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YARN TREATMENT

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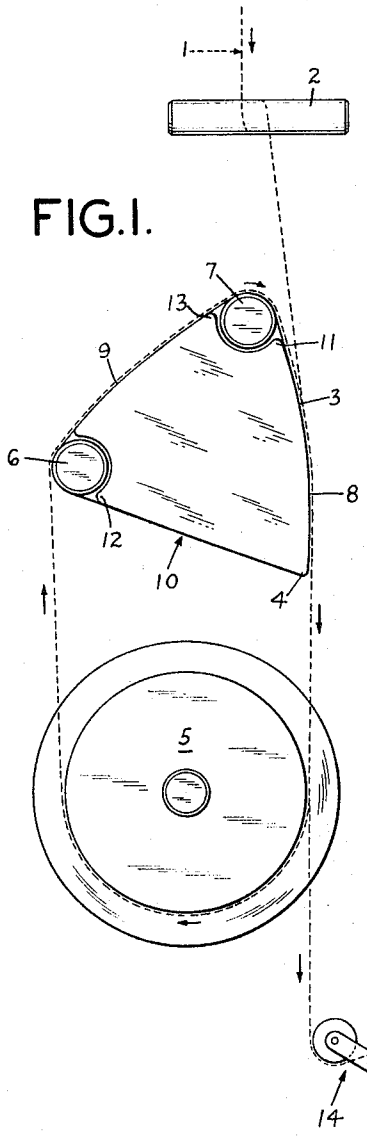

FIG. 1.

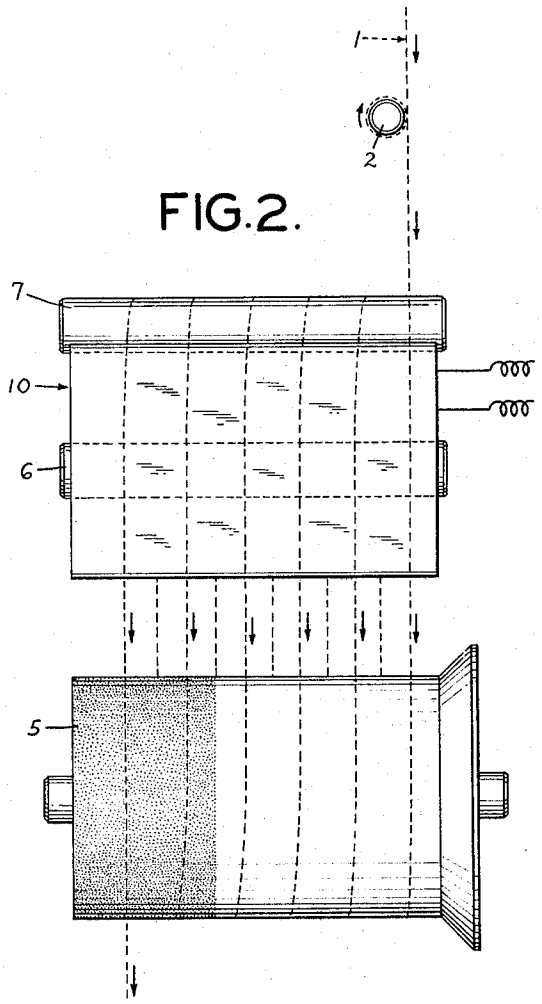

FIG. 2.

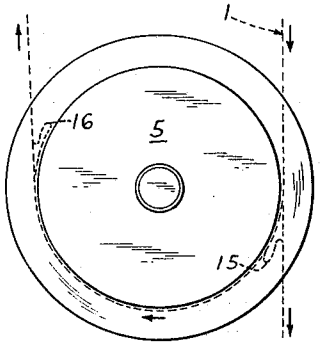

FIG. 3.

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YARN TREATMENT

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3 Claims. (Cl. 28—72)

This invention relates to heat treatment, especially heat treatment at controlled length and preferably including at least partial hot drawing, of molecularly oriented multifilament thermoplastic yarn especially nylon yarn such as polycaproamide yarn and polyhexamethylene adipamide yarn; which yarn is taken up from said heat treatment at high speed of at least 1500 feet per minute, e.g., in a parallel wound package, i.e., in concentric cylindrical layers upon a cylindrical tube.

The take-up of heat treated yarn in a parallel package should be effected at low winding tension of about 0.05–0.25 gram/denier for two reasons. One is that tension introduced during winding becomes a source of increasing pressure upon underlying layers of the yarn in a parallel package resulting in uneven tensions on the yarn in the package and consequent non-uniformity of the yarn. Moreover tension imposed on the yarn near the end of the heat treatment adversely affects certain yarn properties imparted by the heat treatment; e.g., an increase of 0.1 gram/denier winding tension produces in polycaproamide yarn a 1% increase in the shrinkage of the heat treated yarn upon exposure of the yarn to boiling water. Moreover, if such tensions be imposed in a non-uniform manner, the result is non-uniform yarn.

An effective method of heat treating molecularly oriented thermoplastic yarns at controlled length is disclosed in Winckhofer U.S.P. 2,859,472, of November 11, 1958, whereby heat shrinkage and creep of the yarn are reduced. The method involves passing the yarn in a series of wraps around the draw roll and a separator roll as the yarn advances from the draw zone in which molecular orientation is imparted; contacting the wraps as they pass between the rolls with curved heated surfaces; and passing at least the last partial yarn wrap around a sand-blasted or like coarse surface of the draw roll before winding. The sand-blasted surface provides low adhesion with the yarn as it passes to wind-up and allows winding at generally low tension.

We have now found that, particularly when operating at high speeds of wind-up such as 1500 f.p.m. (feet per minute) and higher, difficulties are encountered in this Winckhofer process, which can be overcome by the special operations detailed below which form the subject matter of this invention. The high speed of wind-up requires correspondingly high speed rotation of the above mentioned draw roll; and this speed tends to hold the yarn, when the yarn leaving the draw roll is as low tension, in a loop adhering to the roll. The action is known as "lick-back," and is undesirable because likely to cause jerks on the yarn and indeed interference between successive wraps, with resulting filament or yarn breaks. For overcoming lick-back more tension on the advancing yarn is needed; but an increase in this tension

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by increasing the take-up tension is not desired for the reasons above indicated.

Hence it is clear that low adhesion is needed between the draw roll surface and the yarn leaving the draw roll, as is provided by a matte surface such as a sand-blasted or otherwise coarsened surface at the take-off end of the draw roll.

We have found, however, that at high winding speed and low take-up tension, lick-back tends to occur in earlier wraps as well as in the wrap which is leaving the draw roll; and this, we believe, is connected with tension drop in the earlier wrap because of friction between the succeeding wraps and the heater. The low tension being transmitted back from the wind-up device then becomes momentarily insufficient to pull this earlier wrap off the draw roll and around the heater. Lick-back occurs while tension is building up in the particular wrap, meaning that tensions are non-uniform and filament damage may occur.

In accordance with our invention we provide low winding tension and uniform tension on the yarn being treated and at the same time we assure sufficient tension being transmitted back from the wind-up to avoid lick-back. Our process achieves heat treatment at controlled length of a molecularly oriented multifilament thermoplastic heat shrinkable yarn which is wound up at high speed.

The yarn, at length controlled by passing the yarn in multiple wraps around a draw roll and associated separator roll, is contacted with curved heated surfaces mounted between the draw roll and separator roll to contact both segments of the yarn wraps as they pass between the rolls. At least one full wrap of the yarn around the draw roll contacts this roll upon a polished surface thereof and at least the last full wrap of the yarn around the draw roll contacts this roll upon a matte surface at the take-off end of the draw roll.

More particularly our process comprises maintaining a coefficient of friction of the yarn with each of the curved heated surfaces of not above about 0.1; bringing each full wrap of the yarn into contact with each of the curved heated surfaces on an arc of about 5° to about 25° and making an angle of no more than about 10° as the yarn wraps go over an edge of the curved surface when they enter upon and when they leave said curved surfaces. In addition to the separator roll, the yarn wraps contact no more than one further idler roll, in particular a guide roll taking the wraps from the draw roll to the adjoining curved heated surface; and the wraps contact each idler roll in an arc of at least 10°. The idler rolls are provided with matte surfaces which develop coefficient of friction not above about 0.1 with the yarn.

By limiting the number of idler rolls to not above two and by providing the curved heated surfaces with a matte finish, the yarn lubricated with conventional lubricant and passing about the heater and idler rolls will develop a frictional drag not greater than about 0.1 gram per denier, as is required in our process.

The yarn after passage as described around the draw roll, heater and separator roll is wound at low tension between about 0.05 and about 0.25 gram per denier at a speed of at least 1500 feet per minute.

As is known, thermoplastic yarns can be molecularly oriented by a process known as drawing, whereby the yarn first formed is subjected to tension sufficient to impart permanent elongation to the yarn and develops molecular orientation along the filament axis as indicated by X-ray examination. The manner of drawing influences the yarn properties so that it is important to draw in an effective manner and also in a highly uniform manner. Known devices for aiding the drawing process are draw pins about which the yarn is snubbed and heated surfaces with which the yarn is contacted and drawn during the contact. For yarns which are required to have very good uniformity we have found it is advantageous to utilize our above-described heater as an aid to the drawing process by passing the yarn, incompletely drawn, in contact with one of the curved heated surfaces of the heater hereinafter referred to as the "primary" surface, before the yarn contacts the draw roll. The yarn is drawn on said primary surface by at least 3% of its undrawn length and contacts said surface over an arc of at least 5° but not more than about 20°. The alignment between the threadlines of the incoming yarn and the primary surface of the heater define the angle between this incoming yarn threadline and the threadline of the wraps passing from the separator roll to the primary heated surface. The angle between these threadlines resulting from the alignment above described will be sufficient for the incoming threadline to clear the separator roll and not more than about 20°. A triangular heater positioned to bring these threadlines to such angle of not more than 20° is hereinafter described as "aligned." In preferred operations wherein the heater is aligned as above described, the yarn leaving the heater passes once more into contact with the matte surface of the draw roll, forming a partial wrap thereon, and thence passes directly in a straight line to a point of tension control where substantially constant tension for winding is maintained.

As above pointed out, the yarn during heat treatment by our process is maintained at controlled length by passing it in wraps around the draw roll and separator roll and over the heater positioned between them. This controlled length in general will be maintained within 10% of the length characterizing the yarn as it first passes around the draw roll. If a controlled contraction of length is desired during the heat treatment, the draw roll can be made to taper continuously down in diameter or can be angled toward the separator roll, or can be stepped down in diameter; and similarly if it is desired to further stretch the yarn during heat treatment, the draw roll can be given an appropriate increasing diameter, or angled away from the separator. We find, however, that substantial changes in yarn length are not usually required to obtain the benefits of our process and accordingly in our process the yarn after contacting the draw roll is normally maintained at substantially constant length.

Our process can be carried out on an apparatus comprising a heater approximately triangular in cross section and a draw roll, the heater being provided along one edge with an idler roll to serve as separator roll for yarn wraps around the heater and draw roll; and being provided along a second edge with a second idler roll serving to guide yarn wraps from the draw roll to the heater. The two sides of the triangular heater are outwardly arched heating surfaces; the base will face the draw roll. Such heater is designated a "2-roll heater" herein. Its "primary" heated surface will be brought into alignment with the draw roll so that a yarn wrap passing around the draw roll and the separator roll will make no more than about a 10° angle in advancing over the edge of this surface from the separator roll, and in leaving over the edge of this surface toward the draw roll; and its two heated surfaces will each be intersected to define arcs of about 5°–25° by the common tangents between the separator roll and the draw roll or guide roll respectively.

The drawing illustrates schematically in elevation the process of this invention and apparatus suitable for carrying out the invention, wherein FIGURE 1 is a front view; FIGURE 2 is a side view; and FIGURE 3 is a fragmentary view at draw roll **5** of FIGURE 1 illustrating the phenomenon of "lick-back."

Referring to the drawing, numeral **1** designates undrawn yarn advancing from hold back rolls or the like, not shown. Numeral **2** designates a draw pin around which the yarn is snubbed to create sufficient frictional drag to counteract the tension imposed by draw roll **5**, thus causing drawing at or past the pin **2**. The advancing yarn passes clear of the separator roll **7** and edge **11** of heater **10**, and contacts the primary heated surface **8** at a point **3**, making contact with heated surface **8** over an arc of about 5°–20°. The angle made by this incoming threadline with the threadline **10** of the wraps passing from the separator roll **7** to surface **8** will be not over about 20°.

The yarn passing from edge **4** of the primary heated surface **8** contacts a polished surface of draw roll **5**; then passes in a wrap around idler guide roll **6**, over edge **12** of secondary heated surface **9**, across surface **9**, over edge **13** of surface **9** to separator roll **7**, and back to primary heated surface **8**. The heated surfaces **8** and **9** are each contacted by the yarn wraps over an arc of about 5° to about 25° thus assuring adequate contact of the yarn with the heated surface and at the same time allowing low frictional drag over the heated surface.

In passing over each of the edges **4**, **12**, **13** and **11** of the heater, the yarn wraps make no more than about a 10° angle. This limitation contributes to maintaining the required low frictional drag of not above about 0.1 gram per denier around the heater as above specified and also, we have found, contributes to the uniformity of results obtained in our process. We have observed that there is a tendency for the matte surface of the heater to be worn smooth wherever the yarn in passing over an edge of the heater makes an angle sharper than about 10°. Such wear creates a point of frictional drag which has an appreciable effect on yarn properties leading to nonuniformities in the properties such as dye take-up of the resulting yarn, as measured upon samples from an entire package.

In FIG. 3, small loops of yarn are indicated at **15** and **16**. These illustrate incipient lick-back as it develops when the conditions of our process are not maintained. It will be understood that this lick-back is largely or completely avoided when the conditions of our process are maintained.

At least the last full wrap of yarn around draw roll **5** contacts a matte take-off surface of the draw roll; and when the incoming yarn contacts the primary heated surface **8** as shown in the drawing, a further partial wrap will also contact the matte surface of draw roll **5**. The yarn will then leave the draw roll as indicated by threadline **1** and will preferably pass directly to a point of tension control generally indicated at **14** in the drawing. The yarn tension will be controlled at this point **14** to effect winding at constant tension with conventional winding apparatus such as a parallel winding apparatus or a ring and traveller.

A very important feature of this invention is maintaining low yarn-to-heater surface frictional drag. The frictional drag is determined by wrapping the yarn around the triangular heater-draw roll assembly in four wraps with hard bond finish paper around the draw roll whereby its coefficient of friction with the yarn is negligible; then determining to ±1 gram the weight in grams which is required to start and keep moving a strand of 200 denier, 16-filament yarn.

The results of typical measurements are shown in Table I, compared to results of measurements using a

similar triangular heater symmetrically positioned between the rolls and having no idler guide roll.

TABLE I

	Symmetrically Positioned Triangular Heater	2-Roll Heater Aligned per This Invention
Starting frictional drag, grams	71	11
Frictional drag, grams per denier	0.35	.055
Running frictional drag, grams	64	9
Running frictional drag, grams per denier	0.32	.045

From Table I data, it can be seen that there was about a 6-fold reduction in the frictional drag developed using the 2-roll heater aligned per the invention as compared with the symmetrically positioned triangular heater. Similar tests have shown that using a heater with 2 guide rolls and a separator roll develops at least 50% more drag than the above aligned 2-roll heater of the invention, evidently because the drag arises chiefly from the force required to maintain rotation of the idler rolls.

Frictional drag around the heater results in a drop in tension from one yarn wrap to the preceding. Accordingly it becomes more difficult to maintain low take-up tension without encountering "lick-back" due to too low tension on the advancing yarn, we believe. Such lick-back, as previously noted, increases the probability for breaks and wraps and results in a very substantial decrease in the productivity of full 8-pound packages of zero wrap and zero break yarn. On the other hand if the yarn tension is maintained to avoid lick-back, the reduction of shrinkage by the heat treatment may be impaired. These various effects are more specifically illustrated in Table II and in conjunction with Example 1 below.

TABLE II

	Symmetrically Positioned Triangular Heater	2-Roll Heater Aligned per This Invention
Completed packages, percent	86	94
Breaks per pound	.044	.022
Full packages as "no break, no wrap" yarn, percent	45	60

From Table II, it can be seen that by the invention, a significant improvement in percent of packages completed was obtained. A decrease to ½ the number of breaks per pound was obtained; and a 35% increase in full packages of "no break, no wrap" yarn was obtained over that obtained with the symmetrically positioned triangular heater. The results of the above Table II can be better appreciated when it is recognized that the packages concerned contain a minimum of 5 pounds of yarn, which at 200 denier amounts to over 60 miles of yarn per package.

To obtain the above discussed low frictional drag and to avoid lick-back on any of the rolls, the heated surfaces, the separator roll surface, the guide roll surface, and the take-off end of the draw roll surface are all coarsened, e.g., by blasting with fine abrasive to create matte surfaces having coefficient of friction, a, no greater than about 0.1 where a is defined by the equation:

$$1n(T_1/T_2)=a\Theta$$

T_1 and T_2 being respectively tension applied and tension transmitted around yarn wraps on the surface tested; and Θ being the arc of contact of the test yarn with the surface (in radians).

It is important that the yarn being treated by our invention should contact each idler roll in a peripheral arc of at least 10° to assure uniform turning of the idler roll. With lighter yarns than 200 denier, for example 40 denier yarn, the peripheral arc of contact between the yarn and each idler roll should preferably be at least 30°.

The draw roll surface, other than the take-off end, will be a polished surface with which the yarn makes good frictional contact so as to apply tension to draw and advance the yarn.

The yarn itself will usually be lubricated as is conventional during yarn treating operations, e.g., with a mineral oil/antistatic agent composition.

Yarns to which this invention is applicable are the thermoplastic, heat shrinkable yarns such as those from linear polyamides, e.g., polyhexamethylene adipamide and polycaproamide; linear polyester, e.g., polyethylene terephthalate; and polyolefins, e.g., propylene.

Preferred ranges of operating conditions are pointed out below which are especially applicable to polycaproamide yarns; however, the relationships between preferred ranges, illustrated below, will apply in general to all thermoplastic, heat shrinkable yarns.

The number of wraps encircling the draw roll and the triangular heater establishes, together with the linear yarn speed, the residence time for the yarn to be heat treated. This may vary from two to twenty wraps, and more preferably, is in the range of three to ten wraps. Using our heater with low friction matte surface we find the frictional drag of the yarn passing around the heater is at most only slightly increased as the number of wraps around the heater increases. The residence time thus provided for the yarn in contact with the heater surface of the triangular heater is generally between 0.04 and 1 second, particularly about 0.1–0.5 second for polycaproamide yarns. At yarn residence times of about 0.35 second and longer, comparatively little change in yarn shrinkage is effected for a substantial increase in residence time of the yarn on the heated surface.

The optimum heater temperature depends upon the amount of shrinkage required, the drawing speed, the standards of dye uniformity required for the yarn being drawn and shrunk, and the denier being drawn. We have found for 200 denier polycaproamide yarns using the process and apparatus of this invention, at heater temperatures between 160 and 175° C., there is very little change in the yarn dye level, being less than 2% for the entire range of 15°. However, at temperatures above 190° C. and continuing up to 210° C., there is a significant and dramatic change in dye level, corresponding to the increase in temperature, this change being as high as a 20% increase in dye level for a 10° temperature change.

In this latter case, a small change in temperature would significantly affect the dye level between the ends of the yarn being drawn. Therefore, for 200 denier, 16-filament yarn, as long as the heater temperatures are maintained within the range of 160 to 175° C., the yarns being produced will have good uniformity as to dye level. At heater temperatures of less than 150° C., the yarn shrinkage rate is so reduced that uneconomic yarn residence times of greater than 1.0 second are required on the heater.

It has been found that using the process of this invention, highly reproducible yarn properties are obtained so that the process of this invention is capable of producing polycaproamide textile yarns with a predictable range of shrinkage levels over a wide range of deniers. "Shrinkage" as used herein refers specifically to shrinkage observed by standard test in boiling water. The major process parameters influencing shrinkage are: the heater temperature, the denier of the yarn being treated, and the residence time of yarn on the heater. At residence time

of 0.13 second, the shrinkage, S, can be predicted by the formula:

$$S=[17.8-0.06T]+[12.25-0.06T+0.12(10^{-3})T^2]10^{-3}(D),$$

where S equals the percent total shrinkage, T equals the temperature of the heater in degrees centigrade, and D equals the denier of the drawn yarn. Decreasing the yarn residence time progressively increases the measured shrinkage in boiling water to the point where, at practical operating temperatures, little effect of the heat treatment is observed; and with increasing residence times above 0.35 second, comparatively little further effect of residence time on shrinkage is observed at preferred operating temperatures.

For polycaproamide multifilament yarns, the preferred tension on the yarn advancing to wind-up is between 0.08 and 0.12 gram per denier, and shrinkage has been found to increase by about 1.0% for each 0.1 gram per denier increase in wind-up tension.

Desirable shrinkage levels for various applications are shown in Table III below.

TABLE III

	Percent Total Shrinkage	Major Application
High Shrinkage	14 to 16	Hosiery, Scrim Fabrics.
Medium Shrinkage	9 to 11	Warp Yarns, Texturized Yarns, Automotive Upholstery.
Low Shrinkage	6 to 8	Filling Yarns and Woven Fabrics.

Definitions and test methods employed.—Shrinkage, as the term is used throughout this application, means the total percent of shrinkage or contraction in the length of the yarn upon removal from the package and exposure to boiling water, including the slow retraction or "creep" which occurs upon relief of the tension in the yarn as wound in the package. Shrinkage is determined by wrapping samples of 5 grams ±0.5 gram of yarn to be tested on a Fidelity Automatic Skein Winder, made by Fidelity Machine Company, Philadelphia, Pennsylvania. The skein length on the skein winder reel is 137.2 centimeters. The yarn skein is lightly tied and is removed from the skein winder and placed in a figure 8, in a folded relaxed state in a wire basket. It is boiled in water for 70 minutes. The yarn skein is removed from the basket and centrifuged at 4000 r.p.m. to remove surface moisture.

The skein is then placed in a single loop on a shrinkometer consisting of 2 metal pins mounted on a meter stick, the skein being attached to the fixed upper pin. The lower pin is movable and is equipped with a pointer to the meter stick. A ½-pound weight is suspended on the skein loop and a 1½-pound weight is dropped on the movable lower pin a distance of 20 centimeters, 5 times. The height of the movable pin on the meter stick is measured as the pin rests in the skein loop after each of the 5 test drops. Each test drop reading gives a value for the shrunken length of the skein (L2). The initial length (L1) is taken as ½ the length on the skein winder less the length held under the fixed pin; thus L1 is 66.7 cm. The results of the five tests are averaged and the shrinkage is determined as follows:

$$\frac{(L1-L2)\times 100}{L1}=\text{Percent shrinkage}$$

or,

$$\frac{(66.7-L2)\times 100}{66.7}=\text{Percent shrinkage}$$

Typically polycaproamide yarns when parallel wound on tubes at a tension of 0.1 gram per denier, using the process of this invention, have creep of 0.6% to 0.8%; thus the "net boil shrinkage" is 0.6 to 0.8% less than the shrinkage measured as above.

The following examples are specific embodiments of the invention illustrative of the best mode contemplated by us of carrying out our invention; but are not to be construed in a limitative sense.

Examples 1–4

Using an apparatus and procedure as illustrated in the accompanying drawing and above-described in conjunction therewith, a 16-filament polycaproamide yarn was passed in contact with a heater and drawn thereon by at least 3% of its undrawn length; was contacted in multiple wraps with the heater and draw roll; and was wound up in essentially cylindrical layers, without twist, upon a cylindrical tube forming a so-called parallel package, at 1700 feet per minute and final denier of 200. Various yarns were used, and conditions of heater residence time and temperature were varied as shown in Table IV below, giving the results there shown.

The yarn was taken up at controlled constant tension of 20 grams, equivalent to 0.1 gram per denier. The specific apparatus dimensions and process conditions were as follows in the examples and comparison runs of Tables IV and V below except as otherwise indicated therein.

Length in contact with both heated surfaces of one wrap of yarn, inches	6.4
Width of each of the heated surfaces, inches	2⅛
Diameter of separator roll (7) and of guide roll (6), mm.	21
Diameter of draw roll (5), inches	4.0
Radius of curvature of the heated surfaces, inches	16½
Contact arc on the primary surface of the heater made by each full wrap (8), degrees	10.9
Contact arc on the secondary surface (9) of the heater made by each full wrap, degrees	10.34
Angle between incoming threadline, and the threadline of segment (10) of the wraps between the separator roll and the primary heated surface, degrees	9
Width of draw roll (5), inches	1.34
Width of matte surface on take-off end of draw roll, inch	0.6
Length in contact with draw roll of each full wrap, inches	6.75
Contact arc of each full wrap with draw roll, degrees	193
Length of wrap over primary side of heater from separator roll to point of first contact with draw roll, inches	7
Length of wrap over secondary side of heater from point of last contact with draw roll to top of separator roll, inches	8½
Total length of yarn from point of first contact to point of last contact with draw roll, including 5 full wraps around heater and polished surface of draw roll, 1 full wrap around heater and matte surface of draw roll, and a partial wrap from separator roll to draw roll matte surface, inches	140
Contact time of yarn with heater, second	0.12
Contact time of yarn with heater with 2 additional wraps contacting the polished surface, second	0.14
Reflex angle of threadline at edge (4) where yarn leaves primary heated surface to its point of first contact with draw roll, degrees	183
Distance from centerline of base of triangular heater to periphery of draw roll, inches	1.6

TABLE IV

Triangular Heater Description and Alignment	Type of Yarn Cross Section	Heater Temp. ° C.	Residence Time on Heated Surface Seconds	Breaks Per Pound	Percent Completed Packages	Percent Shrinkage	Percent Full Packages of "O" Break, "O" Wraps, Yarn	Percent Uniformity	Angle * of Alignment, degrees
(A) No guide roll; heater symmetrically fitted over draw roll.	Round	177	0.14	0.045	85	8.6	44		25
(B) 3-Roll, symmetrically fitted over draw roll.	Round	177	0.14	0.032	89	9.5	52		15
(Ex. 1) 2-Roll, aligned	Round	177	0.14	0.031	90	8.6	50		20
(Ex. 2) 2-Roll aligned	Round	177	0.14	0.022	94	8.5	60		9
(Ex. 3) 2-Roll aligned	Fused Trilobal	180	0.12	0.01	90	8.8		Good	9
(C) Same as (A)	Fused Trilobal	195	0.12	0.03	80	7.1		Fair	
(Ex. 4) 2-Roll aligned	"Y"	193	0.20	0.00	93	7.3		Good	
(D) Same as (A)	"Y"	193	0.20	0.05	70	7.7		Unsatisfactory	

*Acute angle between incoming threadline and threadline of segment (10) of the wraps between the separator roll and the primary heated surface.

TABLE V

	Heater	
	No guide roll; symmetrically fitted over draw roll	2-Roll aligned
Uster Uniformity, Percent	6	5
Ultimate Tensile Strength, grams/denier	6.5	6.7
Shrinakge, Percent	8.0	8.3
Range of deviation of shrinkage, and standard deviation average, percent	0.7±0.20	0.5±0.12
Dyeability, percent of standard	101	100
Dye range, percent deviation from standard	±5	±2

As seen in Table V, there is a significant improvement in the denier uniformity (Uster) and the dye uniformity for polycaproamide yarns passed around a 2-roll heater with the primary side aligned in the draw zone in accordance with this invention.

Examples 5–11

Using generally the procedure and apparatus of Examples 1–4, polycarproamide 15-filament yarn was drawn at a draw ratio of 3.64 to a total denier of 50. The yarn contained 0.3% titanium dioxide. The wind-up tension was 4 grams, equal to 0.08 gram per denier. The dimensions of the apparatus employed and string-up zone were substantially as described for Examples 1–4, except the draw roll was 3.88 inches in diameter vs. 4.0 inches in diameter as in the apparatus employed in Examples 1–4.

From Table VI, it can be noted there was a substantial improvement in the shrinkage uniformity throughout the yarn package using a 2-roll aligned heater vs. a triangular heater with no guide roll.

TABLE VI

Type Draw-Shrinkage Heater	Drawn Denier	Number of Filaments	Heater Temp., ° C.	Percent Shrinkage Found	Residence Time on Heated Surface, Second	Breaks per Pound [1]	Package Shrinkage Range	Percent Completed Packages [1]	Calculated Shrinkage Equation	Wind-Up Tension Grams/Denier
(E) No guide roll; heater symmetrically fitted over draw roll	50	15	170	8.7	0.11	0.025	7.5–9.5	88	8.0	0.08
(Ex. 5) 2-Roll aligned	50	15	170	8.5	0.11	0.002	7.8–8.8	95	8.0	0.08
(Ex. 6) 2-Roll aligned	50	15	180	7.7	0.11	0.011		94	7.6	0.08
(Ex. 7) 2-Roll aligned	50	15	190	6.7	0.11	0.002		93	6.7	0.08
(Ex. 8) 2-Roll aligned	50	15	200	6.0	0.11	0.004		94	6.3	0.08
(Ex. 9) 2-Roll aligned	40	12	190	7.5	0.06	0.003		93	[2] 7.3	0.08
(F) Same as (A)	140	32	190	7.1	0.06	0.041		87		0.10
(Ex. 10) 2-Roll aligned	140	32	210	6.0	0.06	0.01		94	5.9	0.10
(Ex. 11) 2-Roll aligned	140	32	190	7.2	0.06	0.015		95	7.18	0.10

[1] Estimated values based on small-scale tests.
[2] Includes correction for decrease in residence time.

We claim:

1. Process for heat treating at controlled length a molecularly oriented multifilament heat shrinkable yarn and winding up said yarn at high speed wherein said yarn is maintained at controlled length by being passed in a series of wraps between a draw roll and a separator roll and is contacted with curved heated surfaces between said rolls along both segments of the yarn wraps as they pass between said rolls, at least one full wrap of said yarn around the draw roll contacting the same upon a polished surface and at least the last full wrap of said yarn around the draw roll contacting the same upon a matte surface; which process comprises:

(1) maintaining a coefficient of friction of said yarn with each of said curved surfaces of not above about 0.1;

(2) contacting each full wrap of yarn with said heated surfaces on each side of the draw roll over an arc of about 5° to about 25° and passing said wraps in an angle of no more than about 10° going over each edge of the heated surface;

(3) contacting each full yarn wrap with no more than 2 idler rolls including the separator roll and contacting each full wrap with each idler roll in an arc of at least 10°, said idler rolls having surfaces which develop coefficient of friction not above about 0.1 with said yarn;

(4) minimizing frictional drag between the yarn and the heated surfaces and idler rolls to not above about 0.1 gram per denier as the yarn passes in the above specified wraps around the heater and idler rolls;

(5) withdrawing the yarn from the rolls and heater under tension between about 0.05 and about 0.25 gram per denier and winding the yarn at a speed of at least about 1500 feet per minute.

2. Process of claim 1 wherein the incoming yarn advancing toward the draw roll is incompletely drawn and makes contact with one of said curved heated surfaces clear of the separator roll and before it contacts the draw roll, making contact with said surface over an arc of about 5° to about 20° and making an angle with the threadline of the wraps between the separator roll and this heated surface of no more than about 20°; wherein the yarn after contacting the draw roll is maintained at substantially

constant length; and wherein the last wrap of yarn around the heater passes thence into contact with the matte surface of the draw roll and thence directly in a straight line to a point of tension control at which substantially constant tension for winding is maintained.

3. Process of claim 1 wherein said yarn is poly-ε caproamide yarn; the temperature of the heater is in the range between 160° C. and 175° C.; the residence time of the yarn in contact with the heated surfaces is in the range between about 0.1 and about 0.5 second; and the tension on the yarn advancing to wind-up is in the range between 0.08 and 0.12 gram per denier.

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