Jan. 16, 1968 S. K. GARIBIAN ETAL 3,364,294

FILAMENT ORIENTATION PROCESS

Filed Sept. 20, 1965 2 Sheets-Sheet 1

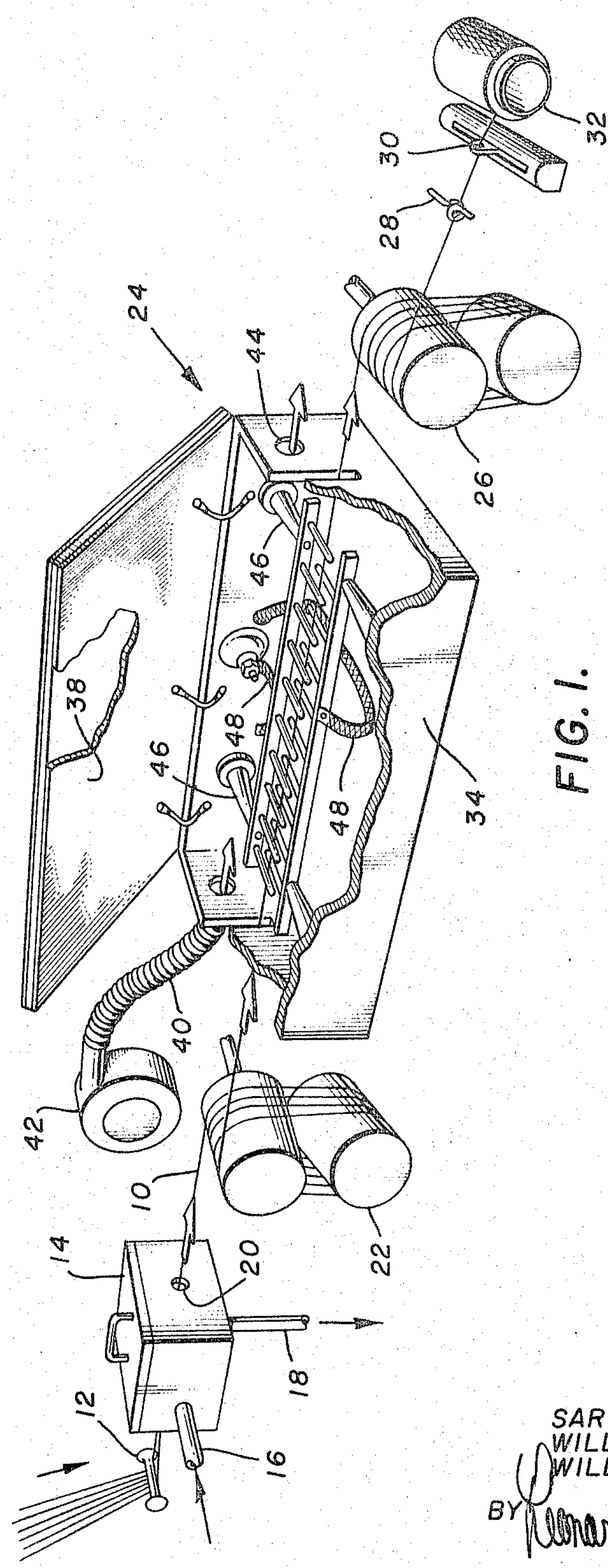

FIG. 1.

INVENTORS
SARKIS K. GARIBIAN
WILLIAM L. CAMPBELL
WILLIAM R. HOCUTT
BY Leonard A. Williams Jr.
ATTORNEY

FILAMENT ORIENTATION PROCESS

Filed Sept. 20, 1965 2 Sheets-Sheet 2

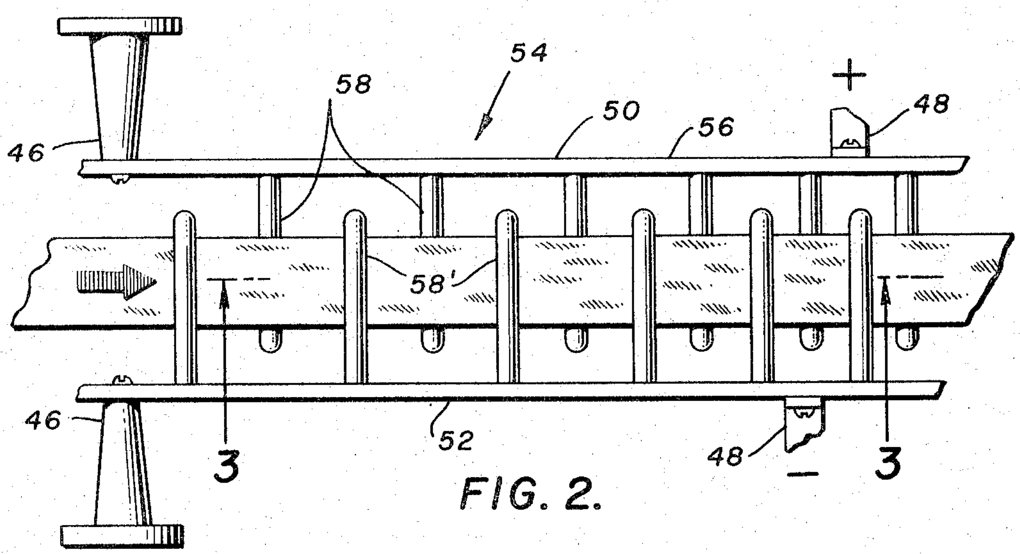

FIG. 2.

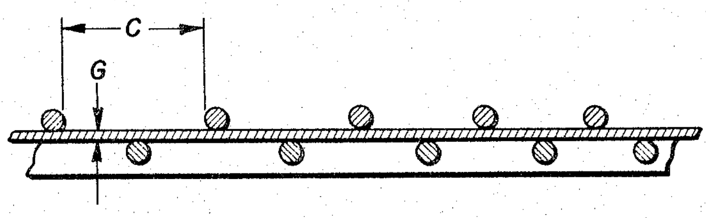

FIG. 3.

INVENTORS
SARKIS K. GARIBIAN
WILLIAM L. CAMPBELL
WILLIAM R. HOCOTT
BY [signature]
ATTORNEY

United States Patent Office

3,364,294
Patented Jan. 16, 1968

3,364,294

FILAMENT ORIENTATION PROCESS

Sarkis K. Garibian and William L. Campbell, Cary, and William R. Hocutt, Raleigh, N.C., assignors to Monsanto Company, St. Louis, Mo., a corporation of Delaware

Filed Sept. 20, 1965, Ser. No. 488,628
5 Claims. (Cl. 264—290)

ABSTRACT OF THE DISCLOSURE

A heavy denier tow drawing process wherein a polyester tow is uniformly drawn by application of dielectric energy. The operation is found particularly efficient in the case of polyester drawing due to the coincidence of the preferred drawing temperature and maximization of the dielectric loss factor at a temperature range of from about 90 to 100° C.

This invention relates to a process for effecting the orientation of synthetic filaments in a highly uniform manner. More particularly, the invention is concerned with the problem of orienting polyethylene terephthalate filaments when processed in the form of heavy denier tows composed of densely spaced filaments.

There is disclosed in U.S. Patent 2,465,319 to Whinfield and Dickson the production of highly useful fibers composed of polyethylene terephthalate, which includes the steps of preparing the polymer, melt-spinning the polymer to form substantially unoriented filaments and drawing the filaments to a permanent increase in length to yield tenacious, oriented fibers. As is well known, the drawing of filaments formed from synthetic organic polymers gives rise to macromolecular orientation along the filamentary axis, as evidenced by characteristic X-ray patterns, along with increased tenacity and reduced elongation at break.

In the textile industry, the various conventional drawing processes, involving the passing of a yarn or tow over, between, or in contact with heated surfaces such as pins, plates and heated gas zones, have proved generally satisfactory for drawing textile and even industrial denier continuous filament yarns. However, these various processes have not been found entirely satisfactory for draw-orienting the much heavier denier tows typically encountered, for example, in staple fiber production. In staple production, it has been found highly desirable, out of considerations for production economy, to combine several hours of production from a number of spinning machines into tows ranging in denier to as high as 2.5×10^6 and drawing the constituent filaments simultaneously.

In attempting to adapt previously known drawing processes to the drawing of such heavy denier tows of polyethylene terephthalate, it has been found that the tow does not draw in a uniform manner; that is to say, random lengths of the various filaments pass through the drawing step with little or no orientation. This is because a uniform and sufficient heating of the individual filaments comprising a tow of this size cannot be achieved by normal tow heating techniques which employ various arrangements and configurations of heated surfaces and zones and which, therefore, rely to a major extent upon heat transfer from filament to filament; consequently, non-uniform drawing unavoidably results due to temperature variations across the filament bundle. In addition to ofttimes serious variations in important physical properties, staple fiber cut from such non-uniformly oriented tows is particularly deficient where such fibers are intended for use in the fabrication of dyed fabrics in that partially oriented or substantially unoriented fibers or fiber sections dye to much deeper colors than the more fully oriented members and appear in the fabric as flecks of darker color.

Fabrics formed from staple fiber not possessing a high order of uniformity in orientation will exhibit such an incidence of dyeing defects as to be unacceptable for many otherwise available markets.

In order to obtain the requisite uniformity in drawing heavy denier tows, it has therefore been found necessary, in most instances, to draw the tow in the form of relatively thin, wide, sheet-like bundles in an attempt to minimize an otherwise undue inter-filament variation in exposure to the influence of conventional heating agents and to promote uniform contact of the individual filaments with the heat source. In an attempt to realize the production economies available in the processing of heavy denier tows, a number of wet-drawing procedures have been proposed involving the use of steam and aqueous or other inert fluid bath, which procedures have been commercially employed with varying degrees of success in obtaining uniformly drawn tows. However, even the more desirable of these "wet-draw" procedures have certain recognized disadvantages, among which are the necessity of a considerable amount of expensive auxiliary equipment (i.e. tanks, pumps, heaters, filters, etc.) large, costly ovens necessary to dry the wet-processed tow, and a generally large machine space requirement to accommodate the several baths and sets of rolls which may be required. Furthermore, even the most successful wet-drawing procedures must be conducted with due regard for tow bundle configuration; that is, very heavy denier tows (in the order of 1×10^6 denier and greater) must be processed in the form of relatively wide ribbons in order that the tow density (measured in denier per inch of bundle width) does not exceed that level beyond which non-uniform heating of the individual filaments, resulting in non-uniform orientation, will unavoidably occur. For example, where it is desired to process a tow size on the order of 2×10^6 denier, it is found that non-uniform drawing reaches undue levels where tow density exceeds 100,000 denier per inch and the tow bundle must be maintained in the form of ribbon at least 20 inches wide. Obviously, substantial economies, in terms of equipment, space and production, would be realized if either a narrower bundle or a heavier tow denier could be accommodated.

On the other hand, the relatively less expensive and less involved implementation of previously disclosed "dry drawing" processes are decidedly lacking in their ability to provide uniformly oriented high denier tows. At best, even moderately heavy denier tows processed according to known dry-drawing methods must be handled in the form of unduly wide ribbon shapes in order that the density of the filament bundle does not exceed that level productive of non-uniform heating and consequent erratic drawing. Though the tow density amenable to conventional dry-drawing processes is not subject to precise definition, it has been found that filamentary bundles having a density of ten to fifteen thousand undrawn denier per inch may be drawn satisfactorily, while filament bundles having a density in excess of about 35,000 undrawn denier per inch do not draw in a uniform manner when processed by the same methods. On the other hand, though satisfactory results may sometimes be obtained by utilizing the more proficient of the wet-drawing methods, as previously related, these operations are characterized by heavy equipment expense and process complications, while still entailing limitations as to bundle denier per unit width and bundle cross-sectional configuration.

With the foregoing problems and considerations in mind, it therefore becomes an object of this invention to provide an improved process for drawing heavy denier, substantially unoriented, polyethylene terephthalate tows without resorting to the complications attending conventional wet-drawing processes and without sacrifice to product quality.

A further object is to provide such a process in which the drawn tow exhibits a high order of inter-filament uniformity in orientation and a consequent low incidence of variation in fiber properties, particularly as regards variations in dye receptivity. Other objects will become apparent from the following description, appended drawing and the claims.

According to the present invention, the foregoing and other objects are attained in the practice of a process wherein a heavy denier, high density tow of substantially unoriented polyethylene terephthalate filaments is draw-oriented under the influence of a dielectric field. More precisely, the most beneficial results are obtained by passing such filaments in the form of a tow having a density in excess of about thirty-five thousand undrawn denier per inch, measured across the width of the tow bundle, through a preheating and moisturizing treatment, wherein the tow is heated to a temperature within the range of 50 to 100° C. and a moisture level of at least 3 percent, preferably greater than 6 percent is imparted thereto; thence passing the thus moistened and preheated tow through a dielectric field while subjecting same to the desired draw ratio, the dielectric field being characterized by a frequency of from 1 to 1200 megacycles per second, and a voltage of from about 2,000 to 25,000 volts. The tow is processed in a manner to insure maximum uniformity of tension upon each of the individual filaments. For greater efficiency and uniformity in heat-up rate, the dielectric field is established in such a manner as to provide an increasing field intensity as yarn moisture decreases during heating. That is, as the yarn is heated in passing through the dielectric field, it will experience a continuous decrease in moisture, with a consequent decrease in its dielectric loss properties, requiring, if a substantially constant rate of heat evolution is to be maintained, an increasing field intensity. Also, it has been found that, if undesired arcing across the electrodes defining the dielectric field is to be avoided when processing yarn containing substantial levels of moisture, the electrodes should be heated sufficiently to avoid condensation of the vapor emanating from the heated yarn at least in those upstream regions of higher yarn moisture level. This may be accomplished in any one of several ways, such as sweeping the space surrounding the dielectric field with heated, dry air or other gas and/or providing auxiliary radiant heaters in the chamber enclosing the dielectric electrode array.

As is well known, dielectric heating, also referred to as electromagnetic heating, involves the application of high frequency, high voltage electrical energy to non-metallic materials. The frequency range normally employed in dielectric heating operations may vary from 1 to 1200 megacycles per second; applied voltages at the electrodes are normally in the range of 2,000 to 25,000 volts. These values are indicative of present-day practice and are not intended to imply that higher frequencies and voltages cannot as well be employed.

High frequency heating is possible only in those materials that are at least moderately molecularly polar. Polar molecules possess a pair of electrical charges of opposite polarity called dipoles. A dipole molecule placed in a constant electrostatic field will attempt to align itself with the potential gradient of the field. This motion is accomplished by the interaction of the electrical field and the charge centers of the molecule, thus creating an aligning torque called a dipole moment. Molecules lacking such polarity are unaffected by a high frequency electrostatic field. Also, certain molecules, even though they possess dipoles, are little affected by electrical fields in that the dipole moments are substantially equal and opposing. Dielectric heating is accomplished by utilization of ultra-high frequencies which elevate the molecules to a highly agitated state, resulting in internally generated heat by molecular friction. The more viscous materials offer greater resistance to such molecular agitation and, consequently, require greater energy input to elevate the temperature to a given level.

The material to be heated is located between two sets of electrodes, one of which is maintained at a high potential relative to the other. The high potential force thus established forces the high frequency field through the material. This field, in passing through the material, creates a high degree of molecular motion throughout the cross section, resulting in a uniform temperature rise in the material regardless of its thermal conductivity, provided the mass has equal density and moisture content. The fact that most non-metallic materials are poor heat conductors leads to non-uniform heating when conventional modes of heating are employed, such as convection, conduction, or radiant heating. When heating materials of thickness by such heat transfer mechanisms, the outside surface necessarily becomes heated far more quickly than the interior regions. It thus becomes evident that a major advantage to be realized in dielectric heating is the uniformity in temperature to be achieved throughout the extremities of the mass and it is primarily by virtue of this attribute, when employed in the manner here disclosed, that one is enabled to conduct a substantially dry-drawing process upon high density, heavy denier tows at levels of orientation uniformity heretofore not attained.

For a more detailed understanding of the practice of the present invention, reference shall now be had to the accompanying drawings as being illustrative of a typical implementation of the process and in which:

FIG. 1 is an overall view of one possible arrangement for conducting drawing operations upon heavy denier tows according to the present invention wherein a suitable tow bundle is formed, passed through a preconditioning chamber to impart desired measures of temperature and moisture content, the tow then being passed through feed and draw roll assemblies which are interposed by a dielectric heating oven, the tow then being gathered in bobbin form or the like by a suitable take-up arrangement;

FIG. 2 depicts, in plan view, an electrode assembly configuration productive of dielectric field characteristics most amenable to the practice of the present invention, and

FIG. 3 is a cross-sectional view taken on line **3—3** of FIG. 2 showing the horizontal and vertical spacing of the individual finger-type electrodes of the upper, high potential and lower, low potential electrode assemblies.

In polyester spinning, as presently commercialized, it is impossible to spin from one spinning machine tows of sufficient denier to enable efficient staple fiber drawing. Consequently, it is necessary to ply together numerous ends from creeled cans or bobbins to obtain the desired total denier of at least 35,000, a figure dictated out of considerations of economic feasibility and not necessarily operability. Thus, individual continuous filament bundles are gathered from a plurality of sources and directed through a suitable constant tension means, not shown, in order to tension each of the individual filaments to as uniform a degree as is practicable with present day devices. An undue variation in individual filament tension will, as is well known, be reflected by an unacceptable degree of variation in individual filament orientation, no matter the advantages of a particular drawing operation.

After passing through the tension regulating means, the individual filament bundles are caused to converge into a relatively flat, heavy denier tow **10** by means of a bar guide **12** or the like. The thusly formed tow may then be passed through a preconditioning chamber **14** wherein the desired conditions of tow temperature and moisture content are established and maintained uniform along the length of tow being processed.

It is to be understood that, though the following discussion will largely be concerned with water as the moisturizing agent, many other polar liquid mediums, such as the glycols, low molecular weight alcohols, and polar finishes, could as well be employed, though water would normally be employed out of economic considerations. The addition of a polar moisturizing agent functions to raise an otherwise low dielectric loss factor that is characteristic of polyester tows. The loss factor is a measure of the ability of a given material under given conditions to absorb dielectric energy, which is thereby converted to internally generated heat energy resulting in a rise in temperature. Although the instant drawing process may be conducted without raising the dielectric loss factor by polar moisture conditioning, the limitations thus imposed on draw speed and draw ratio will normally be found overly restrictive where production costs constitute a significant factor. Likewise, the process may be practiced in the absence of advantages to be gained by preheating the tow, but with similar consequences.

As symbolically indicated in FIG. 1, pre-heating and moisturizing may be accomplished in a single operation by supplying, through inlet 16, a heated polar liquid under pressure which may be atomized or vaporized within preconditioning chamber 14 to be uniformly deposited upon the individual filaments of a suitably flared tow bundle. A trap line 18 communicates with the lower regions of chamber 14 to carry off and recirculate any moisturizing agent which is allowed to condense.

The residence time of the tow within chamber 14 and the quantity and temperature of the moisturizing agent supplied thereto are regulated to impart to the tow, as it departs the chamber through exit port 20, a temperature of at least 50° C. and a moisture content, in the case of water, of at least 3 percent, preferably 6–12 percent, if optimum processing speeds and efficiency of operation are to be realized. The moisture content may, however, be varied up to as high as 30 percent by weight of tow where it is desired that the tow depart the drawing operation with a relatively high residual moisture content, as may be dictated by certain after-treatments, such as washing, crimping and finishing. It has been found that any attempt to operate with moisture contents above 30 percent results in an undue proportion of the dielectric energy being absorbed merely to vaporize such excess moisture levels, as well as to precipitate arcing between the electrodes, resulting in serious tow defects. Moisture conditioning has as its primary purpose the raising of the dielectric constant of the tow to thereby provide rapid heat-up to drawing temperature. In the case of tows of polyethylene terephthalate, it has been found that a moisture content of from about 6 to 12 percent by weight of tow gives optimum results, moisture levels above this range absorbing a disproportionate amount of dielectric energy requiring either or both relatively long electrode assemblies and high field voltage where it is desired to extract the tow from the drawing operation in a relatively dry condition, i.e., below 0.5 percent moisture; on the other hand, an in-coming moisture content below 6 percent results in decreasing heat-up rates to the point that, at levels below 3 percent, the draw speed and draw ratios which must be maintained for uniform draw-orientation are too low to obtain the throughput rates and levels of orientation normally desired. An attempt to increase the throughput to conventional speeds when operating at such low moisture levels results in sporadic migration of the draw point towards the draw roll; whereas, an increase to draw ratios required to impart even conventional levels of orientation will result in migration of the draw point towards the feed roll, the migration in either direction being characterized by a sporadic oscillation resulting in radom orientation values along the length of the tow. We have discovered, therefore, that, if conventional draw speeds and ratios are to be accommodated, the tow must be introduced to the dielectrically heated draw zone at a temperature greater than about 50° C. and 3 percent moisture, a level of at least 6 percent being preferred. As before related, the moisture content should not be allowed to exceed 12 percent where it is desired to extract the tow in a relatively dry condition, but the in-coming moisture content may vary up to 30 percent where it is desired to convey the tow to further processing operations in a moistened condition; at levels above 30 percent however, energies absorbed through vaporization and consequent arcing render such levels undesirable.

The tow, thusly preconditioned, is withdrawn from chamber 14 by feed roll assembly 22, which may comprise a pair of skew-mounted godets which are preferably maintained at or near the temperature of the tow. The tow thus enters the dielectric heating oven, generally indicated by numeral 24, at a temperature greater than about 50° C. and a moisture content greater than 3 percent by weight of tow. The tow passes through the dielectric oven to engage draw roll assembly 26, the peripheral speed of which is maintained at a constant difference above that of the feed roll assembly 22 to thereby impose the desired degree of elongation and consequent orientation to the tow as it is heated to draw temperature within oven 24. On departing the draw roll assembly, the tow may be passed through a suitable guide 28, thence to other processing or through traverse guide 30 and take-up roll 32.

Referring to the details of the dielectric oven 24, the electrode array is seen to be enclosed within a housing 34, the interior surface of which is provided with suitable metallic sheathing 38 to shield vicinal equipment from electrical interference due to high radio frequencies employed.

A conduit 40 communicates with the upstream region of the oven interior to supply a continuous flow of heated, relatively dry gas, as by means of a heater fan 42, which flow is exhausted from the downstream region of the oven interior through exhaust port 44. By this arrangement, the space surrounding the electrode arrangement is constantly swept by a dry, heated gas to retard condensation of the volatilizing polar moisturizing agent as the tow is being heated. Thus, high moisture tow may be processed without generating such moisture levels adjacent the electrodes as will result in condensation thereon and consequent arcing between the electrodes and burning or melting of the tow. Such a sweeping operation also has the advantage of maintaining a uniform temperature throughout the oven interior. If desired, the heating function of the sweep gas may be supplemented by auxiliary radiant heaters, not shown, which may be placed along the oven interior. As shown, the electrode assembly may be mounted within the oven by means of suitable insulated mounting studs 46 which serve to electrically isolate the electrodes from the housing 34. Heavy capacity leads 48 connect the upper and lower electrodes assemblies with a conventional dielectric generator, not shown. In that the details of the dielectric generator do not comprise a part of the present invention and are well known, a detailed discussion would not here be appropriate. It will suffice to understand that many generators of conventional design may be employed in the practice of the present invention to good advantage insofar as they may be capable of rendering a field frequency of from 1 to 300 megacycles per second at from about 2,000 to 25,000 volts.

For a more detailed showing of the configuration of the electrode assembly per se, reference is made to FIGS. 2 and 3, wherein the assembly is seen to comprise an upper, high potential electrode assembly 50 and a lower, low potential electrode assembly 52 which together comprise the total electrode array, generally denoted by numeral 54. The upper and lower electrode assemblies 50, 52, which are of identical construction and electrode spacing, are seen to comprise a bus bar 56 supported at either end within the oven by the previously referred to insulated studs 46. Extending from each bus bar is a plurality of electrode fingers of equal length and decreasing spacing as viewed from left to right in FIGS. 2 and 3 (the tow also passing from left to right). The electrode length and consequent capacity may be varied according to the drawing speed and percent moisture desired in the finally drawn tow. The spacing between the upper, high potential electrode assembly **50** and the lower, grounded electrode assembly **52**, which spacing is denoted by gap labeled G in FIG. 3, is dependent upon the tow thickness being processed, it being desired that this vertical electrode gap be of such dimension to pass the tow tangent to both the upper and lower fingers **58, 58'**, respectively. Where it is contemplated that tows of varying thickness will be processed, it will be found desirable to mount either or both electrode assemblies so that the vertical gap G may be adjusted whereby any air gap between the respective fingers and the tow surface is maintained at a minimum. Undue air gaps between the tow surface and the electrode fingers reduce the dielectric constant between the fingers and necessitate, for a given rate of heat-up, greater power inputs and a consequent loss in efficiency of operation.

As best seen in FIG. 2 the spacing between each electrode finger **58, 58'**, of both assemblies decreases from a maximum at the tow introduction end (the lefthand end as viewed in FIG. 2). Such electrode finger spacing, labeled C in FIG. 3, is systematically decreased until it becomes quite small at the tow departure end. Such an arrangement is found to provide a dielectric field of increasing intensity as one progresses downstream in the direction of tow travel, a cardinal feature in dielectric drawing operations where polar moisturizing agents are being employed to accelerate heat-up rates. That is, the high moisture tow entering the upstream end of the electrode assembly possesses a higher dielectric loss factor than the relatively drier tow passing through the downstream end of the assembly; therefore, a uniform heating rate throughout the dielectrically heated drawing zone may be maintained by increasing the field intensity as the moisture level of the tow decreases during heat-up, such an increasing field intensity being most expediently accomplished by means of the decreasing electrode finger spacing just described.

A further advantage to be found in this electrode spacing arrangement lies in the fact that, in the regions of higher moisture, arcing propensities are a maximum; that is, the threshold beyond which electrode arcing may occur is lower at the upstream end of the electrode assembly than at the downstream end. Therefore, a higher field intensity may be accommodated towards the downstream end where lower levels of moisture are encountered. This consideration joins very nicely with that which grows out of the observation that the field intensity must be increased in the face of decreasing moisture content if a substantially constant heat-up rate is to be maintained.

The outer extremities of the electrode fingers **58, 58'** of the upper and lower electrode assemblies are arranged to overlap an amount at least equal to the width of the tow being processed, as seen in FIG. 2. However, this overlap should be maintained as small as possible in order to provide maximum voltage density in the area served by each pair of upper and lower fingers. As the mass and, consequently, width of tow increases, the overlap is necessarily increased to accommodate such width and, if heat-up rate is to be maintained, the voltage must accordingly be increased to maintain a given field intensity. It will therefore appear that, where it is contemplated that tows of various denier will be processed, either one or both of the upper and lower electrode assemblies should be mounted so as to be adjustable within the plane of FIG. 2 to thereby regulate the electrode finger overlap to that minimum which will accommodate the width of tow being processed. Obviously, the length of the electrode assembly will be determined by, inter alia, the material being processed, draw speed and ratio, polar liquid content, and electrode spacing, both vertical and horizontal.

We have found the drawing of heavy denier tows during dielectrically induced heating to be of particular benefit in the case of polyethylene terephthalate due to the fact that, within its optimum drawing temperature range of 90 to 100° C., its dielectric loss factor approaches a maximum with the result that, as the tow is heated to

drawing temperature, the efficiency of heat conversion increases for a given input of dielectric energy.

The principles and practice of this invention are further illustrated by the following examples, which are not to be construed as limitative in that any variations in materials and conditions elsewhere indicated herein may be substituted in lieu of those set out in these examples.

Example I

The following example is illustrative of the practice of this process in the absence of any preconditioning of the tow, i.e., the tow was drawn at ambient conditions of 65% relative humidity at a temperature of 22° C. A uniformly spaced electrode arrangement was employed under these relatively dry conditions.

Bobbins of as-spun continuous filament polyester yarn from several spinning runs were placed upon a bobbin creel from whence the bobbin yarn ends were plied together into a unified tow bundle of 70,000 total denier. After plying, the tow was forwarded to a constant tension means in order to facilitate placing the filaments of the tow bundle under as nearly uniform tension as was practicable.

From the tension means the tow bundle was forwarded by a pair of feed rolls operated at a peripheral surface speed of 11 f.p.m. The feed rolls were so arranged that one roll was canted with respect to the other to permit making sufficient wraps of the tow thereupon to prevent slippage during drawing. In this instance 8 wraps were found sufficient.

From the feed rolls the tow was forwarded to the dielectric oven, through the dielectric cell therein and out to a pair of draw rolls with one roll canted with respect to the other whereon 8 wraps of the tow was made. The draw rolls were operated at a peripheral speed of 54.5 f.p.m. The differential speed existing between the feed and draw rolls provided a draw ratio of 4.95:1. From the draw rolls the drawn tow was forwarded to a commercial take-up whereon the drawn tow is packaged onto a bobbin for subsequent processing into staple yarn.

The dielectric cell utilized consisted of a pair of multifingered electrodes affixed to high and ground potential bus bars. The electrodes of the cell were arranged in a staggered, parallel and overlapping relationship spaced apart a distance sufficient to permit the passage of the 70,000 denier tow bundle with a tangential contact being made between the tow and the electrodes. Each bus bar had affixed thereto 37 finger electrodes spaced on ½ inch centers. Said electrodes were ¼ inch in diameter.

Employing this cell, the tow bundle was subjected to a uniformly intense dielectric field strength of approximately 8500 volts per inch at an applied voltage of 3000 volts at a frequency of 27 megacycles per second. (The field intensity is calculated by dividing the voltage drop across the electrodes by the distance existing between adjacent high and ground potential electrodes. In the case at hand this distance was about 0.35 inch.)

While in the confines of the cell the tow bundle was uniformly heated throughout its mass to a drawing temperature of 90° C.

Subsequent to drawing the tow was cut into staple samples and examined to determine their physical properties and the degree of level dyeing. These tests revealed the drawn staple had a filament denier of 1.91, a tenacity of 6.55 g.p.d., an elongation of 32.1%, a modulus of 110 g.p.d. and an average dark dye defect count per 100 grains of staple yarn of 45.

The dark dye defect count is determined, in the examples here set forth, according to a procedure wherein a drawn staple sample is prepared by crimping approximately 100 grams of drawn tow to impart 10 to 12 crimps per inch thereto. The crimped tow is then skeined and placed in a hot air oven and heated for 9 minutes at 145° C. The heat set tow is then cut into staple lengths of 1 to 1½ inches and dyed (in the present examples, Celliton fast blue AF dye was utilized). The dyed staple is then hand carded to remove tangles and open the staple bundle. Random samples are then taken from the bundle, weighed to the nearest 0.001 gram and spread to count the dark dyed fibers. This count per given weight of sample is then converted to an average count for 100 grains, where 6.48 grams=100 grains.

Example II

The following example illustrates the process employing the use of a polar moisturizing agent at ambient temperature using graduated electrode spacing.

A continuous filament polyester tow bundle of 63,000 total denier was plied together as described in Example I. From the constant tension means the tow was forwarded through a preconditioning chamber wherein water at a temperature of 10° C. was mist sprayed upon the tow. The tow departed the preconditioning chamber after residing therein for 2.5 seconds with a moisture level of 7.5% by weight of dry tow.

The moisturized tow was then forwarded by feed rolls of the same construction as those in Example I operating at a peripheral speed of 74.4 f.p.m. From the feed rolls, the tow was forwarded into a dielectric oven and through the dielectric cell housed therein wherein the tow was elevated to a uniform temperature of 90° C. by the dielectric energy supplied thereto to facilitate uniform drawing. While the tow was under the influence of the dielectric field, it was simultaneously subjected to drawing provided by a pair of draw rolls, as in Example I, operated at a peripheral speed of 320 f.p.m. The differential in speed between the feed and draw rolls provided a draw ratio of 4.3:1. From the draw rolls, the drawn tow was forwarded to a commercial take-up winder and wound on a bobbin for subsequent cutting into staple yarn.

The dielectric cell utilized was 42 inches in length with the finger electrodes arranged in a parallel and overlapping spaced relationship to provide passage of the tow therethrough. The fingers were overlapped about 1 inch to accommodate this size tow. The finger electrodes were ½ inch in diameter and were spaced along the length of the cell at an ever decreasing center distance such that the widest electrode spacing occurred at the tow entrance end to the cell and narrowest electrode spacing occurred at the tow exit end of the cell. As previously related, this electrode arrangement provides for an increasing field strength to be applied to the tow as it progresses through the cell.

A voltage of 3000 volts at a frequency of 27 megacycles per second was applied to the cell electrodes. This voltage provided a field intensity varying from approximately 1850 volts per inch at the tow entrance to the cell to 3750 volts per inch at the tow exit end of the cell.

Subsequent to drawing the tow was cut into staple lengths and evaluated to reveal that the drawn denier was 1.52 d.p.f., with a tenacity of 5.31 g.p.d., an elongation of 49.8%, a modulus of 45 g.p.d. and an average dark dyed defect count per 100 grains of staple of 9. The moisture content of the drawn tow was less than 0.5%. The specific birefringence of these samples was found to be 0.188 showing a high degree of orientation.

Example III

In the following example, the tow was preconditioned by moisturizing at an elevated temperature. Continuous filament polyester yarns were plied together as in Example I to provide a tow having a total denier of 90,000. The tow was forwarded from the tow bundle forming guide to a constant tensioning means and thence into a preconditioning chamber wherein the tow was subjected to a water mist spray having a temperature of 50° C. The tow departed the preconditioning chamber after residing therein for 1.7 seconds at a moisture level of 9% based on the weight of the dry tow.

The preconditioned tow was subsequently forwarded by means of feed rolls, through the dielectric oven to draw rolls and thence to a commercial take-up winder for packaging onto a bobbin for later processing into staple yarn. All of this equipment was identical to that of Example II.

The feed rolls were operated at a peripheral speed of 76.4 f.p.m. and the draw rolls at 320 f.p.m. to provide a draw ratio of 4.2:1. The dielectric cell was operated at the same voltage and frequency as that in Example II. The dielectric oven was operated at an environmental temperature of 90° C. The moisture content of the drawn tow was measured to be 0.3% by weight.

Subsequent to drawing, the tow was cut into staple yarn and tested for physical properties and was found to have a denier per filament of 1.55, a tenacity of 5.7 g.p.d., an elongation of 44.0%, a modulus of 46 g.p.d. and an average dark dye count per 100 grains of staple of 20. The specific birefringence of these samples was measured to be 0.190.

Example IV

Bobbins of as-spun continuous filament nylon 66 (polyhexamethylene adipamide) yarn from several spinning runs were placed upon a bobbin creel and plied together into a unified tow bundle of 40,000 total denier. After plying the tow, it was forwarded to a constant tension means to impart as nearly a constant tension to each filament of the tow as was possible.

From the tension means, the tow bundle was forwarded by a pair of feed rolls operated at a peripheral speed of 31 f.p.m. The feed rolls were arranged as in Example I.

From the feed rolls the tow was forwarded to the dielectric oven, through the dielectric cell residing therein and out to a pair of draw rolls operating at 125 f.p.m. The differential in speed existing between the feed and draw rolls provided a draw ratio of 4.0:1. From the draw rolls the drawn tow was packaged onto a bobbin by a commercial take-up for subsequent processing into staple yarn.

The dielectric cell, applied voltage, frequency and field intensity utilized were the same as described in Example I.

Physical examination of the drawn tow showed a tenacity of 5.12 g.p.d., an elongation of 26.9%, a modulus of 35 g.p.d., a density of 1.145 g./cc. and a birefringence of 0.523 (vs. 0.060 for normally drawn nylon 66). This indicates the tow was not fully oriented.

Example V

A bobbin of 840/140 nylon 66 (tire yarn) was processed identically as the tow of Example IV with the exception that a draw pin was placed in the dielectric field to localize the draw point. One wrap of the yarn was made around the draw pin. The feed rolls were operated at a peripheral speed of 19.61 f.p.m. and the draw rolls at 125 f.p.m. to provide a draw ratio of 6.37:1.

Physical property examination revealed a tenacity of 9.33 g.p.d., an elongation of 10.9%, a modulus of 67.0 g.p.d., a density of 1.152 g./cc., and a birefringence of 0.640.

It will now be appreciated that there has been herewith disclosed a novel and most beneficial process for the substantially dry-drawing of heavy denier, high density tows of polyethylene terephthalate in an efficient and highly uniform manner, a process unattended by the difficulties and expense typical of conventional wet-drawing operations and which is productive of high quality tows exhibiting a high degree of uniform orientation. Obviously, numerous modifications and variations of the present process are possible in the light of the above teachings. It is, therefore, to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

What is claimed is:

1. The process of uniformly orienting polyethylene terephthalate filaments in the form of a heavy denier tow comprising heating said tow to a temperature greater than about 50° C., imparting a moisture content of from 3 to 30 percent by weight of filament to said tow, further heating said tow to a temperature of at least 90° C. under the influence of a dielectric field, whereby the individual filaments of the tow are heated to a uniform temperature simultaneously drawing said tow under uniform tension at a pre-selected ratio to thereby draw-orient the individual filaments comprising said tow at a uniform temperature.

2. The process of claim **1** wherein the moisture content is within the range from about 6 to 12 percent.

3. The process of claim **1** wherein the dielectric field is characterized by a frequency of from 1 to 1200 megacycles and a voltage gradient of from about 2,000 to 25,000 volts.

4. The process of claim **1** wherein said dielectric field is characterized by an increasing field intensity in the direction of tow travel therethrough to thereby maintain a substantially constant rate of heat evolution in said filaments.

5. The process of claim **1** wherein a continuous stream of dry gas is caused to sweep the space occupied by said dielectric field to thereby minimize electrode arcing tendencies.

References Cited

UNITED STATES PATENTS

2,456,384	12/1948	Conaway	28—62
2,692,875	10/1954	Weinstock et al.	260—85.5
3,032,856	5/1962	Fleissner	28—59.5
3,081,485	3/1963	Steigerwald	219—10.61 X
3,205,334	9/1965	Manwaring	219—10.61
3,263,052	7/1966	Jeppson et al.	219—10.61 X
3,205,334	9/1965	Manwaring	219—10.61

LOUIS K. RIMRODT, *Primary Examiner.*