

June 24, 1969

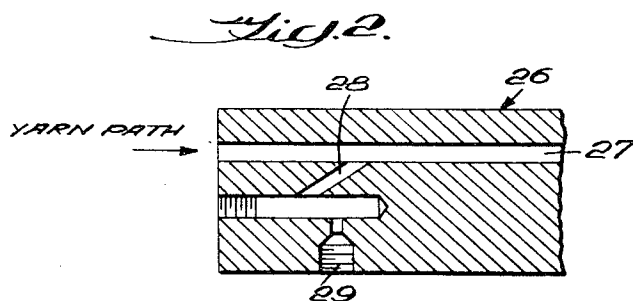
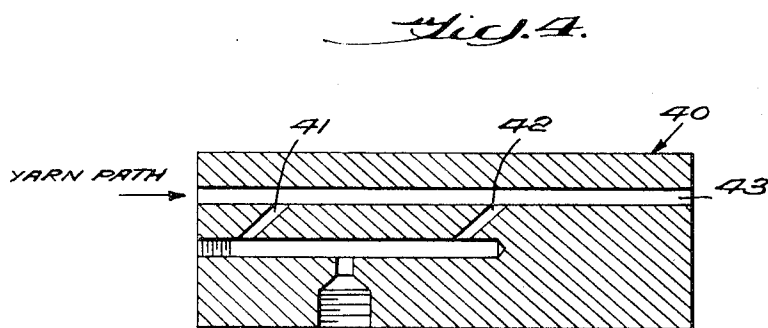
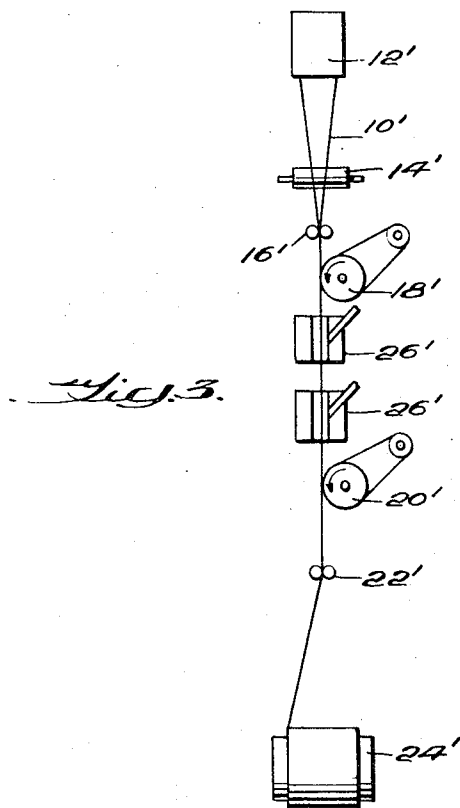
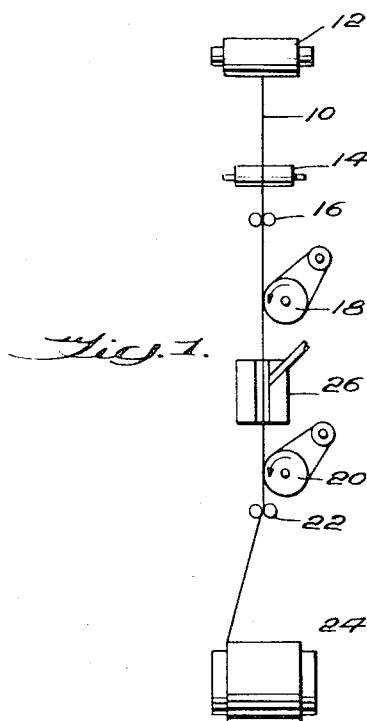
G. PITZL

3,452,130

JET INITIATED DRAWING PROCESS

Filed Feb. 2, 1967

Sheet 1 of 2



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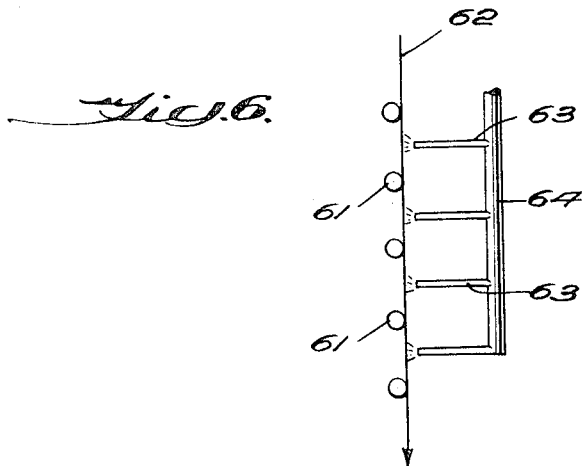
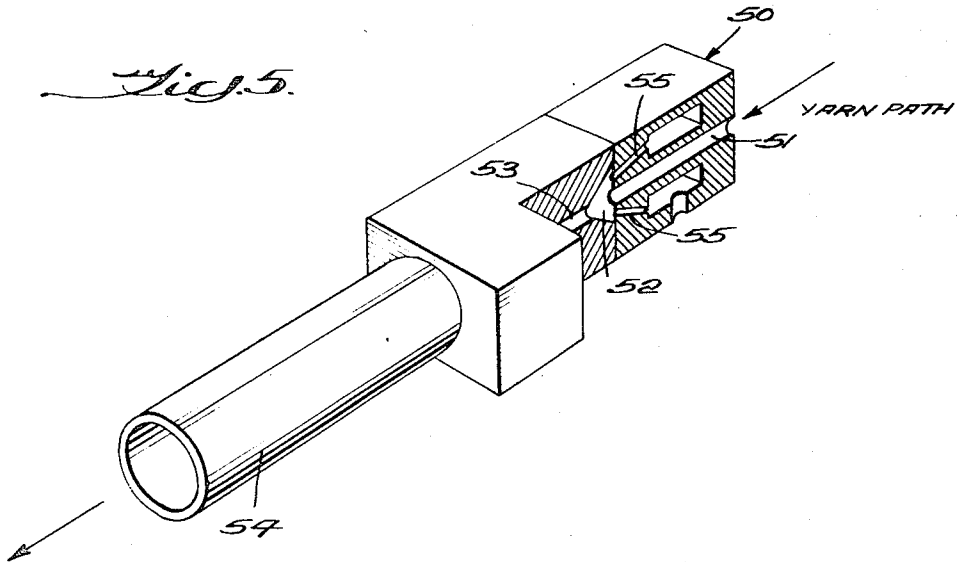
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3,452,130

JET INITIATED DRAWING PROCESS

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Sheet 2 of 2



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3,452,130

## JET INITIATED DRAWING PROCESS

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Continuation-in-part of application Ser. No. 167,083, Jan. 18, 1962. This application Feb. 2, 1967, Ser. No. 613,607

Int. Cl. D01f 7/06; B29c 17/02

U.S. Cl. 264-210

5 Claims

### ABSTRACT OF THE DISCLOSURE

Filaments are orientation drawn by replacement of the usual snubbing device with a jet device through which the yarn advances toward a draw roll. In the jet device, drawing is initiated by exposure to an intersecting jet of a heated gaseous fluid such as air or superheated steam. Fluid temperature and pressure must be such as to heat the yarn to the drawn initiation point in less than ten milliseconds.

This is a continuation-in-part directed to subject matter divided from my copending application Ser. No. 167,083, filed Jan. 18, 1962, now U.S. Patent No. 3,303,169. The invention relates generally to the production of filamentary structures from synthetic linear polymers and more particularly to the processes by which such structures are drawn and oriented.

It is well known that synthetic linear polyamide filaments are usually drawn to increased length in order to produce an oriented structure having high tensile strength. When nylon was first introduced, this step was accomplished merely by tensioning filamentary yarn between feed and draw rolls operated at differential speeds. Although product quality was acceptable, various difficulties such as differential dyeability were encountered as a result of nonuniform tensile properties and variable orientation along the length of the drawn yarn. Subsequently, the use of a snubbing pin in the drawn zone and localization of the drawn point on the surface of the pin were disclosed by Babcock in U.S. Patent No. 2,289,232. With this modification, yarn properties and uniformity are improved substantially but additional process considerations such as the application of finish to the yarn for the purpose of reducing friction are involved. To avoid variations in yarn properties, the amount, distribution and composition of the finish must be controlled carefully. For a given set of process conditions, there is an upper limit on the speed with which yarn can be drawn in order to insure that adequate time is available for the uniform application of finish to each filament of a bundle. Similarly, where a heated pin is employed, there is a limit imposed on drawing speed by the minimum contact time required to heat the running yarn sufficiently.

An additional problem which has been encountered in pin-drawing nylon yarn is that the drawn yarn undergoes a gradual lengthwise retraction with time. These effects are accelerated by heat and moisture. For example, representative nylon yarns have a boil-off shrinkage of 10% or more. Where that degree of shrinkage is excessive, a separate shrinking step prior to utilization of the yarn is required. In addition to the extra processing and handling involved in such preshrinking procedures, the yarn usually suffers a reduction in initial modulus due to a diminution of yarn orientation and is therefore more sensitive to tension variations encountered in subsequent processing stages.

The various improvements and advantages disclosed herein are accomplished in a single-stage drawing process which includes the steps of advancing a filamentary yarn

over feed and draw rolls and substantially instantaneously heating the filaments in the draw zone to a temperature of at least 115° C. as they pass through an enclosure. In the enclosure, a heated, single-phase gaseous fluid is jetted on the filaments in intersecting relationship therewith, thereby initiating drawing, reducing the drawing tension substantially and localizing a significant fraction of the draw in the enclosure.

As noted, the desired effects are attained when a yarn temperature of at least 115° C. and preferably 120° C. or more is reached. With a substantially instantaneous increase in filament temperature to about 140° C. much more stable operation and improved product uniformity are achieved. The maximum operable filament temperature corresponds to the fiber stick temperature which is generally about 20-35° C. below the polymer melting point. When this temperature is reached, it is believed that individual filaments break and stick to the body of the jet enclosure, thereby fouling the yarn passages and rapidly breaking down the thread line. Broken filaments observed under these conditions show evidence of fusing.

Where reference is made herein to a "substantially instantaneous increase" in filament temperature, the relationship between fluid conditions and yarn speed is such that the yarn is raised to the desired temperature in less than ten milliseconds, preferably in less than about one millisecond. Under these circumstances, fluid temperatures above the polyamide melting point are usually required but have no adverse effect on the yarn because of the high rate of speed at which it travels through the fluid jet.

Although a substantially instantaneous increase in filament temperature within the jet enclosure is essential to initiation of drawing, it is apparent that such temperature measurements oftentimes can only be made with great difficulty. Furthermore, in the lower range of operable filament temperatures, small variations can have a large effect on the degree of fiber orientation and, for that reason, the close control of process variables is important. In this respect, it has been found that the reduction in tension resulting from the transfer of heat to the filamentary structures is an accurate reflection of the yarn temperature in the jet enclosure. Since the reduction in tension can be measured readily, it is also useful as a control parameter and has been reported herein as a process characterization. When the temperature and pressure conditions are sufficiently intense to raise the yarn to a temperature of about 115° C., there is a corresponding reduction in tension in the draw zone to about 75% of the tension observed when no heating fluid is supplied. Much greater improvements are obtained when the drawing tension is reduced to the 65% level and below.

In addition to yarn temperature in the jet and tension level in the draw zone, the extent to which the yarn is drawn is another process variable on which the degree of orientation is dependent. However, since as-spun yarn is partially oriented, reference to the draw ratio alone does not give an accurate or reliable indication of the total orientation observed in the drawn yarn. Where the phrase "total draw ratio X" is used herein, the various types of orientation introduced into the yarn have been considered. Thus, the factor X includes the conventional machine draw ratio  $X_m$  which is the ratio of feed and draw roll surface speeds if no slippage occurs. Since the yarn entering the drawing stage may be under slight tension, an added predrawing stretch ratio  $X_p$  may have been imposed; usually this orientation factor is insignificant and can be ignored. The as-spun yarn also has a degree of orientation, produced in the spinning process and measured by filament birefringence, which can be expressed as a draw ratio  $X_s$ . With this information avail-

able, a reasonably accurate indication of the degree of orientation can be obtained by computing the total draw ratio  $X$  which is the product of the machine draw ratio  $X_m$  and the as-spun orientation factor  $X_s$ .

In the following specification and examples, reference is made to the accompanying drawings wherein:

FIGURE 1 is a schematic illustration of an installation useful in the practice of a split process;

FIG. 2 is an enlarged, longitudinal, sectional view of the single orifice jet shown schematically in FIG. 1;

FIG. 3 is a schematic illustration of an installation useful in the practice of a coupled process;

FIG. 4 is a longitudinal, sectional view of a two orifice jet suitable for use as a replacement in the arrangements of FIGS. 1 and 3;

FIG. 5 is a perspective view, partially sectioned of another jet embodiment; and

FIG. 6 is a schematic illustration of an apparatus arrangement which has been included for purposes of comparison.

In the process installation of FIG. 1 (Example I), undrawn nylon filamentary yarn 10 is unwound from a package 12, moistened in its travel over finish roll 14, passed between guide pins 16 and tensioned between driven feed roll 18 and draw roll 20. In order that the filamentary structure will be drawn to several times its extruded length, rolls 18, 20 are operated at differential surface speeds, i.e., roll 20 has a peripheral speed considerably higher than that of roll 18. From roll 20, the drawn filamentary structure passes between pins 22 to a suitable windup 24.

In the draw zone between rolls 18, 20, a jet device 26 of the type shown in FIG. 2 is positioned. Device 26 is provided with a longitudinal passage or enclosure 27 through which the tensioned yarn travels. Intermediate its ends, passage 27 communicates with the orifice of a jet conduit 28, which is disposed at an angle of about 30° with the axis of passage 27. Device 26 is adapted for connection at 29 to a suitable high pressure fitting which functions to deliver a controlled supply of a single-phase heated gaseous fluid to conduit 28 for discharge into passage 27 in intersecting relationship with yarn passing therethrough in the direction indicated.

The process installation of FIG. 3 (Examples II, V) is similar to that shown in FIG. 1 except that yarn 10' is spun from a spinneret 12' and a tandem arrangement of two jet devices 26' is provided in the draw zone between rolls 18', 20'.

In other process installations (Examples III, IV and VII-IX), the jet devices of FIGS. 4 and 5 are substituted for the device 26 of FIG. 1 or for the devices 26' of FIG. 3. The device 40 of FIG. 4 is similar to that shown in FIG. 2, except for the provision of two angularly disposed jet conduits 41, 42 discharging into the longitudinal passage 43 at an angle of 45°. The jet device 50 of FIG. 5 has an initial passage 51 through which yarn travels to expansion chamber 52, passage 53 and tail pipe 54. In chamber 52, heated fluid from four symmetrically disposed jet conduits 55 is jetted onto the yarn in intersecting relationship therewith.

The apparatus arrangement of FIG. 6 includes a plurality of pins 61 which support yarn 62 in the draw zone as heated fluid is discharged thereon from a plurality of jet conduits 63, each in communication with a manifold 64. This arrangement has been disclosed herein for purposes of comparison (Example VI) with operable embodiments wherein the yarn is in a passage or enclosure when exposed to the fluid jet. In this respect, it should be noted that the embodiments of FIGS. 4 and 5 have a passage or enclosure equivalent to that shown at 27 in FIG. 2, i.e., a passage which is completely enclosed except for the yarn inlet and outlet and the jet orifice(s). Other constructions are feasible. For example, a device comprised of a pair of opposed flat plates between which the yarn travels as fluid is jetted thereon

from an orifice in one of the plates is operable under certain conditions. The principal requirement is that the heated fluid must impinge on the yarn in an at least partially restricted zone. Fluid expansion in that zone of contact or impingement contributes to a separation of the yarn bundle and to the substantially instantaneous increase in filament temperature which is essential to the instant process. When these conditions are achieved, heat transfer from the gas to the yarn is optimum, due at least in part to separation of the filaments in the yarn bundle during such treatment (Example III). The separation of the filaments also helps to avoid fusing at high gas temperatures.

Any gas reasonably inert to the yarn may be employed as the jet medium, hot air or superheated steam being preferred in most applications. Other possibilities include nitrogen, carbon dioxide and mixtures thereof. Saturated steam is believed to adversely affect the yarn modulus at temperatures required to obtain minimum yarn shrinkage. In addition, the presence of condensate on the drawn yarn is thought to contribute to product nonuniformity.

The temperature and pressure of the heated, single-phase gaseous fluid must be carefully controlled to maintain a product with uniform properties. At constant pressure, the temperature of the fluid determines the amount of tension in the yarn during drawing as well as the shrinkage and retraction of the product. Any increase in fluid temperature at constant pressure results in a substantial decrease in all three values, the upper limit usually being set by temperatures at which filaments fuse or break in a given jet. Conversely, at constant temperature, an increase in fluid pressure not only results in a decrease in the yarn tension during drawing but also leads to a further reduction in the residual shrinkage and retraction of the drawn yarn. The temperature and pressure selected will also depend on yarn speed because of its relationship to the period of yarn exposure to the jet medium. A comparison (Table I, runs AF and AK) of the relative efficiency of superheated steam and hot air at the same pressure, using the same fluid jet, shows a distinct temperature advantage in favor of steam, as reflected by the level of tension during drawing and by the shrinkage and retraction of the product.

In the examples which follow, the use of different combinations of the illustrated apparatus under various drawing conditions has been described. When polyamide filaments are drawn in accordance with the minimum process requirements, the drawn yarn is characterized by high modulus and tenacity as well as by low shrinkage and retraction. It also has good mechanical quality and excellent property uniformity. Since snubbing elements are not employed, the problems previously encountered with friction and finish uniformity are avoided.

Under the more severe process conditions reported in some of the examples, an unusual and hitherto unobtainable combination of properties is achieved in that the drawn yarn has a break elongation of at least 25%, an initial modulus of at least 38 grams/denier and a boil-off shrinkage of not over 6.5%. X-ray analysis shows that the crystalline structure is highly oriented and has a large transverse area. The average X-ray orientation angle is preferably less than about 14°, and the crystal cross sectional area is at least 1250 square angstroms, preferably at least 1500 Å<sup>2</sup>, measured prior to boil-off, relaxation or annealing treatments. This product is so stable that, even after boil-off, its high modulus is largely retained, and fabrics woven therefrom are characterized by an unusually high crease recovery, indicating superior wrinkle resistance and resilience.

The yarn samples employed in the exemplified tests and comparisons were obtained by stripping representative 130-150 cm. lengths from the extremities and from the longitudinal center of a package, throughout the entire package and yarn length.

Crystal orientation and average lateral crystal dimensions of the high modulus product of this invention are determined from the principal equatorial X-ray diffraction maxima. Polyamide diffraction patterns of this type are

In addition to initiation of drawing, the tabulation shows that more than 25% of the draw must occur (AF

| Run | Fluid | Heat transfer          |                     | Draw zone          |                                |                                   | Yarn properties       |                        |                              |
|-----|-------|------------------------|---------------------|--------------------|--------------------------------|-----------------------------------|-----------------------|------------------------|------------------------------|
|     |       | Fluid temp.,<br>° C.   | Yarn<br>temp., ° C. | Tension,<br>g.p.d. | Tension,<br>percent<br>control | Percent<br>draw in en-<br>closure | Shrinkage,<br>percent | Retraction,<br>percent | Initial mod-<br>ulus, g.p.d. |
| AA  | None  | Draw pin               | -----               | 2.38               | 98.0                           | -----                             | 9.8                   | 2.2                    | 31.6                         |
| AB  | do    | Delocalized<br>control | -----               | 2.43               | 100.0                          | -----                             | 9.9                   | 2.3                    | 31.8                         |
| AC  | Air   | 150                    | 101                 | 2.29               | 94.3                           | 23                                | 9.8                   | 2.2                    | 31.4                         |
| AD  | Air   | 190                    | 110                 | 2.14               | 88.0                           | 24                                | 9.6                   | 2.2                    | 31.4                         |
| AE  | Air   | 200                    | 113                 | 2.07               | 85.2                           | 25                                | 9.5                   | 2.1                    | 32.3                         |
| AF  | Air   | 240                    | 116                 | 1.79               | 73.7                           | 32                                | 8.4                   | 2.0                    | 34.8                         |
| AG  | Air   | 260                    | 119                 | 1.57               | 64.6                           | 51                                | 7.2                   | 1.9                    | 30.1                         |
| AH  | Air   | 275                    | 121                 | 1.50               | 61.7                           | 74                                | 6.1                   | 1.8                    | 30.3                         |
| AI  | Air   | 300                    | 134                 | 1.29               | 53.1                           | 79                                | 5.6                   | 1.5                    | 35.0                         |
| AJ  | Steam | 170                    | 116                 | 1.79               | 73.7                           | 32                                | 8.6                   | 2.1                    | -----                        |
| AK  | do    | 200                    | 119                 | 1.57               | 64.6                           | 51                                | 8.6                   | 2.1                    | -----                        |
| AL  | do    | 220                    | 119                 | 1.57               | 64.6                           | 51                                | 8.6                   | 2.1                    | -----                        |
| AM  | do    | 250                    | 129                 | 1.36               | 56.0                           | 53                                | 8.4                   | 2.1                    | -----                        |
| AN  | do    | 250                    | 122                 | 1.50               | 61.7                           | 74                                | 7.5                   | 1.7                    | -----                        |
| AO  | do    | 250                    | 134                 | 1.29               | 53.1                           | 79                                | 7.9                   | 1.8                    | -----                        |
|     |       |                        |                     |                    |                                |                                   | 6.5                   | 1.4                    | -----                        |

and AJ) in the yarn passage of the jet device in order to achieve the desired combination of properties. Preferably (AG and AK), at least 50% of the draw is localized in that passage. By comparison with the accepted view that 100% of the draw should be localized at a snubbing pin or its equivalent in order to obtain "controlled drawing," it is interesting to note that good yarn properties are obtained at much lower percentages of localization in the present process.

### Example II

In an apparatus arrangement of the type shown in FIG. 3, 34 filament yarn was spun from molten polyhexamethylene adipamide of 33.5 relative viscosity and drawn continuously to a total draw ratio of 4.5X. The yarn was drawn to a final denier of 70 and wound at a speed of 2000 yards/min. (1830 meters/min.), at a tension of 7-10 grams. The two jet devices were spaced apart 1.5 inches (3.7 cm.) along the yarn line. With this tandem arrangement, effective heating of the yarn at the higher winding speed was achieved. Results obtained in a series of tests using superheated steam at different temperatures and pressures are reported in Table II.

The percent crystallinity was determined by the density method of Starkweather and Moynihan, *Journal of Polymer Science*, 22, 363 (1956). The determinations are based on an estimated density of 1.069 for amorphous nylon and a density of 1.220 for the crystalline regions. The density of yarn samples was determined by the meth-

### Example III

Under the conditions shown in Table III, additional runs are made, using the same prepackaged yarn as in Example I and the tandem jet arrangement of Example II. The comparable control (AB from Table I) is included. A comparison of the results obtained in runs BB-BK (Table II) and CA-CC provides additional support for the conclusion that an equivalent combination of properties can be achieved at a somewhat higher tension level with prepackaged as against freshly spun yarn. A similar comparison with runs AJ-AL (Table I) shows that more effective heating is accomplished with the tandem jet arrangement and that incremental property improvements are obtained as the treatment conditions become more severe.

The test is then repeated using the jet embodiment of FIG. 5 in which superheated steam is jetted onto the yarn from four orifices disposed in planes at right angles. Yarn properties and test conditions for runs CE-CI are also reported in Table III. The results show that, with no increase in steam temperature, drawing conditions and yarn properties improve with each increase in steam pressure. On the basis of these improvements, it is believed that an important factor in obtaining the advantages of the process of this invention is to provide gas to the jet conduit at a sufficient pressure so that the yarn bundle will be separated or splayed by vibration or otherwise into its individual filaments as a result of the impingement of

TABLE II

| Run     | Heat transfer  |        |                   |        | Yarn temp., ° C. | Draw zone       |                           | Yarn properties    |                     |                         |                        |
|---------|----------------|--------|-------------------|--------|------------------|-----------------|---------------------------|--------------------|---------------------|-------------------------|------------------------|
|         | Steam pressure |        | Steam temp., ° C. |        |                  | Tension, g.p.d. | Tension, percent, control | Shrinkage, percent | Retraction, percent | Initial modulus, g.p.d. | Crystallinity, percent |
|         | P.s.i.g.       | (Atm.) | Jet #1            | Jet #2 |                  |                 |                           |                    |                     |                         |                        |
| BA----- | None           |        |                   |        | 86               | 1.81            | 100.0                     | 11.4               | 3.0                 | 30.8                    | 35.1                   |
| BB----- | 50             | (4.4)  | 250               | 260    | 106              | 1.79            | 99.0                      | 10.9               |                     | 32.6                    | 35.7                   |
| BC----- | 50             | (4.4)  | 270               | 290    | 114              | 1.64            | 90.5                      | 11.0               |                     | 33.8                    |                        |
| BD----- | 70             | (5.8)  | 250               | 250    | 114              | 1.50            | 82.9                      | 9.6                | 1.7                 | 34.7                    |                        |
| BE----- | 50             | (4.4)  | 280               | 280    | 114              | 1.43            | 79.0                      | 9.4                | 2.0                 | 33.0                    | 37.0                   |
| BF----- | 50             | (4.4)  | 295               | 295    | 115              | 1.36            | 75.2                      | 9.1                |                     | 33.3                    |                        |
| BG----- | 50             | (4.4)  | 290               | 310    | 116              | 1.29            | 71.3                      | 8.0                |                     | 34.6                    | 37.3                   |
| BH----- | 70             | (5.8)  | 280               | 280    | 117              | 1.21            | 66.8                      | 8.5                | 1.4                 | 35.5                    | 39.0                   |
| BI----- | 70             | (5.8)  | 265               | 285    | 120              | 1.14            | 63.0                      | 7.9                | 1.3                 |                         |                        |
| BJ----- | 70             | (5.8)  | 270               | 290    | 125              | 1.07            | 59.1                      | 7.1                |                     | 34.2                    | 40.0                   |
| BK----- | 70             | (5.8)  | 280               | 290    | 125              | 1.07            | 59.1                      | 6.4                | 1.0                 |                         |                        |

od of Boyer, Spencer and Wiley, *J. Poly. Sci.*, 1, 249 (1946).

From a review of the data in Table II, it is apparent that the desirable combination of properties is not achieved, with freshly spun filaments, until drawing tensions are reduced to a somewhat lower level than was required with the prepackaged yarn of Example I. It is also apparent that the yarn properties improve as the treatment becomes more severe. Although good results are achieved when tension is reduced to from 65-70% of the control run BA, a greater incremental improvement is observed when the drawing tension is less than 60% of control. It is observed that the increased stability of the yarn (to retraction and shrinkage) is obtained with some increase in modulus, which is contrary to expectations.

the jet or jets thereon. As evidence to support this hypothesis, drawn 70 denier 34 filament yarn was attached to a fixed support, passed through the jet of FIG. 5 and thence over a pulley. A weight was attached to the yarn. The jet for this experiment was equipped with a glass tail pipe so that the yarn could be more easily observed. Room temperature air was passed through the jet. At an air pressure of 50 p.s.i.g. (4.4 atm.) and at a dead load corresponding to the yarn tension in run CF, the yarn was observed to vibrate. It was observed that the air pressure must exceed 25 p.s.i.g. (2.7 atm.) in order to maintain stable vibration. It was concluded that the air pressure in runs CF-CI is in the range required to initiate and maintain stable vibration or splaying of the yarn bundle, at the drawing tension observed.

TABLE III

| Run               | Heat transfer  |        |                   |        | Yarn temp., ° C. | Draw zone       |                          | Yarn properties    |                     |                         |                  |
|-------------------|----------------|--------|-------------------|--------|------------------|-----------------|--------------------------|--------------------|---------------------|-------------------------|------------------|
|                   | Steam pressure |        | Steam temp., ° C. |        |                  | Tension, g.p.d. | Tension, percent control | Shrinkage, percent | Retraction, percent | Initial modulus, g.p.d. | Tenacity, g.p.d. |
|                   | P.s.i.g.       | (atm.) | Jet #1            | Jet #2 |                  |                 |                          |                    |                     |                         |                  |
| Tandem jets:      |                |        |                   |        |                  |                 |                          |                    |                     |                         |                  |
| AB-----           |                |        |                   |        | 133              | 2.43            | 100.0                    | 9.9                | 2.3                 | 31.8                    | -----            |
| CA-----           | 45             | (4.0)  | 260               | 270    | 138              | 1.22            | 52.3                     | 4.8                | 1.2                 | 32.6                    | -----            |
| CB-----           | 55             | (4.7)  | 240               | 260    | 138              | 1.22            | 52.3                     | 4.8                | 1.2                 | 34.8                    | -----            |
| CC-----           | 55             | (4.7)  | 260               | 280    | 146              | 1.14            | 48.8                     | 3.5                | 0.8                 | 38.1                    | -----            |
| Four orifice jet: |                |        |                   |        |                  |                 |                          |                    |                     |                         |                  |
| CE-----           |                |        |                   |        | 126              | 2.57            | 100.0                    | 11.1               | *21.1               | 28.0                    | 5.3              |
| CF-----           | 50             | -----  | 245               | -----  | 151              | 1.50            | 58.4                     | 6.8                | *23.4               | 34.4                    | 5.8              |
| CG-----           | 90             | -----  | 250               | -----  | 160              | 1.14            | 44.5                     | 5.0                | *20.9               | 37.8                    | 5.5              |
| CH-----           | 100            | -----  | 250               | -----  | 167              | 1.07            | 41.6                     | 4.8                | *22.0               | 39.2                    | 6.0              |
| CI-----           | 105            | -----  | 250               | -----  |                  | 1.00            | 38.9                     | 4.7                | *23.1               | 40.5                    | 5.8              |

\*Elongation, percent.

Example IV

After replacing the illustrated jet device with that shown in FIG. 4, the apparatus arrangement of FIG. 1 was used to draw prepackaged 34 filament 6-6 nylon yarn (birefringence 0.005) of 36.5 relative viscosity at a machine draw ratio  $X_m$  of 4.0. The yarn was drawn to a final denier of about 70 and wound at a speed of 500 yards/min. (450 meters/min.). For purposes of comparison, delocalized control run EA and pin drawn run EB have been included in Table IV.

The increased crystallinity of the test yarns (runs EC-EG) compared with the pin-drawn control yarn (run EB) is readily apparent. The surprising tensile properties of the yarns of this invention are also demonstrated. For example, in the series of runs EC to EG, the yarn tenacity is seen to increase appreciably while the yarn elongation ("break elongation") remains substantially constant.

TABLE IV

| Run     | Heat transfer  |        |                  | Draw zone       |                 | Yarn properties          |                  |                     |
|---------|----------------|--------|------------------|-----------------|-----------------|--------------------------|------------------|---------------------|
|         | Steam pressure |        | Steam temp., °C. | Yarn temp., °C. | Tension, g.p.d. | Tension, percent control | Tenacity, g.p.d. | Elongation, percent |
|         | P.s.i.g.       | (Atm.) |                  |                 |                 |                          |                  |                     |
| EA----- | None           |        |                  |                 | 2.86            | 100.0                    |                  |                     |
| EB----- | None, draw pin |        |                  |                 | 2.50            | 87.5                     |                  | 35.5                |
| EC----- | 50             | (4.4)  | 260              | 116             | 2.07            | 72.4                     | 5.1              | 34.1                |
| ED----- | 50             | (4.4)  | 270              | 119             | 1.86            | 65.0                     | 5.8              | 35.1                |
| EE----- | 50             | (4.4)  | 295              | 121             | 1.79            | 62.6                     | 5.9              | 35.5                |
| EF----- | 60             | (5.1)  | 260              | 123             | 1.72            | 60.2                     | 6.0              | 36.8                |
| EG----- | 60             | (5.1)  | 290              | 126             | 1.65            | 57.7                     | 6.1              | 36.3                |
|         |                |        |                  |                 |                 |                          | 6.3              | 28.2                |
|         |                |        |                  |                 |                 |                          |                  | 36.1                |

Example V

Under the conditions set forth in Table V, freshly spun 6-6 nylon yarn of 36.5 relative viscosity was drawn in an apparatus arrangement similar to that shown in FIG. 3 except for the omission of one of the jet devices and enlargement of the yarn passage or enclosure in the remaining jet device. The heated fluid was superheated steam and the windup speed was 2000 yards/min. (1830 meters/min.) as in Example II. Denier uniformity of

TABLE V

| Run     | Heat transfer             |                 | Draw zone       |                          | Product denier uniformity, percent CV* |
|---------|---------------------------|-----------------|-----------------|--------------------------|----------------------------------------|
|         | Steam temp., ° C.         | Steam pressure  | Tension, g.p.d. | Tension, percent control |                                        |
|         |                           | P.s.i.g. (Atm.) |                 |                          |                                        |
| FA----- | None, pin-drawn control   |                 |                 |                          | 2.1                                    |
| FB----- | None, delocalized control |                 | 2.36            | 100.0                    | 1.8                                    |
| FC----- | 200                       | 70 (5.8)        | 1.57            | 66.5                     | 1.4                                    |

\*Percent coefficient of variation.

this yarn and of two control yarns, as reported in the above table, was determined automatically by capa-

TABLE VI

| Run     | Heat transfer  |        |                  | Draw zone       |                 | Yarn properties          |                    |
|---------|----------------|--------|------------------|-----------------|-----------------|--------------------------|--------------------|
|         | Steam pressure |        | Steam temp., °C. | Yarn temp., °C. | Tension, g.p.d. | Tension, percent control | Shrinkage, percent |
|         | P.s.i.g.       | (Atm.) |                  |                 |                 |                          |                    |
| JA----- | None--control  |        |                  |                 | 3.15            | 100.0                    | 10.5               |
| JB----- | 35             | (3.4)  | 270              | 3.0             | 1.22            | 38.7                     | 4.70               |
| JC----- | 70             | (5.8)  | 100              |                 | 3.15            | 100.0                    | 10.6               |
| JD----- | 70             | (5.8)  | 210              |                 | 2.25            | 71.5                     | 9.0                |
| JE----- | 70             | (5.8)  | 250              |                 | 2.15            | 68.3                     | 8.3                |
| JF----- | 70             | (5.8)  | 290              | 12.0            | 2.07            | 65.7                     | 7.5                |
| JG----- | 70             | (5.8)  | 330              |                 | 2.07            | 65.7                     | 7.6                |

itance variation measurements using a Model C Uster Tester.

Drawing tension for run FC is within the scope of the invention. The data in Table V show that the test yarn (run FC) is more uniform than the pin-drawn control (run FA) or the cold-drawn control (run FB). As in the preceding examples, the mechanical uniformity of the product and the operability level of the process are generally superior to those of the comparable operations involving a draw pin or other snubbing element.

Example VI

Prepackaged 34 filament 6-6 nylon yarn having a birefringence of 0.005 and a relative viscosity of 38.5 was drawn to a machine draw ratio  $X_m$  of 4.0 in an apparatus arrangement of the type shown in FIG. 1. The results obtained under various jet conditions and with different jet devices have been reported in the following table in order to illustrate the advantage of having the heated fluid impinge on the yarn in an at least partially restricted zone. JA is a delocalized control run. In JB, an enclosed two-orifice jet device of the type shown in FIG. 4 was used in place of that shown in FIG. 1. For runs JC-JF, the jet device was replaced with the arrangement of FIG. 6. For run JG, conduits 63 were located opposite pins 61 rather than between them. In JC-JG, temperatures were measured at the orifice of a jet conduit 63. The yarn was drawn and wound at a speed of 500 yards/minute (450 meters/min.).

Because of the numerous filament breaks at the supporting pins, runs JF and JG were deemed inoperable. In JE, drawing tension was reduced to 68% of control JA. However, yarn shrinkage and retraction percentages were considerably in excess of those obtained in test run JB, i.e., with the enclosed jet device of FIG. 4. In run JD, drawing tension was reduced to 71.5% of control JA, but shrinkage remained at the relatively high level of 9.0%.

Example VII

Thirty-four filament, 33.5 relative viscosity poly(hexamethylene adipamide) yarn of 0.005 birefringence was spun at 500 y.p.m. (450 meters/min.) and packaged. The packaged yarn was drawn in the apparatus arrangement of FIG. 1, using the two-orifice jet of FIG. 4, at a draw ratio  $X_m$  of 4.0. The yarn was drawn to a denier of about 70 under the conditions and at the speeds indicated in Table VII. KA is a delocalized (no pin, no jet, room temperature) control run.

X-ray examination of the drawn yarn according to the procedures described previously shows that they have

exceptionally large transverse crystal cross sections, combined with a high degree of orientation, as indicated by the low orientation angles. The results are given in Table VIII along with corresponding values for shrinkage and modulus. Also included, for purposes of comparison, is a pin-drawn control KF prepared from similar yarn spun at 1500 y.p.m. (1370 meters/min.), packaged, then drawn 2.90 $X_m$  at a tension of 2.5 g.p.d. KF has a spun yarn birefringence of 0.020, corresponding to a drawn ratio  $X_s$  of 1.56. The total draw ratio is, therefore, 4.5X.

The novel product obtained under the process conditions of run KD has a conditioned modulus (on the drawing package) of at least 38 g.p.d. and a boil-off shrinkage of not over 6.5%. This product is characterized by a crystallite cross section of at least 1250 A.<sup>2</sup> and an orientation angle of less than 14.5°. Even more desirable products, characterized by a crystallite cross section of at least 1500 A.<sup>2</sup> and an orientation angle of less than 14.0°, are obtained under the process conditions of run KE.

#### Example VIII

Prepackaged 34 filament 6-6 nylon yarn having a birefringence of 0.005 was drawn (LA) in a FIG. 1 apparatus arrangement, using the jet device of FIG. 4. Draw conditions were as follows: steam pressure 30 p.s.i.g. (3.0 atm.), steam temperature 275° C., machine draw ratio  $X_m$  4.0, windup speed 500 y.p.m. (450 meters/min.). A control (LB) was prepared from the same prepackaged yarn under the same draw conditions except that an unheated pin was used. In both runs, modulus

From the tabulated results, it is apparent that jet drawn yarn (LA) has a higher initial modulus than conventionally drawn yarn (LB) and also retains a somewhat greater fraction of the initial modulus after boil-off. The latter improvement correlates well with the improved crease recovery of the scoured fabric.

#### Example IX

Ten filament poly(hexamethylene adipamide) yarn of 35.5 relative viscosity was spun and drawn at the maximum operable machine draw ratio and to a denier of 60 in an apparatus arrangement of the type shown in FIG. 3, using the jet device of FIG. 4. As a treating fluid, steam was delivered to the jet at a pressure of 30 p.s.i.g. (3.0 atm.) and a temperature of 315° C. The drawn yarn was wound at a speed of 2000 yards/min. (1830 meters/min.). Various drawing conditions and yarn properties for test run MA are reported in the following table for purposes of comparison with the corresponding values obtained in run MB in which the jet device was replaced with an unheated draw pin.

TABLE VII

| Run     | Windup speed         |                | Heat transfer |                   |            |               | Draw zone        |                 |                          |      |
|---------|----------------------|----------------|---------------|-------------------|------------|---------------|------------------|-----------------|--------------------------|------|
|         | Y.p.m. (Meters/min.) | Steam pressure |               | Steam temp., ° C. | Steam flow |               | Yarn temp., ° C. | Tension, g.p.d. | Tension, percent control |      |
|         |                      | p.s.i.g.       | (Atm.)        |                   | C.f.m.     | (Liters/min.) |                  |                 |                          |      |
| KA----- | 1,000                | (910)          | Delocalized   |                   | Control    | None          | -----            | 2.64            | 100.0                    |      |
| KB----- | 1,000                | (910)          | 30            | (3.0)             | 280        | 2.9           | (82)             | 116             | 2.00                     | 75.7 |
| KC----- | 1,000                | (910)          | 40            | (3.7)             | 285        | 3.6           | (102)            | 117             | 1.79                     | 67.8 |
| KD----- | 750                  | (640)          | 40            | (3.7)             | 285        | 3.6           | (102)            | 124             | 1.57                     | 59.4 |
| KE----- | 500                  | (450)          | 40            | (3.7)             | 285        | 3.6           | (102)            | 139             | 1.36                     | 51.5 |

TABLE VIII

| Run     | Yarn properties |                    |                  |                     | Crystallite dimensions      |                               |                       | Orientation angle |      |         |
|---------|-----------------|--------------------|------------------|---------------------|-----------------------------|-------------------------------|-----------------------|-------------------|------|---------|
|         | Mi, g.p.d.      | Shrinkage, percent | Tenacity, g.p.d. | Elongation, percent | Width, A., D <sub>100</sub> | Breadth, A., D <sub>100</sub> | Area, A. <sup>2</sup> | IA                | IO   | Average |
|         |                 |                    |                  |                     |                             |                               |                       |                   |      |         |
| KA----- | 34.1            | 10.7               | 5.0              | 27.3                | 34                          | 23                            | 780                   | 15.7              | 14.7 | 15.2    |
| KB----- | 37.5            | 9.5                | 5.4              | 28.2                | 36                          | 25                            | 900                   | 14.2              | 14.0 | 14.1    |
| KC----- | 37.6            | 7.8                | 5.5              | 25.2                | 39                          | 25                            | 975                   | 14.2              | 13.6 | 13.9    |
| KD----- | 38.2            | 6.5                | 5.4              | 25.2                | 43                          | 29                            | 1,250                 | 12.4              | 12.4 | 12.4    |
| KE----- | 38.2            | 5.5                | 5.0              | 30.3                | 52                          | 33                            | 1,720                 | 12.3              | 12.0 | 12.2    |
| KF----- | 33.5            | 10.0               |                  |                     | 37                          | 23                            | 850                   | 15.0              | 16.0 | 15.5    |

was determined on as drawn yarn samples and also after boil-off. Thereafter, fabric samples were prepared from the yarns of runs LA and LB by weaving 104 x 76 count taffeta and scoured in the conventional manner. The crease recovery is determined by means of a modified Monsanto crease recovery test which provides an accurate measurement of fabric resilience. All results are reported in Table IX.

TABLE IX

| Run-----                        | LA   | LB   |
|---------------------------------|------|------|
| As drawn, Mi, g.p.d.-----       | 40.4 | 27.8 |
| After boil-off, Mi, g.p.d.----- | 22.1 | 14.2 |
| Percent crease recovery:        |      |      |
| Warp-----                       | 66.1 | 43.3 |
| Filling-----                    | 79.5 | 56.3 |
| Average-----                    | 72.8 | 54.9 |

The generally accepted method for measuring crease recovery is the Monsanto test which has been described as the "Vertical Strip Crease Recovery Test" in the American Society for Testing Materials Manual. For the purposes of this example, the test was modified by placing a plate 0.070 inch (1.8 mm.) thick within the fold of the fabric being creased, thus producing a much less sharp crease in the fabric than obtained by the standard method. Recovery from this crease (in two minutes) was determined according to the specified test procedure.

TABLE X

| Run-----                                      | MA   | MB   |
|-----------------------------------------------|------|------|
| Draw ratio, $X_m$ -----                       | 5.60 | 4.80 |
| Drawing tension, g.p.d.-----                  | 2.75 | 2.75 |
| Tenacity, g.p.d.-----                         | 8.7  | 6.6  |
| Elongation, percent-----                      | 16.2 | 20.3 |
| Modulus, g.p.d.-----                          | 40.5 |      |
| Shrinkage, percent-----                       | 8.4  | 10.4 |
| Crystallinity, percent-----                   | 38.3 | 33.0 |
| Coefficient of denier variation, percent----- | 1.4  | 2.0  |

From Table X, it is apparent that the process of the invention (run MA) permits drawing at higher draw ratios to obtain yarn of higher tenacity, modulus, crystallinity and denier uniformity, at constant drawing tension, as compared to conventional pin drawing (run MB).

When the test was repeated, using yarn spun from high viscosity vacuum-finished poly(caproamide), similar results were obtained.

#### Example X

A polymer mixture consisting of 80 parts polyhexamethylene adipamide and 20 parts polyhexamethylene isophthalamide is spun to a 14 filament yarn at 130 yards per minute (119 meters per minute) and immediately drawn (without packaging) at the maximum operable machine draw ratio. For test purposes (run NA), a jet similar to that shown in FIG. 2 is used in the draw zone. This jet, however, has a constricted yarn inlet, slightly larger than

the yarn bundle. The outlet, for yarn and steam, is rectangular in cross section. There is a narrow slot parallel with and connected to the yarn passage, permitting easy stringup. The jet is fed with 250° C. superheated steam at 50 p.s.i.g. For comparison, a control NB is also run at maximum operable draw ratio, using identical yarn and an unheated snubbing pin in the draw zone. Yarn properties are given in the following table.

TABLE XI

| Run.....                               | NA   | NB   |
|----------------------------------------|------|------|
| Draw ration, $X_m$ (max.).....         | 5.6  | 5.2  |
| Yarn tenacity, g.p.d.....              | 7.8  | 6.5  |
| Break elongation, percent.....         | 15   | 20   |
| Modulus Mi, g.p.d.....                 | 59   | 50   |
| Shrinkage at 160° C. dry, percent..... | 11.7 | 15.0 |

## Example XI

A composite filament yarn is prepared substantially as described in British Patent 950,429. The filaments consist of a sheath of 6-6 nylon (polyhexamethylene adipamide) of 40 relative viscosity and an eccentrically disposed core of a random copolymer which is 50 weight percent 6-6 and 50 percent 6-10 nylon (polyhexamethylene sebacamide) of 48 relative viscosity. Technical grade sebacic acid is used. Substantially equal amounts of each component are used in each composite filament. The polymers are melted and extruded to a 7 filament yarn using a spinneret arrangement substantially as in FIG. 2 of the British patent. The spinning speed is 1000 yd./min. (915 meters/min.). The birefringence of the component of spun yarn having the higher birefringence is 0.016. After quenching by a transversely directed current of air, the filaments are forwarded to the draw zone by means of a feed roll and associated separator roll and pass in multiple wraps around a pair of driven draw rolls, thence to a tension let-down roll followed by a reciprocating traverse, surface driven windup. The final yarn denier is about 41. Spinning speed is kept constant at 1000 yd./min. (915 meters/min.), and the draw ratio is varied by changing the speed of the draw rolls. For most of the tests, a jet similar to FIG. 2 is placed in the draw zone. The yarn passage 27 is rectangular in cross section,  $\frac{3}{32}$  inch wide by  $\frac{1}{4}$  inch deep (2.4 mm. x 6.3 mm.), and it is about 5 inches (12.7 cm.) long. Air inlet 28 is 0.08 inch (2.0 mm.) in diameter. An inverted U-shaped warn guide is placed in the yarn passage 27, just before the point where hot air contacts the yarn. The air pressure is 80 p.s.i.g. (6.45 atmospheres). Yarn temperatures in the jet enclosure are estimated from measurements of yarn temperatures outside the jet enclosure.

Properties of the yarns produced under various operating conditions are reported in Table XII, along with uniformity of sonic modulus, denier uniformity and yarn quality.

It is observed that when the jet is not used (Run 1), a draw of 3.04 is the maximum that can be used; when this

low draw, yarn uniformity is poor. When hot air is introduced into the jet, the draw initiation point moves into the jet enclosure, even at higher draw ratios. In Run 4, it is noted that an air temperature of 150° C. is insufficient to raise the filaments to the required temperature. Under these conditions, the draw initiation point moves out of the jet enclosure and numerous yarn defects (broken filaments) are observed. It is further observed that increasing air temperatures permit the use of higher drawn ratios to provide increased yarn tenacity, along with improved uniformity of sonic modulus and interfilament denier, and also fewer defects such as broken filaments.

## Example XII

In order to develop the maximum crimp potential in the composite filament yarn of Example XI, the drawn yarn is subjected to a "precrimping" heat treatment. In this case, the precrimping step is carried out by passing the yarn through another jet supplied with heated air at 90 p.s.i.g. (7.1 atm. absolute), after it leaves the draw rolls. The precrimping jet is like the draw jet, except that the yarn path channel is expanded in a funnel-like cross section to give an exit air velocity of about 60 ft. (20 meters) per minute. The unheated "tension let-down rolls" are operated at a lower surface speed than the draw rolls, to permit the drawn yarn to retract (relax) and crimp in the jet. It is then cooled and stretched enough to remove the crimp prior to windup. The development of final crimp occurs after this yarn is converted to fabric (e.g., knitted or woven), as it is boiled off. The "crimp retraction" of the yarn against restraint is a measure of the crimp obtainable when the fabric is boiled off, and is measured as described on page 5, lines 16-46 of British 950,429. In preparation for these tests, the effect of different draw ratios was studied. The air temperature in the draw jet was increased until the draw initiation point was observed to enter and remain within the jet enclosure. It was observed that this occurred at a drawing tension of 35 to 40 grams, independent of draw ratio. A draw ratio of 3.7 and an air supply temperature of 210° C., 80 p.s.i.g., were selected as giving good tenacity, yarn uniformity and operability.

Under the above drawing conditions, air temperatures in the precrimping jet are varied in order to obtain the greatest crimp retraction. The extent of yarn relaxation between draw rolls and windup is 16%. The results are listed in Table XIII.

TABLE XIII

| Run No. | Precrimping jet air temp., ° C. | Crimp retraction, percent |
|---------|---------------------------------|---------------------------|
| 1.....  | 220                             | 27.1                      |
| 2.....  | 230                             | 27.1                      |
| 3.....  | 240                             | 26.7                      |
| 4.....  | 250                             | 23.8                      |

TABLE XII

| Run No. | Machine draw ratio | Draw jet        |                  | Yarn properties |                 | Yarn quality                 |                           |                         |                            |
|---------|--------------------|-----------------|------------------|-----------------|-----------------|------------------------------|---------------------------|-------------------------|----------------------------|
|         |                    | Air temp., ° C. | Yarn temp., ° C. | Ten., g.p.d.    | Elong., percent | Percent sonic mod. variation | Percent denier uniformity | Per 10 <sup>3</sup> yd. | Per 10 <sup>3</sup> meters |
| 1.....  | 3.04               | Unheated        | Unheated         | 3.8             | 54              | 20.0                         | 2.5                       | 1.1                     | 1.2                        |
| 2.....  | 3.1                | 275             | 143              | 3.6             | 42              | 9.0                          | 1.4                       | 0.13                    | 0.14                       |
| 3.....  | 3.3                | 300             | 148              | 3.8             | 32              | 9.0                          | -----                     | 1.9                     | 2.1                        |
| 4.....  | 3.5                | 150             | 81               | 4.7             | 38              | 15.7                         | -----                     | 42.3                    | 44.3                       |
| 5.....  | 3.5                | 300             | 144              | 4.4             | 29              | 8.8                          | 1.5                       | 0.20                    | 0.22                       |

ratio is exceeded, the draw initiation point moves to the feed roll and broken filaments are produced. Even at this

Best results are observed when the precrimping jet is operated at 10 to 30° C. above the draw jet.

When superheated steam is used in the draw jet in place of heated air, similar results are obtained, but at somewhat lower steam temperatures, due to its greater efficiency as a heat transfer fluid.

The process of this invention is useful in the drawing of most synthetic linear polycarbonamides or "nylons," such as those disclosed in U.S. Patents Nos. 2,071,250 and 2,071,253. The preparation and spinning of these compounds is described in U.S. Patents Nos. 2,130,948, 2,163,636 and 2,477,156. Particular examples of such polyamides are those prepared from suitable diamines and dibasic acids, e.g., from hexamethylene diamine and adipic acid and their amide-forming derivatives, and also from terminal-amino carboxylic acids, e.g., from omega amino caproic acid, omega amino undecanoic acid and their amide-forming derivatives, such as caprolactam. Yarns spun from copolyamides, grafted polyamides, blends of polyamides with other compatible polymers and differentially shrinkable polyamide components may also be drawn to good advantage in the process of this invention.

The process is particularly useful in drawing polyamide yarns at high speeds, requiring substantially instantaneous yarn heating. Although marked improvements are obtained at 500 y.p.m., the higher velocity jets disclosed herein, which effectively heat the filaments to the required temperature at exposure times (in the jet enclosure) in the order of from 0.01 to 0.001 second, permit drawing speeds of 2,000 y.p.m. or more, a level unattainable by prior art processes.

As disclosed in detail in my copending application Ser. No. 591,850, filed Nov. 3, 1966, the process is also useful in the drawing of filamentary yarns spun from polyesters. Particular examples are polyethylene terephthalate and the copolyester prepared from ethylene glycol and a 98/2 mixture of the dimethyl esters of terephthalic/5-(sodium sulfo)-isophthalic acid. Other examples of crystallizable, linear condensation polyesters are polyethylene terephthalate/isophthalate (85/15), poly-p-hexahydroxyene terephthalate, polydiphenylolopropane isophthalate, polydiphenylolopropane carbonate, the polyethylene naphthalene dicarboxylates and poly-m-phenylene isophthalate.

The instant process permits very effective single stage drawing, and may be followed by such important operations as setting, relaxing, twisting, crimping, alternate twisting, false twisting, and the like. The instant process is also useful in drawing filaments of modified cross section, e.g., "Y," propeller-shaped, triolbal, etc., since substantially no distortion of the desired cross section is involved.

Advantages of the instant invention over prior art procedures include reduced drawing tensions, leading to improved process operability and product mechanical uniformity; elimination of snubbing elements, thereby avoiding frictional problems and the necessity for uniform finish application; and the provision of yarn having reduced shrinkage and retraction values, such yarn being provided in a single step and characterized by both a high retention of initial modulus and improved crystallinity. The drawn yarn can be packaged at reduced tension, owing to its dimensional stability. Furthermore, this yarn can be prepared over a wide range of tenacities at a given elongation. The process can be carried out in a rapid, continuous and economic fashion using either freshly-spun or packaged yarn.

Use of freshly-formed or as-spun yarn, prior to initial packaging, in the practice of this invention is particularly advantageous. Since the as-spun yarn is relatively amorphous, maximum reductions in drawing tension plus added flexibility in drawing and associated operations are facilitated. The necessity of a separate drawing stage or step is eliminated, thereby leading to better mechanical quality due to reduced handling, uniformity of lag time (between spinning and drawing) and elimination of an intervening packaging step. Over-all process economy results. How-

ever, freshly-formed yarn is substantially amorphous and more stringent control of fluid temperature and pressure during drawing is required in order to insure uniform levels of shrinkage and retraction. When yarn of minimum shrinkage is desired, it has been found that more uniform property levels are obtained when the spin-draw operation is followed immediately by a coupled, controlled relaxation stage. The additional reductions in shrinkage and retraction are not accompanied by an unacceptable reduction in initial modulus when the process of this invention is employed in the drawing stage.

After drawing with extremely hot air or superheated steam, it may be desirable to treat the yarn with moisture, preferably prior to packaging, in order to permit the yarn to regain its normal or equilibrium moisture content. Such moisture may be supplied during a subsequent relaxation stage merely by using steam as the relaxing medium. This combined procedure usually leads to further improvements in yarn properties.

The filamentary structures of this invention may contain the usual textile additives such as delustrants, antioxidants and the like. In this respect, the presence of an antioxidant may be desirable when gas at very high temperature is employed. Suitable antioxidants are disclosed in U.S. Patents Nos. 2,705,227, 2,640,004, and 2,630,421. Other useful additives are disclosed in U.S. Patents Nos. 2,510,777 and 2,345,700. In addition, finish may be applied to the structures, though the uniformity of finish application is not as critical as it is in drawing over or about snubbing elements.

The products of this invention are useful in all conventional textile and industrial applications, especially those which require yarn of improved dimensional stability. Because of their reduced retraction values, the drawn yarn can be packaged on inexpensive disposable shipping cores. The high modulus makes them especially suitable for use in fabrics requiring improved resilience and wrinkle resistance.

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

1. In a high speed process, the steps of: drawing nylon filamentary yarn and, in the draw zone, separating the yarn and heating the filaments substantially instantaneously to the draw initiation point by passing the yarn through an enclosure and, in said enclosure, impinging a jet of a single-phase heated gaseous fluid thereon in intersecting relationship therewith, the time-temperature-pressure relationship of yarn exposure being such as to heat the yarn to a temperature of at least 115° C. in the enclosure.

2. The process of claim 1 wherein the fluid is superheated steam.

3. The process of claim 1 wherein the fluid is air.

4. In a high speed process, the steps of: drawing nylon filamentary yarn in a single stage and, in that stage separating the yarn and heating the filaments substantially instantaneously to the draw initiation point by passing the yarn through an at least partially restricted zone and, in that zone, impinging a jet of a single-phase high temperature gaseous fluid thereon in intersecting relationship therewith, the time-temperature-pressure relationship of yarn exposure in said zone being such as to reduce the drawing tension to no more than 75% of the tension on the yarn in the absence of said fluid.

5. In a high speed process, the steps of: drawing filamentary yarn spun from a composition consisting essentially of polyhexamethylene adipamide and, in the draw zone, separating the yarn and heating the filaments substantially instantaneously to the draw initiation point by passing the yarn through an at least partially restricted zone and, in that zone, impinging a jet of a single-phase heated gaseous fluid thereon in intersecting relationship therewith, the time-temperature-pressure relationship of yarn exposure

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in said zone being such as to heat the yarn to a temperature of at least 115° C.

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