

Feb. 7, 1967

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FORWARDING JET

Filed Jan. 15, 1965

3 Sheets-Sheet 1

Fig. 1.

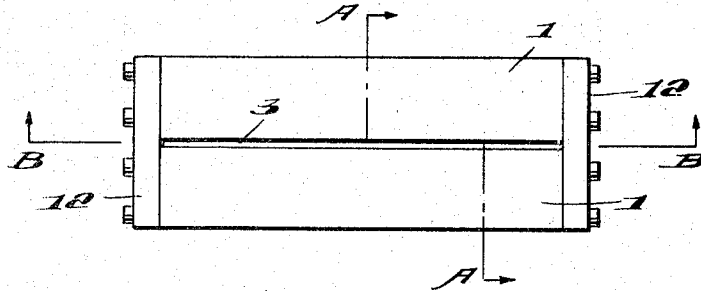


Fig. 2.

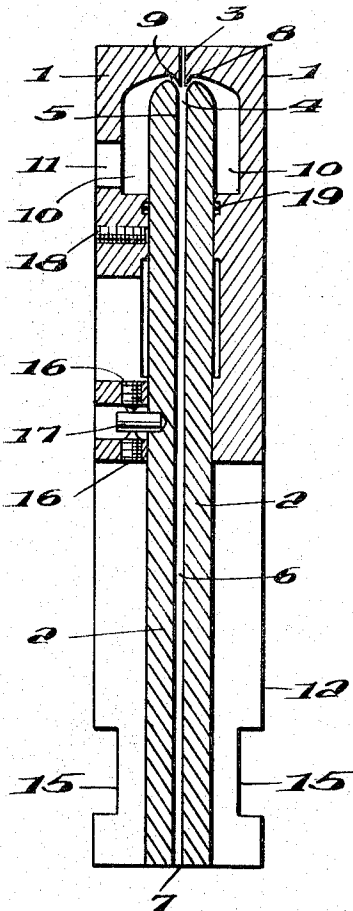
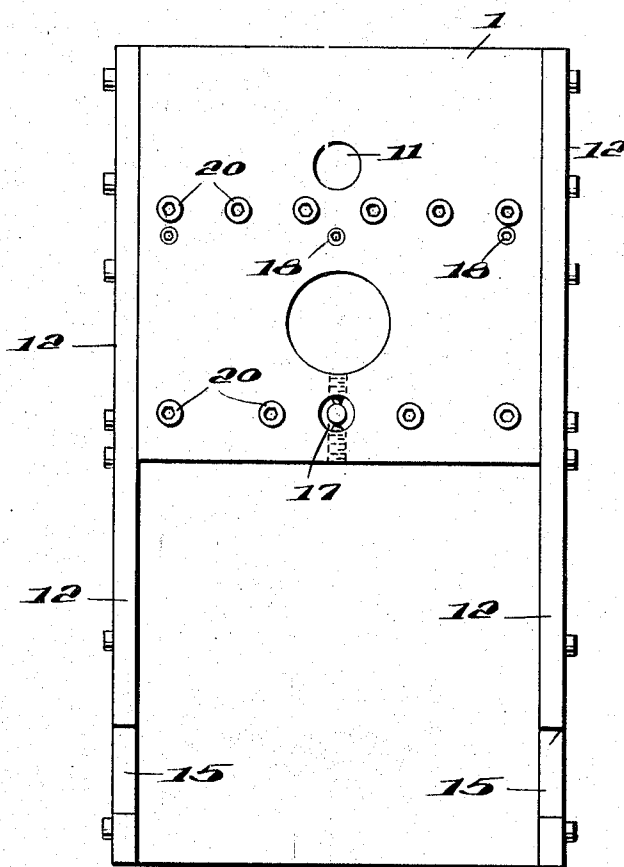


Fig. 3.



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3 Sheets-Sheet 2

Fig. 4.

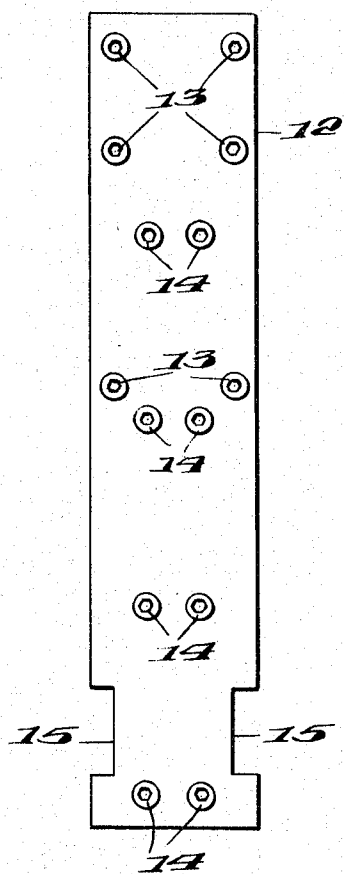


Fig. 5.

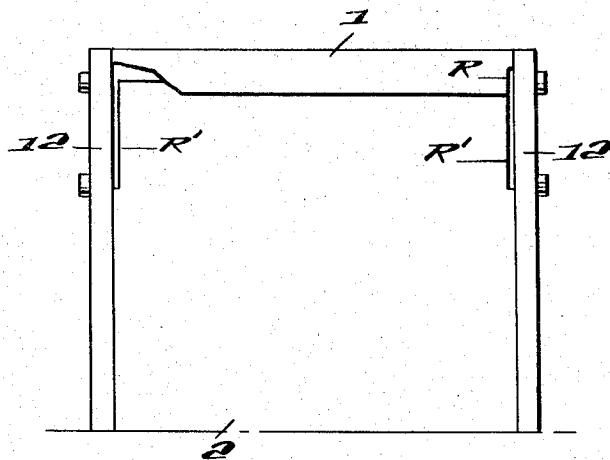
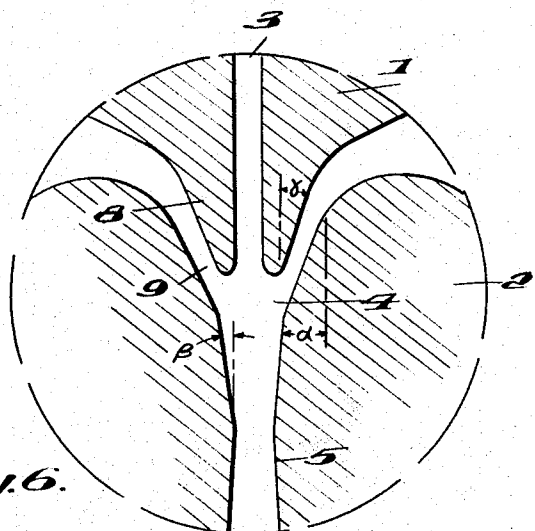


Fig. 6.



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Fig. 8.

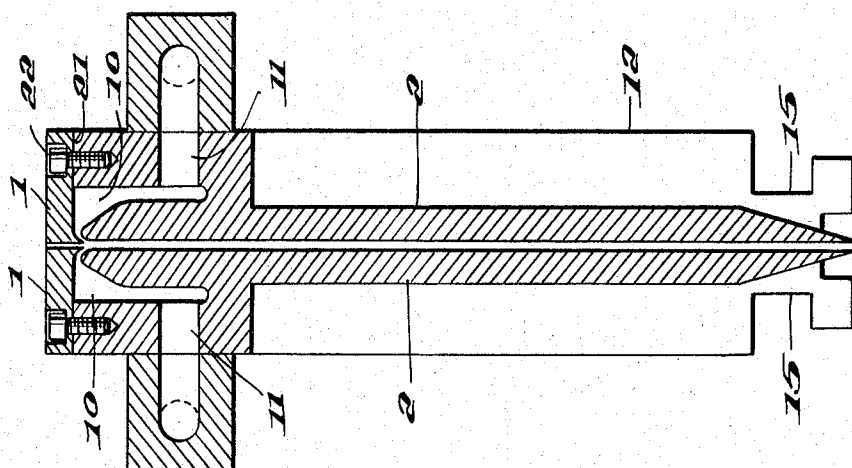
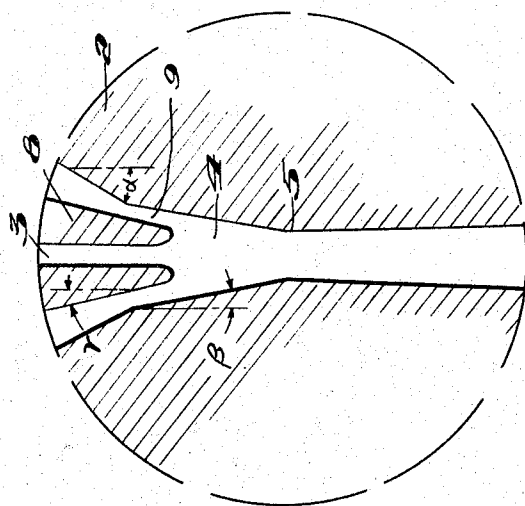


Fig. 7.



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FORWARDING JET

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5 Claims. (Cl. 18—1)

This invention relates to filament-forwarding jet devices in particular to jet devices which utilize the tension exerted by a high-velocity gas stream to effect forwarding of the filaments.

Jet devices have been used in the textile industry for many years to effect drawing, texturing, stripping, annealing, crimping, bulking, interlacing, etc. of synthetic yarns. In most cases the filament passageways of these prior devices have had round cross sections. Recently jet devices with slot-shaped cross sections have been developed, as exemplified by Claussen and Meyer, U.S. Patent 3,055,080, issued September 25, 1962, and Dyer and Gallagher, U.S. Patent 3,081,951, issued March 19, 1963. The slot jet devices described in these patents were designed to impart bulk, fluffing, and filament entanglement by means of turbulent gas streams and accordingly they are not suitable for forwarding a strand of filaments while the filaments are maintained substantially free from entanglement.

Forwarding of filaments with a minimum of entanglement and bunching is required in a recently developed process for the production of nonwoven webs from continuous synthetic organic filaments. In this process involving an integrated filament-spinning, orientation, and laydown operation such as described in British Patent 932,482, a multi-filament strand of continuous filaments is electrostatically charged and forwarded toward a receiver, the filaments are allowed to separate due to the repelling effects of the applied electrostatic charge, and are then collected on the receiver as a random nonwoven web which is essentially free from filament aggregates. Jets are ideally adapted for use as filament-forwarding devices in this process, since the forwarding tension exerted by the jet can be used to direct the filaments towards a receiver and can then be rapidly released thus permitting the filaments to separate from each other due to the electrostatic charge. Round jets are suitable for this purpose when handling a comparatively small number of filaments, for example, up to 200 per jet, but with the larger filament strands, up to 1000, as are required for economical commercial operation, round jets are less satisfactory.

In large-scale commercial operation of the above-described web laydown process, wherein the output from several spinnerets is utilized, it has been found that mechanical drawing of the freshly-spun synthetic filaments with draw rolls is desired in order to obtain uniform filament properties from spinneret to spinneret and, therefore, throughout the nonwoven web. In order for a roll-drawing system to operate properly, it is necessary to provide a tension on the filaments leaving the last draw roll to strip the filaments from the roll and prevent slippage of filaments on the draw roll. While draw jets with a round cross section are capable of producing the required tension, they do not conform geometrically to the ribbon-shape of the filament strand as it leaves the draw roll. With large filament strands, for example, those containing several hundred filaments in ribbon form, this lack of conformity of the jet structure to the strand geometry causes bunching of the filaments with a resulting ropiness in the nonwoven web. However, mere conformity of the jet structure to the ribbon shape of the

2

filament strand does not mean acceptable performance in the laydown process of the above-described patent, and it has been found necessary to develop a jet of novel and highly specialized design.

The complex nature of this design problem will be readily apparent from the seemingly mutually incompatible performance requisites of suitable jet devices. Thus, not only must the jet be capable of imparting adequate tension (greater than about 0.10 g.p.d.) to the filament strand as it enters the jet, it must perform the following additional functions: (1) aspirate sufficient gas to allow filament stringup and restringing of broken filaments; (2) maintain a uniform velocity-profile throughout the jet over a range of operating gas pressures and flows, thereby maintaining the filaments in a spread configuration; and (3) forward the filaments while maintaining a low level of jet air turbulence, thus minimizing filament roping and entanglement.

In certain embodiments of the above-described filament laydown process for nonwoven webs, it is desired to heat-relax poly(ethylene terephthalate) filaments to develop spontaneous elongation, as described in Kitson and Reese, U.S. Patent 2,952,879, prior to the formation of the nonwoven web. This heat-relaxation can be carried out by supplying hot air to the jet used to forward the filaments after the draw-roll operation, but it makes further demands on the performance characteristics of the jet. Thus aspiration at the filament entrance to the jet is required, but it is preferably maintained as low as possible to minimize dilution of the hot relaxing gas. As the poly(ethylene terephthalate) filaments approach relaxation temperatures (about 120 to 140° C.), it is desired that the tension on the filaments be decreased to a level of less than about 0.010 g.p.d., thus permitting the filaments to relax, while still being sufficient to advance the filaments with excellent separation.

It is the purpose of this invention to provide a jet device for forwarding filamentary materials with a minimum of filament entanglement.

It is another purpose to provide a jet device which can handle large strands of continuous filaments in ribbon-like form.

It is still another purpose to provide a jet device in which a uniform gas-velocity profile is maintained throughout the jet.

An additional purpose is to provide a jet device which can be used to heat-relax poly(ethylene terephthalate) filaments while they are being advanced toward a receiver on which they are collected as a random nonwoven web.

These and other purposes are attained in accordance with this invention by providing a filament-forwarding jet device having a filament passageway with a generally rectangular cross section and through which the filaments pass in essentially straight-line travel along the centerline of the device. The jet housing has mounted therein a filament-entrance member and an effuser member, as described more fully below.

The jet device comprises two filament-entrance plates terminating in lip portions, two effuser plates, and two end plates. The filament-entrance plates are placed adjacent each other so as to form, in cooperation with the end plates, the filament-entrance member of the jet device. The effuser plates are so designed and placed adjacent each other as to form, in cooperation with the end plates, a mixing section, throat opening, effuser section and filament exit of the jet device. From immediately below the lip portion of the filament-entrance plates, the filament passageway converges to the throat opening, thus constituting the mixing section. The effuser section of the filament passageway diverges from the throat opening to

the filament exit. The lips of the filament-entrance plates extend into the mixing section and coact with the effuser plates to form two nozzle openings having a width at the narrowest point of from 0.006 in. (0.015 cm.) to 0.020 in. (0.051 cm.) and through which high-velocity gas may be fed into each side of the filament passageway at the mixing section. The throat opening of the filament passageway has a width of from 0.021 in. (0.053 cm.) to 0.08 in. (0.20 cm.), with the proviso that the width of the throat opening is at least 3.5 times the width of each nozzle opening. The filament-entrance plates and the effuser plates further coact to form plenum chambers leading to the nozzle openings. Inlets are provided to supply gas under pressure to the plenum chambers. The end plates coact with the filament-entrance plates and effuser plates to close the sides of the filament passageway, the nozzle openings and the plenum chambers. They also hold the two filament-entrance plates and two effuser plates in the desired relationship to form the filament passageway.

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

FIGURE 1 is a top view of a jet device of this invention;

FIGURE 2 is a cross-sectional view of the jet on line A—A of FIGURE 1;

FIGURE 3 is a side view of the jet of FIGURE 1;

FIGURE 4 is an end view of the jet of FIGURE 1;

FIGURE 5 is a side view of the top portion of the filament passageway of the jet on line B—B of FIGURE 1, with a part of the nozzle plate cut away to show the top edge of the effuser plate;

FIGURES 6 and 7 are detailed cross-sectional views of two embodiments of the filament entrance, mixing section, and nozzle openings of the jets of this invention;

FIGURE 8 is a cross-sectional view of a jet of this invention having an alternative design of the filament-entrance plates and effuser plates.

Referring to FIGURES 1 and 2, the slot-shaped filament passageway is shown as being formed in the filament-entrance member by filament-entrance plates 1 and in the effuser member by effuser plates 2. The filament passageway consists of filament-entrance section 3 having an inlet for filaments and aspirated air, and an exit into the mixing section 4, throat opening 5, effuser section 6, and filament exit 7. The lips 8 of the filament-entrance plates coact with the upper ends of the effuser plates to form nozzle openings 9 on both sides of the filament passageway, as shown in greater detail in FIGURES 6 and 7. The filament-entrance plates and effuser plates also coact to form plenum chambers 10 which are provided with inlets 11 for supplying gas under pressure. Thermal insulation may be attached to the plenum side of the effuser plates in the area opposite inlet 11 to minimize formation of hot spots by impingement of high-velocity, hot inlet gas. End plates 12 cooperate with the filament-entrance plates and the effuser plates to close the sides of the filament passageway, the nozzle openings and the plenum chambers and to hold the filament-entrance and effuser plates in the desired relationship to form the filament passageway. FIGURE 4 shows a suitable design for the end plates. The filament entrance plates are attached to the end plates by means of screws 13 and the effuser plates are attached by means of screws 14.

Notches 15 in the end plates are provided to permit ready attachment of jet extensions, diffusers or relaxing chambers at the filament exit. The ends of the effuser plates in FIGURE 2 are ideally suited for addition of jet extensions, while those in FIGURE 8 are adapted to receive a diffuser having curved side plates to spread the ribbon of filamentary material, or a relaxing chamber, for example, as taught in the patent to Cope U.S. 3,156,752 but modified to have its filament passageway conform to the slot-shape of the filament passageway of the jet devices of this invention.

Adjustment of the relative position of the filament-entrance plate and effuser plate is made by means of set screws 16 acting on pin 17, and by means of set screws 18. (See FIGURES 2 and 3.) Screws 16 are used to slide the effuser plate relative to the filament-entrance plate and thereby vary the width of the nozzle opening while adjustment of screws 18 imparts a rocking movement to the filament-entrance plate and thereby provides for adjustment of the nozzle opening so that its width is uniform throughout. In this manner the jet is adjusted to give a uniform gas-velocity profile. A seal 19 is provided to eliminate gas leakage from the plenum chamber. Screws 20 are then tightened to hold the effuser and filament-entrance plates after the nozzle opening has been properly adjusted.

The maintenance of a uniform gas-velocity profile is of extreme importance to the proper functioning of the jet devices of this invention. Dirt particles or any other extraneous materials in the nozzle opening will disrupt the uniform profile and give inferior results such as entangled or bunched filaments. In the preferred jet devices of this invention, an additional structural feature is utilized to maintain a uniform velocity profile over a range of operating pressures of the gas supplied to the plenum chambers. This feature is illustrated at R in FIGURE 5 where the side of the lip portion of the filament-entrance plates is relieved so that it does not contact the end plate. This relief, which need only be of the order of 0.0001 to 0.0002 in. (0.0002 to 0.0005 cm.) and preferably is as low as possible to avoid excessive gas leakage between the lip and end plate, permits the entire length of the lip to deflect uniformly under the force resulting from the pressure differential from one side of the lip to the other. Thus, the adjustments of the nozzle openings for uniform flow hold over a wide range of flows (for example, 0 to 50 s.c.f.m.; 0 to 1400 liters/min.). The relief permits the entire lip to deflect as a cantilever beam with a built-in base. Without the relief, the sides of the lip are not free to deflect while the middle portion does deflect. This causes the nozzle opening to vary across the length of the opening as the pressure and temperature are changed and gives a nonuniform gas-velocity profile. The sides of the effuser plates at the ends where they coact with the lips to form the nozzle openings, can also be relieved as indicated at R' in FIGURE 5 to eliminate nonuniform deflection.

FIGURE 8 illustrates an alternative design for the filament-entrance plates and effuser plates. In this design, the filament-entrance plate is fastened to the top portion 21 of the effuser plate by screws 22.

The geometry of the nozzle openings and the mixing section and throat opening of the filament passageway is shown in FIGURES 6 and 7. In these figures, α is the angle which that surface of the effuser plate which forms one wall of the nozzle opening makes with the centerline of the jet. β is the angle which the effuser plate makes with the centerline of the jet below the nozzle opening. γ is the angle which that surface of the lip of the filament-entrance plate which forms one surface of the nozzle opening makes with the centerline of the jet. $\alpha - \gamma$ represents the convergence angle of the gas passageway leading to the nozzle opening. The convergence angle of the filament passageway from the mixing zone to the throat opening is 2β . Alternatively, β can be zero, in which case the convergence angle of the filament passageway is 2α .

In the design of the optimum jet device for use in forwarding filaments without filament entanglement, the significant performance criteria are (1) the amount of high pressure (primary) gas used by the jet; (2) the tension applied to the filaments, and (3) the level of aspirated (secondary) gas. The consumption of primary gas is of importance because high gas flows are detrimental to the quality of the nonwoven web being laid down. Moreover, high gas flows are costly, particularly when heated gas is used in the jet to effect the heat-relaxation of the

filaments. The tension applied to the filaments should be sufficient to prevent their slipping on the draw rolls and to strip them from the rolls. The tension should also be controlled so that heat-relaxation can be effected if desired. The aspirated gas should be at a level sufficient to provide for string-up of the filaments at the start-up of the process and for self-stringing of broken filaments when needed; but it should be at the minimum needed for those purposes, particularly when the primary gas is heated, in order to avoid excessive cooling of the primary gas. The effects of the dimensions of the jet devices of this invention on the above performance criteria are described in the following sections. These remarks apply to jets 3 to 8 in. (7.6 to 20 cm.) wide.

It is preferred that the length of the filament-entrance member be as small as possible, not over 1.0 in. (2.5 cm.), to decrease the pressure drop in the section and improve the suction of the aspirated gas. Owing to construction geometry, the minimum usable length is about 0.5 in. (1.3 cm.) A length of about 0.6 in. (1.5 cm.) is preferred.

In the context of this application the term "width" applies to the narrow dimension of the cross section of any passageway, perpendicular to the axis of the passageway.

The width of the filament-entrance-member passageway should be reduced to a minimum to reduce the distance from the filament-entrance plate lip to the jet centerline, thereby minimizing the velocity drop of the high pressure air from the lips to the filaments and obtaining more efficient generation of tension on the filaments. As the width of the filament-entrance-member passageway is decreased, there is a simultaneous increase in pressure drop along the passageway and consequent decrease in aspiration. These are both small and can be ignored, however, because of the shortness of the length of the filament-entrance member. The minimum width of the passageway is dictated by the process-operability considerations and is about 0.015 in. (0.038 cm.). Widths above 0.030 in. (0.076 cm.) produce poor results in efficiency of gas utilization.

The thickness of the lips of the filament-entrance-plate should be held at a minimum for the same reasons indicated above for the width of the filament-entrance member passageway. The minimum value of the lip thickness to permit reasonably rigid beam sections is 0.010 in. (0.025 cm.). Thinner lips are fragile and, moreover, their deflections under the forces resulting from differential gas pressures are large and very difficult to maintain uniform. Similar considerations apply to the lip angle γ . This angle should be minimum to reduce the angle of the axis of the gas stream emerging from the nozzle opening with the centerline of the jet to the lowest possible value. This minimizes the energy waste due to velocity components perpendicular to the filaments. Angle γ , however, should not be reduced below 10° since the beam section of the lips would then be too weak for a long span and would lead to excessive deflection.

The effuser plate angle α should be minimum for the same reason as having angle γ minimum. Jets in which the convergence angle ($\alpha - \gamma$) of the gas passageway leading to the nozzle openings is 2° are suitable, thus an operable value for α is 12° . It is essential, however, that the nozzles direct air or other fluid at the moving filament bundle at an angle of less than 16° to ensure nonentanglement of the filaments with resulting nonuniform sheets.

The convergence angle (2β) of the filament passageway from the mixing section to the throat opening and the length of the mixing section determine the configuration of the mixing section. Optimum mixing sections allow for the development of sufficiently long shear areas to attain adequate levels of tension and aspiration. Variations in the convergence angle from about 2° to 8° and in the mixing length from 0.15 to 0.50 in. (0.38 to 1.27 cm.) give satisfactory levels of tension and aspiration. From

the over all geometry of the mixing section, a convergence angle of 4° and the mixing length of 0.2 in. (0.5 cm.) appear optimum.

The width of the nozzle opening affects both the tension and aspiration developed by the jet devices of this invention. Both of these responses increase with decreasing widths of the nozzle openings, although the magnitude of the responses to variations in width become less pronounced at the wide openings. These facts indicate that the width should be reduced to a minimum, especially since reduction at the low range is more significant. The minimum width is about 0.006 in. (0.015 cm.), since below this level, it is difficult to maintain the uniformity in the nozzle openings which is essential for a uniform gas-velocity profile. Jets with widths above 0.02 in. (0.05 cm.) are relatively inefficient in the use of primary gas. A preferred width is 0.011 in. (0.038 cm.).

The width of the throat opening in the filament passageway also affects both the tension and aspiration developed by the jet. The effect on tension follows the pattern observed with the nozzle opening, that is, the tension increases as the width of the throat opening decreases. This effect is considerably less pronounced at the wider openings. Aspiration, on the other hand, approaches being directly proportional to the width of the throat opening. The indication from the foregoing is that the width of the throat should be reduced to a minimum to improve the tension characteristics and reduce gas consumption. There is a limit to this reduction, however, because it was found that when the ratio of the width of the throat opening to the width of the nozzle openings approaches 3.5, the gas aspiration becomes unstable and a jet can be made to change from positive aspiration to blowback simply by touching the filament entrance. At ratios below 3.5, blowback occurs continuously. The width of the throat opening can be between 0.021 in. (0.053 cm.) and 0.08 in. (0.2 cm.), provided the above-defined ratio is maintained over 3.5. A preferred throat opening, when the width of the nozzle opening is 0.011 in. (0.038 cm.) is 0.050 in. (0.127 cm.).

The filament passageway diverges from the throat opening to the filament exit. The purpose of this is to permit the gas velocity to decrease and thereby to reduce the tension on the filaments. As indicated previously, reduction of the tension is desired to permit full relaxation of the filaments when they reach relaxation temperature. A divergence angle of 2° is adequate to obtain the desired reduction in tension.

Since the filament passageway is divergent, the width of the filament exit will be greater than the width of the throat opening. It has been found that tension and aspiration developed by the jet are affected by variations in the width of the filament exit in the same general way that they are affected by the width of the throat opening. There are differences, however, which lead to advantageous results. In the first place, significant reductions in the width of the filament exit and accompanying decreases in aspiration can be obtained without inducing instability, but the filament exit must be maintained sufficiently large to prevent blowback due to development of excessive back pressure in the filament passageway. Aspiration can, however, be reduced to very small values without the jet becoming unstable. A second difference is that, at widths above about 0.1 in. (0.25 cm.), changes in aspiration induced by variations in jet exit width are very small. Accordingly, widths above about 0.2 in. (0.5 cm.) are not used to control aspiration. From the foregoing it is apparent that the jet exit provides a convenient means for regulating the jet aspiration. The width can either be increased to increase aspiration to a desired value, at the expense of tension, or decreased to reduce aspiration while also obtaining higher tension. By adjustment of the width of the throat opening and the filament exit both the tension and aspiration characteristics of the jet can be controlled.

The length of the jet from the nozzle openings to the filament exit also affects both the tension and aspiration developed by the jet, and should be from 4 to 36 inches (10 to 92 cm.) but other factors such as space limitations or the desired filament residence time from the standpoint of heat transfer determine the exact length to be used. In general, increased length increases the tension and decreases the aspiration. These effects were found in tests carried out with a 3-in. (7.6 cm.) wide jet of the design shown in FIGURES 1 through 5 and having a length, as defined above, of 12 in. (30 cm.). Other jet dimensions were as follows:

Filament-entrance member:

Length (axial) ----- 0.6 in. (1.5 cm.)

Width (narrow dimension,
of passageway X-section) - 0.016 in. (0.041 cm.)

Width of nozzle openings ----- 0.016 in. (0.041 cm.)

Width of throat opening ----- 0.038 in. (0.097 cm.)

Width of filament exit ----- 0.080 in. (0.203 cm.)

An 18-in. (46 cm.) length of extension plates was added to give a total length of 30 in. (76 cm.) and an exit width of 0.140 in. (0.356 cm.). A measure of the tension generated by the jet was obtained by inserting a 1-in. (2.5 cm.) wide ribbon of a continuous-filament nonwoven web of poly(ethylene terephthalate) fibers and determining the tension on the web at various flows of primary gas (air). Previous studies have shown that results obtained with the ribbon of nonwoven fabric corresponded closely with results obtained with a ribbon of 200 filaments evenly spaced over a span of 2.5 in. (6.4 cm.). The ribbon of nonwoven web is preferred for use in measuring the tension because of the difficulty in handling the delicate filaments.

The results, which are summarized below, indicate an increase in tension of about 30 to 40% with the longer jet, while the aspiration rate with the longer jet is considerably lower, particularly at the low flow rate.

Primary Air ¹	12-in. Jet		30-in. Jet	
	Tension (g.)	Aspirated Air ¹	Tension (g.)	Aspirated Air ¹
20-----	160	5.8	230	1.0
25-----	310	5.9	410	2.8
28-----	390	6.0	520	3.4

¹ In s.c.f.m.

In addition studies of the effect of jet length on tension, the ribbon of nonwoven web was inserted at various lengths into the 30 in. (76 cm.) jet. A plot of the total tension on the ribbon against the length of ribbon in the jet indicated low tension values in the filament-entrance member. This was expected since air velocities are low due to low aspiration values. The tension increased to a high value in the mixing section and continued to increase at a much lower rate as the ribbon was moved toward the exit. It was found that 54% of the total tension for the 12-in. (30 cm.) jet and 41%, for the 30-in. (76 cm.) jet, were produced in the mixing section. This is a desirable effect for the above-described web-laydown process since it permits development of a considerable part of the stripping tension near the entrance of the jet. The filaments are then subjected to lower tension which makes heat-relaxation possible. Since the level and distribution of the tension can be regulated by modification of the mixing section and throat opening of the jet, the length can be adjusted to suit the process requirements related to relaxation kinetics, rather than tension and aspiration.

Additional static threadline-tension measurements were carried with a 3-in. (7.6 cm.) wide jet having the following dimensions:

Jet length (overall) ----- 12 in. (30 cm.)

5 Width of filament-entrance member ----- 0.020 in. (0.051 cm.)

Width of nozzle openings ----- 0.011 in. (0.028 cm.)

Width of throat opening ----- 0.050 in. (0.127 cm.)

10 Width of filament exit ----- 0.130 in. (0.330 cm.)

The tension developed on a ribbon of 108 nylon monofilaments (10 denier) (1.1 tex) with a flow of 35 s.c.f.m. (980 liters/min.) of primary air per side of the jet was 105 g. This corresponds to about 0.1 g.p.d. With another jet of the same dimensions except that the width of the throat opening was 0.052 in. (0.132 cm.), the tension exerted on a moving strand of 192 electrostatically-charged poly(ethylene terephthalate) filaments (3 denier; 0.3 tex) was measured by determination of the drag on the filaments as they were passed over Al Si Mag rods attached to a strain gauge. At a primary air flow of 35 s.c.f.m. (980 liters/min.), the total measured tension was 64 g., which corresponds to 0.111 g.p.d. The tension on a strand of 96 filaments was 32 g., thus the tension was proportional to the number of filaments. This is indicative of good filament separation in the jet. In typical operation of the jets of this invention with heated primary air to effect heat-relaxation of poly(ethylene terephthalate) filaments, air at 150 to 250° C., is introduced into the two plenum chambers under pressures of about 15 to 40 p.s.i.g. (1.1 to 2.8 kg./cm.²). It then expands to sonic or supersonic velocities through the nozzle openings into the mixing section and then into the effuser section at velocities greater than the velocity of the filaments, which may be of the order of 4,000 y.p.m. (3,660 m./min.). This high-velocity air imposes the necessary tension on the filaments. The two air streams also create shear zones that entrain air from the filament entrance member thus providing aspiration for string-up or self-stringing during operation. A suitable level of aspiration for these purposes is 1 s.c.f.m. per inch of jet width (11 liters/min. per centimeter of jet width). The two air streams also impinge on the filaments at a high velocity and provide the desirable effect of concentrating a major portion of the total tension in the mixing section of the jet.

In addition to the advantage that the slot-jet devices of this invention conform geometrically to the ribbon-like shape of the filament strand coming from a draw-roll operation, other unexpected advantages result from their use. These include the ability to maintain a higher electrostatic charge level for a given number of filaments, thus permitting greater separation of the filaments prior to their laydown as a nonwoven web. Another advantage is that the air-velocity distribution with slot-jets is so superior that a lower gross stripping tension is required than with a round jet (0.08 g.p.d. vs. 0.10). In addition a substantially different and more desirable laydown pattern is obtained with the slot-jet. A flat wide swath replaces the bell-shaped and narrow swath obtained from a round jet. The wide swaths can be more easily blended to form uniform, wide nonwoven webs. An additional advantage is that the output from several slot-jets can be blended merely by butting the narrow side of one jet to the next, thus forming a uniform curtain of filaments which leads to a uniform nonwoven web. This blending cannot be obtained with round jets.

What is claimed is:

1. An improved filament-forwarding jet device which comprises a jet housing having mounted therein a filament-entrance member and an effuser member, each member defining an inlet, a passageway of generally rectangular cross section, and an exit all in axial alignment, said filament-entrance member projecting into the inlet of said effuser member for feeding a bundle of fila-

ments to the effuser inlet, means for supplying fluid under pressure including two nozzle openings of generally rectangular cross section between the filament-entrance member and the inlet of the effuser member, each having a width of between about 0.006 and 0.020 inch and presenting a fluid-entrance angle of less than 16° with the axis of the effuser-member passageway, the effuser-member passageway having a throat portion whose width is at least 3.5 times that of each nozzle opening, but less than about 0.08 inch, said filament-entrance-member passageway having an axial length of between about 0.5 and 1.0 inch, and said effuser member passageway having an axial length between the nozzle openings and the filament exit of from about 4 to 36 inches.

2. The jet of claim 1 wherein the width of the filament-entrance-member passageway is between about 0.015 and 0.030 inch.

3. The jet of claim 1 wherein the nozzle opening has a pair of walls that converge in the downstream direction at an angle of at least 2°.

4. An improved filament-forwarding jet device which comprises a pair of filament-entrance plates terminating in lip portions and a pair of effuser plates, each of said pair of plates cooperating with the same pair of end plates to constitute, respectively, a filament entrance and an effuser member with axially aligned rectangular passageways extending through each of said members, the lip portions of the filament-entrance plates and the vicinal

portion of the effuser plate cooperating to define a mixing section and two rectangular nozzle openings communicating therewith for the introduction of fluids under high pressure, each of said nozzle openings having a width of between about 0.006 and 0.020 inch and presenting a fluid-entrance angle of less than 16° with the axis of the effuser-member passageway, the filament-entrance-member passageway having a length of between about 0.5 and 1 inch, said effuser member passageway having an axial length between the nozzle opening and the filament exit of from about 4 to 36 inches, and the throat portion of the effuser-member passageway having a width that is at least 3.5 times that of each nozzle opening but is less than about 0.08 inch.

5. The device of claim 4 wherein the lips of the filament-entrance plates and the vicinal portion of the effuser plates are relieved so as to be out of contact with the end plates.

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3,081,951	3/1963	Dyer et al.	28—1 X
3,156,752	11/1964	Cope	264—345

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