

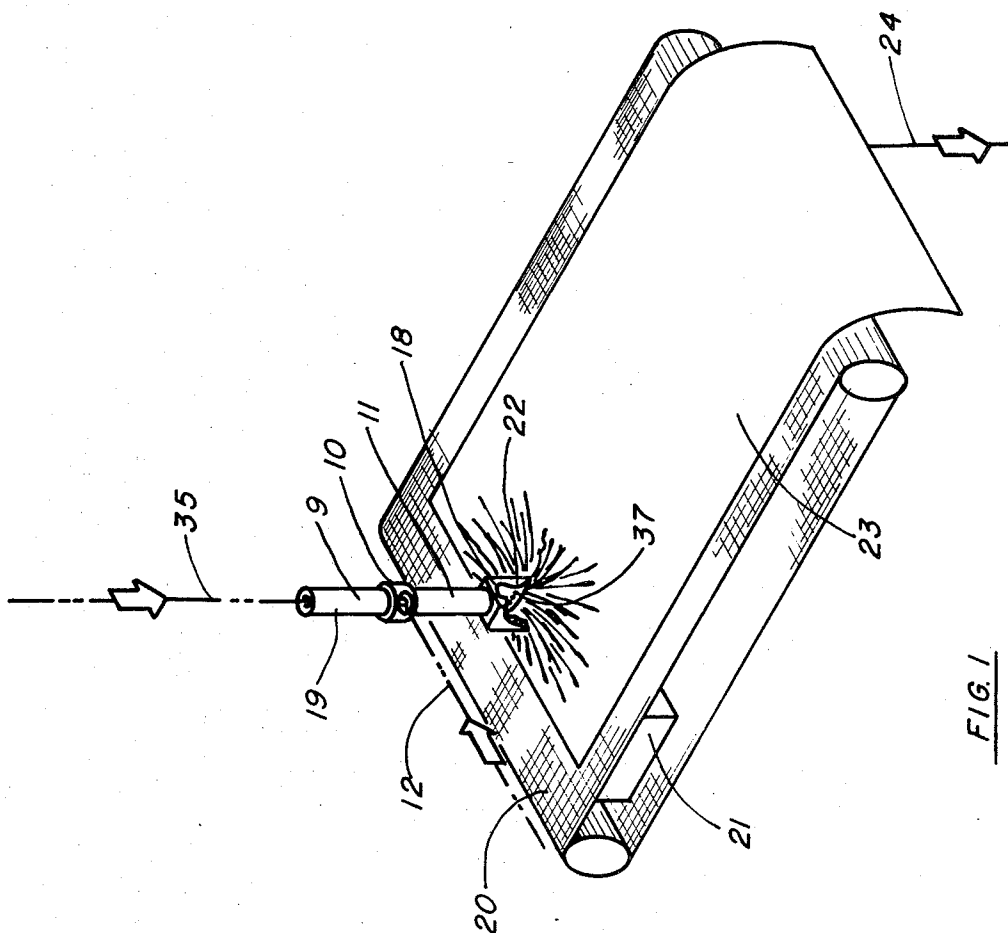
June 12, 1973

W. P. LIPSCOMB ET AL
FORAMINAL APPARATUS FOR SPLAYING AND DEPOSITING NONWOVEN
FILAMENTARY STRUCTURES

3,738,894

Filed Sept. 28, 1971

2 Sheets-Sheet 1



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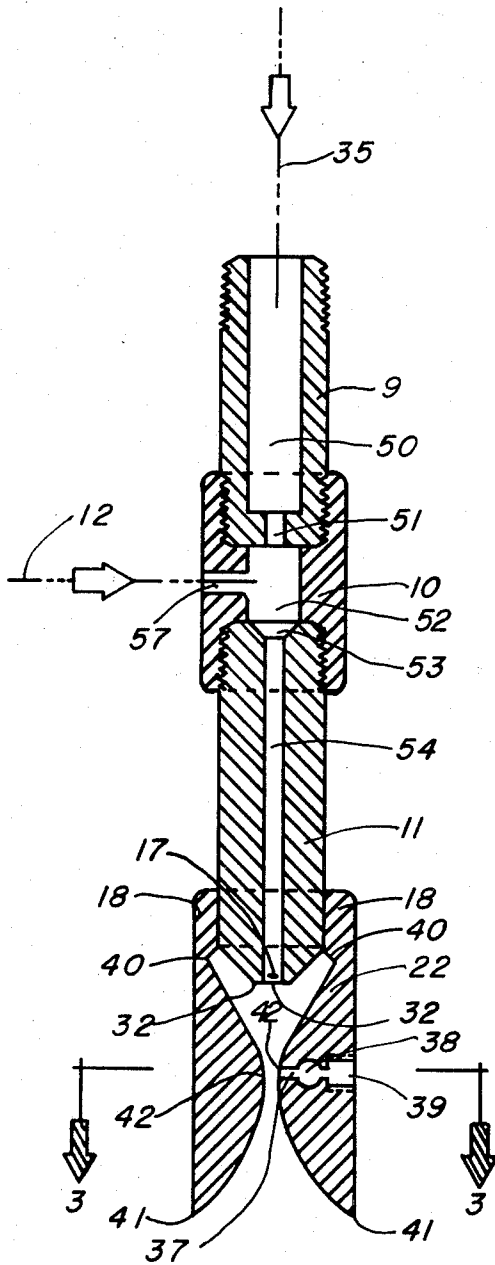


FIG. 2

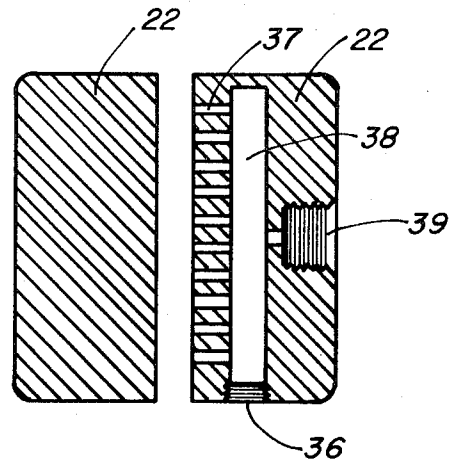


FIG. 3

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**FORAMINAL APPARATUS FOR SPLAYING
AND DEPOSITING NONWOVEN FILA-
MENTARY STRUCTURES**

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6 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus for augmenting dispersal and improving deposition of a plurality of continuous filaments onto a continuously moving surface whereby random distribution of the filaments is provided for the production of uniformly distributed nonwoven webs. Such apparatus comprises a foraminal splaying device having two opposing surfaces with holes extending through at least one of the two opposing surfaces. Compressed gas, e.g. air, is discharged through the holes in substantially parallel columns so as to interpenetrate a filament bundle passing between the two opposing surfaces. The two opposing surfaces of the splaying device have continuous surfaces of curvature which surfaces exhibit a converging to diverging pattern as the opposing surfaces extend from the exit of the aspirator. The foraminal splaying device is positioned near the exit of an aspirator so as to spread the filaments in substantially all directions and thereby to provide greater openness and greater random laydown of filaments.

CROSS-REFERENCE TO RELATED APPLICATIONS

The invention herein set forth is related to the inventions described in copending applications Ser. No. 184,420 entitled "Two-Planar Deflector for Dispersing and Depositing Nonwoven Filamentary Structures," filed on Sept. 28, 1971 in the name of Walter P. Lipscomb and Garland L. Turner and Ser. No. 184,421 entitled "Apparatus for Splaying and Depositing Nonwoven Filamentary Structures" filed on Sept. 28, 1971 in the name of Walter P. Lipscomb and Eli B. Shelburne, Sr., wherein different apparatus for improving the dispersal and deposition of a plurality of continuous filaments onto a continuously moving surface are disclosed.

BACKGROUND OF THE INVENTION

This invention relates to an improved apparatus for improving the dispersal and deposition of filaments. In particular, it relates to an apparatus for augmenting the dispersal of continuous filaments onto a receiving surface so as to form a nonwoven web of randomly disposed filaments.

Nonwoven webs formed from continuous filamentary materials which have been laid on a receiving surface in a random configuration are well known in the art. In the formation of such webs, great care is frequently taken to ensure that the filaments are maintained apart from each other and that interfilamentary entanglement and the formation of filament aggregates are avoided.

Nonwoven webs comprising multi-filaments are commonly formed by withdrawing the filaments from a source of supply, such as a melt spinnerette, and then depositing the filaments at high velocity onto a moving surface by means of an aspirator. In the production of nonwoven products having a substantial width, there must be provided either a plurality of aspirators for depositing a plurality of filamentary bundles in a random manner upon the moving surface or there must be provided a

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means, normally unduly complicated and cumbersome, to move the aspirator over the width of the product to be produced.

When depositing filaments from a conventional aspirator onto a collecting surface, the filaments will spread out within the confines of the aspirator boundary. However, the filament distribution in the jet stream is not always uniform and random and is often restricted to a small laydown area; for example, a web width not exceeding eight inches when a fixed aspirator jet is situated at a distance of one to three feet from the receiving surface.

Some of these deficiencies have been overcome by forwarding the filaments between surfaces patterned so as to utilize the principle of aerodynamics known as the Coanda effect before the filaments are massed in web form. The principle, named for its discoverer, Henri Coanda, was applied to a useful structure in U.S. Pat. 2,052,869. Such structure was used to control the discharge into an elastic fluid atmosphere of a stream of another elastic fluid moving at high velocity, wherein means were provided to alter flow of the elastic fluid of the atmosphere induced by the fluid stream issuing from its high velocity source. In this manner, the fluid stream was diverted in a direction generally contiguous to a diverting contour of an extension to the outlet conduit of the high velocity source. Such flow diversion commenced generally at the area of substantial contact of the fluid stream with the slower velocity elastic fluid of the atmosphere. Adaptation of such a Coanda structure to spread, to a great degree, the filaments exiting from an aspirator jet without sacrificing other desirable objects at the expense of such greater spreading would be of great benefit to many producers of nonwoven webs. Such greater spreading of the filaments, if accompanied by no loss in strength or in other desirable properties in the resultant web, would improve yarn openness and thus broaden the web width by providing greater filament coverage per pass on a filament receiving surface. Utilization of such a device would reduce manufacturing costs as well as produce wider webs having greater randomness and uniform filament distribution.

SUMMARY OF THE INVENTION

In accordance with this invention, it has been found, surprisingly, that even greater openness and greater randomness of filament laydown can be obtained through the use of a foraminal splaying means having opposing surfaces with compressed gas discharge holes extending through at least one of the opposing surfaces, between which surfaces a filament bundle passes.

The holes are arranged on such opposing surface in a manner so as to release columns of compressed gas through the holes, such columns intersecting the filament bundle in order to spread substantially the filaments of the bundle. The filaments are deposited onto a receiving surface in a randomly dispersed manner to form a nonwoven web of randomly disposed filaments substantially uniformly distributed throughout said web.

More specifically, the invention features an apparatus for spreading while depositing filaments onto a receiving surface which comprises, in combination, an aspirator to forward filaments at a high velocity and a foraminal splaying device having a plurality of compressed gas holes on at least one of two opposing surfaces of such foraminal splaying device for spreading the filaments substantially in all directions from the foraminal splaying device onto the receiving surface. Consequently, the area of filament deposition on the receiving surface is effectively enlarged in all directions. Preferably, the compressed gas holes have diameters ranging from approximately 0.003 inch to ap-

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proximately 0.030 inch. Such holes are preferably spaced apart at a center-to-center distance ranging from 2.5 times to 10 times the hole diameters. The foraminal splaying device is preferably formed so as to make use of the principle of aerodynamics known as the Coanda effect. Accordingly, the two opposing surfaces of the splaying device are characterized by having continuously smooth surfaces of curvature, which opposing surfaces form a converging to diverging pattern as the surface of curvature develops from the exit of the aspirator.

In a preferred embodiment of this invention, the compressed gas holes are generally on a line extending across one of the two opposing surfaces in a direction substantially perpendicular to the direction of motion of the filaments. Such a line is generally coincident with the line of greatest convergence on this opposing surface of the splaying means. Each of such compressed gas holes has a diameter preferably ranging from approximately 0.010 inch to approximately 0.020 inch. Air is being discharged through such holes at a pressure of approximately from 3 p.s.i.g. to 100 p.s.i.g. More preferably, there are approximately from 5 to 15 discharge holes along this line of greatest convergence of the foraminal splaying means.

Advantageously, the combination of the foraminal splaying device with the aspirator may be reciprocated above a moving receiving surface in a direction substantially transverse to the forward motion of the receiving surface. Further advantageously, this combination may be made a part of a plurality of substantially similar combinations and then reciprocated at essentially the same rate and stroke in a pattern such that filaments from a given combination can overlap those of the next adjacent combination so as to further increase web width.

A feature of this invention is its capability to spread filaments exiting therefrom in substantially all directions due to the presence of the compressed gas holes, thereby providing a highly random and broad filament distribution in the filament product. Conventional Coanda splaying devices spread the filaments generally only in the direction of the diverging opposing surfaces of the Coanda splaying device.

Another feature of this invention is its quick and easy adaptability for use with many conventional aspirators in dispersing and depositing filamentary materials onto a moving receiving surface.

The method utilizing the apparatus of this invention comprises, in general, the utilization of the foraminal splaying device in combination with an aspirator whereby filaments, preferably forwarded from a spinnerette of a spinning mechanism and thereafter from a drawing mechanism, are forwarded through a high velocity fluid jet of the aspirator. Subsequent thereto, the aspirator jet stream propels the filaments through the foraminal splaying device whereby the filaments are separated and forwarded onto a continuously moving, preferably foraminal, surface in the form of a uniform nonwoven web comprising randomly disposed, substantially uniformly distributed filaments. Deposition of the filaments may be aided by a suction chamber located underneath the moving surface.

The described apparatus can be readily used for greater separation of filaments, or alternately, strands, yarns, slivers or other similar forms of materials, or mixtures thereof. Such materials include any fiber-forming thermoplastic polymer from which filaments can be obtained. These materials include: polyamides, for example, poly-(epsilon-caprolactam) (hereinafter nylon 6) and poly-(hexamethylene adipamide) (hereinafter nylon 66); linear polyesters, for example, poly(ethylene terephthalate); acrylonitrile polymers and copolymers; olefinic polymers, for example, polyethylene, polypropylene, and polyvinyl chloride; and cellulose acetates. Preferred materials include nylon 6, nylon 66 and poly(ethylene terephthalate).

The invention will be more clearly understood and ad-

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ditional objects and advantages will become apparent upon reference to the discussion below and to the figures which are given for illustrative purposes.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a schematic perspective view depicting a preferred embodiment of the apparatus employed for carrying out the invention.

FIG. 2 is a fragmentary front elevation view of an apparatus as depicted in FIG. 1, showing an aspirator and a foraminal splaying device in section.

FIG. 3 is a sectional view of the apparatus of FIG. 2, taken on line 3—3 thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawings and particularly to FIG. 1, a bundle of freshly formed filaments 12 enter inlet aperture 57 of an aspirator such as aspirating jet 19. The filaments are formed from the spinnerette of a melt spinning apparatus (not shown). Subsequent to spinning, the filaments may also be attenuated and oriented on a drawing apparatus (also not shown). Filament bundles having a broad range of denier, i.e. 30 to 3400 total denier, may be used in the apparatus of this invention. Within aspirating jet 19 the filaments are acted upon by a high velocity fluid medium such as air, which is supplied through inlet conduit 35. Aspirating jet 19 comprises an air nozzle 9, a collar 10 and a diffuser 11. The filament bundle 12 is forwarded via the high velocity aspirating medium from the jet exit 17 to the foraminal splaying device 22. In foraminal splaying device 22 the filaments of the bundle are subjected to substantially parallel columns of compressed air issuing from holes 37 in a direction substantially perpendicular to the direction of motion of the filaments so as to impart a tension on the filaments in a centric, diametrical direction. Upon release of such tension during filament passage out of the splaying means 22, the filament bundle 12 spreads extensively in generally all directions as a result of forces accumulated in resistance to such tension. Thereafter, the filaments 12 are deposited in a wide and random manner on receiving surface 20. Foraminal splaying device 22 is affixed securely to the exit end of jet 19 via extension 18. On receiving surface 20, preferably a foraminal continuously moving conveyor with a suction chamber 21 provided beneath that portion of conveyor 20 on which the filaments are being laid down, the filaments are deposited in a random manner to form web 23. Upon passing from receiving surface 20, web 23 is forwarded to further processing units 24 (not shown), such as fusion rolls to bond the web 23.

In FIG. 2, the aspirating jet 19 comprises a hollow air nozzle 9 which is externally threaded at each end and which has an air inlet conduit 35 attached to its upper end; a hollow collar 10 which is internally threaded at both ends so as to connect air nozzle 9 with diffuser 11 and which has an inlet aperture 57 for receiving filament bundle 12; and a hollow diffuser 11 which is externally threaded at its upper end and through which the filaments and high velocity air are propelled onto foraminal splaying device 22 and thereafter onto a receiving surface. The annular internal aperture 57 is arranged to direct the filaments entering therein downwards, i.e. in direction of air flow. The internal dimensions of collar 10 and diffuser 11 are arranged so as to minimize twisting, knotting and entanglement of the filaments passing therein. The diameter of nozzle passageway 51 is preferably from 20 percent to 33 percent of the nozzle passageway length. Also, cross-sectional area of nozzle passageway 51 is preferably from 25 percent to 35 percent of the cross-sectional area of diffuser passageway 54. Further, the diameter of diffuser passageway 54 is preferably from 2 percent to 10 percent of the length thereof. Still further, the maximum diameter of diffuser entrance chamber 53, which is conical in shape,

is most preferably approximately 2 times the diameter of the diffuser passageway 54. The cross-sectional area of diffuser passageway 54 is designed such that the cross-sectional area of filament bundle 12 passing therein ranges preferably from 0.1 percent to 5 percent, most preferably from 0.2 percent to 1.5 percent, of the diffuser passageway cross-sectional area. The respective lengths and diameters of air nozzle entrance chamber 50 and of collar chamber 52 are not critical. However, such lengths and diameters should be used as are practical, i.e. compatible with the overall operation of the process herein described.

Although the foraminal splaying device 22 works especially compatibly with the preferred aspirating jet 19 as described in FIG. 2 and as described in greater detail in patent application Ser. No. 184,542 entitled "Process and Apparatus for Production of a Nonwoven Web," filed on Sept. 28, 1971 in the name of Walter P. Lipscomb and Garland L. Turner, it has been designed to work compatibly with many conventional aspirators. In general, such conventional aspirators are especially suitable for use with the apparatus of this invention if these aspirators forward the filament bundle at a high velocity, generate sufficient pull therein to maintain the filaments under minimum tension, open and separate the filament bundle during the exiting of the filaments from the aspirators, and prevent filaments from undergoing any substantial twisting, knotting or entanglement therein.

Referring now to FIG. 3, as well as to FIG. 2, extension 18 of the foraminal splaying device 22 is attached securely to the bottom portion of diffuser 11 by a suitable means, such as welding or bolting. Foraminal splaying device 22 is patterned so as to make use of the principle of aerodynamics known as the Coanda effect. Splaying device 22 involves a modification and utilization of this principle. Splaying devices suitable for use in this invention include any device having continuously smooth, preferably symmetrical, opposing surfaces of curvature in accordance with Coanda's aerodynamical principle. Such opposing surfaces form a converging to diverging pattern as the surfaces extend in distance from the aspirator passageway exit 17. Preferred is a splaying device similar to that shown in FIG. 2 wherein there are two such opposing surfaces, each of which develops from a line (shown as point 40 in FIG. 2) which is above exit 17 to a line (shown as point 42) of maximum convergence and thereafter to a line (shown as point 41) of maximum divergence. The lines of maximum convergence and the lines of maximum divergence are more preferably perpendicular in reference to the center-line of aspirator exit passageway 54, so as to enhance symmetrical splaying patterns. Experience has shown that the minimum distance between the lines 42 of maximum convergence for effective filament spreading is at least as great as the diameter of aspirator exit passageway 54.

The essential feature of this invention is the use of compressed gas holes on the opposing surfaces of the suitable splaying device 22. The degree of filament spreading and randomness, and consequently of web width, is greatly increased without appreciably affecting the other properties of the nonwoven web 23 by providing at least two holes 37 through at least one of the opposing surfaces of the foraminal splaying device 22 for the release of a compressed gas through these holes. Although the compressed gas holes may be provided successfully on more than one surface of the foraminal splaying device, the degree of filament spreading is especially enhanced in an efficient manner when compressed gas holes are positioned on only one opposing surface of the foraminous splaying devices such that the number of such holes on such opposing surface is greater on or in close proximity to the line of maximum convergence of such opposing surface than are the number of holes on the surface area between the line of maximum convergence and the line of minimum convergence of such opposing surface. More preferably, a superior degree of filament spreading as well as efficient

conservation of compressed air requirements and of the number of holes necessary to attain such superior spreading has been realized by placing all holes in close proximity to, and most preferably on, the line of maximum convergence. It is preferred that the holes are placed on or near this line of greatest convergence because of the greater tendency at that narrow flow area to form compressed gas columns easily and to resist interplay by adverse aerodynamical phenomenon, i.e. turbulence. It is believed that compressed gas exits these holes in the form of parallel comb teeth so as to impart a tension, and possibly a small degree of pulsation, on the filament bundle which travels generally perpendicular to these parallel columns of compressed gas. Consequently, the filaments are spread generally into smaller bundles under this tension between the compressed gas columns. Subsequent to passing these compressed gas columns, the filaments in each smaller bundle spread extensively in generally all directions in resistance to such tension. Thereafter, the separated filaments are deposited in a highly random manner on a receiving surface. Because of the diverging surface of curvature of the Coanda splaying means, this spreading is not restricted due to spatial limitation and is probably augmented.

Each of the compressed gas holes on the opposing surface of the foraminal splaying device should have effective diameters which favor the formation of discrete compressed gas columns having sufficient integrity to penetrate the filament bundle during passage through the foraminal splaying device. The effective diameter ranges preferably from approximately 0.003 inch to approximately 0.030 inch, more preferably from approximately 0.010 inch to approximately 0.020 inch. With values of effective hole diameter less than 0.003 inch, the compressed gas column tends to ripple turbulently and to become indistinct. With effective hole diameter values greater than 0.030 inch, the compressed gas column tends to exhibit boundary turbulence, to be too large in relation to the filament bundle which the column is designed to separate, and to project a volume of compressed gas which is too large in relation to the compressed gas volume used for forwarding the filament bundle.

Preferably, the center-to-center distance between the compressed gas holes ranges from approximately 2.5 times to approximately 10 times the hole diameter. With center-to-center hole spacing less than 2.5 times the hole diameter, the compressed gas columns tend to impact the filament bundle as a whole rather than to interpenetrate the bundle. With center-to-center spacing greater than 10 times the hole diameter, the compressed gas columns are too far apart to effectively interpenetrate the filament bundle. Still further, the holes along the most preferred location on the line of greatest convergence are preferably of a number which is capable of effectively and efficiently interpenetrating the filament bundle. A suitable range of the number of holes on such line of greatest convergence is from 5 to 15. Also, the greater the ratio of hole depth or length to hole diameter is, then the greater the likelihood of reducing turbulence in the flow of compressed gas exiting each hole and of increasing the coherence and straight-line penetrating power of the compressed gas after exiting the hole and forming a column; both of these latter effects are desirable for purposes of this invention. A practical and preferred range of length-to-diameter ratios for each hole is from 4-1 to 10-1. In addition, compressed gas, such as air, is discharged through each hole via entry port 39 and chamber 38 which is sealed by plug 36. The compressed gas is discharged preferably at a pressure of from 3 p.s.i.g. to a pressure which is less than approximately 90 percent of the aspirating medium pressure, preferably from 6 p.s.i.g. to 30 p.s.i.g. Generally, compressed gas pressure through each hole should be sufficient to form a compressed gas column that has adequate integrity to support itself and yet not so high as to consume compressed gas inefficiently.

In operation, the aspirating medium, which may be a pressurized fluid such as air, is introduced from a supply source, not shown, into chamber 50, at a pressure preferably less than 120 p.s.i.g. Such media enters and flows through nozzle passageway 51 and exits therefrom as a high velocity stream. The high velocity fluid stream exiting nozzle passageway 51 engages filaments 12 entering the aperture 57 with sufficient energy to propel the filaments through collar chamber 52 into diffuser 11, which is characterized by an initially diverging entrance chamber 53. Subsequently, the propelled filaments are splayed in a wide and random manner, via passage between the compressed gas columns emanating from holes 37 on splaying means 22. Then the filaments are deposited on a receiving surface which normally takes the form of a conveyor belt moving at a predetermined constant speed and at a predetermined distance from the foraminal splaying device exit 41. The receiving surface should be placed below the foraminal splaying device of this invention at a distance such that effectiveness and efficiency of random dispersal of filaments thereon in a uniform manner is achieved. The pressurized state of such aspirating media and of the compressed gas used in the holes 37 of the foraminal splaying device 22 is contingent upon several conditions and thus may be varied to meet the specified circumstances. Some factors which influence operating pressures are the aspirating jet design, aspirating media pressure consumed, type and nature of filament-forming polymer, degree of orientation to which filaments have been subjected, and the resulting properties of the nonwoven product. For convenience and economics, both the aspirating medium and the compressed gas may be air.

We have found that it is especially advantageous in the process utilizing this invention to fix the combination of the foraminal splaying device with the aspirating means, or a plurality of such combinations in parallel, on a reciprocating bar or similar mechanism and to reciprocate such combination or plurality of combinations in a direction substantially transverse to the direction of forward motion of said moving receiving surface. Preferably, a plurality of such combinations are reciprocated at a rate and stroke in such a pattern that the filaments from a given combination overlap those from adjacent combinations. A suitable means of reciprocation is described in greater detail in the aforementioned patent application, Ser. No. 184,542 entitled "Process and Apparatus for Production of a Nonwoven Web," filed on Sept. 28, 1971.

The following example is provided as further illustrative of the present invention. The enumeration of details therein, however, should not be considered as restrictive of the scope of this invention.

In an example, nylon 6 is melt spun into a 70-filament bundle 12 of 1100 denier. The filament bundle 12 is forwarded through aperture 57 into aspirating jet 19 at a rate of 1500 feet per minute. In collar chamber 52, the filament bundle 12 is subjected to air as the aspirating medium at a pressure of 40 p.s.i.g. The diameter of air nozzle passageway 51 is 0.040 inch. Bundle 12 is forwarded to and through diffuser passageway 54 by the aspirator jet stream. The diameter of diffuser passageway 54 is 0.072 inch. Thereafter, filament bundle 12 exits from jet 19 into foraminal splaying device 22. The jet 19 with splaying device 22 is reciprocated at a stroke of 10 inches with a frequency of 70 cycles per minute. The foraminal splaying device is constructed of stainless steel and is similar in physical profile to the splaying device shown in FIGS. 2 and 3. The splaying device 22 has the following physical characteristics: distance along the aspirator exit axis from aspirator exit to lines of greatest convergence is 0.375 inch; distance along the aspirator exit axis from lines of greatest convergence to lines of greatest divergence is 0.5 inch; distance between lines of maximum convergence is 0.078 inch; distance between lines of maximum divergence is 0.5 inch. Ten (10) compressed gas holes 37, each having a 0.015 inch diameter, are interspaced at a center-to-center distance

of 0.050 inch substantially on the line of maximum convergence of one of the two opposing surfaces of the foraminal splaying device 22. The length-to-diameter ratio of each hole is 4-1. Air pressure at each hole is 20 p.s.i.g. Upon passage from foraminal splaying device 22, filaments of bundle 12 open up considerably and are deposited on a continuously moving foraminal horizontal conveyor 20 which is moving at a speed of 8 feet per minute and is at a distance of 12 inches from the closest portion of foraminal splaying device 22.

Nonwoven webs produced in a process using the foraminal splaying device of this invention are characterized by a random filament distribution throughout. The appearance of webs is uniform, and it is essentially free of filament aggregates. Through the use of the splaying device of this invention, uniform web coverage per pass may exceed that using the aspirator alone by values of 33 percent and greater.

The nonwoven web or other useful construction processed from a coherent filament bundle prepared in accordance with this invention may serve a variety of useful purposes, particularly in the manufacture of nonwoven products, such as carpet backing, wall covering, insulation, coating substrates, interfacing, filters, and the like.

Various modifications and other advantages will be apparent to one skilled in the art, and it is not intended that this invention be limited to details presented by way of illustration except as required by express limitations in the appended claims.

What is claimed is:

1. In an apparatus for depositing a bundle of filaments onto a moving receiving surface in a randomly dispersed manner to form a nonwoven web of randomly disposed filaments substantially uniformly distributed throughout said web, said apparatus comprising an aspirating means for forwarding the bundle of filaments at high velocity to the moving receiving surface, the improvement comprising a foraminal splaying device for augmenting spreading of the filaments while advancing said filaments from said aspirating means to said moving surface, said foraminal splaying device having two opposing surfaces with a plurality of compressed gas discharge holes on at least one of the opposing surfaces, said holes arranged on said opposing surface so as to release columns of compressed gas through said holes, said compressed gas columns intersecting said bundle of filaments passing between said opposing surfaces from said aspirating means in order to spread substantially said filaments of said bundle, said two opposing surfaces being characterized by continuously smooth surfaces of curvature and by forming a converting to diverging pattern as said surface of curvature develops and extends from the exit of said aspirating means.

2. The apparatus of claim 1 wherein said compressed gas holes are generally on a line extending across only one of the two opposing surfaces in a direction substantially transverse to the direction of motion of the axis of said filament bundle, said line being generally coincident with the line of greatest convergence on one of said opposing surfaces, said compressed gas being air and being forced through said holes in substantially parallel columns in said substantially transverse direction.

3. The apparatus of claim 2 wherein the diameter of said compressed gas holes ranges from approximately 0.003 inch to approximately 0.030 inch at said opposing surface of said splaying means and said air is discharged through each of said holes at a pressure of at least 3 p.s.i.g.

4. The apparatus of claim 3 wherein the center-to-center distance between said compressed gas holes ranges from 2.5 times to 10 times the diameter of each of said compressed gas holes.

5. The apparatus of claim 4 wherein the length of each of said compressed gas holes ranges from 4 to 10 times the diameter of each hole.

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6. The apparatus of claim 5 wherein the diameter of said compressed gas holes ranges from 0.010 inch to 0.020 inch at said opposing surface and said air is discharged through each of said holes at a pressure ranging from 6 p.s.i.g. to 30 p.s.i.g.

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DANIEL J. FRITSCH, Primary Examiner

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