PROCESS OF STEAM DRAWING AND ANNEALING POLYESTER YARN

Filed Nov. 3, 1966

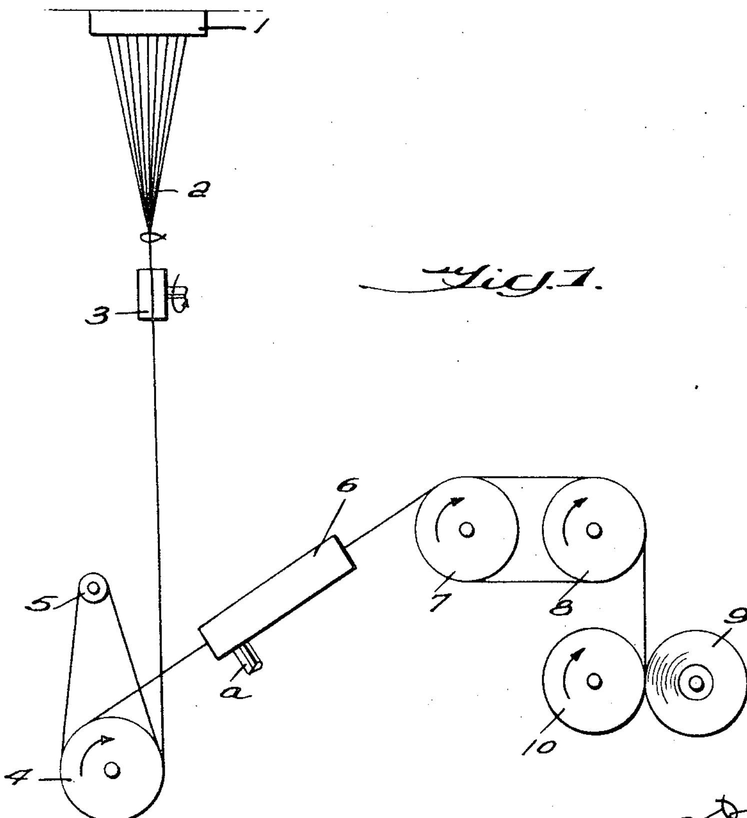

Fig. 1.

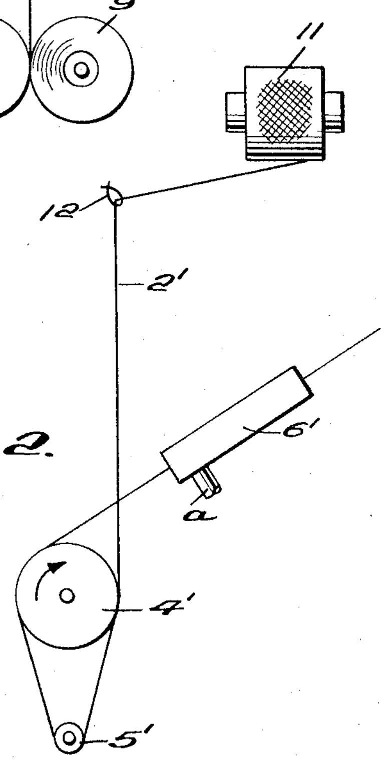

Fig. 2.

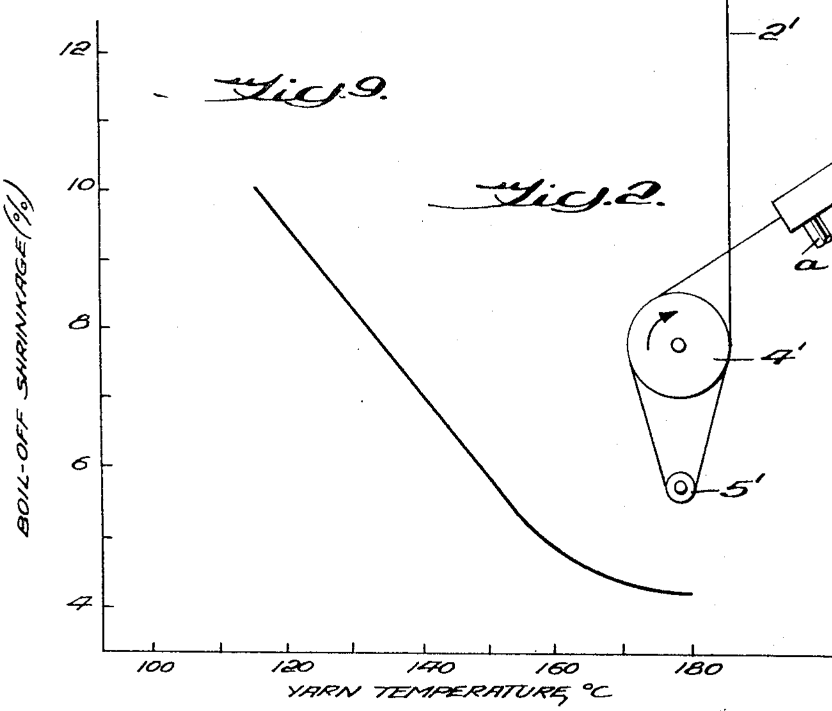

Fig. 9.

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Fig. 6.

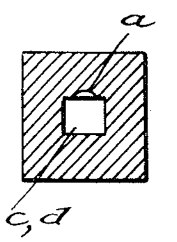


Fig. 3.

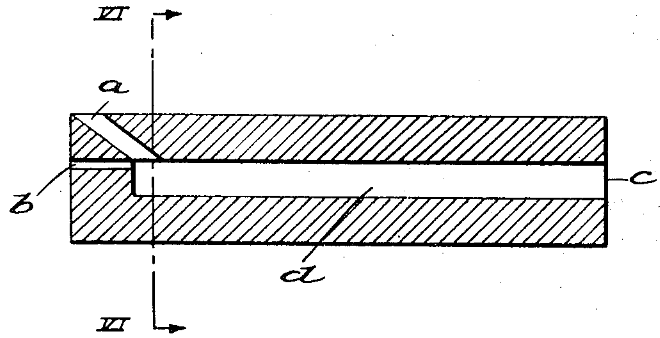


Fig. 7.

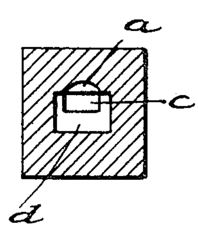


Fig. 4.

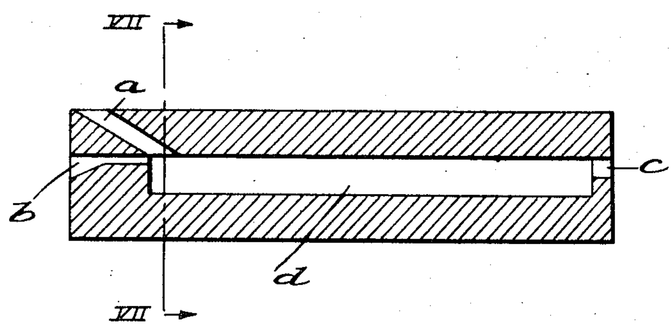


Fig. 8.

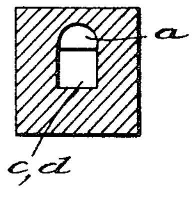
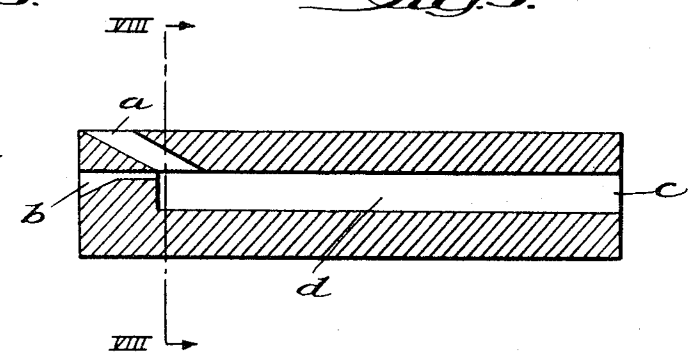


Fig. 5.



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PROCESS OF STEAM DRAWING AND ANNEALING POLYESTER YARN

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Continuation-in-part of application Ser. No. 274,454, Apr. 22, 1963. This application Nov. 3, 1966, Ser. No. 591,850

Int. Cl. D01d *5/12;* D02j *1/22*

U.S. Cl. 264—290 5 Claims

ABSTRACT OF THE DISCLOSURE

Within an enclosure, an advancing bundle of polyester filaments is heated to at least the second order transition temperature by an asymmetric impingement of steam, thereby initiating drawing.

This application is a continuation-in-part of my copending application Ser. No. 274,454, filed Apr. 22, 1963, now abandoned. The invention relates to production of filamentary structures from synthetic linear condensation polymers and, more particularly, to a process improvement involving the transfer of heat to and the rapid elevation in temperature of such structures in a draw zone.

In the production of filamentary structures from synthetic linear polyesters such as polyethylene terephthalate, it is customary to draw the filaments to several times their as-spun length in order to enhance such physical properties as tenacity and elongation. It is known that such yarns can be drawn to advantage if heated where drawing occurs. Accordingly, polyester yarns have been drawn in a heated liquid or vapor bath, over a heated draw roll and over a heated snubbing device such as a hot pin or a hot plate.

In the manufacture of polyester textile yarns, the drawing step is extremely critical in that nonuniform drawing leads to nonuniform dyeing which, in turn, leads to commercially unacceptable fabrics. In order to control drawing so that all the filaments in the yarn bundle are drawn simultaneously, it is known that the yarn length in which drawing occurs must be restricted to a certain area and not wander back and forth. Initiation of drawing and localization of the draw point on a snubbing pin has disadvantages, particularly when bunching of the filaments occurs, so that uneven drawing results, i.e., when the filaments are not lying flat, when the filaments cross over or when several layers of filaments are drawn over the pin. These situations are accentuated at high speeds.

In commercial production, drawn polyester yarns normally have a boil-off shrinkage in the order of 10–15%. Consumer prefrence, however, dictates a reduction to shrinkage levels less than 10%, the reduction normally being accomplished by annealing, e.g., by passing drawn yarn in several wraps over large heated rolls or by exposing the drawn yarn, at constant length, to a high dry-heat temperature for an extended period of time.

The present invention has as its most important objective the provision of process improvements which facilitate a rapid and uniform transfer of heat to undrawn polyester filamentary yarn advancing axially at a high speed.

A corollary objective is to provide effective and efficient processes for drawing polyester filamentary yarn rapidly and uniformly.

Another object of the present invention is the provision of a procedure in which such yarns can be drawn and simultaneously annealed.

These and other objectives are accomplished in a high speed process which involves the advance of a bundle of polyester filaments in a substantially uninterrupted path of travel through an enclosure positioned between feed and draw rolls. Within the enclosure, steam is jetted onto the bundle in an asymmetric impingement intersecting the bundle's path of travel. The temperature-pressure relationship of the impinging steam is such as to localize the draw initiation point by opening up the yarn bundle and raising the individual filaments substantially instantaneously to at least their second order transition temperature.

The basic process and its variations are described more fully in the following specification and examples wherein reference is made to the accompanying drawings in which:

FIGURE 1 is a schematic illustration of an apparatus arrangement useful in a continuous spin-draw process;

FIG. 2 is a partial schematic of an apparatus arrangement useful in a split spin-draw process;

FIGS. 3–5 are longitudinal sections taken through different jet devices used in various exemplified tests of the apparatus arrangements shown schematically in FIGS. 1 and 2;

FIGS. 6–8 are transverse sections taken on corresponding lines in FIGS. 3–5; and

FIG. 9 is a typical graph of the relationship between peak yarn temperature in the enclosure and boil-off shrinkage of homopolymeric polyester yarns which have been drawn and annealed in accordance with the present invention.

The coupled spin-draw apparatus of FIG. 1 includes a spinneret **1** from which polyester filaments **2** are spun. After convergence, the filament bundle passes over a finish roll **3**, in several wraps around feed roll **4** and its separator roll **5**, through a jet enclosure **6**, in several wraps around draw rolls **7**, **8**, and thence to a package **9** which is surface driven by a roll **10**. The yarn can contact finish roll **3** either tangentially or in a partial wrap.

In the split process of FIG. 2, filamentary yarn is spun, packaged and subsequently withdrawn from the package **11**, through a guide **12**, around feed rolls **4'**, **5'** and through a jet enclosure **6'** by draw rolls of the type shown in FIG. 1.

Various tests of the arrangements shown in FIGS. 1 and 2 are described and compared hereinafter. In each test run, the jet enclosure **6** (or **6'**) took the form of one of the three devices shown in FIGS. 3–8, each of which has an angularly disposed steam entrance port *a*, a yarn inlet *b*, a yarn exit *c* and an interior yarn passage *d*. With these devices, steam jetting from port *a* intersects the yarn advancing through passage *d* in an asymmetric impingement. The area relationship between the steam inlet and outlet is such in the devices of FIGS. 4, 5 as to facilitate development of critical steam flow at the outlet and therefore of condensation on the yarn at temperatures in excess of 100° C. within the enclosure.

Where used herein, the phrase "asymmetric impingement" refers to the jetting of steam onto and in intersecting relationship with the filament bundle, i.e., from one side of the bundle. The yarn entrance port *b* must be so designed that the yarn is held in the path of the impinging jet, i.e., it must be centered on the steam entrance port *a* and must be of equal or narrower width.

By "enclosure" is meant the passage or space *d* through which the filaments travel in a device of the type shown in FIGS. 3–8, i.e., the passage which extends from the end of inlet *b* to exit *c*. As such, it is completely enclosed except for openings *a*, *b*, *c*, and is normally filled with steam. Its shape is not critical except that the proper area relationship of the steam entrance port and the jet exit must be maintained when critical flow is desired.

The term "lubricating finish" refers to a yarn coating of a suitable textile treating agent or a combination of agents such as mineral, vegetable, and animal oils, as for example, a light mineral oil, olive oil and sperm oil, a process oil such as sulfonated and sulfated esters and their salts or a synthetic material such as a silicone oil, diethylene glycol, a mono-, di- or triester such as is prepared from a 12- to 18-carbon monocarboxylic acid, e.g., stearic, and a 2- to 16-carbon mono- or polyhydric alcohol, e.g., sorbitan, glycerol or glycol. The treating agent may also be a soap such as an alkanolamine or alkali metal salt of a fatty acid, a wax, a biocide or an antistat such as a condensate of from 3 to 20 mols of ethylene or other alkylene oxide with one mol of a compound with an active H atom, e.g., a fatty acid or fatty alcohol containing from 4 to 20 carbon atoms or a salt of an alkyl or oxyalkylene phosphate. The textile treating agents are preferably combined with an organic liquid diluent, such as a hydrocarbon, a halogenated hydrocarbon, an alcohol, an ester or a ketone or an ether, preferably with a high-boiling liquid such as kerosene. If desired, these agents may be emulsified in water in accordance with principles known to the art. The lubricating finish will usually have a concentration of about 5–30% "solids" so as to deposit from about 0.05 to 2.5% solids on the yarn.

By "polyesters" is meant fiber-forming linear condensation polymers containing in the polymer chain the carbonyloxy linking radicals

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

Polymers containing oxy-carbonyloxy radicals are comprehended within this group. In the absence of an indication to the contrary, a reference to polyesters is meant to encompass copolyesters, terpolyesters and the like. The polyesters may, if desired, contain additives, e.g., delustrants, viscosity boosters and the like.

Examples of crystallizable, linear condensation polyesters are polyethylene terephthalate, polyethylene terephthalate/isophthalate (85/15), polyethylene terephthalate/5-(sodium sulfo)isophthalate (97/3), poly(p-hexahydroxylene terephthalate), poly(diphenylolpropane isophthalate), poly(diphenylolpropane carbonate), the polyethylene naphthalene dicarboxylates (especially those derived from the 2,6- and 2,7-isomers) and poly(m-phenylene isophthalate).

Filaments spun from these polymers may have round or nonround cross seition, e.g., Y, cruciform and the like. The filaments may be composed of one component or of two polyesters differing from each other in one or more ways so as to form a bicomponent filament.

By "essentially simultaneously" is meant the period of time a given point in the yarn length is in the jet enclosure which, at the speeds contemplated herein, ranges from 0.25–10 milliseconds. Where reference is made to a "substantially instantaneous" elevation to the second order transition temperature, it is indicative of the lesser period of time during which the yarn is exposed directly to the impinging steam jet. As disclosed in U.S. Patent 2,556,295 to Pace, crystalline polyethylene terephthalate has a second order transition temperature (Tg) of about 80° C. The amorphous undrawn polyester has a Tg of about 67° C.

Where reported, boil-off shrinkage is determined on a skein of test yarn, the length of which is measured before and after a 60-minute boil-off treatment to permit calculation of the percent change in length.

Previous efforts to draw polyester yarns at high speeds without the use of a snubbing device have yielded filaments with undrawn lengths of relatively large cross section. Heating the yarns by a jet of steam without an enclosure also has provided this undesirable result. When such filaments are dyed, the undrawn lengths dye to a darker shade than do the drawn portions, because of the ease of absorption of a greater amount of dye. Physical properties such as tensile strength will also vary in an unevenly drawn filament. As a further consequence, intermediate lengths will be overdrawn, often resulting in broken filaments and sub-marginal mechanical quality. In the practice of this invention, the snubbing device is omitted but undrawn segments are avoided by asymmetrically impinging a jet of steam at near sonic velocity on the yarn bundle in the draw zone. It is believed that the high velocity steam opens the bundle and allows uniform heat transfer to the individual filaments. By impinging the high velocity steam onto the yarn bundle asymmetrically, the bundle is opened and the rapid and surprisingly uniform transfer of heat to the filaments permits localization of the draw initiation point and consequent uniform drawing. According to this invention, it is a requisite that the yarn be heated substantially instantaneously, in the draw zone, to a temperature of at least the second order transition temperature, so that the draw initiation point will not wander and, thus, cause nonuniform drawing. In this connection, satisfactory drawing performance has been achieved in jet enclosures as short as one inch. From this, it has been concluded that passage through the enclosed asymmetrically impinging steam jet is sufficient exposure for drawing and that the period of time involved in this substantially instantaneous elevation of the yarn to at least the second order transition temperature is less than a millisecond. In order to achieve this necessary, rapid and uniform elevation in temperature, it is desirable to utilize the heat transfer capabilities of condensing steam.

Steam temperature depends upon yarn denier, steam pressure, yarn speed and the draw ratio. In general, at a given draw ratio, an increase in yarn speed requires an increase in steam temperature. At draw ratios greater than 5.0 and at speeds in excess of 2500 y.p.m., steam temperatures of 200–300° C. have been found to give satisfactory results and temperatures up to 450° C. have been used with no adverse effects. At draw ratios ranging approximately from 3 to 5 and at drawing speeds in excess of 2500 y.p.m., steam temperatures of 150 to 250° C. have been adequate to achieve uniform drawing performance.

The maximum operable temperature is related to the fiber's stick temperature. When this temperature is reached, it is believed that individual filaments break and stick to the body of the jet device, thereby causing a breakdown in the thread line. Steam temperatures above the polymer melting point may be used provided that they do not heat the yarn to the polymer stick point.

In drawing polyester yarns, according to the principles of the invention, steam pressure must be sufficiently high to insure fluid velocities of at least 500 feet/sec. at the point of impingement but steam pressure, as such, is not critical. Supply pressure will normally range from 30–150 p.s.i.g. As noted previously, uniform drawing of polyester filaments is obtained by jetting such high velocity steam onto the yarn asymmetricaly. The impinging steam opens up the yarn bunde and permits the individual filaments to be rapidly and uniformly heated. Although sonic impingement velocities of 1500–2000 feet per second are preferred, a velocity of 500 feet per second has been used successfully with asymmetric impingement at drawing speeds as high as 2750 y.p.m. Although the high velocity steam deflects the yarn from its path and brings it into grazing contact with the interior lip of the yarn entrance port *b*, this presents no problem since the draw initiation point is located downstream from the entrance port.

Drawing yarns at high draw ratios to obtain maximum tenacity requires location of the jet within six inches of the feed roll. This requirement is also preferred for moderate draw ratios, i.e., even in situations where maximum tenacity is not required. When the jet-to-feed-roll distance becomes too great, the yarn can draw at the feed roll rather than in the jet and yarn uniformity is lost. This is believed to be caused by the high draw forces imposing a tension on the filaments high enough to overcome their yield stress and cause the polymer to undergo creep or coldflow. When the time period during which this force is applied is sufficient to permit the initiation of drawing before the steam impingement point, the yarn can begin to draw prior to the jet and the draw initiation point will then recede to the feed roll.

Since an increase in temperature lowers the yield stress, impingement of the steam onto the yarn is preferably carried out in a manner to prevent any appreciable escape of steam at the yarn entrance port of the jet. This is best achieved by impinging the steam in the direction the yarn is traveling and impingement angles of 25–65° give satisfactory results.

Synthetic linear polyester yarns drawn according to the process of this invention are found to be remarkably free from dyeing nonuniformities and, in particular, those short-length dyeing nonuniformities which have hindered full development of polyester yarns. Furthermore, the process of this invention may be operated at windup speeds of 3200 y.p.m. and higher without loss of uniform dyeing properties. The outstanding advantages resulting from this invention are the attainment of uniform heat transfer at high speeds and this in a small amount of equipment space.

The residual shrinkage of polyester yarn is primarily dependent on the highest temperature that the yarn has reached. With homopolymers, it has been found necessary to raise yarn temperature above 115° C. in order to obtain a boil-off shrinkage less than 10% (FIG. 9). Previously, such an annealing effect has been accomplished on advancing yarn by relatively long periods of exposure to roll surfaces heated to moderate temperatures of 120–250° C. or by exposure to high temperature gases of about 450° C. In this invention, filament temperature can be raised to above 115° C. in the jet enclosure by utilizing the rapid heat transfer capabilities of condensing steam. In addition to a substantially instantaneous yarn temperature elevation for drawing purposes, condensation of steam on the yarn after its passage through the impinging jet but within the enclosure has the further effect of raising yarn temperature sufficiently to provide annealed yarn in which the attained shrinkage is less sensitive to the water content of the yarn from, for example, an aqueous finish. In order to obtain condensation at useful temperatures, the steam in contact with the yarn, i.e., in passage *d*, should be above atmospheric pressure.

In this invention, yarn is kept in contact with steam at elevated pressures in the jet enclosure by designing the jet so that critical flow occurs at the yarn entrance and exit, e.g., as in FIG. 4. Critical flow has been defined as a natural phenomenon which occurs when a compressible fluid attains sonic velocity at the exit of a pressurized system. Turbulence associated with sonic velocity undoubtedly contributes to the over-all efficiency of the system by stripping off the air layer that surrounds the incoming filaments.

The peak temperature that the yarn reaches will depend upon steam temperature and pressure in the jet, yarn speed and the length of the jet enclosure. For the annealing effect, the yarn speed and the length of the jet enclosure must be such that the yarn is exposed to condensing steam at elevated pressures for a length of time sufficient to allow the yarn to reach the temperature of the condensing steam and to crystallize. In the process of this invention, this occurs in the inordinately short time of less than 10 milliseconds. Since the heat transfer during condensation is much more effective in raising yarn temperature than is convection, superheating the steam, e.g., steam at 50 p.s.i.g. by as much as 25–50° C., has little effect on yarn temperature and, hence, on shrinkage values obtained in condensation jets. That is, the maximum temperature that the yarn reaches is that of the condensation temperature corresponding to the steam pressure in the jet. As a consequence, boil-off shrinkage values resulting from the use of a jet exhibiting critical flow, e.g., the type shown in FIG. 4, are a function of the steam saturation temperature and not the temperature of the superheated supply steam. It is nevertheless desirable to use superheated steam to prevent flooding of the jet, although excessive superheat is to be avoided since in extreme cases the yarn can be heated above the saturation temperature of the steam by convection and effective control of maximum threadline temperature will be lost.

In achieving shrinkage levels of less than 10%, steam pressure is a more important measurement than is steam temperature for selecting annealing conditions. Test runs have shown that steam pressures corresponding to condensation temperatures of 120–185° C. result in satisfactory annealing at yarn speeds in excess of 2500 y.p.m.

EXAMPLE I

Apparatus for drawing yarn is set up as shown in FIG. 2. Polyethylene terephthalate polymer having a relative viscosity of about 25 and containing 0.3% titanium dioxide as a delustrant is melt spun into a yarn having 34 filaments and wound to a package **11**. The yarn **2'**, protected by a lubricant, is fed by feed roll **4'** to enclosure **6'** at a speed of 833 y.p.m., drawn to a denier of about 70 at 2,750 y.p.m. and wound to a package of the type shown at **9** in FIG. 1. In each run, the treating fluid is jetted onto the yarn bundle at a velocity greater than 500 feet per second. The drawing conditions and properties of the drawn yarns are reported in the table. Runs 1, 2 and 4–8 show polyester filaments being drawn in their passage through different jet device embodiments within each of which the yarn intersects an asymmetric steam impingement; observed drawing uniformity indicates the tabulated steam supply temperatures are sufficiently high to raise the filaments to or beyond their second order transition temperatures. Runs 1 and 4–8, in which the yarn has a boil-off shrinkage of 10% or less are representative of an optimum process in which the annealing effect is achieved. In run 3, air is used as the treating fluid and the poor uniformity of the drawn yarn reflects the superiority of steam versus air as a treating fluid.

Yarn from each run was woven into a taffeta fabric which was scoured ½ hour at 70° C., heat set 8 seconds at 160° C. and then dyed with Celanthrene Brilliant Blue FFS (CI61505) for 1 hour at 100° C. Inspection of the dyed fabric revealed the presence or absence of short length dyeing nonuniformities. In the table, the symbol U refers to a highly uniform fabric while the symbol N refers to a nonuniform fabric, i.e., to a fabric showing a multiplicity of sections in which the filaments have absorbed a greater amount of dye than in neighboring sections.

A comparison of runs 1 and 5 shows that raising the steam temperature has little effect on yarn shrinkage when condensation jets are used; the slightly higher boil-off shrinkage in run 5 is attributable to a higher winding tension. A comparison of runs 1, 6 and 7 shows the effect of increased steam pressure (higher saturation temperature) on yarn shrinkage.

In run 8, steam pressure in the jet body at the steam entrance port *a* (FIG. 5) is 41 p.s.i.g. and the saturation-condensation temperature corresponding to this pressure is 142° C. From the graph of FIG. 9, it can be seen

TABLE

Run	Jet					Treating fluid			Yarn properties		
		Dimensions (in.)									
	Type	Length	Yarn passage	Yarn exit	Steam port (dia.)	Type	Temp. (° C.)	Pres. (p.s.i.g.)	Ten. (g./d.)	Elong. (percent)	Boil-off shrinkage (percent)
1 (U)	Fig. 4	5	0.10 x 0.078	0.046 x 0.050	0.053	Steam	153	50	4.5	29.0	8.2
2 (U)	Fig. 3	5	0.10 x 0.078	0.10 x 0.078	0.053	do	155	50	4.3	27.5	11.3
3 (N)	Fig. 5	7	0.080 x 0.063	0.080 x 0.063	0.080	Air	163	50	3.8	15.5	11.3
4 (U)	Fig. 5	7	0.080 x 0.063	0.080 x 0.063	0.080	Steam	161	50	4.6	26.5	6.4
5 (U)	Fig. 4	5	0.10 x 0.078	0.046 x 0.050	0.053	do	188	50	4.4	30.0	8.4
6 (U)	Fig. 4	5	0.10 x 0.078	0.046 x 0.050	0.053	do	186	30	4.2	29.5	10.0
7 (U)	Fig. 4	5	0.10 x 0.078	0.046 x 0.050	0.053	do	232	120	4.6	25.2	4.3
8 (U)	Fig. 5	5	0.080 x 0.063	0.080 x 0.063	0.080	do	153	50	4.6	28.0	6.7

that one would expect a boil-off shrinkage of 6.8% in yarn heated to this temperature. Comparison of this value with the measured yarn shrinkage of 6.7% shows that boil-off shrinkage is related to the steam saturation-condensation temperature.

EXAMPLE II

Apparatus for drawing yarn is set up as shown in FIG. 1. Polyethylene terephthalate polymer having a relative viscosity of about 27 is melt-spun into a yarn having 50 filaments, converged and advanced over lubricating roll **3** and feed roll **4** to a steam jet three inches in length. The jet has a steam port with a diameter of 0.125 inch, a cavity diameter of 0.188 inch and a cavity length of 2.75 inches. Except for a circular passage *d*, its design is generally similar to that shown in FIG. 3. Superheated steam at a temperature of 300° C. and a manifold pressure of 50 p.s.i.g. is impinged asymmertically on the yarn at an angle of 30°. The yarn is drawn at a speed of 2890 y.p.m., at a draw ratio of 5.78, to a final denier of 220. The drawn yarn has a tenacity of 7.4 g./d., an elongation of 11.3%, a boil-off shrinkage of 8.0% and a high degree of uniformity. Such a low boil-off shrinkage is indicative of the annealing effect.

EXAMPLE III

Apparatus for spin-drawing yarn in a continuous process is set up as shown in FIG. 1. A copolyester prepared from ethylene glycol and a 98/2 mixture of the dimethyl esters of terephthalic/5-(sodium sulfo)-isophthalic acid is melt spun into a 50-filament yarn. The yarn **2** is fed by roll **4** to jet **6** at a speed of 976 yards per minute, passed over draw rolls **7, 8** heated to 160° C., drawn to a denier of about 77 at 2750 yards per minute and packaged. The jet is the same as that shown in FIG. 3 except for provision of a stringup slot. It is connected to a steam supply having a temperature of 180° C. and a pressure of 60 p.s.i.g. The yarn is drawn in its passage through the jet enclosure, annealed in its passage over heated rolls **7, 8**, and packaged. It has a tenacity of 2.8 grams per denier, an elongation of 15.5%, a boil-off shrinkage of 5.2% and a high degree of uniformity. Such a low boil-off shrinkage is indicative of the annealing effect.

EXAMPLE IV

Apparatus for spinning and drawing yarn in a continuous process is set up as shown in FIG. 1. A copolyester prepared from ethylene glycol and a 98/2 mixture of the dimethyl esters of terephthalic/5-(sodium sulfo) isophthalic acid, having a relative viscosity of about 19.5 and containing 0.45% titanium dioxide as a delustrant is melt spun into a 34-filament yarn. The yarn **2** containing a water base finish applied by roll **3** (angle of wrap, 9°51′) is fed by roll **4** to jet **6** at a speed of 1100 yards per minute, drawn to a denier of about 70 at 300 yards per minute, passed over draw rolls **7, 8** heated to 120° C., and packaged. The jet has an impingement angle of 30° and is similar to that shown in FIG. 3 except for provision of a stringup slot. It is supplied with steam having a temperature of 175° C. and a pressure of 30 p.s.i.g. The yarn is drawn in its passage through the jet enclosure, annealed in its passage over heated rolls **7, 8** and then packaged. It has a tenacity of 2.8 grams per denier, an elongation of 29.0%, a boil-off shrinkage of 8.0%, and a high degree of uniformity.

EXAMPLE V

Apparatus for spin-drawings yarn in a continuous process is set up as shown in FIG. 1. Polyethylene terephthalate polymer having a relative viscosity of about 25 and containing 2.0% titanium dioxide as a delustrant is melt spun into a 34 filament yarn. The yarn **2**, containing a water-base finish applied by roll **3** (angle of wrap, 9°51′), is fed by roll **4** to jet **6** at a speed of 880 yards per minute, drawn to a denier of about 70 to 3046 yards per minute, passed over draw rolls **7, 8** heated to 126° C., and packaged. The jet has an impingement angle of 30° and is similar to that shown in FIG. 3 except for provision of a stringup slot. The jet is supplied with steam having a temperature of 200° C. and a pressure of 50 p.s.i.g. The yarn is drawn in its passage through the jet enclosure, annealed in its passage over heated rolls **7, 8** and then packaged. It has a tenacity of 4.3 grams per denier, an elongation of 29.0%, a boil-off shrinkage of 8.2% and a high degree of uniformity.

EXAMPLE VI

Apparatus for spinning and drawing yarn in a continuous process is set up as shown schematically in FIG. 1. Polyethylene terephthalate having a relative viscosity of about 50 and containing 0.10% titanium dioxide is melt spun into a yarn of 192 filaments. The yarn **2** is protected by an oil-base finish in the amount of 0.10% "solids" by weight. The finish consists of 77 parts of refined kerosene and 33 parts of di-(2-ethylhexyl) ester of polyethylene glycol of molecular weight about 200 (an antistatic lubricant). From finish roll **3**, yarn **2** is fed by roll **4** to jet **6** at a speed of 513 yards per minute, drawn to a denier of 1260 at 2745 yards per minute, treated again with the above ester to provide 1.1% "solids" by weight of treated yarn, passed over draw rolls **7, 8** heated to 160° C. and packaged. The jet has an impingement angle of 30° and is similar to that shown in FIG. 3 except a stringup slot is provided. The steam port is a slot having a width of 0.2 inch and a length of 0.625 inch, with slot width being parallel to the direction of yarn travel. The jet is supplied with steam having a temperature of 380° C. and a pressure of 50 p.s.i.g. The yarn is drawn and annealed in its passage through the jet enclosure, further annealed in its passage over heated rolls **7, 8** and then packaged. It has a tenacity of 9.2 grams per denier, an elongation of 15.0%, a 160° C. dry heat shrinkage of 9.4%, a boil-off shrinkage of but 3.8% and a high degree of uniformity.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. In the high speed production of filamentary yarn, the steps of: advancing a bundle of polyester filaments in a substantially uninterrupted path of travel through an enclosure positioned between spaced feed and draw rolls; and jetting steam on said bundle, within said enclosure, in an asymmetric impingement intersecting said path of travel, the velocity of jetting steam being sufficiently high to open the bundle, the temperature-pressure relationship of the impinging steam being such as to raise the individual filaments substantially instanta-

neously to at least their second order transition temperature and to thereby initiate drawing.

2. The process of claim **1** wherein superheated steam is jetted on the bundle and the time-pressure relationship in said enclosure is such as to lower the steam to its saturation temperature and raise said filaments essentially simultaneously to a temperature above 115° C.

3. The process of claim **1** wherein superheated steam is jetted on the bundle, the enclosure has a restricted outlet and the time-pressure relationship in said enclosure is such as to lower the steam to its saturation temperature and raise said filaments essentially simultaneously to a temperature above 115° C.

4. The process of claim **3** wherein said filaments are melt upon and advanced continuously to said feed rolls.

5. The process of claim **1** wherein said raw rolls are heated to a temperature of at least about 120° C.

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DONALD J. ARNOLD, *Primary Examiner.*

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,452,132 Dated June 24, 1969

Inventor(s) Gilbert Pitzl

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

At line 55 in column 1, "prefrence" should be -- preference --.

At line 67 in column 7, "300" should be -- 3000 --.

In column 9, at line 15 (line 2 of claim 4), "upon" should be -- spun --; and at line 16 (line 1 of claim 5), "raw" should be --draw--.

SIGNED AND
SEALED
JAN 27 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents