Aug. 1, 1967 J. P. DE GUZMAN 3,334,161

FILAMENT FORWARDING JET DEVICE

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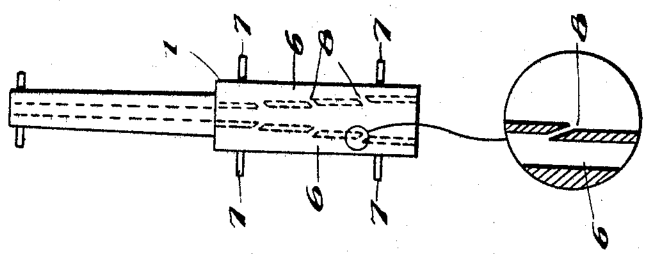

Fig. 4.

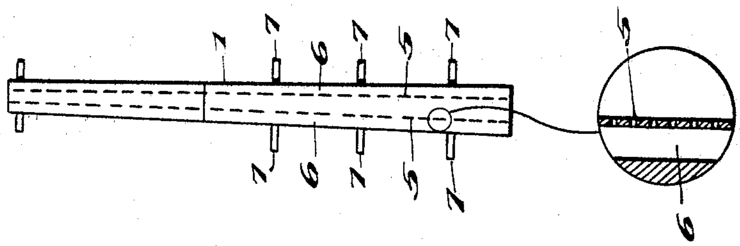

Fig. 3.

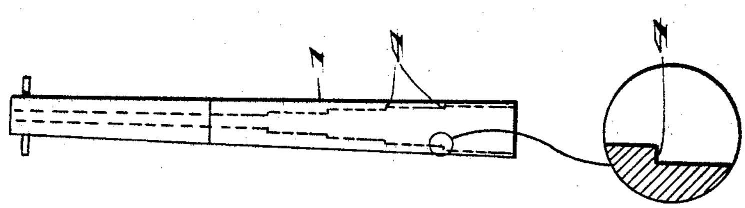

Fig. 2.

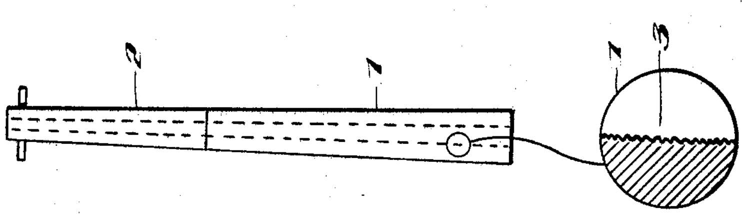

Fig. 1.

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Fig. 7.

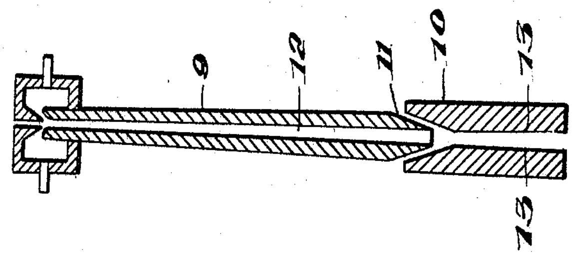

Fig. 6.

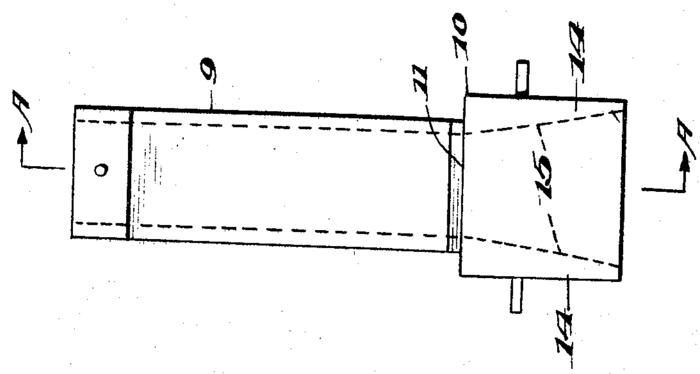

Fig. 5.

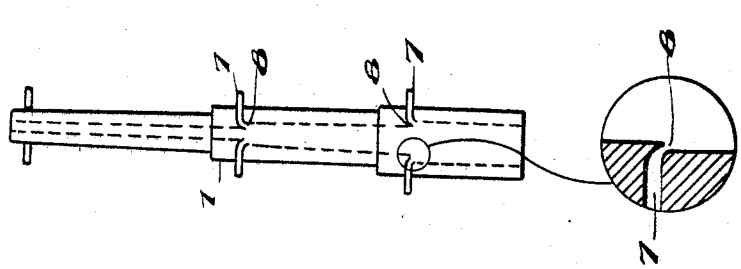

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Fig. 9.

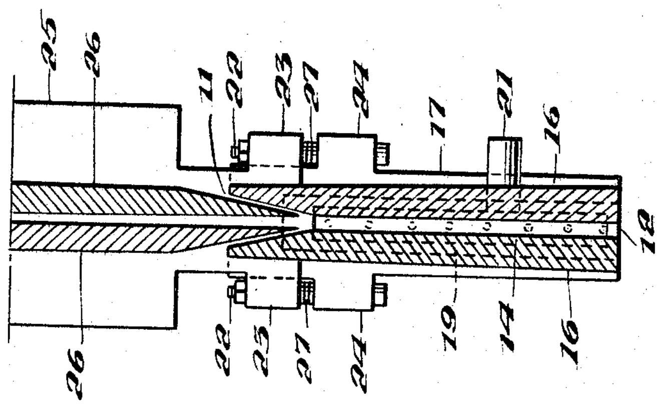
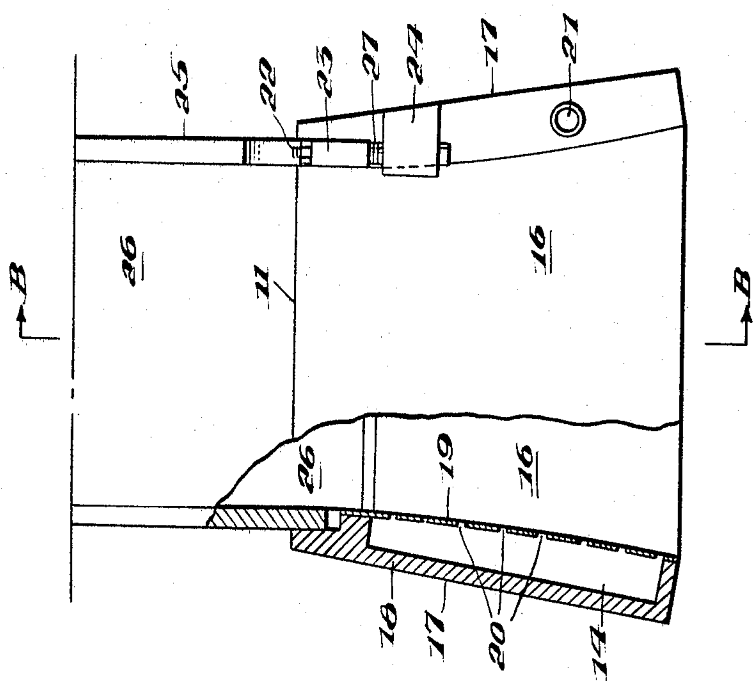


Fig. 8.



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FILAMENT FORWARDING JET DEVICE

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8 Claims. (Cl. 264—24)

This invention relates to an improved process and apparatus for forwarding strands of textile filaments and particularly to the forwarding of filaments by means of a high-velocity fluid stream flowing through an enclosed channel.

The forwarding of filaments by means of a high-velocity fluid stream in a jet device is well known in the textile art and is an especially valuable technique for use in a recently developed process for the manufacture of nonwoven fabrics composed of continuous synthetic organic filaments. In this process, which is described in British Patent 932,482, a multifilament strand of continuous filaments under tension is electrostatically charged by known techniques, for example, by triboelectric charging or by passing the filaments through a corona discharge zone; the charged filaments are then forwarded by means of a jet device toward a web-laydown zone; the tension on the filaments is released as they exit the jet device thereby permitting them to separate due to the repelling effect of the applied electrostatic charge; and the filaments, while thus separated, are collected as a nonwoven web. The filaments are randomly and uniformly distributed throughout the web so obtained and are essentially free from filament aggregates or bunches. This arrangement of the filaments is highly desired since it yields an isotropic web with outstanding uniformity of opacity and full utilization of the strength of the constituent filaments.

In the jet device, primary air or other fluid supplied to the jet is at high pressure and enters the device at an angle to and in the direction of the filament stream. This provides tension for forwarding the filaments toward the receiver in the web-laydown zone. A diffuser section, either integral with the jet device or attached at the exit of the jet device may be employed to obtain a wider area of web laydown. The diffuser section defines a filament passageway that becomes wider in the downstream direction.

The foregoing process, however, makes severe demands upon the jet device used to apply the forwarding tension. In various operating procedures within the scope of the above-described process, the jet device provides the forwarding tension to (1) draw the filaments as they are extruded from a spinneret, (2) pull the filaments from yarn packages or (3) strip the filaments from a mechanical drawing apparatus, for example, draw rolls. The jet device must not only apply adequate tension to forward the strand of filaments, it must do so while avoiding excessively turbulent fluid flow which would lead to filament entanglements and undesirable bunching of the filaments.

In the general process described in the aforementioned British patent, a high electrostatic charge on the filaments is desired to obtain good filament separation and to avoid ropiness in the nonwoven web. But a high charge tends to drive the filaments into contact with the walls of the jet device. This leads to inhomogeneities in the nonwoven web and frequently to plugging of the jet device. In order to avoid these problems, the jet device must be designed and operated to minimize contact of the filaments with the walls of the jet device.

In certain applications the jet devices are also used to effect heat treatment of the filaments, for example, to generate the property of spontaneous elongation as described in Kitson and Reese, U.S. Patent 2,952,879. This places additional demands on the jet device since the hot filaments are more prone to stick to the walls of the jet device on contact therewith thus increasing the chance of filament aggregates in the nonwoven web and plugging of the jet device.

The foregoing demands on the performance of the jet device are further increased by the requirements of commercial manufacture, namely the production of a wide nonwoven web and economical operation. Thus the high number of filaments forwarded by each jet device in commercial operation, which may amount to 700 to 800 or more, accentuates the need for avoiding contact of filaments with the walls of the jet device.

The handling of large numbers of filaments is best accomplished by the use of slot jet devices, that is, jets which have a rectangular cross section of high aspect ratio (ratio of the length to width of the rectangular cross section) as described in copending and coassigned application Ser. No. 425,839 to Cope et al. filed on Jan. 15, 1965, 3,302,-237. This is particularly true when the filament strand being forwarded has a ribbon shape, such as is inherently formed when the filaments are attenuated mechanically by means of draw rolls, or when the filaments are passed into contact with a cylindrical bar as in the step of application of an electrostatic charge by triboelectric charging or by corona discharge techniques. In such jets, the ribbon of filaments moves between two closely-spaced walls which correspond to the long sides of the rectangular cross section. Avoidance of contact by this entire ribbon of filaments with the wide walls of the jet is required.

It is the purpose of this invention to provide a process for forwarding a flat ribbon of filaments having a high electrostatic charge thereon.

It is a further purpose to provide a filament-forwarding process which minimizes the contact of the filaments with the walls of the enclosed channel through which they are moving.

An additional purpose is to provide a slot jet device which uses a high-velocity fluid stream to impart a forwarding tension to a flat, multifilament strand of continuous, electrostatically-charged filaments and in which contact of the filaments with the walls of the jet device is minimized.

These and other purposes are attained in accordance with this invention by forwarding continuous filaments by means of a high-velocity fluid flowing through an enclosed channel having a rectangular cross section of high aspect ratio and generating thick boundary layers of fluid adjacent to the two walls of the channel corresponding to the long sides of the rectangular cross section. This generation of boundary layers may be utilized in the body of a filament-forwarding jet device or in the diffuser section used at the exit of the jet to spread the filaments. In either case, the generation of the boundary layers is effected to prevent contact of the filaments with the wide walls of the enclosed channel.

In the body of slot jet devices, the narrow walls usually increase in dimension in the direction of flow of the fluid stream while the wide walls generally remain constant in dimension, thus only the narrow dimension of the channel diverges. Divergence angles of up to about 6° are used for the walls in the body of filament-forwarding jet devices while a divergence considerably greater than 6° is usually used for the walls in the diffuser section. In the diffuser section of the jet device, both the narrow and the wide walls usually increase in dimension in the direction of flow of the fluid stream. The wide walls increase in dimension sufficiently rapidly that the narrow walls spread outwardly at an angle greater than 6°. Generation of a thick boundary layer adjacent to the wide walls, i.e., the slower moving fluid layer at the periphery of the fluid stream, can be used to prevent filament contact with the interior walls of the slot jet device both in the body and diffuser section. These thicker layers can be created by roughening the interior of the wide walls as by blasting with abrasives, by coating, or by other suitable means. Stepped increases in the internal cross-sectional area create a turbulent boundary after the step. Another and preferred technique is to introduce additional fluid into the jet device at a small angle with the flow of the primary fluid stream in the device thus augmenting the boundary layer. This additional fluid may be introduced under pressure or by aspiration into the primary fluid stream.

While the generation of thick boundary layers along the wide walls of slot jet devices according to this invention is highly beneficial and prevents contact of the filaments with the walls, the generation of thick boundary layers on the narrow walls is to be avoided because it leads to nonuniform velocity profiles and bunching of the filaments in the webs that are obtained. Indeed, it has been found to be highly beneficial for the narrow walls to be porous or perforated thereby permitting the withdrawal of at least a portion of the boundary layer through the walls. This leads to more uniform velocity profiles in the body of the jet device. By withdrawal of fluid from the boundary layer along the narrow walls of diffuser sections attached at the exit of the jet, the fluid stream and the filaments contained therein expand smoothly and uniformly, thus permitting the laydown of a wide area of deposition of filaments on the web-laydown receiver. This method is the subject of a copending and coassigned application to Ralph A. Franke, 431,691 filed on even date herewith.

The invention will be further understood by reference to the drawings in which

FIGURES 1–5 are end views of slot jets and illustrate schematically various designs of jet extensions which provide for generating thick boundary layers of fluid streams;

FIGURE 6 is a schematic side view of a slot jet having a diffuser section attached at the exit end;

FIGURE 7 is a cross-sectional view of FIGURE 6 taken along line A—A;

FIGURE 8 is a side view of a specific embodiment of a diffuser attached at the exit of a slot jet device, with a part broken away to show the interior construction; and

FIGURE 9 is an end view along line B—B of FIGURE 8.

In the foregoing discussion the term "fluid stream" is intended to encompass both liquid and gas streams. The preferred fluids for forwarding filaments are gases and the preferred gas, based on cost and ready availability, is air. For convenience in the ensuing discussion and without limiting in any way the scope of this invention, the fluid stream will be referred to as air.

In FIGURE 1, a jet extension **1**, such as may be attached to a jet device **2** to provide for a longer residence time for filaments being forwarded through the device, is illustrated. A longer residence time may be desired in order to provide for adequate exposure to elevated temperature, for example in the heat-relaxation of poly (ethylene terephthalate) filaments to develop spontaneous elongatability. The development of spontaneous elongatability by this technique places especially severe demands on the jet device because not only are the hot filaments more prone to stick to the jet walls, but also at the very low tension (less than 0.01 g.p.d.) required for the filaments to relax, the electrostatic charge on the filaments drives them toward the jet walls causing filament aggregation and plugging of the jet. While high charge levels are desired for good filament separation, they accentuate the problem of the filaments being driven toward the jet walls.

Since thick boundary layers have been found to keep the filaments away from the jet walls, the effectiveness of various techniques for generating boundary layers can be measured by determining the maximum electrostatic charge that can be applied to the filaments while maintaining operability, that is, non-plugging of the jet device. The techniques described below are applied only to the walls corresponding to the long side of the rectangular cross-section area of the filament passageway. A 30 in. (76 cm.) long jet device as in FIGURE 1, except having smooth wall surfaces, is capable of relaxing filaments at air temperatures of 165°. The maximum charge that can be placed on 192 poly(ethylene terephthalate) filaments (3.7 d.p.f.) (0.41 tex.) and maintain operability in this equipment is 36,000 c.g.s. electrostatic units (e.s.u.) per square meter of filament surface.

When the inner wall surfaces of the lower 18 in. (46 cm.) are roughened by sandblasting as indicated at **3** in the detailed view in FIGURE 1, it is possible to obtain a charge level of 46,500 e.s.u. per square meter of filament surface. Sandblasting with No. 80 grit appears to be optimum. A smoother surface obtained with finer grit does not provide an adequate boundary layer while too coarse a surface causes the filaments to hang on the protrusions.

In FIGURE 2, a 12 in. (30 cm.) long jet with an 18 in. (46 cm.) long extension **1** having stepped expansions **4** for generation of thick boundary layers is illustrated. With expansions ranging from 0.020 to 0.030 in. (0.051 to 0.076 cm.) per side and placed every 3.5 in. (8.9 cm.) down the length of the extension, a maximum charge level of 46,500 e.s.u. per square meter of filament surface is obtained.

FIGURE 3 illustrates a 12 in. (30 cm.) long jet with a 12 in. (30 cm.) long extension having porous walls **5** and chambers **6** to which the air is supplied through inlets **7**. With photo-etched plates having 0.006 in. (0.015 cm.) diameter holes and 140 holes per square inch (22 per square centimeter), and with air flows through the porous walls of 1.2 times the primary air flow, a charge level of 64,500 e.s.u. per square meter of filament surface can be obtained.

FIGURE 4 illustrates a jet extension having slits **8** through which air is introduced at a small angle to the primary air stream. The air is supplied to the slits from chambers **6** and inlets **7**. At each slit, there is a stepped expansion in cross-sectional area. In order to avoid excessively turbulent flow and the resulting filaments entanglements, it has been found that the angle at which the auxiliary air streams merge with the primary stream should be less than 30° and preferably is no greater than 15°.

FIGURE 5 illustrates another embodiment which utilizes multiple additions of air through slits **8**, spaced at 10 in. (25 cm.) intervals at an angle of 7.5° with the primary air stream, and stepped expansions in internal cross-sectional area. This embodiment differs from that in FIGURE 4 in having separate inlets **7** for each slit. This permits additional control over the temperature and/or velocity of the auxiliary air being added. A maximum charge level of 51,000 e.s.u. per square meter of filament surface is obtainable with this arrangement. This technique of introduction of auxiliary air at a small angle to primary air stream is a very effective method to generate thick boundary layers. The auxiliary air can be introduced under pressure as illustrated in FIGURES 4 and 5 and can also be introduced by aspiration into the primary air stream.

In FIGURES 6 and 7, a slot jet **9** has a diffuser section **10** attached at the jet exit with slit openings **11** therebetween through which air is aspirated as the primary air stream passes through filament passageway **12**. The aspirated air merges with the primary air stream at a small angle, e.g. 15°, and forms thick boundary layers along the wide walls **13** of the diffuser. The diffuser is also provided with vacuum chambers **14** for removing a portion of the boundary layer through the performated narrow walls **15** of the diffuser.

FIGURES 8 and 9 illustrate in further detail an embodiment of a diffuser which employs the boundary-layer regulation of this invention and which is designed for attachment at the exit of a filament-forwarding slot jet device. The diffuser housing is formed by side members **16** and end members **17**. Side members **16** are positioned adjacent to each other and form the wide sides of the filament passageway **12**, corresponding to the long sides of the rectangular cross-section. The filament passageway between these sides diverges at a small angle of the order of about 2° or less. The edges of the side members spread outwardly at an angle greater than 3° and coact with the end members to form a filament passageway having an included angle between the end members of greater than 6°. Vacuum chambers **14** in the end members are formed by housing **18** and perforated plates **19**. Plates **19** form the narrow sides of the filament passageway corresponding to the short sides of the rectangular cross-section. The perforations **20** in plate **19** are positioned, as shown best in FIGURE 9, to open into the filament passageway. Air is withdrawn from the filament passageway through the perforations by means of a vacuum applied to chamber **14** through inlet **21**.

The diffuser section is attached at the exit of the jet device, shown fragmentarily in FIGURES 8 and 9, by means of screws **22** through flanges **23** and **24** on the end plates **25** of the jet device and the end members **17** of the diffuser section, respectively. The position of the diffuser section, in particular the side members **16**, relative to the effuser plates **26**, is adjusted by means of washers **27**. The slit openings **11** between the effuser plates **26** and the side members **16** permit the aspiration of air into the filament passageway and the formation of a thick boundary layer of air along the interior surfaces of the side members **16**. This prevents contact of the filaments with these sides of the diffuser section and thus eliminates this cause of filament bunching and possible plugging of the jet device. The width of the slot openings is normally adjusted to be in the range of 0.010 to 0.070 inch (0.025 to 0.178 cm.).

In the embodiment of a diffuser section shown in FIGURES 8 and 9, the regulation of the boundary layers is accomplished in two different manners. The boundary layers adjacent to the narrow sides of the filament passageway are decreased by withdrawal of a portion of the air, and the boundary layers adjacent to the wide sides of the filament passageway are augmented by aspiration of additional air into the filament passageway.

A thin coating (e.g. 0.000010 in.; 0.000025 cm.) of a fluorocarbon telomer release agent may be applied to the interior surfaces of jet devices to retard adherence an permit easy removal of polymer drips and accumulation which could otherwise cause plugging of the jet devices.

Example

Poly(ethylene terephthalate) filaments are spun from a spinneret with 250 holes (0.009 in. diameter x 0.012 in. long) (0.023 cm. x 0.030 cm.), quenched with air at 18° C., drawn as a ribbon of filament from the spinneret by means of 2 draw rolls operating at a surface speed of 3920 yd./min. (3580 m./min.), and then passed into a 5 in. (12.7 cm.) wide slot jet which strips the filaments from the last draw roll. The slot jet is of the type described in FIGURE 6 and has an exit of 5 in. x 0.130 in. (12.7 cm. x 0.330 cm.). The jet is supplied with 78 s.c.f.m. (2200 l./min.) of air at 240° C. to provide for heat relaxation of the filaments thereby developing the property of spontaneous elongation as described in Kitson and Reese, U.S. Patent 2,952,879.

A diffuser as illustrated in FIGURES 8 and 9, is attached at the exit of the slot jet. The diffuser has an entrance of 5 in. x 0.140 in. (12.7 cm. x 0.356 cm.), an exit of 6.5 in. x 0.280 in. (16.5 cm. x 0.712 cm.) and is 4.75 in. (12.1 cm.) long. A slot, 0.050 in. (0.127 cm.) wide is provided at the juncture between the jet and diffuser along each of the wide walls, as indicated by the numeral **11** in FIGURES 8 and 9. The slot makes a 15° angle with the center line of the diffuser. Air is aspirated into these slots to create boundary layers which prevent the filaments from contacting the walls. The included angle formed by the two narrow walls at the diffuser exit is 30.8°. The walls are formed to the shape of a segment of a circle with a radius of 17.5 in. (44.5 cm.). There are 28 perforations of 0.0625 in. (0.159 cm.) diameter in each of the narrow walls providing an open area of 13%.

Filaments of 79/21 copolymer of poly(ethylene terephthalate)/poly(ethylene isophthalate) are spun from a spinneret with 54 holes (0.009 in. diameter x 0.012 in. long) (0.023 cm. x 0.030 cm.) and quenched with air at 18° C. The copolymer filaments are spread by means of convex guides into a ribbon of the same width as the ribbon of poly(ethylene terephthalate) filaments and the two ribbons are then combined on the first draw roll to give a uniform distribution of the copolymer filaments throughout the composite ribbon. The composite ribbon has a width of 4.25 in. (10.8 cm.). Before being combined on the first draw roll, each of the two ribbons of filaments is electrostatically charged with 2 corona discharge devices of the type described in Di Sabato and Owens, U.S. Patent 3,163,753. The corona discharge devices are located between the spinnerets and the draw rolls. Since the copolymer filaments shrink more than the poly(ethylene terephthalate) filaments during the heat-relaxation step in the slot jet, thereby causing a greater concentration of charge on the copolymer filaments, the charging of the filament ribbons is individually controlled before they are combined so that all the filaments have the same level of charge, 66,000 c.g.s. electrostatic units per square meter of filament surface, when they exit from the diffuser.

By application of suction, corresponding to 20 in. (51 cm.) of water, to the perforations in the diffuser, 2 s.c.f.m. (57 l./min.) of air is removed and boundary layer build-up and separation of the air stream from the narrow walls is prevented. The air being aspirated into the slots at the diffuser entrance keeps the ribbon of filaments separated from the wide diffuser walls by 0.03 in. (0.08 cm.). When the slots are closed, the filaments touch the hot walls, and stick to them, eventually causing plugging of the diffuser.

What is claimed is:

1. In a slot jet device suitable for the forwarding of filaments under tension in a fluid stream, said device having means defining a filament passageway therethrough, said passageway having a rectangular cross section, and means for introducing high pressure fluid at an angle to and in the direction of filament travel to assist in maintaining their movement through the passageway and wherein a fluid boundary layer forms against the walls of the passageway as the fluid stream passes through; the improvement comprising means for augmenting the boundary fluid layer adjacent the wide walls of the filament passageway to minimize contact of the filaments with such walls.

2. The jet device of claim **1** wherein the augmenting means are fluid supply openings in the wide walls downstream of the high pressure gas inlet means.

3. The jet device of claim **1** wherein the augmenting means are stepped expansions in the width of the filament passageway in the downstream direction.

4. The jet device of claim **1** wherein the augmenting means are roughened interior surfaces of the wide walls of the filament passageway.

5. In a process wherein a multifilament strand of continuous synthetic organic filaments is electrostatically charged while under tension and then forwarded by means of a high-velocity fluid stream through a slot-jet device toward a web-laydown zone and collected thereon as a nonwoven web, the said jet device having a diffuser section to achieve a wide area of laydown, the improvement comprising augmenting the layer of fluid adjacent the wide walls of the jet device.

6. The process of claim 5 wherein augmentation is achieved by supplying additional fluid along the wide walls of the jet device.

7. In the forwarding of a plurality of continuous filaments through a confining channel having a rectangular cross section by means of a high-velocity fluid stream, the improvement comprising supplying additional fluid along the wide walls of the rectangular channel.

8. In a slot jet device suitable for the forwarding of filaments therethrough under tension in a fluid stream, and including a diffuser section defining a rectangular filament passageway located at the exit of the jet device and in open communication therewith, said device having means for introducing high pressure fluid at an angle to and in the direction of the filament travel to assist in maintaining the filament movement through the passageway and wherein a boundary layer of fluid forms against the walls of the passageway of the diffuser section as the fluid stream passes through, the improvement comprising means for augmenting the boundary layer adja-

cent the wide walls of the diffuser filament passageway to minimize contact of the filaments with such walls.

References Cited

UNITED STATES PATENTS

984,195	2/1911	Cooper.	
2,810,426	10/1957	Till	264—24
2,908,045	10/1959	Stevens	28—72 X
2,924,868	2/1960	Dyer	28—1
2,938,256	5/1960	Bauer et al.	28—1
3,036,357	5/1962	Cook et al.	28—1
3,259,952	7/1966	Caines	28—1
3,262,178	7/1966	Aspy et al.	28—1
3,262,181	7/1966	Hawkins et al.	28—72

FOREIGN PATENTS

167,509	8/1953	Australia.
544,276	7/1957	Canada.
932,482	7/1963	Great Britain.

WILLIAM J. STEPHENSON, *Primary Examiner.*