	500	62	62	500	500	70	85	0.067	1.10
3	150	38	500	65	61	800	800	70	85	0.067	1.10
4	150	7	211	65	-----	500	500	60	90	0.155	1.22
5	55	36	500	58	-----	500	500	60	85	0.047	1.43
6	75	49	500	58	-----	500	500	60	85	0.047	1.43
7	300	7	100	65	-----	1,500	1,500	60	90	0.220	1.08

In this table the air flow in cubic feet per minute is calculated for one hundred spinning cabinets. The figures under the spinnerette orifice column represent one side of the equilateral triangle. The extrusion speed in meters per minute represents the rate at which the spinning solution is forced out of the spinnerette. This, in co-operation with the draft rate enables the filaments to change from the initial triangular cross-section to the Y-shaped cross-section while properly drying.

Draft may be defined rather broadly as the ratio of the linear velocity of wind-up of the filaments to the linear velocity of extrusion of the spinning solution. More specifically, draft may be defined as the ratio of the linear velocity at which the filaments are wound onto and off the godet roll of a dry spinning cabinet to the calculated average linear velocity at which the quantity of spinning solution necessary to the formation of any one of the plurality of filaments comprising the bundle of filaments wound onto and off the godet roll is extruded through any one of the plurality of orifices in the spinnerette employed in the spinning operation, the velocities being expressed in the same units of distance per unit time. For example, if the filaments are wound up at the godet roll at the same linear velocity that the spinning solution is extruded from the spinnerette, the draft is 1.0 thus signifying that the linear speed of wind-up is 100% of the extrusion speed. Similarly, if the filaments are wound up or withdrawn from the cabinet at the godet roll at a linear speed 50% greater than the speed of extrusion, the draft is 1.5 and so on.

Other columns of Table I are more or less self-explanatory

6

when considered in connection with FIGURE 1 of the drawings and the related description. Temperatures in the drying cabinets averaging from 40 to 90° C. are usable.

EXAMPLE 2

The cellulose acetate spinning solution of Example 1 was spun into Y-shaped cross-section filaments of 75 denier per strand using the apparatus and its general operation as previously described. The spinnerette had 19 equilateral triangular orifices. The conditions of operation are shown in Table I where they are identified as No. 2.

EXAMPLE 3

The cellulose acetate spinning solution of Example 1 was spun into Y-shaped cross-section filaments of 150 denier per strand. The spinnerette had 38 equilateral triangular orifices. The above described spinning equipment was used with the operating conditions shown as No. 3 in Table I.

EXAMPLE 4

A different spinning solution consisting of 30.0% cellulose acetate, 1.75% water and the remainder being acetone solvent was spun into Y-shaped cross-section filaments of 150 denier per strand. The spinnerette had 7 equilateral triangular orifices. The above-described spinning equipment was used with the operating conditions shown as No. 4 in Table I.

Table I

EXAMPLE 5

Another spinning solution consisting of 26.5% cellulose acetate, 0.6% titanium dioxide pigment, based on the weight of the cellulose acetate, 1.75% water and the remainder being acetone solvent was spun into Y-shaped cross-section filaments of 55 denier per strand. The same spinning equipment was employed with the operating conditions shown as No. 5 in Table I.

EXAMPLE 6

A spinning solution of the composition shown in Example 5 was spun into Y-shaped cross-section filaments of 75 denier per strand. The same spinning equipment was employed with the operating conditions shown as No. 6 in Table I.

EXAMPLE 7

A spinning solution consisting of 26.5% cellulose acetate, 1.75% water, the remainder being acetone was spun into Y-shaped cross-section filaments of 300 denier per strand. The spinning equipment herein described was employed using a spinnerette having 7 equilateral triangular orifices. Conditions of operation are shown as No. 7 in Table I.

We have found that satisfactory Y-shaped cross-section filaments can be prepared under a satisfactory range of spinning and solution conditions. A primary requisite for optimum Y-shaped cross-section yarn is that the spinning draft should be above 1.0 and preferably above 1.2. However, somewhat deformed Y-shaped cross-section filaments may be obtained using spinning drafts of 0.7

to 1.0. But as indicated above, for purposes of attaining uniformity of cross-section a draft above 1.0 is preferable.

The temperatures listed in Table I are temperatures employed to produce a quality product with a particular cellulose ester-acetone solution. These temperatures may vary somewhat. Changes in cellulose ester composition or changes in cellulose ester to acetone ratios may require some changes in these temperatures.

We have also found that our spinning process employing spinnerettes having equilateral triangular orifices operates very well over a range of deniers per filament of 1.5 to 43, although higher denier filaments can be satisfactorily made by our invention.

That the bulk of the Y-shaped cross-section fiber, because of its increased surface area, is greater than the clover-leaf or regular cross-section fiber of equivalent denier is shown clearly in the following Table II where comparisons of equivalent samples of regular and Y-shaped cross-section yarn made from the same spinning compositions are set forth.

Table II
BULK TESTS ON REGULAR AND Y SECTION
CONTINUOUS FILAMENT YARNS

Yarn	Bulk factor	Specific volume, cu. in./lb.	Percent difference
Regular 55/13/3.....	163.7	34.5	30.5
Y 55/13/3.....	214.1	45.1	
Regular 55/36/3.....	155.2	23.7	37.3
Y 55/36/3.....	214.0	44.9	
Regular 75/19/3.....	164.9	34.7	30.3
Y 75/19/3.....	213.8	45.2	
Regular 75/49/3.....	158.0	33.3	29.6
Y 75/49/3.....	205.5	43.2	
Regular 150/7/3.....	149.5	31.5	41.0
Y 150/7/3.....	210.5	44.4	
Regular 150/33/3.....	154.1	32.4	36.8
Y 150/33/3.....	210.4	44.3	
Regular 300/7/3.....	158.0	33.2	33.4
Y 300/7/3.....	211.0	44.3	

In Table II the numerical expressions 55/13/3 and the like represent continuous filament yarn in terms of total denier, filament count, and twist. For example, 55/13/3 designates a continuous filament yarn having a total denier of 55 made up of 13 filaments and having 0.3 turn per inch of twist. The denier per filament of such a yarn is the total denier divided by the number of filaments. In this example 55 divided by 13 equals approximately 4 denier per filament.

The data in Table II are determined by a test which we have developed in which yarn is wound under a specified tension until it fills a spool of a known volume. The amount of yarn required to fill this volume is weighed. From this weight the "Bulk Factor" and "Specific Volume" are calculated. The "Bulk Factor" is calculated by the following formula:

$$(\text{Volume of spool} \times \text{density of fibers} + \text{weight of yarn to fill spool}) \times 100 = \text{bulk factor}$$

This formula expresses the bulk as a percentage ratio of the space occupied by the yarn to the space which would be occupied by solid material from which the yarn is made.

The "Specific Volume" is determined by converting the weight of yarn on the spool to cubic inches per pound.

The column shown as "Percent Difference" expresses as a percentage, the percentage difference between the bulk factor, or the specific volume, in the regular and Y-shaped cross-section yarn. It will be noted that in continuous filament yarn the Y-shaped cross-section yarn has from 29.6 to 41.0% more bulk than regular yarn. This difference can be seen visually when comparing the skeins from which these data were obtained.

Similar data are shown in Table III relative to staple fiber yarn made from regular and Y-shaped cross-section fibers of the same cellulose ester composition.

Table III

BULK TESTS ON REGULAR
AND Y SECTION STAPLE FIBERS

Yarn	Bulk factor	Specific Volume, cu. in./lb.	Percent difference
Regular 20/1, 2 D/F, 2".....	282.0	59.2	33.3
Y 20/1, 2 D/F, 2".....	389.0	81.9	
Regular 20/1, 3 D/F, 2".....	262.0	55.2	54.2
Y 20/1, 3 D/F, 2".....	405.0	85.0	
Regular 12/1, 5 D/F, 2".....	267.5	56.3	37.4
Y 12/1, 5 D/F, 2".....	368.0	77.4	

In Table III the staple fiber yarns are designated by their cotton count and their ply. For example, 20/1 designates a staple fiber yarn made up of a single end, which is 20s cotton count. This table also shows the denier per filament (2 d./f.) etc. and the staple length of the fibers (2") etc., from which the staple yarns are spun. The bulk factor and specific volume are determined as described above in connection with Table II. It will be evident that with samples of yarn of the same composition, denier and length and varying only in cross-section, i.e. between regular and Y section, that the Y section staple has from 37.4 to 54.2 more bulk.

The luster of the Y-shaped cross-section yarn is appreciably greater than that of the regular or clover-leaf cross-section of equivalent denier and composition. Luster is measured by means of a photo-electric cell. The filaments are wound in a parallel manner around a flat piece of cardboard or other similar flat surface. Light reflected off these panels to the photoelectric cell imparts a potential which is translated into a numerical luster level. On comparative tests the clover-leaf panel of filaments record 0.77 volt whereas the Y-shaped cross-section filaments of the same denier record 0.83 volt.

EXAMPLE 8

Staple fibers made from Y-shaped cross-section cellulose acetate yarn were employed as a filling material in a pillow. Because of their bulk they were found to be satisfactory for this purpose. A similar sized pillow containing the same weight of cellulose acetate staple fibers of equivalent denier of regular cross-section evidenced less bulk and did not resist matting under pressure.

EXAMPLE 9

Cigarette filters were prepared from Y-shaped cross-section cellulose acetate fibers. Their interesting bulk and stiffness properties permit the construction of filters of interesting design.

EXAMPLE 10

Rugs were prepared from Y-shaped cross-section cellulose acetate fibers alone and with other cellulose acetate fibers, rayon, nylon, wool, etc. The bulk and stiffness properties of the Y-shaped fibers permit the construction of rugs of improved design.

The operation of our process is now described in connection with the production of less uniform Y-shaped cross-section filaments through spinnerettes having triangular orifices other than equilateral.

A spinning solution of the composition described in Example 1 was spun through the individual spinnerettes which have triangular orifices other than equilateral as shown in FIGURES 6, 8, 10, 12 and 14, each of which was installed in a separate spinning cabinet like that shown in FIGURE 1. The cross-section of the filaments thus produced are shown respectively in FIGURES 7, 9, 11, 13 and 15.

The cross-section of the filament shown in FIG. 7 is of a modified Y-shape having substantially no center leg. Contrasted to this cross-section that of FIG. 9 has a long center leg which is a little more than twice the length of the other two legs which are of similar size. The cross-section of the filament of FIG. 11 is somewhat intermedi-

ate between those of FIGS. 7 and 9 and may be described as of a Y-shape having a center leg somewhat longer than the other two legs which are symmetrical. The angle between the other two legs is greater than in the case of the cross-section shown in FIG. 9. The cross-section of FIG. 13 is somewhat like that of FIG. 7 except that the center leg is now half as long as the other two symmetrical legs. In FIG. 15 the cross-section of the filament approaches that of a true Y-cross-section in that the center leg is about the length and size of the other two legs but the angles between the legs are not quite equal.

The spinning conditions and the characteristics of the resulting fibers are tabulated in Table IV where they are compared to fibers spun through spinnerettes having the equilateral triangle orifices. The increase in bulk of the fibers spun through these modified triangular orifices over the prior art fibers shown in FIGURE 5, as well as the variance in bulk between the fibers produced from the various triangular orifices is also apparent in Table IV.

While these yarns were spun as 150 denier, 7 filament, 20 d./f. they can be prepared as both filament and staple yarns in all standard deniers and filament counts.

Yarn was spun from each of the odd triangular-shaped orifices at both 65° and 70° C. candle filter temperatures. At this particular spinning draft 1.25, these yarns would not spin when a candle filter temperature above 70° C. was employed. The data show that slightly increased stretch values were obtained by employing the 70° C. extrusion temperature. Data also show that yarns obtained from the odd triangular orifices have less strength than those of uniform Y-shaped cross-section obtained from the equilateral triangular orifices. Percent stretch for Nos. 50750 and 70753 yarns which have cross-sections very similar to the uniform Y-shaped cross-sections yarn was about the same as the latter, while stretch for the other types of cross-section is about 3% lower.

Although each of the yarns shown in Table IV showed an increase in bulk over the regular cross-section, none showed an improvement in bulk over the uniform Y-shaped cross-section yarn. Values, however, for Nos. 50750 and 50753 were comparable therewith.

Each yarn shown in Table IV was woven as filling yarn for preparing a small satin fabric. The yarn spun from the 120°, 30°, 30° triangle showed a slight scintillating effect. The other types of yarn displayed about the same fabric appearance as that made when employing a spinnerette having the equilateral triangle orifices.

section filaments through spinnerettes having modified equilateral triangular orifices.

The cellulose acetate spinning solution of the compositions described in Example 1 was spun through the spinnerettes which have the modified triangular orifices shown in FIGURES 16, 18, 20 and 22, each of which was installed in a separate spinning cabinet of the type shown in FIGURE 1. The cross-sections of the filaments thus produced are shown respectively in FIGURES 17, 19, 21 and 23. In FIGURES 17 and 19 the cross-sections nearly resemble one another. In FIGURE 19 the Y has bulbs on the ends of the legs of the Y. In FIGURE 23 the Y has approached clover-leaf cross-section and the filament has lost some of the physical characteristics of the true Y section.

The spinning conditions and the characteristics of the resulting fibers are tabulated in Table V where they are compared to fibers spun through the equilateral triangle orifices as well as the regular fibers of the type shown in FIGURE 5.

The fraction X shown in connection with FIGURES 16, 18, 20 and 22, i.e. $\frac{1}{6}$, $\frac{1}{5}$, $\frac{1}{4}$ and $\frac{1}{3}$, refers to the length of the sides of the equilateral triangle which is removed from each apex of the triangle in rounding off the apices of the triangle.

We have found that the rounding of the corners of the triangular orifice causes the ends of the Y-shaped filament to become rounded and this effect becomes greater as more of the corner is removed. As the orifice shape becomes nearly circular, the yarn cross-sections and resemble in appearance the regular cross-section shown in FIGURE 5. The yarns show small increases in strength and stretch as the ends of the Y become more rounded and the shear strength appears to improve slightly according to the twistability and Walker abrasion tests. It appears that these changes in Y-shaped cross-section from the more perfect Y-shaped cross-section give not only a slight improvement in strength and stretch but a reduction in waste and ply in staple processing. The gain in this respect is obtained at the expense of lessening the bulk as is apparent in Table V. It is also apparent that control of the bulk of this modified Y-shaped cross-section yarn can be achieved by employing the modified spinnerette orifices shown in FIGURES 16, 18, 20 and 22. The change in bulk is explained by reference to FIG-

Table IV

PHYSICAL PROPERTIES OF YARNS SPUN FROM VARIOUS TYPES OF TRIANGULAR HOLE SPINNERETTES

No.	50741	50741	50744	50744	50747	50747	50750	50750	50753	50753	51214
Candle filter temp., ° C.	65	70	65	70	65	70	65	70	65	70	65
Jet:											
Number holes	(1) 7	(1) 7	(1) 7	(1) 7	(1) 7	(1) 7	(1) 7	(1) 7	(1) 7	(1) 7	(2) 7
Hole type	.110	.110	.110	.110	.110	.110	.110	.110	.110	.110	.115
Equiv. diameter	120-30-30	120-30-30	24-78-78	24-78-78	78-60-42	78-60-42	84-48-48	84-48-48	48-66-66	48-66-66	60-60-60
Degrees in angles	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.32
Spin. draft	300	300	300	300	300	300	300	300	300	300	300
Spin. speed, meters/min.	85	85	85	85	85	85	85	85	85	85	85
Bottom air temp., ° C.	151	149	148	148	150	147	151	151	149	150	144
Denier	1.10	1.09	1.02	1.02	1.13	1.14	1.11	1.11	1.10	1.13	1.20
Dry, g./d.	33.0	34.0	30.0	30.4	33.0	36.4	36.0	36.2	35.5	37.0	36.8
Dry, percent stretch	0.62	62	0.68	.57	0.61	0.64	.63	.63	.63	0.65	.63
Wet, g./d.	43.0	45.0	39.4	40.2	42.5	45.9	45.7	48.2	46.0	48.5	45.6
Wet, percent stretch	1.30	1.35	1.25	1.20	1.27	1.27	1.28	1.27	1.27	1.26	-----
IPS, g./d.	30.0	30.5	28.0	28.0	30.0	31.8	29.7	34.0	31.0	33.2	-----
IPS, percent stretch	77	77	77	77	77	78	76	76	77	78	75
Luster	178.06	-----	184.53	-----	186.63	-----	192.66	-----	196.78	-----	196.70
Bulk factor	37.395	-----	38.75	-----	39.195	-----	40.40	-----	41.328	-----	41.30
Specific volume, cu. in./lb.	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Bulk increase over regular cross-section approx., percent	20	-----	25	-----	26	-----	30	-----	33	-----	33

1 Odd triangular.

2 Equilateral triangular.

The operation of our process is now described in connection with the production of modified Y-shaped cross-

FIGURES 17, 19, 21 and 23 which show the legs of the Y in various angular relations and of different shape.

No.	50045	50047	50048	50049	50050
Cross-section	Reg.	Y	$\frac{1}{2}$ X	$\frac{1}{2}$ X	$\frac{1}{2}$ X
Denier/filaments	150	150	150	150	150
Jet size	7.10	7.155 Δ	7.161 Δ	7.164 Δ	7.169 Δ
Spin speed	300	300	300	300	300
Bottom air temp.	85	85	85	85	85
Candle filter temp.	65	65	65	65	65
Draft	1.0	1.0	1.0	1.0	1.0
Denier	148	148	148	147	146
Elongation, percent stretch:					
Suter wet	46.6	45.6	47.0	47.7	48.2
Suter dry	37.3	36.8	38.0	39.0	38.7
Suter loop	11.8	3.5	5.0	4.1	4.7
Suter knot	18.4	14.1	15.5	17.9	16.2
Strength, g./d.:					
Suter wet	.63	.63	.63	.64	.63
Suter dry	1.19	1.20	1.19	1.19	1.20
Suter loop	.80	.61	.64	.62	.67
Suter knot	1.0	.73	.77	.77	.93
Walker abrasion	26	1	2	2.5	3.3
Twistability	42.5	37.6	38.2	40.6	41.2
Bulk increase, percent	0	32.0	24.0	22.6	19.0

While particular emphasis has been made to employing cellulose acetate spinning solutions, our process will also operate satisfactorily with other single and mixed organic acid esters such as those containing 2 to 4 carbon atoms.

We have noted that yarns composed of Y-shaped cross-section and modified Y-shaped cross-section filaments are much stiffer and more resilient than yarns having normal or cloverleaf cross-sections. The effect on stiffness of cross-sectional shape can be estimated by comparing moments of inertia of fibers having different shapes but the same cross-sectional area. By this method we have determined that Y-shaped cross-section filaments are approximately 60% stiffer than regular filaments of equal size. Furthermore, we have found that when a plurality of Y-shaped cross-section filaments are collected in a bundle as in a yarn strand or in a batting, a greatly increased resilience or stiffness is noted which is more than would be expected from the increase in stiffness of individual fibers. We attribute this effect to the interlocking or tongue and groove mingling of the legs of the Y-shaped cross-section filaments making up the mass of fibers. This interlocking of fibers causes much greater resistance to interfiber slippage than can be obtained in a bundle of normal filaments. Thus the aggregate stiffness of a bundle of Y-shaped cross-section filaments is much greater than the sum of the stiffnesses of the individual fibers.

The inherent properties of cellulose acetate fibers of the Y-shaped cross-section described herein are such that they offer numerous desirable properties in both woven and knitted fabrics. In such fabrics as ninons, marquisesettes, and voiles, the Y-shaped cross-section fibers produce fabrics having desirable crispness and stiffness which are usually obtained only by special processing techniques or by special finishing. In flat fabrics, such as taffetas, twills and satins, the increased bulk of the Y-shaped cross-section fibers produce fabrics having greater cover and thickness for a given weight of material. On the other hand there is the possibility of using less material to produce fabrics of the same cover and thickness thereby decreasing the cost. Yarns having a Y-shaped cross-section produce fabrics with less tendency for the yarns to slip resulting in higher seam strength. This characteristic is particularly important in certain fabrics, for example, satins and twills. Loom finished taffetas have a crisper feel when made from Y-shaped cross-section yarns.

Knitted fabrics from yarns with Y-shaped cross-sections exhibit increased body and hand which make them more desirable for certain uses such as sport shirts, men's ties, and dress goods. Yarns spun from staple fiber of Y-shaped cross-section exhibit increase in bulk and stiffness as do the filament yarns. In addition, fabrics from these yarns have a wool-like feel or hand. In all of the fabrics which have been produced from cellulose acetate fibers of the Y-shaped cross-section fabric properties have been obtained which are desirable and which are not obtained in cellulose acetate fibers of regular cross-section.

Cigarette filters were made from the yarn produced through each of the above-described spinnerette orifices.

While the filaments produced from the various spinnerette orifices vary in cross-section, the individual filaments from a single spinnerette all have substantially the same cross-section. The angles between the legs of the Y will be consistently the same or consistently different depending on the particular spinnerette employed.

This is a continuation-in-part of our copending application Serial No. 476,142 filed December 20, 1954, and entitled "Process and Apparatus for Spinning Synthetic Filaments and Fibers of Increased Bulk and Stiffness and Products Produced Therefrom."

We claim:

1. A spinnerette having filament forming orifices in the form of equilateral triangles whose apices have been rounded off to arcs of equal radii.

2. A spinnerette having filament forming orifices in the form of equilateral triangles whose apices have been rounded off to arcs having a common center.

3. A spinnerette having filament forming orifices in the form of equilateral triangles whose apices have been rounded off to arcs of equal radii and whose sides have been thus reduced to $\frac{1}{2}$ of their length.

4. A spinnerette having filament forming orifices in the form of equilateral triangles whose apices have been rounded off to arcs of equal radii and whose sides have been thus reduced to $\frac{1}{2}$ of their length.

5. A spinnerette having filament forming orifices in the form of equilateral triangles whose apices have been rounded off to arcs of equal radii and whose sides have been thus reduced to $\frac{2}{3}$ of their length.

6. A spinnerette having filament forming orifices in the form of equilateral triangles whose apices have been rounded off to arcs of equal radii and whose sides have been thus reduced to $\frac{2}{3}$ of their length.

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