

Sept. 23, 1958

A. L. BREEN
METHOD AND APPARATUS FOR PRODUCING
BULKY CONTINUOUS FILAMENT YARN

2,852,906

Filed Aug. 20, 1953

4 Sheets-Sheet 1

FIG. 1

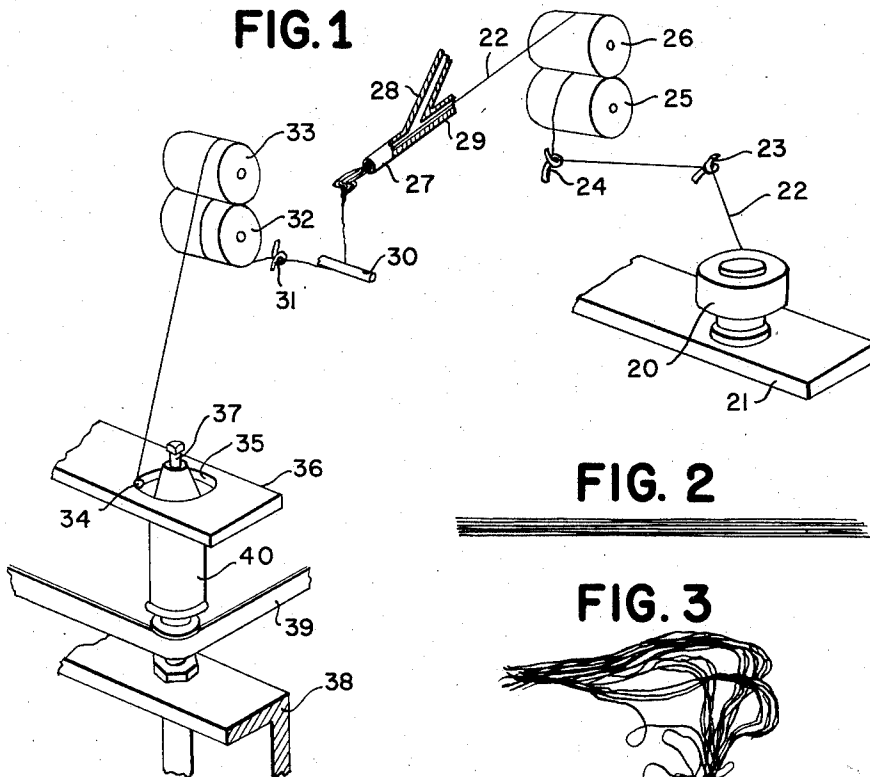


FIG. 2

FIG. 3



FIG. 5



FIG. 7

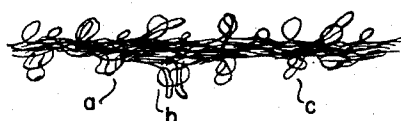


FIG. 4

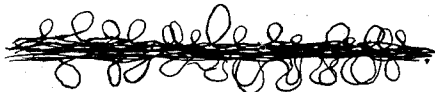
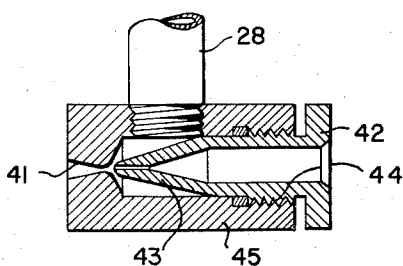


FIG. 8



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FIG. 9

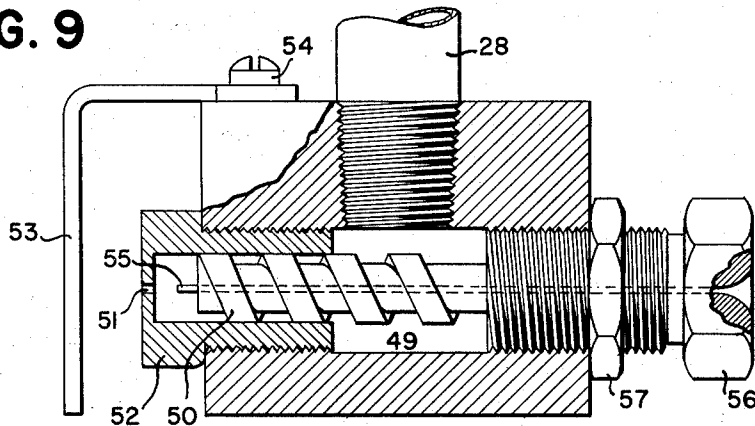


FIG. 10

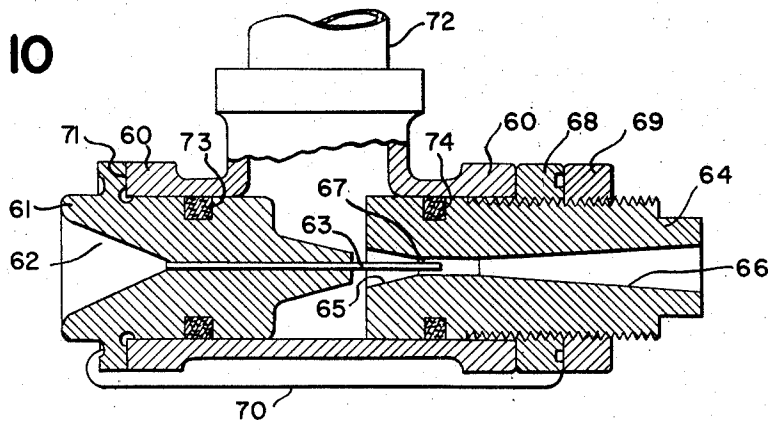
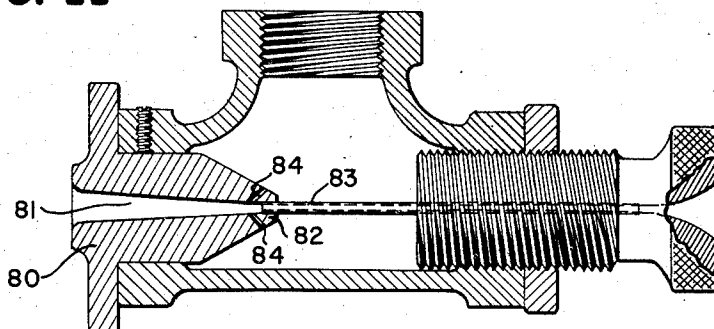


FIG. 11



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FIG. 14

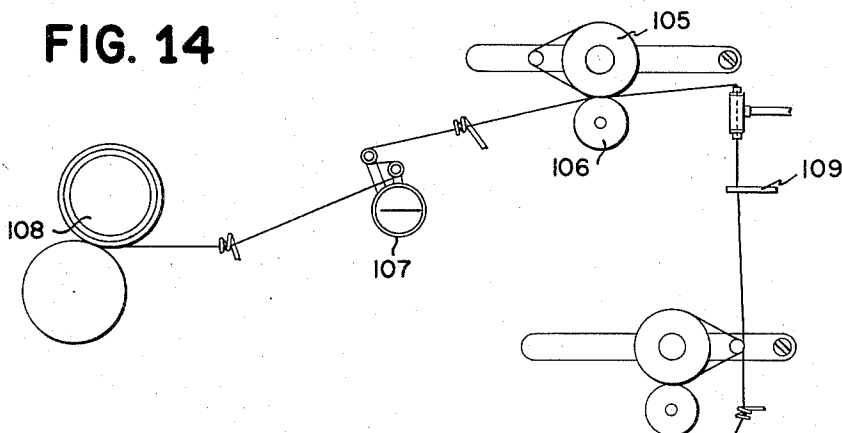
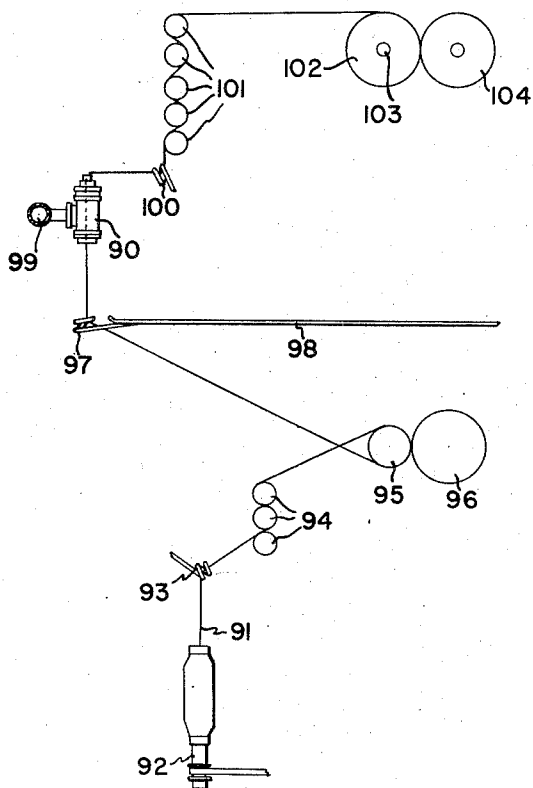


FIG. 13



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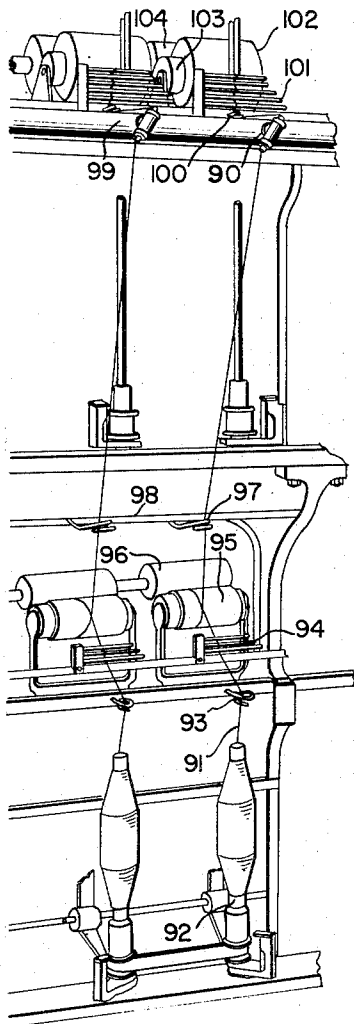


FIG. 12

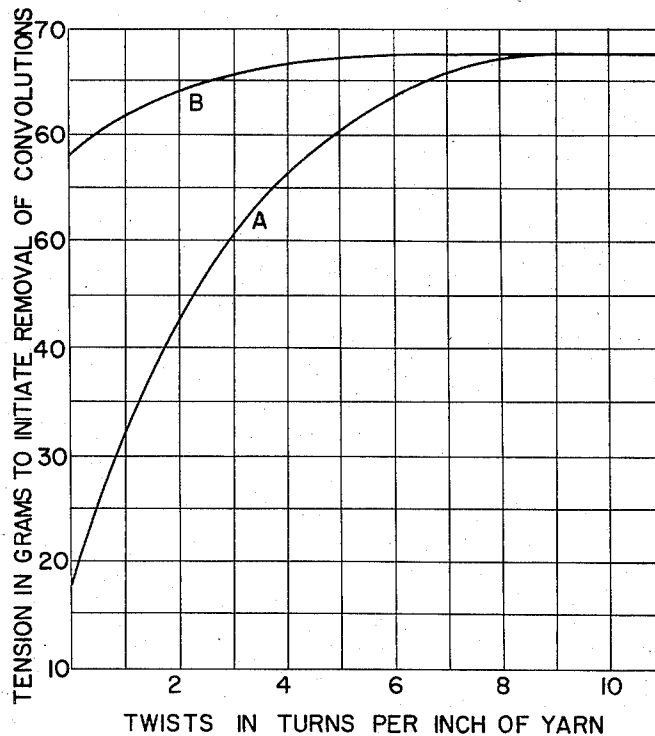


FIG. 6

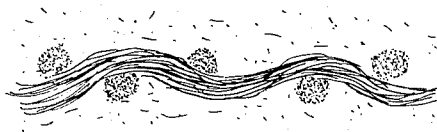


FIG. 15

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2,852,906

METHOD AND APPARATUS FOR PRODUCING BULKY CONTINUOUS FILAMENT YARN

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Application August 20, 1953, Serial No. 375,372

11 Claims. (Cl. 57—34)

This invention relates to process and apparatus for treating a bundle of continuous filaments, such as a yarn or thread, to produce a multifilament yarn of greatly increased bulk, and to the novel bulky yarn produced. More particularly, the invention claimed herein relates to a process and apparatus for preparing a bulky yarn composed of a plurality of individually convoluted filaments.

This application is a continuation-in-part of my co-pending application, Serial No. 261,635, filed December 14, 1951 now Patent No. 2,783,609.

With the outstanding exception of silk, all natural animal, vegetable and mineral fibers exist in only relatively short lengths. The production of yarn from such staple fiber is a time-consuming operation which usually requires a complex series of operations to align the fibers, combine them into an elongated bundle, and draw the bundle to smaller diameter while twisting to prevent excessive slipping of adjacent fibers past each other. Further spinning operations finally produce yarn or thread useful in textile operations.

All, or nearly all, artificial fibers are produced most easily as continuous filaments. Formation of continuous filaments into yarn is much simpler than staple processing. Continuous filament yarns may be made very strong because of the absence of loose ends that are unable to transmit imposed stresses. However, because of their extreme uniformity and lack of discontinuities, conventional continuous filament yarns are much denser than their staple counterparts. The filaments lie close together in the yarn, and adjacent strands of continuous filament yarn in fabrics are closely spaced. This compactness limits the amount of insulating air space present. The lack of occluded air space greatly restricts the usefulness of such continuous filament fabrics. Lightness, covering effectiveness, and warmth-giving bulk are essential for many uses. Hence a large amount of the total continuous filament production of such fibers as viscose rayon, cellulose acetate, nylon and polyacrylonitrile has been cut into short lengths for spinning into staple yarn.

Previous efforts to produce continuous filament yarn having the desirable qualities of staple yarn have been unsuccessful. These efforts have been concerned primarily with modifying the internal structure of the filaments, as by physical or chemical distortion. Mechanical crimping or twisting of filaments has produced undulating or spiralled fibers, but the effect has been disappointing. Similar unsatisfactory results have been obtained by imparting motion to the spinning head and by chemical treatment of the spun filaments. All known methods have been unsatisfactory for one reason or another, such as insufficient bulkiness, unsatisfactory distribution of stress-bearing portions of the filaments, undesirable modification of fiber properties, impermanence of form, or complexity and expense of the operations.

It is an object of the present invention to provide continuous filament yarn having a bulkiness at least as great as that of staple yarn spun from comparable fibers and having the same average number of filaments per cross-

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section. Another object is to provide multifilament yarn resembling spun staple in its desirable lightness, covering effectiveness and warmth-giving bulk but retaining the characteristic continuous filament freedom from loose ends, fuzziness and pilling. Another object is to provide bulky multifilament yarns of finer deniers than can be spun practicably from staple. A further object is to provide a process for preparing continuous filament yarn having a bulk equal or superior to that of comparable staple yarn without abrading or cutting the constituent filaments and without deforming or otherwise modifying their structure. A still further object is to provide such a process which is suitable for rapidly and economically treating ordinary multi-filament continuous yarn to greatly increase the bulk without the use of moving mechanical parts other than in the windup. Yet another object is to provide suitable apparatus for practicing the above process. Other objects of the invention will become apparent from the following description and claims.

In this invention, a yarn fulfilling the above objectives has been produced, composed of a plurality of substantially continuous, individually convoluted filaments. The individual filaments have coils, loops or whorls at random intervals along their lengths. The most obvious characteristics of the novel continuous filament yarn are its bulkiness and the presence of a multitude of filament loops irregularly spaced along its surface. These readily visible filament loops contribute to bulkiness, but the less obvious convolutions of the filaments within the yarn provide a lateral interfilament spacing which is important in producing the bulk and resulting garment warmth of fabrics made from this yarn.

The convolutions of the filaments may be held in place by the twist usually imparted to yarn. When this is done, the absence of internal structural change may be shown by untwisting the yarn and taking it apart, whereupon the individual filaments will return to substantially their original condition. When ordinary straight filaments are used to prepare the bulky yarn, substantially straight filaments are obtained by unbulking the yarn. Of course, crimped, wavy or curly filaments could be processed according to this invention, and such filaments would resume their respective starting configurations when separated from the yarn. Some reduction of tensile strength below that of ordinary continuous filament yarn may be expected because, at any given point in the bulked yarn of this invention, some of the filaments may not be placed under tension when the yarn is pulled, but this may be minimized or offset by increased twist, production of the loop-within-a-loop configuration described below, or by a treatment, such as steaming, to impart a permanent set.

A similar yarn might be prepared from a bundle of continuous filaments by tedious hand manipulation. An individual filament would be separated and slack formed in the filament. The slack would be taken up by forming a minute coil or loop in the filament and holding it in place by twisting the filament bundle or by encircling this loop by a similar convolution formed in a nearby filament. Repetition of this operation at intervals along each and every filament could eventually give the desired yarn structure.

In accordance with this invention a process has been devised for producing the described yarn structure rapidly with surprising simplicity.

In the preferred process of this invention, a stream of air or other compressible fluid is jetted rapidly from a confined space to form a turbulent region. Yarn to be treated is fed into the fluid stream so that the yarn is supported by it and the individual filaments are separated from each other and whipped about violently in the turbulent region. Merely removing these separated fila-

ments from the turbulent region for reassembly into a yarn accomplishes the desired result of forming loops and other convolutions at random intervals along each filament and irregularly spaced on different filaments. The filaments are whipped about in the turbulent zone sufficiently to form convolutions that are retained during withdrawal, windup and further processing.

The invention will be better understood by reference to the drawings. In these drawings, which illustrate preferred embodiments of the invention,

Figure 1 is a schematic perspective view of suitable equipment for manufacturing bulky continuous filament yarn in accordance with the invention,

Figure 2 is a side view showing the appearance of untreated yarn being fed to the air jet (enlarged about ten times),

Figure 3 is a side view of the yarn leaving the air jet and being pulled downward out of the turbulent zone (enlarged about ten times),

Figure 4 is a side view showing the appearance of treated yarn before twist is applied (enlarged about ten times),

Figure 5 is a side view showing the appearance of bulky yarn after twist has been applied (enlarged about ten times),

Figure 6 is a graph showing how the yield point (initial loop-removal tension, measured as described below) increases with the twist applied to bulky yarn,

Figure 7 is a side view of yarn treated by a modification of the bulking process (enlarged about ten times),

Figure 8 is a modified form of air nozzle for use in practicing the invention,

Figure 9 is another modification of nozzle,

Figure 10 is a further modification of nozzle,

Figure 11 is a still further modification of nozzle,

Figure 12 is a front perspective view of a two-deck up-twister machine modified for practicing the invention,

Figure 13 is a schematic side view of the apparatus shown in Figure 12,

Figure 14 is a side view of another modification of apparatus suitable for practicing the invention, and

Figure 15 shows the arrangement of filaments in a cross-sectional slice taken through fabric woven from the bulky continuous filament yarn of this invention (enlarged about 50 times).

Referring to Figure 1, the continuous filament yarn to be treated may be supplied from any suitable source, such as a yarn package 20 supported on a creel 21. Untwisted yarn will normally be used, but twisted yarn can be used satisfactorily by increasing the filament-separating action, as shown later in the examples. The yarn can also be supplied directly from the spinning process by which it is produced, without any intermediate wind-up. The yarn 22, from whatever source is selected, passes through guides 23 and 24, between feed rolls 25 and 26, and to air nozzle 27. This nozzle consists of a compressed air pipe 28 screwed or brazed into yarn tube 29, shown partly in section. The pipe and tube are arranged at an angle so that a flow of air is produced through the tube sufficient to carry the yarn along. The tube 29 can be as little as 1 inch long and 0.05 inch inside diameter.

The appearance of the yarn entering the air jet 27 is shown in Figure 2. The filaments are relatively straight and closely packed, giving the yarn a rod-like appearance. As shown in Figure 3, the yarn leaving the air jet is blown apart by the air stream. High speed motion pictures have shown that the individual filaments are whipped around violently by the turbulent air. As the filaments are withdrawn from the region of turbulence, they are swirled into convolutions which may be held in place by adjacent filaments of the reforming yarn bundle. After passage through the turbulent zone and reforming into a yarn, the appearance of the bundle of filaments may be as shown in Figure 4. These fila-

ments are only loosely grouped and a strong pull would remove the bulkiness if it were not stabilized by additional treatment, preferably by twisting the filaments together.

The loose bundle of filaments is directed by guides 30 and 31 to take-up rolls 32 and 33, and then passes to a wind-up device such as the down-twister shown. As is usual with this device, the yarn is given a twist as it is wound by passing through a traveller guide 34 sliding around on ring 35 mounted on ring rail 36. The yarn is collected on spindle 37, supported by spindle rail 38 and rotated by belt 39, to form a package of finished yarn 40. The appearance of twisted yarn produced in this way is shown in Figure 5. In the actual yarn loops may be less than 1 millimeter in size. The loops and other convolutions of individual filaments are firmly held in place by friction between filaments. Increasing the twist increases this friction between filaments and holds the convolutions more firmly in place.

Figure 6 shows the effect of increasing amounts of twist on the yield point of typical yarns. Yield point may be defined roughly as the tension required to initiate removal of the convolutions. It is measured by tensioning the yarn and plotting points on the resulting stress-strain curve. At first, a steep, nearly straight line results representing the elastic modulus. As slippage occurs, the points generally scatter about a less steep line. Prolongation of these lines results in a point of intersection, and it is the stress at this point that is plotted as the ordinate in Figure 6. For the sample shown by curve A, the yield point started at a low value of 20 grams for zero twist, increased rapidly to a value of about 64 grams at a twist of 6 turns per inch, and leveled off at a value of about 69 grams for twists above 10 turns per inch of yarn. The yarn used for the observations from which curve A was drawn was made by the process of this invention from 150 denier, 40 filament, 0 twist "Acele" (cellulose acetate yarn made by E. I. du Pont de Nemours and Company), using a feed rate of 28.9 yards per minute, an air pressure of 18 pounds per square inch gage, an air flow of 0.49 cubic feet per minute, measured at 760 mm. of mercury pressure and 70° F., and had a final denier of 190. For common textile deniers sufficient resistance to ordinary tensions can be provided by a yield point of at least 0.15 gram per denier, although higher values are preferable.

If desired, yarn of the type shown in Figure 7 may be formed that requires little or no twist to provide relatively high yield points. The reason for the increased stability of this product is the frequent occurrence of snarls formed by entangled loops, e. g., a frequent encircling of the nodes of loops by other loops, most clearly seen at points a, b, and c in Figure 7. An attempt to stretch this modified yarn will cause tightening of many of the encircling loops, thus preventing encircled portions from unlooping, and holding the filament bundle together. As shown by curve B of Figure 6, at zero or low twists the yield point of this yarn is much higher than that of the simple product shown in Figure 5. The yarn tested to determine curve B was prepared from the same 150 denier, 40 filament, 0 twist "Acele" acetate yarn used in connection with curve A, and under identical conditions except that the air pressure was increased to 25 pounds per square inch gage, giving an air flow of 0.55 cubic feet per minute. The final denier was increased to 205 as a result of the more complex yarn structure shown in Figure 7.

Yarn having the snarled or entangled loop structure is produced by a compounding of the ordinary looping action. This may be brought about in any one or more of a number of ways such as increasing the length of time the yarn is within the turbulent zone, increasing the turbulence in the zone, or setting up variations in the extent of turbulence. Adjustment of conditions to vary the bulky yarn produced according to this invention from the form

shown in Figure 5 to the more complex structure of Figure 7, or to any intermediate configuration, must be determined by experiment in a particular case.

In the process of this invention it is only necessary for the yarn to be passed through a zone of sufficient turbulence for a sufficient distance to separate the filaments and form them into the described convolutions. The yarn need not be passed through an air jet or nozzle of the types described, but can be passed through a turbulent stream, however formed. Likewise, air need not be used as the turbulent medium; other gases or liquids can be used. Piezoelectric or magnetostrictive transducers might be employed with similar effect, but the fluid jet method is so inexpensive and easy to install, operate and maintain, that it is naturally preferred, as the best known mode of operation.

The extremely simple air nozzle 27, shown in Figure 1, is adequate to accomplish effective yarn treatment as described above. However, smoother operation and more efficient use of air is provided by the modification shown in Figure 8, in which a stream-lined air nozzle 41 is provided in place of the simple yarn tube 29 of Figure 1. Automatic threading or stringing up is assured by addition of yarn guiding member 42 having a conical inner end 43 through which the yarn end can be introduced into the air stream in position to be carried with the air through nozzle 41. This member is threaded at 44 into a supporting body 45, providing for adjustment of the distance between cone end 43 and inlet end of air nozzle 41. Air is fed to the nozzle through pipe 28.

In the nozzle shown in Figure 9, the air is introduced into a central chamber 49 within the nozzle, passes from the chamber through a helical passageway formed by screw member 50, which gives the air a swirling motion, and leaves the nozzle through an orifice 51. It is convenient to form this orifice in a plug 52 screwed into the nozzle body. Although not necessary, it is sometimes desirable to break up and deflect the jetted stream of air, as with a baffle 53, which is merely a plate bent at right-angles and attached to the nozzle with a screw 54. The yarn is conducted through screw member 50 to the vicinity of the orifice by a tube 55 and is caught up by the air stream and carried out of the orifice. The best diameters for the tube and orifice will depend on the yarn being treated. For yarn of about 100 to 400 denier, satisfactory diameters are 0.023 inch inside diameter for the tube and about 0.04 inch for the orifice. The screw member 50, which supports the tube 55, is threaded into the nozzle body. The clearance between the inner end of the tube and the orifice is adjusted by the distance the screw member is turned, a hex nut 56 being attached or formed integrally on the outer end of the member for this purpose. When a satisfactory adjustment has been found the screw member is locked in position by a hex nut 57. The outer end of tube 55 is preferably flared to receive the yarn and when stringing-up. Proper adjustment will make the jet self stringing, i. e. when an end of yarn is placed in the flared inlet of the tube the air stream will provide sufficient vacuum to pull the yarn through the tube and then blow it out of the orifice, greatly simplifying the starting up operation.

The nozzle shown in Figure 10 offers advantages in more efficient use of air, ease of adjustment to optimum conditions, and a single nozzle may be used for processing a wider variety of yarns without adjustment. The housing 60 may be a standard 1/4 inch plumber's T. The yarn enters through guide member 61, provided with a funnel-shaped portion 62 to receive the yarn end when stringing up. The hypodermic needle 63 of appropriate size provides a passage for conducting the yarn into the nozzle 64. The nozzle has the shape of a conventional venturi tube with the entrance 65 tapering inward so that opposite sides are at about a 20° angle with each other, and the exit 66 diverging more gradually so that opposite sides are at about a 7° angle with each other. The

overall length of the venturi tube may suitably be about 1.3 inches with the diverging exit portion about 1.0 inch long. The arrangement of guide member 61, needle passage 63 and nozzle 64 makes the device self-stringing when a yarn end is fed to it.

The needle 63 is adjusted to extend into the entrance of the venturi and stop in the venturi throat 67. This adjustment is important for best performance. The manner of adjustment shown is to thread the outside of the nozzle and provide positioning and locking nuts 68, 69. The nozzle slides with a snug fit into the housing 60 until nut 68 rests against the housing. It is held in this position by springs, one of which is indicated at 70. The guide member 61 likewise slides into the housing with a snug fit until shoulder 71 is positioned against the housing. It may also be held in position by spring 70 and other similar springs. Advantages for this construction are that it can be taken apart easily for cleaning and the parts can be rotated to adjust the needle in the venturi throat. However, either or both parts may be held in position by set screws passing through the housing, or the parts may be threaded into the housing as in Figure 9.

Air is supplied to the nozzle through pipe 72, which is threaded or soldered into the T housing. The air passes through the venturi around the needle 63, the venturi throat 67 being sufficiently larger than the needle to permit passage of the required volume of air. Gasket material may be placed in groove 73 around member 61 and groove 74 around the nozzle to prevent air leakage.

Figure 11 shows another modification which requires no adjustment to get the yarn guide needle properly positioned in the nozzle 80. Except for the internal design of the nozzle, the construction may be identical with that described in connection with Figure 10 and will not be redescribed. The principal air passage 81 through the nozzle has the same shape as the diverging portion of the venturi described above, but the throat 82 fits snugly around the yarn tube or needle 83. Little or no air can pass around the needle. Instead, the air is led past the needle to the start of the diverging portion of passage 81 through a plurality of small holes 84 drilled at a forward angle through the base of the nozzle. Two such holes are shown, but six or more holes equally spaced around the throat 82 are desirable.

The performance of the air jet may be improved by providing for eccentric operation on the yarn. The holes 84 in Figure 11 may be of unequal size, be spaced unevenly, and/or be drilled at different angles. The yarn guide needle may be off-center in the venturi throat, an adjustment which is quite simply made with the type of nozzle construction shown in Figure 10.

The process has been specifically illustrated as used in connection with a downtwisting operation. However, it will be obvious to one skilled in the art that the process may be practiced in conjunction with other yarn processing operations. Thus by similar simple modifications of existing equipment, the process can be practiced on an uptwister, a cotton spinning frame or in spooling operations. As mentioned earlier, twisted yarn may be processed as well as untwisted yarn. If the yarn already has all of the twist desired, the yarn from the bulking treatment would be collected with a simple rewinder instead of a downtwister.

An adaptation of the equipment and process for use with an uptwister is illustrated in Figures 12 and 13. A portion of a conventional two-deck uptwister machine is shown in Figure 12 after modification by substitution of a bulking nozzle 90 for each spindle in the upper deck. The operation is made clear from the schematic side view shown in Figure 13. The starting yarn 91, wound on spindle 92 in the lower deck, is passed through pig-tail guide 93, finger guides 94, and is metered to the air jet nozzle 90 after one or more wraps around a rough rubber-covered uptwister bobbin 95, which is sur-

face driven by lower drive roll 96. The yarn is passed through a pig-tail guide 97, mounted at the lower edge of the oil drip plate 98, and into the nozzle 90. The air, supplied to the nozzle through pipe 99, loops and tangles the filaments of the emerging yarn to form a bulky yarn as previously described. The yarn is pulled away from the nozzle at right angles to the air stream through pig-tail guide 100. It passes through the five-fingered tension guide 101 and is traversed and wound into package 102 in conventional manner on windup roll 103, which is surface driven by roll 104.

The above arrangement provides a good degree of flexibility in operation. Since the lower deck position is used as the feed system and the upper deck position is used for windup, the two can be varied independently to provide the required yarn speed and overfeed (difference between yarn feed and windup) for the desired bulking treatment. These are important because increased speed increases the filament loop size and decreases the number of loops per unit length, while the amount of overfeed places an upper limit on the amount of bulking which can be accomplished. The tension guide 101 provides a frictional drag so that the yarn can be withdrawn from the nozzle 90 under a low tension suitable for a high degree of bulking and yet be wound under a higher tension which is sufficient to impart a high stability to the yarn and provide a firm package. For example, the yarn may be drawn up to 10% or more as it is being rewound while the other conditions of speed, overfeed air pressure, etc., remain suitable to provide a 30% increase in denier. The degree of twist imparted to the yarn can be adjusted by changing the speed of spindle 92. If the yarn already has the desired amount of twist, the spindle can be kept stationary, or the yarn can be supplied in any of the ways usual for yarn processing generally.

For a more positive control of overfeed and draw, the tension guide 101 can be replaced with driven draw feed rolls similar to the nozzle feed rolls 95 and 96. Such a modification is shown in the machine of Figure 14. The draw feed rolls are indicated at 105 and 106. Tension gauge 107 indicates the tension applied. A re-winder 108 suitable for winding packages of 2 pounds or more has been substituted for the conventional up-twister windup roll. A yarn cleaner 109 is shown adjacent to the entrance of the nozzle to prevent it from being plugged by knots or loose fibers on the yarn. This may simply have a slit barely large enough to accommodate the yarn. In other respects the component parts are similar in construction and operation to those shown in Figures 12 and 13, and will not be redescribed.

A fairly abrupt removal of the yarn from the turbulent region is conducive to formation of a better product. This may be accomplished by guiding or pulling the yarn from the turbulent stream, as described, or the turbulent stream may be diverted from the yarn by suitable means such as a baffle plate having a hole to admit the yarn. The baffle plate 53 in Figure 9 may be provided with a hole through which the yarn is passed, the air stream being deflected aside by the plate. The rate of windup as compared with the rate at which yarn is supplied to the jet, will limit the amount of bulking action possible by restricting the amount of reduction in length which occurs as the loops form.

The air pressure required depends upon the type of nozzle, the type of yarn, the yarn speed and the effect desired. In general, it is easier to obtain yarn uniformity when high air pressures are used, but the cost of compressing air makes it desirable to operate near the minimum pressure which will give adequate uniformity. Higher pressures are required for higher yarn speeds, but economics favor higher speeds because the air cost per pound of product drops off rapidly as the through-put is increased. Use of a wide range of air pressures is illustrated in the examples which follow. The simple nozzle

shown in Figure 1 required quite high air pressures. Quite low air pressures were used with the nozzle shown in Figure 9, but both of these nozzles were relatively inefficient, in the amount of air used per pound of product, in comparison with the diffusor type of nozzle shown in Figures 8, 10 and 11. Typical air requirements for nozzles of the latter type when processing yarn at speeds of 50 to 100 yards per minute is about 40 pounds per square inch and between 2 and 4 cubic feet per minute at standard temperature and pressure. Similar observations apply when using other gases or vapors such as steam.

The process and products of the invention will now be illustrated by the following examples, which are not to be construed as limiting the scope of the invention:

EXAMPLE 1

Apparatus equivalent to that in Figure 1, and using the nozzle shown in Figure 1 was used to process 150 denier, 40 filament, 0 twist, dull "Acele" cellulose acetate yarn. The yarn was unwound for treatment from a spool by the tension created by the fluid jet, with a friction tension device interposed between the spool and the nozzle to limit the yarn speed to approximately 13 yards per minute (calculated from the windup speed and ratio of final denier to starting denier). The nozzle was supplied with nitrogen at 150 pounds per square inch gage pressure, giving a gas consumption of approximately 0.4 cubic feet per minute at 760 mm. and 70° F. The yarn was wound up at 10 yards per minute and twisted to 6 turns per inch with an up-twister. The finished bulky yarn had a denier of 195 and the average filament loop size was about 0.5 mm.

The yarn treatment was repeated with different gas pressures and different yarn speeds to show how the size of the filament loops was affected. The changed conditions and the resulting loop sizes are given in Table I. The loop sizes are compared qualitatively because they are difficult to classify numerically. Generally speaking, however, "V. S." (very small) means that most of the loops were less than 0.5 mm. in size, "small" means that the predominating loop size was about 0.40 to 0.75 mm., "medium" means that the predominating loop size was about 0.5 to 1.5 mm., and "large" means that most of the loops were over 1.5 mm. in size.

Table I

EFFECT OF VARYING OPERATING CONDITIONS ON LOOP SIZE

	A	B	C	D
Gas Pressure, Lbs./sq.in. gage....	150	150	300	390
Yarn Feed, Yds./min.....	54	31	54	54
Yarn Wind-up, Yds./min.....	40	18	37	35
Loop Size.....	Large	Medium	Small	V. S.

EXAMPLE 2

Apparatus of the type shown in Figure 1, but using the nozzle shown in Figure 9, was used to process 150 denier, 100 filament, 0 twist, dull "Acele" yarn. The yarn was fed to the air jet at 21 yards per minute and rewound after treatment at 18 yards per minute at a spindle speed of 5800 R. P. M. to impart a Z twist of 9 turns per inch. The air pressure was 5 lbs./sq. in. and the air consumption 0.21 cu. ft./min. The finished yarn had a denier of 175, a tenacity of 0.71, and an elongation of 20.9%. Untreated 8 Z twist yarn had a denier of 150, a tenacity of 1.2, and an elongation of 26.

EXAMPLE 3

Apparatus of the type shown in Figure 1, but using the nozzle shown in Figure 9, was used to process 200 denier, 80 filament, 0.32 twist, bright yarn of "Orlon" acrylic fiber. The yarn was fed to the air jet at 27.5 yards per

minute and rewound after treatment at 22.8 yards per minute at a spindle speed of 4700 R. P. M. to impart a Z twist of 6 turns per inch. The air pressure was 15 lbs./sq. in. and the air consumption was 0.26 cu. ft./min. The finished yarn had a denier of 258, a tenacity of 1.98 and an elongation of 17.6. Untreated 6 Z twist yarn had a denier of 200, a tenacity of 4.0 and an elongation of 19.

EXAMPLE 4

Apparatus of the type shown in Figure 1, but using the nozzle shown in Figure 9, was used to simultaneously blend and process 150 denier, 60 filament, 2 S twist, bright textile "Cordura" viscose rayon yarn and 150 denier, 40 filament, 0 twist dull "Acele" cellulose acetate yarn. The two yarns were unwound from separate spools and fed together to the air jet at 21 yards per minute. The treated blend was rewound at 18 yards per minute and a spindle speed of 5820 R. P. M. to impart a 9 Z twist. The air pressure was 10 lbs./sq. in. and the air consumption was 0.25 cu. ft./min. The finished yarn blend had a denier of 342, a tenacity of 0.74, and an elongation of 12.7. A similar blend which had not received the bulking treatment had a denier of 300, a tenacity of 1.27 and an elongation of 16%.

In Examples 1 to 4 the treatment increased the denier by 30.0%, 16.7%, 29.0% and 14.0%, respectively. This is some indication of the extent to which filaments have been formed into convolutions, but does not indicate the surprising increase in bulk which these convolutions impart to the yarn by maintaining the filaments in spaced relationship. In general, this increase in bulk is at least 80% for packaged yarn, as shown by the following two examples:

EXAMPLE 5

Apparatus of the type shown in Figure 1, but using the nozzle shown in Figure 8, was used to process 75 denier, 30 filament, 0.3 Z twist, bright yarn of "Orlon" acrylic fiber. The yarn was fed to the air jet at 54.0 yards per minute, treated with air supplied at 80 lbs./sq. in., and rewound after treatment at 45.0 yards per minute with a 3 S twist. The yarn was wound on a quill adapted for accurate measurement of volume at a tension of 20 grams. The yarn bulk was 3.3 cc./gm. as compared with 1.2 cc./gm. for the untreated yarn, or an increase in bulk of 175%. The bulk was markedly superior to that of otherwise comparable spun staple yarn.

EXAMPLE 6

Apparatus of the type shown in Figure 1, but using the nozzle shown in Figure 8, was used to process 150 denier, 0 twist dull "Acele" cellulose acetate yarn. Two plies of this yarn were fed simultaneously to the air jet at 21.6 yards per minute, treated with air supplied at 10 lbs./sq. in., and the combined treated yarn was rewound at 18.0 yards per minute with an 8 Z twist under a tension of 68 grams. The yarn bulk was 2.0 cc./gm. as compared with 1.1 cc./gm. for the untreated yarn, or an increase in bulk of 82%, even though the yarn was wound under considerable tension.

Since the purpose in treating yarn in accordance with this invention is to improve properties of fabrics in which it is used, the most practical way of showing the increase in bulk achieved is by observation made on such fabrics.

EXAMPLE 7

Fabrics were prepared in a 2 x 2 twill weave from untreated continuous filament viscose rayon yarn, from bulky yarn produced by treating the yarn in accordance with this invention, and from staple yarn spun from cut filaments. A comparison of the results is given in Table II. The bulk was measured by ASTM Method D-76-49 at 3 lbs./sq. in. with an Ames gage.

Table II

COMPARISON OF FABRICS WOVEN FROM THREE VISCOSE RAYON YARNS

Type of Yarn	Denier of Yarn	Fabric Count	Thickness In Inches	Weight, oz./sq. yd.	Bulk, cc./gm.
Untreated.....	300	63 x 60	0.013	5.01	1.9
Treated.....	340	64 x 68	0.021	5.95	2.6
Spun Staple.....	313	68 x 62	0.0195	5.65	2.6

EXAMPLE 8

Plain weave fabrics of comparable count were prepared from untreated continuous filament yarn made of "Orlon" acrylic fiber, from bulky yarn produced by treating the same yarn in the manner described in the previous examples, and from staple yarn spun from cut filaments. The fabric bulk was determined by ASTM Method D-76-49 using an Ames gage at a pressure of 3 lbs./sq. in. A comparison of the results is given in Table III.

Table III

COMPARISON OF FABRICS WOVEN FROM THREE DIFFERENT YARNS OF "ORLON" ACRYLIC FIBER

Type of Yarn	Denier of Yarn	Fabric Count	Thickness In Inches	Weight, oz./sq. yd.	Bulk, cc./gm.
Untreated.....	100	81 x 72	0.008	2.12	2.1
Treated.....	125	80 x 64	0.015	2.36	4.8
Spun Staple.....	133	93 x 60	0.0125	3.32	2.8

The results of Examples 7 and 8 show the marked superiority in bulk of fabrics woven from the yarn of this invention in comparison with fabrics woven from ordinary continuous filament yarn. In general the increase in bulk is at least 30% when measured under the severe conditions described. The results also show that the bulky yarn may be equal, or even markedly superior, to spun yarn in this respect. The way in which the filaments are spaced is shown visually in Figure 15. Fabric woven of bulky yarn was immersed in methyl methacrylate and the monomer was polymerized to hold the filaments in position. Then a cross-sectional slice 50 microns thick was cut from the fabric. The slice was too thin to show the filament convolutions as such, but the reproduction of a photomicrograph of the slice in Figure 15 clearly shows the effect which the convolutions have in keeping the filaments spaced apart. Intersections of loops with the plane of the cut appear as irregularly shaped dots.

Bulky yarn can be prepared by the process of this invention from any continuous textile fibers regardless of their origin. However, since the filament convolutions of each filament are held in place by adjacent filaments, the process is operative only with multifilaments. The minimum number of filaments which can be processed satisfactorily into bulky yarn varies with the fiber, depending upon such factors as smoothness of surface, denier per filament, and the bending modulus, but any of the continuous multifilament materials referred to as yarn in the textile trade can be prepared in this bulk form. The process described has been applied successfully to the production of bulky yarn from a wide variety of commercial fibers, as indicated in Table IV. In this table the starting material is designated by numbers indicating the yarn denier, the number of filaments and the twist in turns per inch, respectively, the type of twist, if any, and the trade designation. The designation "nylon" refers to polyhexamethylene adipamide and "polythene" refers to polymerized ethylene fibers. "Orlon," "Acele," and "Dacron" are trade-marks of E. I. du Pont de Nemours and Company for acrylic, cellulose acetate and polyester fibers, respectively. "Vinyon" N is a vinyl chloride-acrylonitrile copolymer produced by Union Carbide and Carbon Corp. "Fortisan" is a high tenacity rayon regenerated by saponi-

fication of cellulose acetate and produced by the Celanese Corporation of America. "Fiberglas" is spun glass produced by Owens Corning Fiberglas Corp. The nozzle shown in Figure 8 was used in the examples of Table IV, with the indicated air pressure given in lbs./sq. in. gage. The air consumption is in cu. ft./min. at 760 mm. and 70° F. Yarn speed is in yards per minute.

Table IV
BULKY YARN PREPARATION FROM VARIOUS MATERIALS

Ex. No.	Starting Material	Yarn Feed	Speed Wind-up	Air Pressure	Air Consumption	Final Denier
9	70-34-1/2Z Nylon	50	35	52	0.68	286
10	150-40-0 "Acele"	50	41	52	0.68	169
11	70-34-1/2Z Nylon	82	66	52	0.66	161
12	75-30-0 Visc. Rayon	50	38	48	1.20	80
13	40-34-1/2S "Dacron"	31	26	52	0.88	50
14	40-34-1/2S "Dacron"	25	19	49	1.24	54
15	40-34-1/2S "Dacron"	24	18	50	1.25	247
16	150-40-0 "Acele"	24	18	50	1.25	240
17	40-13-1/2Z Nylon	150	112	50	0.71	212
18	150-40-0 "Acele"	50	36	40	1.06	46
19	40-13-1/2Z Nylon	48	41	50	1.18	359
20	300-60-0 Visc. Rayon	48	41	50	1.18	345
21	300-120-0.3Z "Orlon"	48	41	50	1.18	354
22	280-136-1/2Z Nylon	48	41	52	1.19	340
23	280-136-1/2Z "Dacron"	48	42	60	1.25	301
24	100-60-0 Visc. Rayon	38	26	68	1.28	319
25	150-40-0 "Acele"	38	26	68	1.38	203
26	70-34-1/2Z Nylon	38	26	68	1.28	243
27	100-60-0 Visc. Rayon	38	26	68	1.28	201
28	100-60-0 Visc. Rayon	38	26	68	1.28	201
29	Raw China Silk	21	19	76	1.84	149
30	130-160-3Z "Vinyon" N	24	18	50	1.21	164
31	90-120-3Z "Fortisan"	21	17	43	1.11	106
32	108-60 Casein	21	18	50	0.93	130
33	110-115 "Fiberglas"	21	20	70	1.30	112
34	66-20-7Z Polythene	21	18	41	1.07	76

Example 4 has illustrated application of the bulking treatment to yarn having an initial twist of 2 turns per

The examples of Table V were performed with the nozzle shown in Figure 10, using the apparatus shown in Figures 12 and 13 for all except the examples having package sizes of 1.0 and 1.5, respectively, where the similar apparatus shown in Figure 14 was used. The percent overfeed appearing in the table was calculated as follows:

$$\text{Overfeed (percent)} = \frac{F-W}{W} (100)$$

where F is the rate of feed of yarn to the bulking nozzle, here determined by the surface speed of feed rolls 95 and 96 of the apparatus used, and W is the rate of windup of the treated yarn. The difference in the two speeds results from the shortening of the yarn in the bulking treatment, hence the percent overfeed is an indication of the percent increase in bulkiness accomplished by the process. This will become evident by comparing the initial and final deniers with the percent overfeed in Table V.

The percent instability is an indication of how well the yarn will process in knitting and weaving operations. It was determined by suspending a preload of 0.01 gram per denier by a length of the yarn measuring 1 meter as preloaded, increasing the load to a total of 0.5 gram per denier for 5 seconds, reducing the load to 0.05 gram per denier, and measuring the final length. The percent increase in length is the percent instability given in the table.

It is important that the bulked yarn be stabilized against such permanent deformation under the stresses it will encounter in processing and use. The yarn leaves the air jet under little or no tension, and some of the convolutions introduced are easily removed even from yarn having a high twist. One way to stabilize the yarn is to prestress it under a greater tension that it will subsequently encounter. This removes convolutions which are not sufficiently firmly locked in place but, of course, also reduces the bulkiness. The process as illustrated has included this prestressing as a part of the windup operation. Thus, in the examples of Table V, the bulked yarn

Table V
BULKING TREATMENT APPLIED TO TWISTED YARN

Material	"Dacron"	"Dacron"	"Dacron"	Nylon	Nylon	Nylon	Nylon	Nylon	Nylon	"Orlon"	Rayon	Acetate
Starting Denier	70	140	210	40	70	70	200	210	560	200	300	300
Filaments	34	68	102	34	34	34	65	102	272	80	60	80
Twist (T. P. I., Z)	.5	.5	.5	.5	.5	5.0	.5	5.0	5.0	5.0	5.0	5.0
Feed Speed (Y. P. M.)	45	45	45	45	45	100	45	300	65	45	45	45
Windup Speed (Y. P. M.)	34	34	34	34	34	83	34	250	50	34	34	34
Overfeed (percent)	32	33	33	33	33	20	33	20	33	33	33	33
Final Denier (nominal)	90	180	270	50	90	84	260	250	700	260	390	400
Instability (percent)	6	4	2.3	2.3	2	2	2.2	5.3	2.2	2.2	2.3	2.0
Air Pressure (p. s. i.)	30	35	40	40	40	35	40	70	40	23	23	23
Air Consumption (C. F. M.)	2.2	2.5	2.6	2.5	2.5	2.5	2.5	4	2.5	1.5	1.7	1.5
Needle Size (I. D., 0.001 in.)	16	16	16	28	16	16	20	16	20	20	20	20
Venturi Throat (0.001 in.)	70	70	70	70	60	60	70	60	70	70	70	70
Spindle Speed (R. P. M.)	7,300	7,300	7,300	7,300	7,300	7,300	7,300	0	0	0	0	0
Twist Added (turns)	4.5	4.5	4.5	4.5	4.5	0	4.5	0	0	0	0	0
Package Size (lbs.)	.25	.25	.25	.25	.25	1.0	.25	1.5	.25	.25	.25	.25

inch, and Examples 29, 30 and 33 (Table IV) have illustrated application of the treatment to yarns having initial twists of 3, 3 and 7 turns per inch, respectively. The other examples have been concerned with treatment of yarns having from 0 to 1/2 turns per inch of twist immediately after bulking, and have relied upon the windup device to introduce the desired twist, a downtwister being disclosed for this purpose. Table V further illustrates application of the process to several types of yarns which have a twist of about 5 turns per inch as they enter the bulking nozzle. This is an adequate twist for most uses, so they do not need to be twisted after bulking. In half of these examples the starting yarn had the desired final twist, while in the remainder the desired twist was introduced with an uptwister before bulking as indicated in the next to last line.

is stressed during passage from the tension guide 101 to the windup roll 103 (Figure 13), or between the draw feed roll 105 (Figure 14) and the windup roll. When using a downtwister, as illustrated in Figure 1, the yarn is stressed during passage from take-up rolls 32, 33 to the downtwister.

Such prestressing sometimes reduces the effectiveness of the bulking treatment by an undesirable amount. The stability can be improved by increasing the twist, but low twist yarns are often required. When applying the bulking treatment to yarn which has been twisted, as with the uptwister adaptation described, a knotty or nubby yarn will be produced if the twist is too high, although this effect may sometimes be desirable. The entangled loop structure discussed in connection with Figure 7 provides improved stability, and this may be obtained

by using lower yarn speeds or higher air pressures or higher overfeeds. These all involve changes in operating conditions, which may not be desirable. Stress-bearing filaments can also be used to provide stability, e. g., unbulked filaments can be plied with bulked yarn, or some of the filaments passing through the air jet can be kept under such tension that little or no bulking of these stress-bearing filaments occurs. That is, a group or bundle of filaments can be fed to the air jet at a lower rate, e. g., at substantially the speed of the windup device, than the rest of the filaments, thereby keeping such group of filaments under tension and preventing the formation of loops therein.

Bulky yarn may be stabilized after production by treating it with size, wax, heat or chemicals to set the convolutions or hold them in place. Various procedures known to the prior art may be adapted to this purpose, and filaments may be set so firmly in the bulked configuration that they will retain their convolutions even though the twist, initially used to hold it in place, is removed.

The proper use of sizing has been found to make low twist yarn completely stable against loss of bulk during further textile processing. For example, a 70-34½ Z nylon yarn was bulked 33% and single end sized in a continuous operation, depositing 8% of polyacrylic acid size on the yarn in the form of a 10% aqueous solution with a size roll rotating at 4 revolutions per minute in a direction opposite to the yarn. This yarn was completely stable to stresses up to the breaking tension. When woven as filling yarn in a 70-34 continuous filament nylon warp, no loss of bulk in fabric form and no difference in pile resistance was noted in comparison with the same starting yarn bulked and twisted to 86-34-5 Z. These two yarns were also knitted into socks, which were finished and dyed. The hand, bulk, covering power and run resistance of the ½ twist, sized-yarn socks appeared to be superior to that of the corresponding socks knitted of unsized 5 Z twist yarn. Single end sizing of bulked yarn should be accomplished before windup because loss of bulk occurs when removing the unsized bulky yarn from a package. An alternative method is to apply the size to the yarn package.

Heat-setting, especially steaming, effectively improves stability. Appropriate temperatures and procedures for a given material will be similar to treatments used in the prior art for twist or fabric setting. As an illustration, a 70-34-5 Z nylon was bulked at 33% overfeed and heat set by three methods:

- (a) Hot air at 160° F. wet bulb, 170° F. dry bulb, for 2 hours,
- (b) Steam at 227° F. for 90 minutes,
- (c) Steam at 274° F. for 1 hour.

The amount of instability, determined as previously described, was reduced about 30% by treatment (a) and about 60% by treatment (b). Treatment (c) gave a somewhat better product and the treatment time was shorter.

Regenerated cellulose filaments which will crimp spontaneously when treated with a swelling agent are disclosed in U. S. Patent No. 2,515,834 to W. D. Nicoll. Bulky yarn formed with these filaments in the uncrimped condition will have the bulkiness improved by crimping the filaments as described in the patent, as by immersion in a warm dilute aqueous solution of caustic. Crimping in this way is also simpler because the filaments will crimp satisfactorily with the bulky yarn under tension whereas the filaments ordinarily have to be relaxed (free of tension) when crimped.

Table IV has illustrated the preparation of blended yarns by feeding two different types of yarns simultaneously to the air jet. Any number of yarns may be combined in this way. A uniform blend of different types

of filaments can be prepared during the bulking treatment with no more difficulty than when bulking yarn from a single source. This is an important advantage because of the increasing recognition being given to blends as a way of obtaining combinations of desirable textile properties not obtainable with a single type of fiber. Yarn composed of a mixture of staple fibers has been easy to prepare by conventional textile methods, but has been difficult to accomplish with continuous filaments. Since the bulky yarn of this invention will compete with spun staple for many uses, it is fortunate that uniform mixtures are so easily prepared.

A different purpose for mixing two different fibers arises when preparing very low denier bulky yarns. If the yarn denier is too low to bulk satisfactorily it can be bulked in combination with a second material which is then removed with a solvent which does not affect the first material. For example, a 30 denier, 10 filament, bulked nylon yarn was found quite difficult to prepare from nylon alone with a given equipment. It was readily prepared by bulking a 10 filament nylon yarn simultaneously with a 30 filament acetate yarn to obtain a 130 denier bulked yarn and then removing the acetate filaments from the mixture by dissolving them in acetone. A mixture of fusible and infusible fibers could be processed in a similar way, using heat instead of a solvent.

Even when bulking a single type of fiber it is sometimes desirable to feed yarn simultaneously from more than one source of supply. In this way larger yarns can be built up. Furthermore, since knots will not ordinarily pass through a bulking nozzle, bulked yarn prepared from a single source will be limited in length by the length of yarn on the supply package. By feeding from more than one package, arranged so that the packages are not exhausted at the same time, bulked yarn can be made of any desired length by starting a new package as soon as a yarn end is reached.

This application has been primarily concerned with the production of uniform bulky yarn composed of continuous filaments. However, a number of novelty effects may be obtained by changes in the air flow. By using higher pressures to obtain high jet velocities a yarn structure was prepared which had the appearance of a hybrid between bulky continuous filament yarn and a staple yarn. Sufficient force was applied to break some of the filaments so that both loops and free ends were in evidence. With still higher velocity jets, all of the filaments are broken to produce flock particles which may have a wide range of lengths. When using extremely low jet velocities and overfeeding a knotty or nubby bulky yarn is produced. The knots are randomly spaced at intervals of about ¼ inch to 3 or more inches, depending on the conditions, and consist of complete convolutions of the entire yarn bundle except for a few filaments wrapped about the intersections with sufficient tenacity to impart stability. A thick and thin yarn, wherein the thick sections contain most of the convolutions, is produced by a pulsating air jet. Most of the above novelty effects are accentuated when treating a mixture of different types of filaments.

The most practical designs of air nozzles known have been disclosed, but the process is so flexible that a wide variety of nozzles can be used more or less satisfactorily. Jetting devices which depart more widely from those shown include multiple orifices or multiple venturis and combinations of air jets in succession to accentuate the bulking action. The turbulence of the jet may be increased by cross jets. The filament separation may be accomplished or supplemented by other means, such as an electrostatic field to induce like charges on the filaments, causing them to separate and balloon outward.

The advantages of this invention are many. The bulky yarn has the desirable properties of spun staple yarn and avoids the necessity of cutting continuous filaments into staple and then reforming the staple into yarn. The

bulky yarn is simply and economically prepared, by a process which requires little equipment, directly from the continuous filament bundle initially produced in synthetic-fiber manufacture. The bulky yarn is superior to spun staple for many purposes because of its freedom from loose ends. However, it can be made to resemble spun staple in this respect, if desired, by cutting or singeing the protruding filament loops to provide loose ends. The unmodified hand of fabrics made from the bulky yarn usually is stiffer than that of corresponding staple materials, making them more suitable for use in draperies, suits, overcoats, etc.

The yarn is sufficiently uniform to be handled easily by textile machinery and to form highly uniform fabrics without the sacrifice of bulk or of fiber interlocking characteristic of some mechanically crimped yarn having too regular a structural pattern. The yarn has been used without difficulty on both automatic weaving and automatic knitting machines. The increased covering effectiveness of fabric made with the bulky yarn permits the production of more fabric from the same weight of yarn and, in addition, by greatly extending the utility of artificial fibers, enables them to replace expensive or scarce fibers in many uses.

Another advantage is the suitability of this process to combining filaments of extremely fine denier into light bulky yarns, having a highly uniform appearance, for which there is no spun staple counterpart. More than one kind of filament may be processed simultaneously to create yarns with a desirable blend of fiber characteristics. Intermittent impulsing of the multifilament being processed can be used to produce a novelty yarn having alternating smooth lengths and bulked regions produced according to the described process.

The simplicity of the new process permits its use at any point in yarn manufacturing or winding with no interruption of processing routine and little outlay for new equipment. Distinct advantages of the process are that it requires little supervision, demands very little maintenance because of its freedom from moving parts, and does not involve temperature or humidity control.

Since many different embodiments of the invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited by the specific illustrations except to the extent defined in the following claims.

What is claimed is:

1. A process for making bulky continuous filament yarn from a bundle of substantially straight continuous filaments which comprises passing the filament bundle through a fluid jet, jetting the fluid with sufficient force to separate the filaments and form the filaments individually into convolutions, and removing the filaments from the jetted fluid and combining the convoluted filaments into a yarn while avoiding tension sufficient to remove the convolutions.

2. A process for making bulky continuous filament yarn which comprises jetting a stream of compressible fluid rapidly from a confined space to form a turbulent region, feeding continuous filament yarn into the fluid stream so that the yarn is supported by the stream and the individual filaments are separated and whipped about violently in the turbulent region, removing the filaments from the turbulent region with resultant formation of convolutions, and reassembling the filaments into yarn while avoiding tension sufficient to remove the convolutions from the filaments.

3. A process for making bulky continuous filament yarn which comprises passing a bundle of filaments through a high velocity air jet under conditions such that the filaments are separated and whipped about sufficiently to form convolutions, removing the filaments abruptly from the air jet, twisting the filaments together to form a yarn, and throughout the process avoiding tension

which would straighten out the convolutions of the filaments.

4. Apparatus for making bulky continuous filament yarn which comprises a fluid nozzle adapted to create a turbulent zone, means for feeding yarn continuously through the turbulent zone, means for supplying fluid to said nozzle under a pressure which will provide sufficient turbulence to separate the yarn filaments and form them into convolutions, and means for withdrawing the separated filaments from the turbulent zone and reforming them into yarn.

5. Apparatus for making bulky continuous filament yarn which comprises a fluid nozzle adapted to jet a stream of fluid to form a turbulent zone, means for feeding yarn continuously into the fluid stream to pass with the stream into the turbulent zone, means for supplying fluid to said nozzle under a pressure which will provide sufficient turbulence to separate the yarn filaments and form them into convolutions, and means for withdrawing the separated filaments from the turbulent zone and reforming them into yarn.

6. Apparatus for making bulky continuous filament yarn which comprises a source of yarn to be treated, feed rolls for supplying the yarn for treatment at a controlled rate, an air nozzle adapted to pass the yarn through the nozzle with an air stream, means for supplying air to the nozzle under a pressure which will provide a zone of turbulence beyond the nozzle sufficient to separate the yarn filaments and form them into convolutions, take-up rolls for withdrawing the separated filaments from the turbulent zone, and yarn winding means for twisting the filaments into a yarn and winding the yarn into a package.

7. A process for making bulky continuous filament yarn which comprises passing a bundle of filaments through a high velocity air jet under conditions such that the filaments are separated and whipped about sufficiently to form convolutions, removing the filaments abruptly from the air jet and collecting the bundle of filaments in orderly form on a take-up device without imparting additional twist to the bundle of filaments, said bundle of filaments having sufficient twist to set said convolutions therein.

8. A process for making bulky continuous filament yarn which comprises passing a bundle of filaments through a high velocity gas jet under conditions such that the filaments are separated and whipped about sufficiently to form convolutions, removing the filaments abruptly from the gas jet, twisting the filaments together to form a yarn, and throughout the process avoiding tension which would straighten out the convolutions of the filaments.

9. A process for making bulky continuous filament yarn which comprises passing a bundle of filaments through a high velocity air jet under conditions such that the filaments are separated and whipped about sufficiently to form convolutions, removing the filaments abruptly from the air jet, and reassembling the filaments into yarn while avoiding tension sufficient to remove the convolutions from the filaments.

10. A process for making bulky continuous filament yarn which comprises passing a bundle of filaments through a high velocity fluid jet in a manner such that the jet operates eccentrically on said bundle of filaments and under conditions such that the filaments are separated and whipped about sufficiently to form convolutions, removing the filaments abruptly from the fluid jet, and reassembling the filaments into yarn while avoiding tension sufficient to remove the convolutions from the filaments.

11. Apparatus for making bulky continuous filament yarn which comprises a fluid nozzle having a venturi throat adapted to create a turbulent zone, means for feeding yarn eccentrically with respect to said venturi

throat and continuously through the turbulent zone, means for supplying fluid to said nozzle under a pressure which will provide sufficient turbulence to separate the yarn filaments and form them into convolutions, and means for withdrawing the separated filaments from the turbulent zone and reforming them into yarn. 5

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,852,906

September 23, 1958

Alvin L. Breen

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 21, for "bene" read -- been --; column 4, line 19, for "formly" read -- firmly --; column 5, line 69, for "The" read -- A --; column 6, line 41, for "shart" read -- start --; column 7, line 52, for "conductive" read -- conducive --; column 13, line 33, for "pile" read -- pill --.

Signed and sealed this 23rd day of December 1958.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
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