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Marshall

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[54] PNEUMATIC DRAFTING OF FIBROUS STRANDS

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[51] Int. Cl. **D01g 25/00**
[58] **Field of Search** 19/236, 258, 156.3, 145.5; 57/58.89, 58.91; 28/72.12

[56] **References Cited**

UNITED STATES PATENTS

3,001,242	9/1961	Heffelfinger	19/145.5
3,523,300	8/1970	Tabata et al.	57/58.91
3,604,194	9/1971	Edagawa et al.	57/58.89

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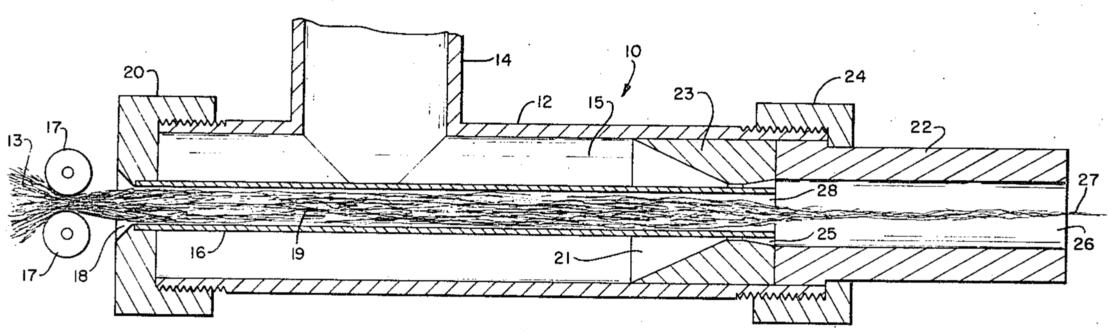
[57] **ABSTRACT**

A twist-free strand of textile length fibers is pneumatically drafted at its leading end into a high velocity fibrous stream which may be decelerated and diffused in a plenum chamber from which it is removed as a fibrous web.

4 Claims, 4 Drawing Figures



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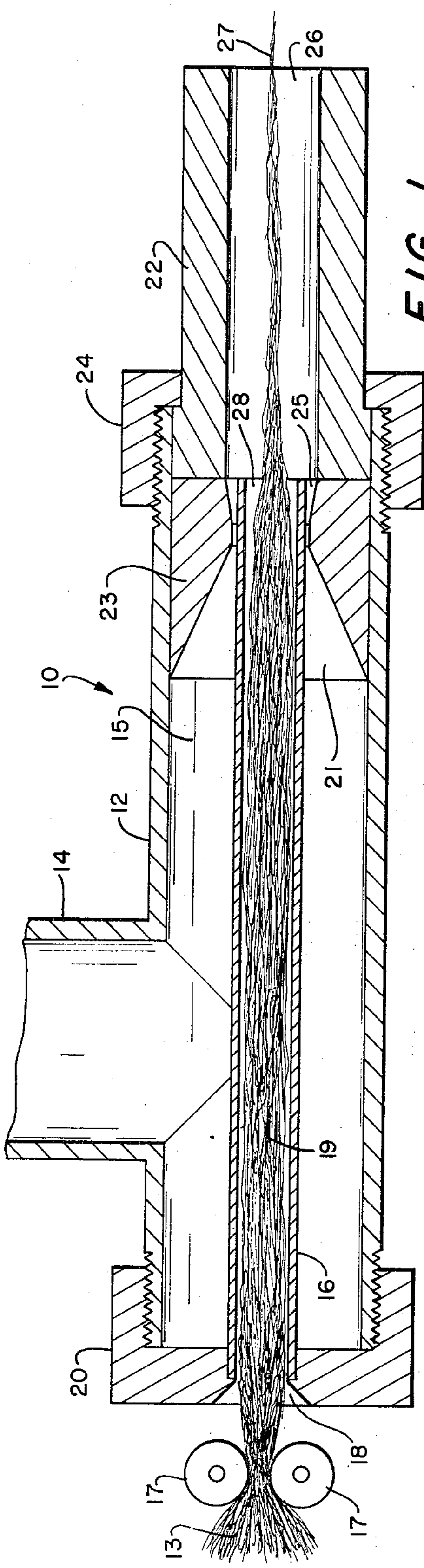

FIG. 1

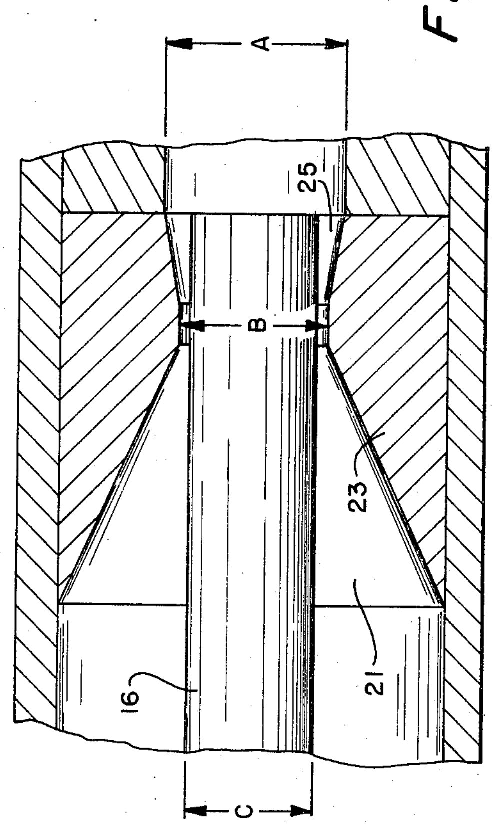

FIG. 2

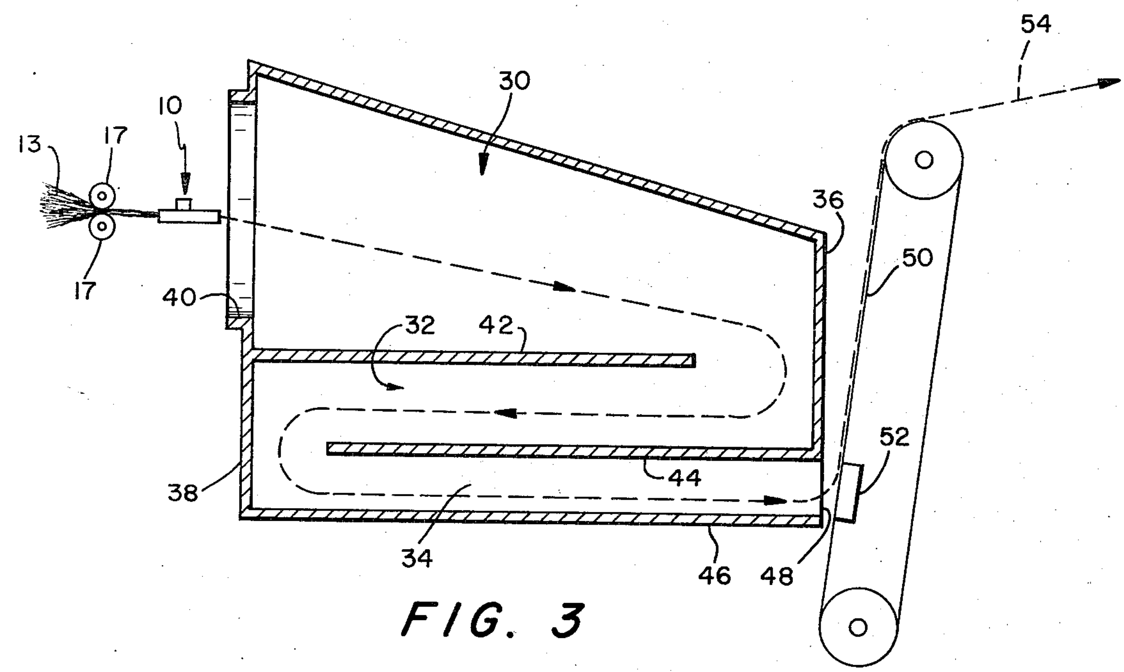

FIG. 3

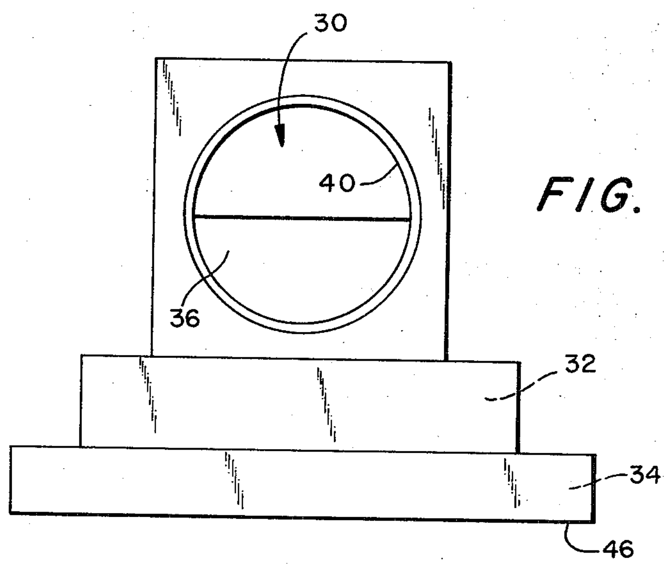

FIG. 4

PNEUMATIC DRAFTING OF FIBROUS STRANDS

This invention relates to a process for the pneumatic drafting of individual textile-length fibers from a twist-free strand comprising a multiplicity of such fibers, and to a process for depositing the resulting air-borne fibers in the form of a fleece or web. More particularly it relates to a process for exposing a twist-free tip-draftable strand such as a top or sliver of textile-length fibers to the action of a fluid jet stream of high velocity, creating a fluid stream of individualized fibers, and decelerating and diffusing said fluid stream in a plenum chamber.

In the formation of fibrous webs to be fashioned into nonwoven fabrics, batting, coil, and the like, it is customary to feed a supply of staple fibers to a card, garnett, air-lay machine, or the like, which separates discrete and small groups or clumps of fibers from the feed mass and assembles these discrete clumps in the form of a fibrous web.

There are at least two disadvantages in the production of such fibrous webs by conventional methods. First, man-made fibers are produced in the form of a bundle or tow of continuous filaments, which must be cut to staple length by a tow cutter, for formation into card webs. Second, and more importantly, the conventional web-forming devices mentioned above do not separate fibers completely from each other, but instead they pluck off small groups or clumps of fibers from the main fibrous mass, so that card webs and garnett webs have a blotchy appearance. Furthermore, a fibrous web composed of fibrous clumps or aggregates does not develop the tensile strength which it would possess if the fibrous elements were substantially completely separated from one another and then reassembled in web form.

In my copending U.S. Pat. application Ser. No. 110,446, filed Jan. 28, 1971, there is described a process wherein textile filamentary material is shattered into staple fiber length by the action of a cryogenic fluid stream operating at velocities of at least Mach 1.5 and temperatures below -100° F., as by use of a Laval jet. In such a process, the filamentary material is held under restraint at a point distant from the propelling action of the air stream.

It is also known to draft twisted yarns into a dispersion of fibers, as set forth in U. S. Pat. No. 3,001,242, to Heffelfinger. In twisted yarns, however, the fibers are in considerable frictional engagement, and to prevent clumps of fibers from being detached from the yarn, only a few of the fibers in the yarn cross-section may be exposed to the dispersing air stream at any one time. For this reason, restraint on the yarn must be applied at a point which is less than one fiber length from the discharge end of the yarn delivery tube. This involves a criticality in delivery tube dimensions, and a constant readjustment of the tube length as the staple length of the yarn being processed is varied. It also makes it difficult to create a uniform dispersion of fibers from a yarn of natural fibers such as cotton, where the fiber length of, for example, a carded yarn varies from fiber to fiber.

It has now been found that if an untwisted top or sliver of staple fibers, comprising a large number of fibers in cross-section, is fed to the propulsive zone of a high-velocity fluid stream, the elements of criticality in feed tube length vs. point of air impact disappear. Preferably, though not essentially, the twist-free strand is fed to a delivery tube by a pair of feed rolls situated at a point which is removed from the exit end of the guide tube by a distance which is greater than the staple length of the fibers in the strand. In this manner, the pneumatic force exerted on the strand is not spent to any appreciable extent in shattering restrained fibers, as in U.S. Pat. Ser. No. 110,446, but in the detachment and acceleration of free fibers into a stream that is highly attenuated in average fiber density.

This stream of fibers is then decelerated by diffusion into a plenum chamber and drawn therefrom in the form of a fibrous web or fleece. The process of this invention, therefore makes possible the use of a web-forming device that is less expensive, smaller, lighter, and less demanding of maintenance than conventional web-forming devices. It is also capable of forming webs of fibers which because of usually low denier, or because of lack of crimp, or finish, are not usually processable by conventional devices. Additionally, since the process of this invention results in an air-borne fiber dispersion in which substantially all fibers are separated from one another, the resulting fibrous webs display a uniformity of density and freedom from mottled or blotchy appearance which cannot be realized with conventional web-forming techniques.

It is therefore a primary object of this invention to provide a process for the aerodynamic drafting of a twist-free fibrous strand into a low-density high-velocity stream of parallelized individual fibers, and for the conversion of said stream, by diffusion and deceleration, into a fibrous web of improved properties.

Other objects of the invention will be more fully understood from the following description and drawings, in which:

FIG. 1 is a cross-sectional view of a tip-draftable sliver of textile-length fibers being aspirated through and attenuated by a jet stream of fluid.

FIG. 2 is an enlarged cross-sectional view, partly broken away, of the throat section of the nozzle of FIG. 1.

FIG. 3 is a cross-sectional side view of a plenum chamber suitable for the deceleration and diffusion of the air-borne stream of fibers of FIG. 1.

FIG. 4 is a front elevation of the plenum chamber of FIG. 3.

Referring to FIG. 1, a tip-draftable strand of textile-length fibers **13** is fed at a rate controlled by the metering rolls **17, 17** to an aspirator nozzle **10**.

By "tip-draftable" strand is meant a twist-free sliver or top of textile length fibers, commonly one inch to 6 or 8 inches in length, assembled together into a coil or strand wherein the fibers are generally parallelized and are so free of frictional engagement by entanglement, twist, or crimp that aerodynamic drafting exerted on the tip of the strand draws off individual fibers, not clumps or clusters of fibers.

The strand in compressed and restrained form is fed through the tapered opening **18** into the guide tube **16**, located substantially along the central axis of the nozzle.

In its basic form the nozzle **10** comprises a cylindrical chamber **15** with wall portion **12** capped at one end by an inlet cap **20** containing a tapered inlet **18** for the introduction of a tip-draftable strand, to which is affixed the guide tube **16**. The other end of the chamber **15** is capped by an exit cap **24**, which restrains the straight exit section **22** and the convergent-divergent nozzle section **23** of the device. For convenience in machining, sections **22** and **23** are separate pieces, fitting in sliding relationship in the chamber **15.** In operation they are held against lateral displacement toward the inlet tube by the air pressure in the chamber **15.**

Air under pressure is fed to the chamber **15** by means of the air connection **14.** The distance to which the guide tube **16** projects past the nozzle portion **23** of the device is adjustable by means of the threaded cap **20.**

In operation, air under pressure is fed to the air inlet **14,** and is converted to a convergent stream of air in the convergent section **21** of the nozzle, whence it diverges in the divergent section **25** (in the form of a concentric fluid stream.) The strand of textile-length fibers **19** remains substantially constant in cross-sectional population during its traverse through the guide tube until it is attenuated by the fluid stream in a zone situated at or near the exit end of the guide tube **16.** There is thus formed a high velocity, low pupulation density fibrous stream **27,** which is expelled together with the air stream through the nozzle orifice **26** in the cap **24.**

The attenuation of fiber density, (as mentioned above,) is apparently initiated in a zone at or near the tip **28** of the guide tube **16,** where the draftable fibrous strand comes under the influence of the concentric air stream in the divergent portion **25** of the nozzle. Attenuation is one of extreme degree. In a typical example, a rayon top of **191, 317** denier, **34,785** filaments, with a filament length of 6 inches, was fed at a rate of 11.7 feet per minute to a nozzle of the type shown in FIG. **1,** operating at 85 PSIG air pressure at the air inlet **14.** The estimated velocity of the fibers in the divergent portion of the nozzle was 60,000 feet per minute, meaning that the number of fibers in an average cross-section of the air stream was 6.78, compared to the 34,785 fibers in an average cross-section of the undrafted strand. Such attenuation factors, of over 5,000 times, are characteristic of the process of this invention.

The dimensions and relative proportions of a suitable nozzle will of course vary with the denier of the tip-draftable strand used as a source of fibers, and with the output poundage at which it is desired to operate the process. The device of FIG. **1** may, for example, be formed from a 10 inch length of brass pipe 2 inches I.D., with a similar piece of pipe **14** silver-soldered thereto.

The employment of tip draftable strands of greater denier, for higher poundage output, will necessitate larger filament input tubes and larger nozzles: however, the scaling-up of the apparatus is a matter of engineering detail.

In calculating the net throat area of a nozzle, it will be obvious that the gross throat area (B of FIG. **2**) must be reduced by the area occupied by the strand feed tube (C of FIG. **2**).

The following types of nozzles have been found suitable for the conversion of tip-draftable strands into a stream of individual fibers:

	A	B	C
Throat Diameter	0.624 in.	1.120 in.	0.562 in.
Angle of Divergent Taper	5.7°	5.7°	2.7°
Exit Section Diameter	0.704 in.	1.200 in.	0.600 in.
Exit Section Length	5.00 in.	5.00 in.	5.00 in.
O.D. of Guide Tube	0.50 in.	1.00 in.	0.50 in.
I.D. of Guide Tube	0.380 in.	0.750 in.	0.380 in.
Net Throat Area	0.110 in.	0.20 in.	0.0517 in.

Type B, with guide tube inside diameter of 0.750 inches, is suitable for processing heavy fibrous strands of up to 500,000 denier.

Although frequent reference has been made above to air streams and air-powered jets, it will be obvious that the nozzle may be powered by steam or other gaseous fluids.

DECELERATION AND DIFFUSION

In order to decelerate the high-speed stream of individual fibers to a manageable velocity, it has been found convenient to employ a plenum chamber, into which the high-speed fibrous stream is exhausted. Such a device is shown in FIGS. **3** and **4,** in side and front elevation respectively.

Referring to FIG. **3,** there is shown a suitable plenum chamber with the side panel removed. A tip-draftable strand, **13,** is fed at a controlled rate by the feed rolls **17, 17,** to the nozzle **10** containing the jet which creates an air stream of high velocity. The resulting high speed fibrous stream, as it issues from the jet device **10,** diffuses a stream of individually separated short fibers into the upper chamber **30.** Although various types of plenum chamber may be used, for convenience and economy of space the device as shown is divided into an upper, middle, and lower chamber **30, 32,** and **34** respectively, separated by the plates **42, 44,** and **46** which extend the full width of the chamber. Plates **42** and **44** do not extend the full length of the chamber, however, so that the path of the decelerating fibers is a serpentine one, as shown by the dotted line. The rear and front partitions, **36** and **38,** act as baffles, deflecting the air stream, so that a constant and substantially uniform flow of fibers, at a manageable velocity, emerges from the plenum chamber exit **48** to impinge on the upper surface of the screen conveyor belt **50.** If desired, a conventional vacuum box **52** may be mounted on the under side of the porous conveyor to bleed off the last traces of air and assure proper deposition of the fibrous web **54** on the conveyor.

In some case, where the web is to be subjected to subsequent treatment such as lamination with another substrate, it is convenient to interpose between the conveyor screen and the fibrous stream a layer of permeable supportive material such as gauze, cellulose tissue, porous nonwoven fabric, or the like. Such expedients are well-known in the art, and are not shown.

The term "manageable velocity" as employed above means a stream velocity at which the fibers can be deposited continuously onto a moving porous belt with substantial absence of fiber clumping or deflection of the stream. The purpose of the plenum chamber or diffusor, therefore, is to spread the high speed jet stream over a large cross section, so that the kinetic energy of the stream is transferred to pressure, by diffusion. This pressure forces the air through the porous conveyor, which filters out the fibers in web or fleece form. A convenient range of exit velocity — that is, the air velocity at which the decelerated fibrous stream impinges on the porous conveyor belt — has been found to be 3 to 30 feet per second.

At the divergent section of the jet, the air stream is at high velocity. Throttling this velocity down to a manageable exit velocity is a function of the parameters of the plenum chamber, which can be calculated from a consideration of the volume of air be handled.

The invention will be illustrated by the following examples. In each case the draftable strand was fed to the jet at a rate controlled by the feed rolls **17, 17** and a three-section plenum chamber was used as in FIGS. **3** and **4**. The upper chamber **30** was 20 inches square in cross-section, with a circular opening 40 of 16 inch diameter. The middle chamber **32** was 30 inches wide and 6 inches deep, while the bottom chamber 40 inches wide and 4.5 inches deep. The length of the plenum chamber was 40 inches.

EXAMPLE 1.

A 191,317 denier rayon top, consisting of 34,785 fibers in cross-section, each fiber being 5.5 denier and approximately 6 inches long, was prepared from a continuous filament rayon tow cut by a Pacific Converter and then pin-drafted. It was passed between restraining rolls to a jet of Type A in the table above operating at an air pressure of 85 PSIG at a rate of 2.19 feet per minute or 1.88 pounds per hour. The distance between the rolls **17, 17** and the entrance **18** of the guide tube was approximately one-half inch, and the strand substantially filled the guide tube. The high velocity air stream of fibers was fed directly from the exit section of the nozzle **10** to the plenum chamber of FIG. **3**, whence it was collected on the conveyor screen as a light, uniform web 40 inches wide, of 6-inch fibers weighing 6.63 grams per square yard, at a rate of 5.78 feet per minute.

EXAMPLE 2.

Using the same apparatus and feed strand as in Example 1, the air pressure was increased to 125 PSIG. The input rate of the strand was increased to 4.31 feet per minute, or 3.72 pounds per hour.

The resulting 40 inch web weighed 13.06 grams per square yard and was produced at a rate of 5.78 feet per minute, as in Example 1.

By scaling up the denier of the tip-draftable strand and the dimensions of the nozzle, web weights can be varied from 6 to over 400 grams per square yard, at

output rates ranging from 2 to 120 pounds per hour, employing twistless strands of from 30,000 to 500,000 denier.

Having thus described my invention, I claim:

1. The method of forming a high-velocity low-population fluid stream of discretely separated textile-length fibers which comprises

feeding a twist-free strand composed of substantially parallel overlapping textile-length fibers through a guide tube open at both ends, said strand being between 30,000 and 500,000 denier;

maintaining said strand substantially constant in cross-sectional poulation through a substantial portion of the length of said guide tube;

subjecting the free end of said strand to the action of a fluid stream in the form of a concentric fluid flow having a high velocity;

drafting and attenuating said strand into a high-velocity low-population fluid stream of discretely separated textile-length fibers in said tube; and

expelling said strand with said fluid stream from said tube.

2. The method according to claim **1** in which the twist-free strand is a strand of viscose rayon fibers.

3. The method according to claim **1** in which the cross-section fiber population of the strand is held substantially constant by feeding the strand between a pair of feed rolls situated at a distance from the exit end of said guide tube which is greater than the average length of the fibers in said strand.

4. The method of forming a fibrous web of staple textile-length fibers which comprises

forming a high-velocity fluid stream of discretely separated fibers according to the method of claim **1**,

decelerating and diffusing said fibrous stream by expansion of said stream into a plenum chamber,

and collecting the fibers from said stream from said plenum chamber in the form of a fibrous web.

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