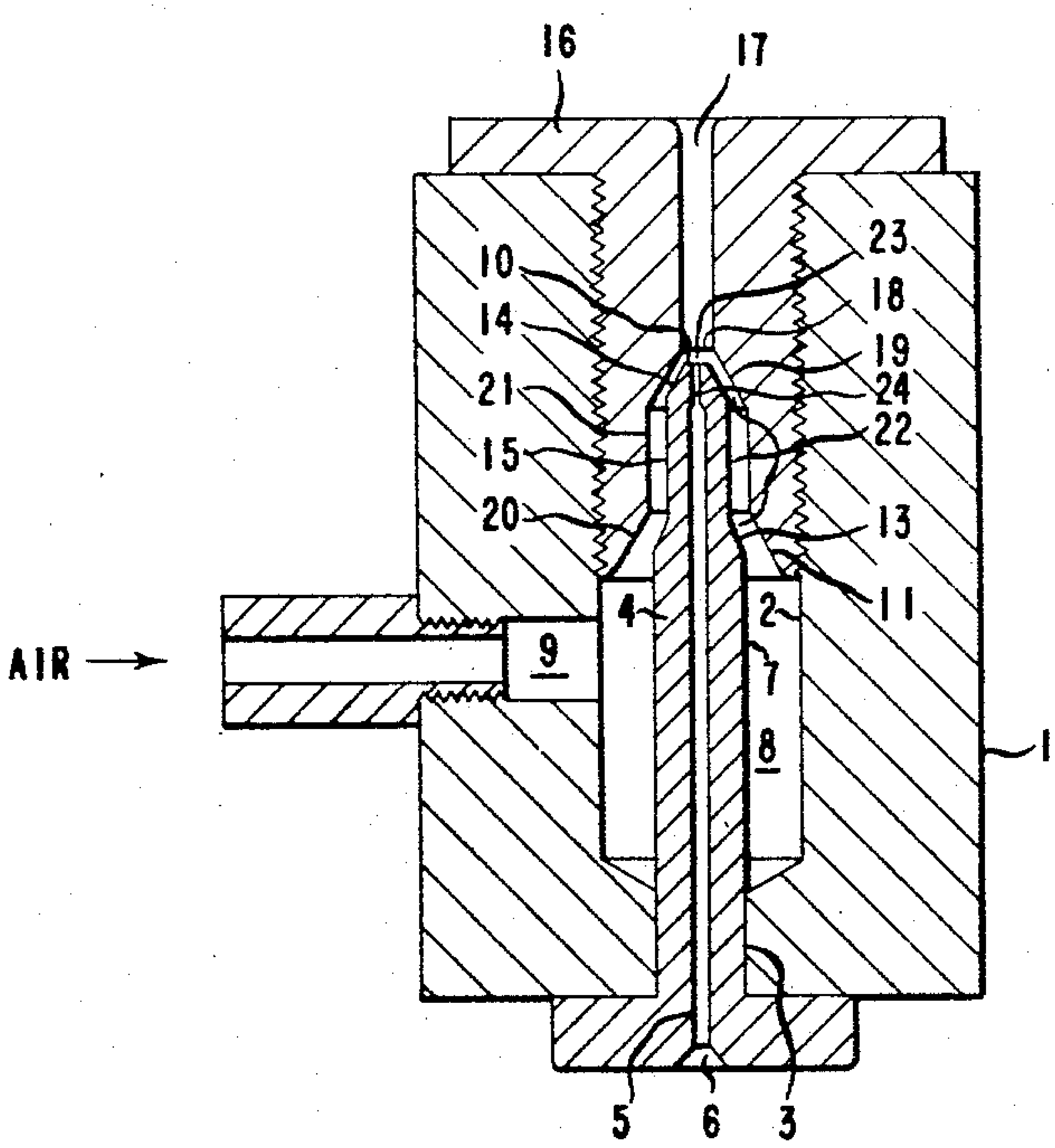
Aug. 8, 1961 C. L. LOVELAND ET AL 2,994,938

YARN-TREATING APPARATUS

Filed June 30, 1959




INVENTORS
CHESTER L. LOVELAND
PACIFIC J. THOMAS

BY Raymond F. Blomstedt

ATTORNEY

United States Patent Office 2,994,938 Patented Aug. 8, 1961

1

2,994,938

# YARN-TREATING APPARATUS

Chester L. Loveland, Dalton, and Pacific J. Thomas, Wyoming, Pa., assignors, by mesne assignments, to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

Filed June 30, 1959, Ser. No. 824,024
4 Claims. (Cl. 28—1)

This invention relates to a process and apparatus for treating a bundle of filaments such as a yarn to produce a bulky strand composed of a plurality of individually crimped filaments.

Artificial fibers are normally produced most easily as continuous filaments. These continuous filament yarns are very strong because of the absence of loose ends that are unable to transmit imposed stresses. Their extreme uniformity and lack of discontinuity, however, makes conventional continuous filament yarns much more dense than yarns made from staple fibers. The production of yarn from staple fibers, however, is time-consuming and requires a complex series of operations to crimp the fibers, align the fibers into an elongated bundle and then to draw the bundle to successively smaller diameters. The final spinning operation, which involves a high degree of twist, finally binds these discontinuous fibers together to produce a coherent yarn with considerably increased bulk. The occluded air spaces give them a lightness, covering power, and warmth-giving bulk not normally possible with continuous filament yarns. Thus, to get staple fibers that can be processed on conventional wool or cotton spinning equipment, it has been the practice to cut continuous filament yarns such as rayon, acetate, nylon, as well as the polyacrylic and polyester fibers into short lengths for spinning into staple yarn.

Recent developments in the textile industry have provided useful routes for improving the bulk and covering power and recoverable elongation of continuous filament yarns without resorting to the staple spinning systems of the prior art. A well-known process for making stretch yarn involves the steps of twisting, heat-setting and then backtwisting to a low final twist level. Another yarn of improved bulk is prepared commercially by the steps of twisting, heat-setting and backtwisting on-the-run using a false-twisting apparatus. This end product can be further modified by hot relaxing to improve the bulk and handle. Still another bulk yarn is being prepared by the well-known stuffer box technique wherein the yarn is steamed to heat-set while it is in a compressed state in the stuffer box.

All of these yarns of the prior art are produced by a process which has the common elements of deforming the yarn mechanically and then heat-setting either with or without an after-relaxation step. It was not until the recently disclosed product in U.S. 2,783,609 to Breen and its process of manufacture became known that an entirely new technique became available for improving the bulk of continuous filament yarns. This technique involves exposing a filamentary material to a rapidly moving turbulent fluid, thereby inducing a multitude of crunodal filament loops at random intervals along the individual filaments. These loops and snarls of entangled loops increase the bulk of the continuous filament yarns considerably and result in fabrics of improved cover, bulk, handle, and the like. With the invention of Breen, a new tool is available for the bulking of filamentary structures, i.e., a turbulent fluid. Fluids, of course, have been used for yarn treating in many of the prior art operations such as drying, extracting, transporting, and the like. Until the invention of Breen, however, they had not been used to entangle, convolute, and bulk a filamentary material. It has now been discovered, however, that a new

2

apparatus for utilizing the turbulent fluid technique results in new yarn products that have certain unique properties, particularly with respect to the uniformity of the yarn products produced and the reproducibility of those products from one machine to another.

It is an object of the present invention to provide a new apparatus for producing bulky yarns of the type and in accordance with the general process disclosed in U.S. 2,783,609 and U.S. 2,869,967 to Breen. Another object is to provide an apparatus for producing substantially more uniform bulky yarns than has been possible with known apparatus using the fluid jet technique of the Breen patent. The apparatus of this invention will be more readily understood by reference to the drawing which represents a sectional view of a preferred embodiment of the fluid-treating apparatus of this invention.

In the apparatus shown in the drawing, the housing **1**, pierced lengthwise by cylindrical channel **2**, which in this embodiment is restricted at one end to form neck **3**, contains needle **4** which is also cylindrical in cross section. Needle **4** is pierced by an axial cylindrical channel **5** having a flared mouth **6** for introducing yarn into the apparatus. The cylindrical body **7** of needle **4**, which preferably has an exterior diameter of 0.187 inch and a length of 0.6 inch, is smaller in cross section than channel **2**, which preferably has an interior diameter of 0.42 inch, thereby forming a right cylindrical annular plenum chamber **8** which surrounds the needle body **7** within the apparatus and this plenum chamber is supplied with compressible fluid, preferably air, through lateral conduit **9** from a source of air not shown. The tip of the needle preferably has a length of 0.41 inch and is tapered in this embodiment from the body **7** at its inner extremity **11** toward the flat inner end of the needle **10**, which preferably has a diameter of 0.066 inch, by means of two right conical shoulders **13** and **14**, where the corresponding cones have vertex angles between about 30° and about 120°, separated by a right cylindrical section **15** which preferably has an exterior diameter of 0.140 inch and a length of 0.28 inch. These right conical shoulders preferably will be 0.066 inch in height and have the same slope, an angle of 60° being preferred, but shoulder **14** may have a slope (apex angle at the vertex of the corresponding cone) less than that of shoulder **13** but equal in degrees to at least 75% of the apex angle of shoulder **13**. The width of the annulus surrounding the tip of the needle (the difference between the outside and inside diameters of a cross section of the annulus) should be substantially the same throughout the length of the needle tip, that is, from point **11** where the tip of the needle meets body **7** to the flat inner end **10** of the needle. Cylindrical annulus **8** surrounding the body of the needle within the apparatus should be at least as wide (difference between minimum and maximum diameters) as the annulus surrounding the tip of the needle and desirably will be somewhat larger in order to insure smooth operations and adequate air velocity for crimping yarn.

Removably inserted in the opposite end of cylindrical chamber **2** away from needle **4** is orifice block **16** closely fitted into housing **1** to prevent air leakage. Orifice block **16** is longitudinally adjustable within channel **2** and is perforated by an axial cylindrical yarn outlet **17**, the inner end **18** of which coincides with the smaller end of the tapered annular channel within the apparatus. The inner end of this yarn outlet is spaced from and concentric with the yarn passageway **5** in needle **4** and is larger in cross-sectional area than yarn inlet **5**. Yarn inlet **5** may be uniformly cylindrical throughout but preferably will have a nozzle **24** of reduced cross-sectional area at the inner end of the needle at shoulder **14** to maintain friction on yarn passing through the needle at a minimum. The conduit **17** terminates inside the apparatus in a wide mouth section of circular cross section which surrounds the tip portion of yarn needle **4** and has a geometry complementary to that of the tip of the yarn needle being in the form of two conical sections **19** and **20** separated by an intermediate cylindrical section **21** and preferably exceeding the cross-sectional diameter of the yarn needle at each point along its length by about 0.08 inch, so that when the apparatus is fully assembled as shown in the drawing the tip of the needle is surrounded by a tapering annular plenum chamber **22** of substantially uniform width throughout and formed by the spaced apart conical sections and intermediate cylindrical sections of the needle tip and the surrounding orifice block mouth, respectively.

Preparatory to operation, the orifice block **16** is adjusted longitudinally within the housing to provide for the smoothest throughput of air or other compressible fluid and no further adjustment is necessary. Needle **4** is fixed within the housing during manufacture in order that it may be centered precisely in the center of cylindrical chamber **2** and require no further adjustment. Since there is only a single simple adjustment to be made in operating the apparatus, uniformity of processing from one machine or one plant location to another and from one operator to another can be maintained within very close limits permitting the production of uniform yarn products with a very minimum of control and without the need for highly skilled operators.

In operation, air is forced into annular chamber **8** within the housing **1** by way of lateral conduit **9**, whence it passes through tapered annulus **22** to the tip of needle **4** while at the same time increasing in velocity due to its increasing confinement along this path. A zone of turbulence **23** is created between the flat end **10** of the needle and the inner end **18** of yarn outlet **17** as the fluid rushes into this area from all sections of the conical annulus, thence passing to the exterior of the apparatus through conduit **17**. Yarn is fed into zone of turbulence **23** from yarn tube **5** where it is agitated violently and whipped about and removed via conduit **17** along with the high velocity air. The yarn is removed from the air stream immediately upon issuing from conduit **17** by withdrawing it to one side. It is important that the apparatus have dimensions such that air or other compressible fluid utilized will have a velocity equal to at least ½ sonic velocity and preferably sonic velocity where it first strikes the yarn in the zone of turbulence **23** and that the cross-sectional area of the outlet conduit **17** be of sufficient size to maintain back-pressure in the yarn inlet **5** at a minimum without decreasing yarn velocity in the zone of turbulence substantially.

The apparatus of this invention is especially suitable for carrying out the bulking process disclosed in U.S. 2,783,609 and U.S. 2,869,967 to Breen, but is particularly useful for treatment of glass yarns or for the simultaneous treatment or combining of two or more yarn ends to provide composite yarn products having special aesthetic characteristics in addition to high bulk. It is one of the important and surprising attributes of the apparatus of this invention that more uniform bulky yarn products both of synthetic filaments and glass filaments can be made than was possible heretofore.

Another advantageous characteristic of the apparatus of this invention is the fact that it permits different operators to produce bulky yarn products having the same highly uniform characteristics. This arises because the jet has only one adjustment and this can be regulated solely upon the effective throughput of air. In prior known fluid treatment apparatus several adjustments were usually possible and necessary and could only be made by a skilled operator after examination of yarn products produced and an evaluation of the quality and uniformity of the bulk and other characteristics of that product. Because no two operators, however skilled, evaluated yarn product characteristics exactly alike and because the fluid treating apparatus was not susceptible to precise adjustment, quality of bulky yarn products with prior art apparatus varied substantially from operator to operator, from machine to machine, and from one plant location to another. The apparatus of the present invention remedies that situation.

The absolute and relative dimensions of the yarn inlet tube **5** and the outlet conduit **17** may be varied fairly widely but outlet tube **17** must be the larger. One advantageous attribute of the apparatus of this invention is the effectiveness in processing a great variety of yarn counts without necessity of a change in the dimensions. For example, with a yarn inlet tube diameter of 0.028 inch, yarns varying in denier from about 80 to 1300 or more may be readily processed using an outlet tube diameter of 0.056 inch. An inlet tube diameter of 0.040 inch with an outlet tube diameter of 0.070 inch is suitable for processing yarns varying in denier from about 1000 to 5000 and is especially good for processing glass fiber yarns or mixing two or more synthetic organic filament yarns. Generally, the needle end **10** is spaced from outlet tube end **18** by a distance of about 0.008 inch to 0.020 inch. The characteristics of the yarn product usually suffer if these latter limits are exceeded. The width of the conical annulus **22** surrounding the tip of the needle is desirably uniform throughout and an annulus having a minimum diameter of $\frac{9}{64}$ inch and a maximum diameter of $\frac{14}{64}$ inch is suitable for processing most yarns as providing an air velocity in the zone of turbulence **23** of at least ½ sonic and sometimes supersonic depending upon the other characteristics of the apparatus, thereby making the yarn bulking procedure exceedingly efficient from the standpoint of economy of air consumption and yarn throughput while at the same time producing an unusually uniform product both from the standpoint of the size of the loops and whorls in the bulky yarn product and their uniform disposition throughout the bulky yarn.

Of course, a particular fluid treating apparatus having certain selected interior dimensions may be chosen for its peculiar effectiveness with a certain yarn and its economy of air consumption, manufacturing expense, or other factors. Apparatus employing the principles of the present invention but differing somewhat in configuration will be obvious to those skilled in the art. In one such variation, for example, the annulus **22** shown in the drawing comprising the two annular conical sections separated by a cylindrical annulus may be replaced by two contiguous annular conical sections, thereby eliminating the cylindrical annulus. Similarly, a device having three contiguous annular conical sections about the tip of the needle or any number of such conical annular sections with a cylindrical annulus intermediate adjacent sections would also be feasible although much more difficult to manufacture. The apparatus shown in the drawing is particularly preferred in this invention because a more highly uniform bulky product is attained under normal operating conditions with high throughput of yarn and efficient consumption of air than with other apparatuses of this type.

The process and apparatus of this invention can be used to crimp and bulk any natural or synthetic filamentary material. Certain thermoplastic materials such as polyamides, e.g., poly(epsilon caproamide), poly(hexamethylene adipamide); cellulose esters; polyesters, e.g., polyethylene terephthalate, poly(hexahydro-p-xylylene terephthalate), etc.; polyvinyls and polyacrylics, e.g., polyethylene and polyacrylonitrile, as well as copolymers thereof, are particularly suitable for producing the uniformly bulked products described herein. While the preferred form of material is continuous filaments, the process and resultant improvements occur with staple yarns as well. Both types of materials can be made into bulky yarns and fabrics having improved bulk, covering power (opacity) and hand.

This apparatus and process are useful for both monofilament yarns in textile deniers as well as the heavier carpet and industrial yarn sizes either singly or combined in the form of a heavy tow. Fine count and heavy count staple yarns can be processed both singles and plied. The process and product are also not restricted in the case of the synthetic materials to any one particular type of filament cross section. Cruciform, Y-shaped, delta-shaped, ribbon, and dumbbell and other such filamentary cross sections can be processed at least as well as round filaments and usually contribute still more bulk than is obtained with round filaments. By proper design of the jet and process, multiple ends of yarn may be handled either in the form of warp sheets, ribbons, or tows.

In using the apparatus of this invention yarn is fed into the yarn inlet tube at an overfeed which will depend upon the character of the feed yarn as well as the particular characteristics desired in the product. When the apparatus is used to combine and bulk two or more yarns, one or both of them may be fed into the apparatus with overfeed and, if both are fed with overfeed, the overfeed with one yarn may be the same or different from that applied to the other. Overfeeds as high as 400% have been utilized effectively.

Although the invention has been illustrated with air, steam or any other compressible fluid or vapor may be utilized. Air is particularly preferred because of its cheapness and convenience.

The configuration and accompanying characteristics of the yarn produced by the apparatus of this invention depend in part upon the amount and velocity of the air characteristics of the apparatus, yarn speed, and the yarn fibers being treated. For optimum bulking the apparatus perimeters must be carefully determined. The size of the yarn inlet **5** as well as that of the yarn outlet **17** depends upon the type and denier of the yarn being processed. The yarn inlet **5** should be just large enough to allow passage of the yarn with a minimum of drag due to friction and yet be small enough to minimize the flow of air back through this yarn inlet from the plenum chamber. The outlet tube **17** must be large enough to allow the crimped yarn to exit along with the treating air without imposing excess tension on the yarn bundle and without reducing substantially the metering action of the conical annular plenum chamber surrounding the tip of the needle.

The efficient bulking action of this apparatus apparently results from the action of high velocity fluid on the individual yarn filaments as the yarn passes through the zone of turbulence at the tip of the yarn inlet needle. It appears that the yarn is opened up due to the action of the fluid in the zone of turbulence and that the individual filaments within the yarn bundle are separately whipped about and randomly twisted so that they become intimately entangled and interlocked with adjacent filaments while at the same time being formed into loops and whorls uniformly through the yarn bundle to provide the desired bulking action. Apparently also, a fluid vortex is formed so that in addition to the loopy characteristics in the yarn product and the individual twist, intermingling and interlocking of fibers within the yarn bundle, the yarn bundle itself assumes an alternate twist configuration which remains in the yarn after it is removed from the apparatus. Quite possibly it is the interlocking and intermingling of the yarn fibers within the bundle which make this apparatus particularly suitable for bulking fiber glass yarns because processing such a fiber glass yarn produces a compact yarn bundle which is coherent and further processable in the same manner as a unitary strand. Prior art fluid treating apparatuses for bulking yarns have been ineffective for the treatment of fiber glass yarns since the resulting product was usually neither coherent nor unitary. Because of the unifying results produced by the apparatus of this invention, the feed yarn may be twisted or untwisted and quite obviously the product may be twisted or not, as desired. Where a zero twist yarn is fed to the apparatus, the product is a bulked yarn in which the filaments are intermingled and interlocked with one another besides being uniformly loopy throughout and there is no need to twist this product for further processing.

*Example I*

Using the fluid treating apparatus shown in the drawing having a yarn inlet diameter of 0.028 inch and a yarn outlet diameter of 0.056 inch, three fiber glass yarns (150 1/01Z) were fed into the jet at a rate of 34 yards per minute and another fiber glass yarn (150 1/01Z) was simultaneously fed into the jet at 70 yards per minute. Air pressure supplied to the jet was 60 p.s.i.g. The bulked composite yarn leaving the jet was wound up at 30 yards per minute, being withdrawn from the air stream issuing from the jet at the jet exit. The yarn product was a bouclé.

*Example II*

Using the jet of Example I, three strands of fiber glass yarn (150 1/01Z) were fed into the jet at 100 yards per minute and wound up at 90 yards per minute. Air pressure supplied to the jet was 70 p.s.i.g. This yarn was also a bouclé.

*Example III*

Two yarns, one a 150–40–0 blue acetate yarn and the other a 150–40–0 red acetate yarn, were fed into the jet of Example I simultaneously at the rate of 50 yards per minute and wound up at 41 yards per minute. Air pressure supplied to the jet was 40 *p.s.i.g.* The yarn product was a homogeneous mixture of the bulked blue and red acetate yarns and having a uniform bulk throughout due to the uniform disposition of loops and whorls throughout the yarn product bundle.

*Example IV*

A 140–68–1/2Z nylon yarn was fed into the jet of Example I at 35 yards per minute and two effect yarns, one a 300–80–5Z blue acetate yarn and the other a 100–80–5Z blue acetate yarn, were fed into the jet simultaneously with the nylon yarn at the rate of 130 yards per minute. The bulked product was removed from the jet and wound up at 31 yards per minute. Air pressure supplied to the jet was 50 p.s.i.g. The product was a chenille-type yarn having a nylon core and an acetate effect component.

We claim:

1. A yarn-treating apparatus comprising a housing perforated by a cylindrical channel, a yarn needle of circular cross section having an axial yarn passageway for introducing yarn into the apparatus, said needle being positioned in and concentric with the cylindrical housing channel and closely fitted into one end of the housing channel and comprising a cylindrical body portion and an inner tapered tip portion, both within the housing channel, the body portion being substantially smaller in cross section than the housing channel to provide an annular plenum chamber, the tip portion extending from the body portion to a flat inner end of the yarn needle and diminishing in cross section toward the inner end in at least one graduated step in the form of a cylindrical section separated from the flat inner end and the body portion of the yarn needle, respectively, by shoulders, each in the form of a right conical section having a vertex angle between about 30° and about 120°, the vertex angle of the shoulder adjacent the inner end being at least 75% of the vertex angle of the shoulder adjacent the needle body; a cylindrical orifice block closely fitted into the opposite end of the housing channel from the yarn needle and longitudinally adjustable within said channel, said orifice block being perforated by an axial yarn outlet spaced from and in-line with the yarn passageway, said outlet being circular in cross section throughout and tubular at its outer end, but widened at its inner end to form a mouth-section surrounding the tip portion of the yarn needle and having a geometry complementary to that of the tip of the yarn needle but of substantially larger cross-sectional area, thereby forming the outer walls of an annular chamber about said tip, which annular cham-

ber diminishes in diameter in the direction of the tip of the needle in the same step-wise manner as the diameter of the needle tip diminishes in size; an air conduit for introducing air into the annular chamber surrounding the body of the needle.

2. A yarn-treating apparatus comprising a housing perforated by a cylindrical channel and having the following relative dimensions, a yarn needle of circular cross section having an axial cylindrical yarn inlet with a nozzle diameter of 0.028 to 0.040 inch for introducing yarn into the apparatus, said needle being positioned in and concentric with the cylindrical housing channel and closely fitted into one end of this housing channel and comprising a cylindrical body portion with an exterior diameter of 0.187 inch and a length of 0.6 inch and an inner tapered tip portion having a length of 0.41 inch, both within the housing channel, the housing channel having an interior diameter of 0.42 inch to provide an annular plenum chamber about the needle body, the tip portion of the needle extending from the body portion to a flat inner end of the yarn needle having a diameter of 0.066 inch with the yarn needle diminishing in cross section from the needle body toward the inner end in at least one graduated step in the form of a cylindrical section 0.140 inch in diameter and 0.28 inch long, which cylindrical section is separated from the flat inner end and the body portion of the yarn needle, respectively, by shoulders each in the form of a right conical section 0.066 inch in height and having a vertex angle of 60°; a cylindrical orifice block closely fitted into the opposite end of the housing channel from the yarn needle and longitudinally adjustable within said needle, said orifice block being pierced by an axial yarn outlet in-line with the yarn passageway and spaced from the end



of the yarn needle a distance between about 0.008 inch and about 0.020 inch, said outlet being circular in cross section throughout and cylindrical at its outer end with a diameter of 0.056 to 0.070 inch but widened at its inner end to form a mouth-section surrounding the tip portion of the yarn needle and having a geometry complementary to that of the tip of the yarn needle but exceeding the cross-sectional diameter of the yarn needle at each point along its length by about 0.08 inch, thereby forming the outer walls of an annular stepwise tapered chamber about said needle tip, which annular chamber diminishes in diameter in the direction of the tip of the needle in the same step-wise manner as the diameter of the needle diminishes in size; an air conduit for introducing air into the annular chamber surrounding the body of the needle.

3. The yarn-treating apparatus of claim 2 in which the yarn inlet diameter is 0.040 inch and the yarn outlet diameter is 0.070 inch.

4. The yarn-treating apparatus of claim 2 in which the yarn inlet diameter is 0.028 inch and the yarn outlet diameter is 0.056 inch.

**References Cited** in the file of this patent

UNITED STATES PATENTS

2,829,420 Griset ---------- Apr. 8, 1958
2,852,906 Breen ---------- Sept. 23, 1958
2,884,756 Head ---------- May 5, 1959

FOREIGN PATENTS

811,373 Great Britain ---------- Apr. 2, 1959