PROCESS AND APPARATUS FOR PRODUCTION OF A NONWOVEN WEB

Filed Sept. 28, 1971 4 Sheets-Sheet 1

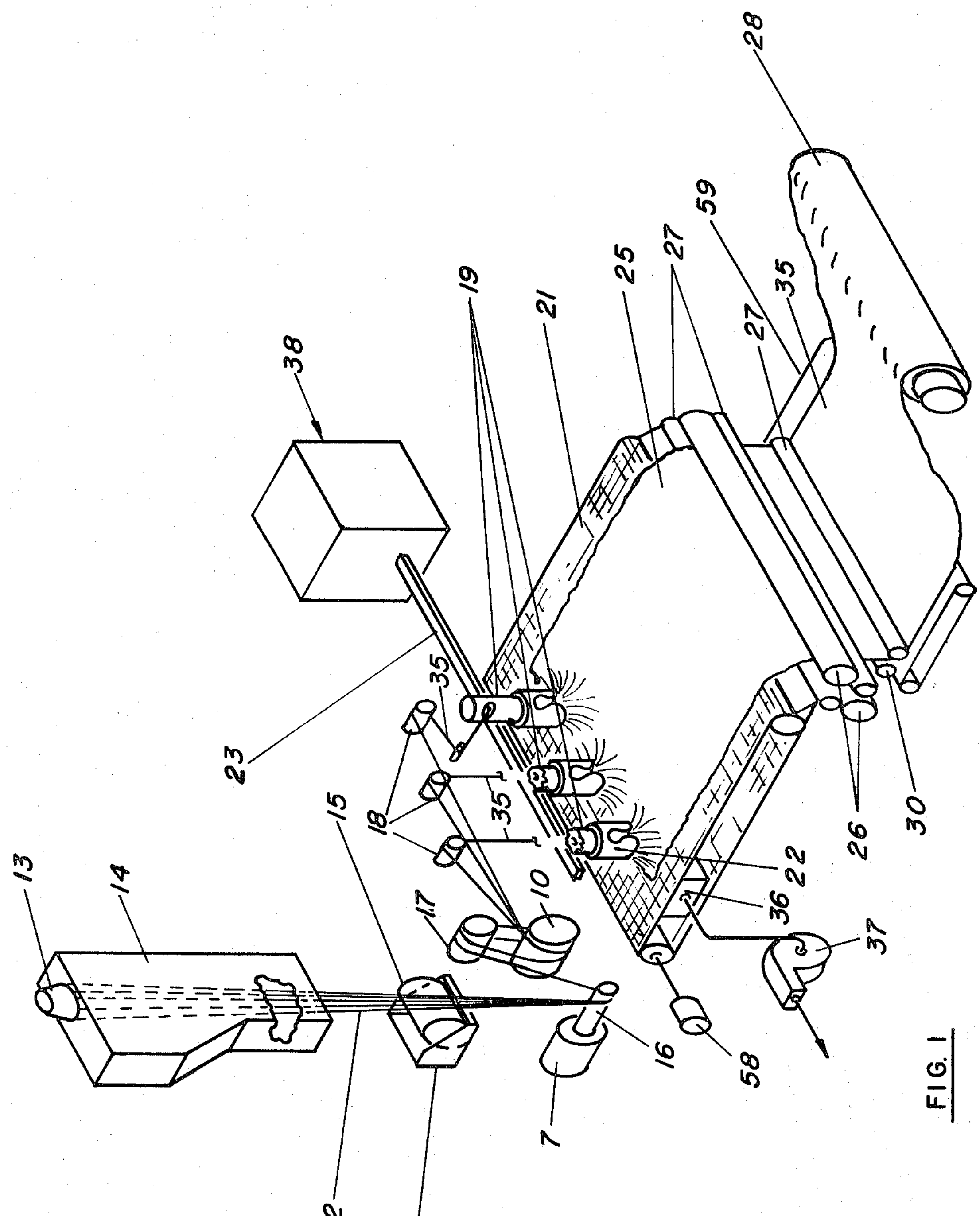

FIG. I

INVENTORS
Walter P. Lipscomb
Garland L. Turner
BY Patrick L. Henry
ATTORNEY

PROCESS AND APPARATUS FOR PRODUCTION OF A NONWOVEN WEB

Filed Sept. 28, 1971

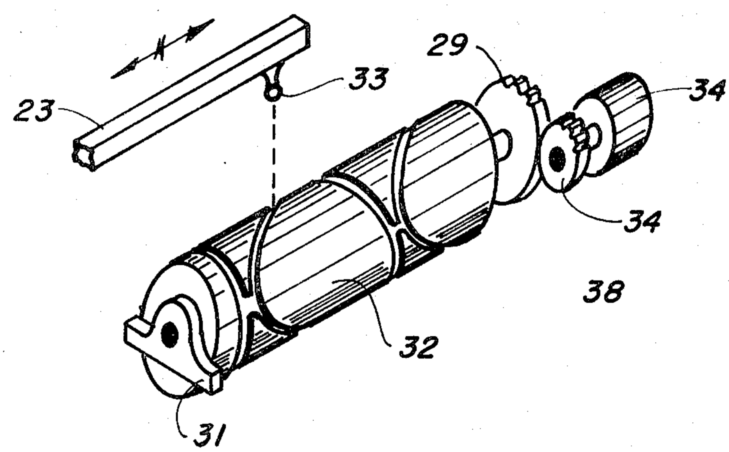

FIG. 5

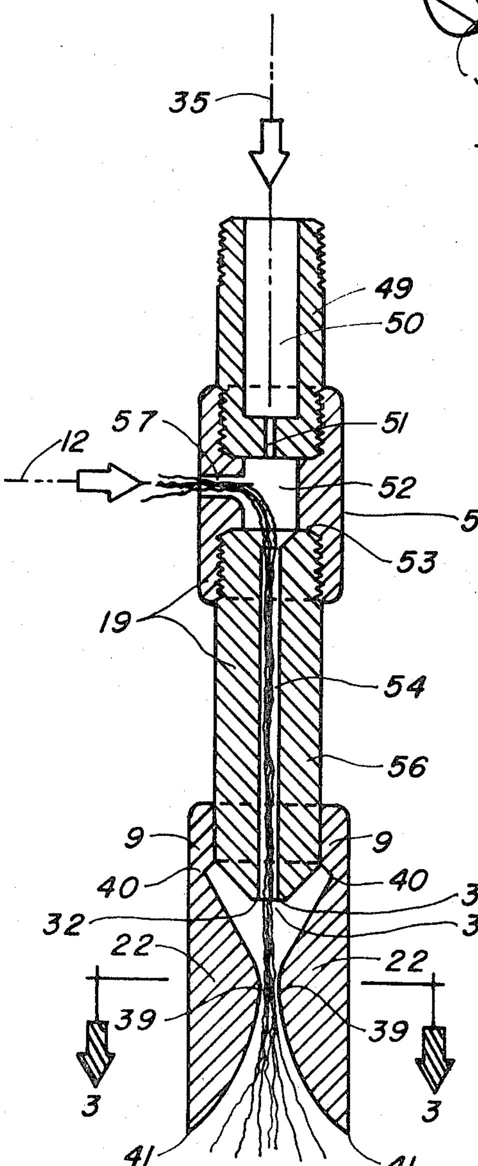

FIG. 2

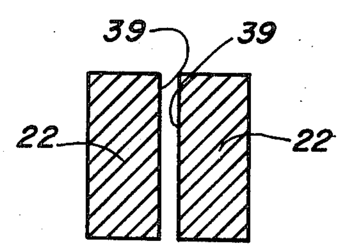

FIG. 3

INVENTORS
Walter P. Lipscomb
Garland L. Turner

PROCESS AND APPARATUS FOR PRODUCTION OF A NONWOVEN WEB

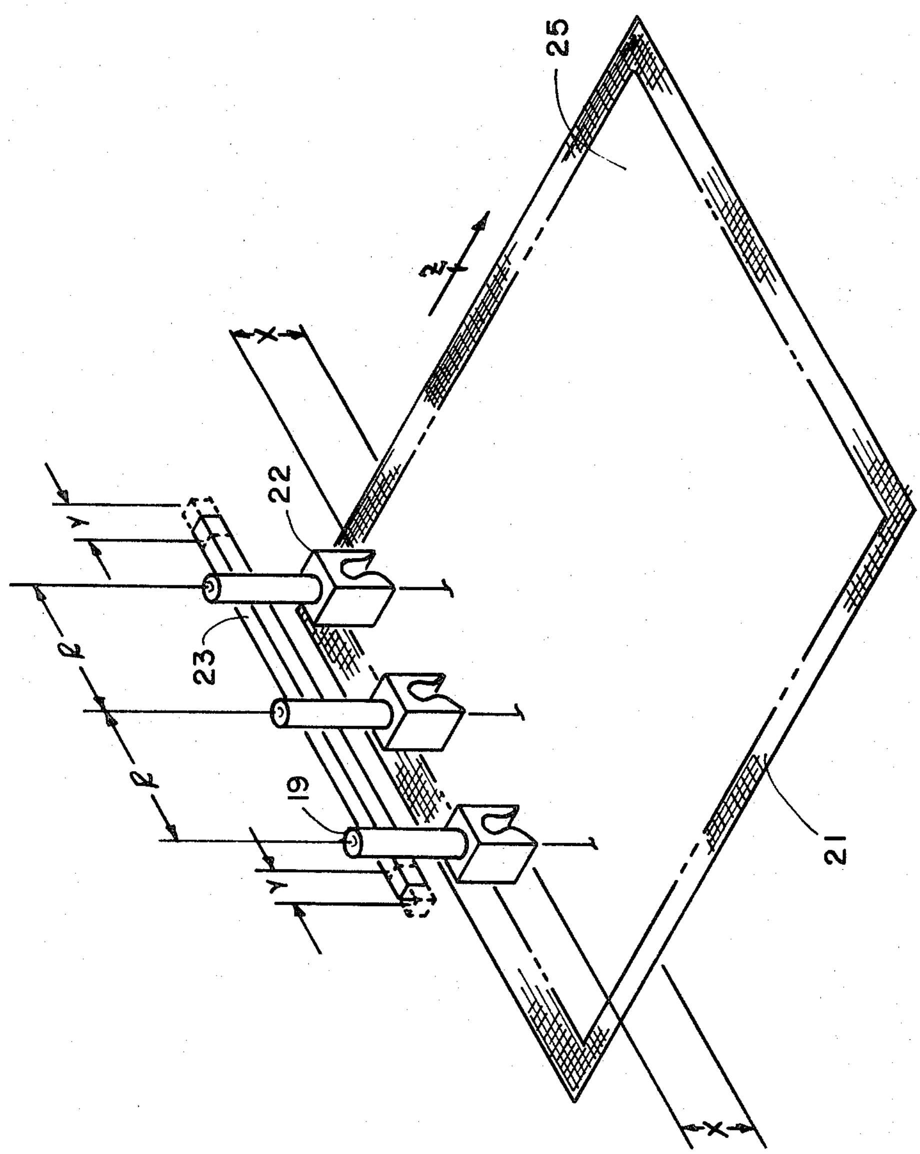

FIG. 4

INVENTORS
Walter P. Lipscomb
Garland L. Turner

PROCESS AND APPARATUS FOR PRODUCTION OF A NONWOVEN WEB

Filed Sept. 28 1971 4 Sheets-Sheet 4

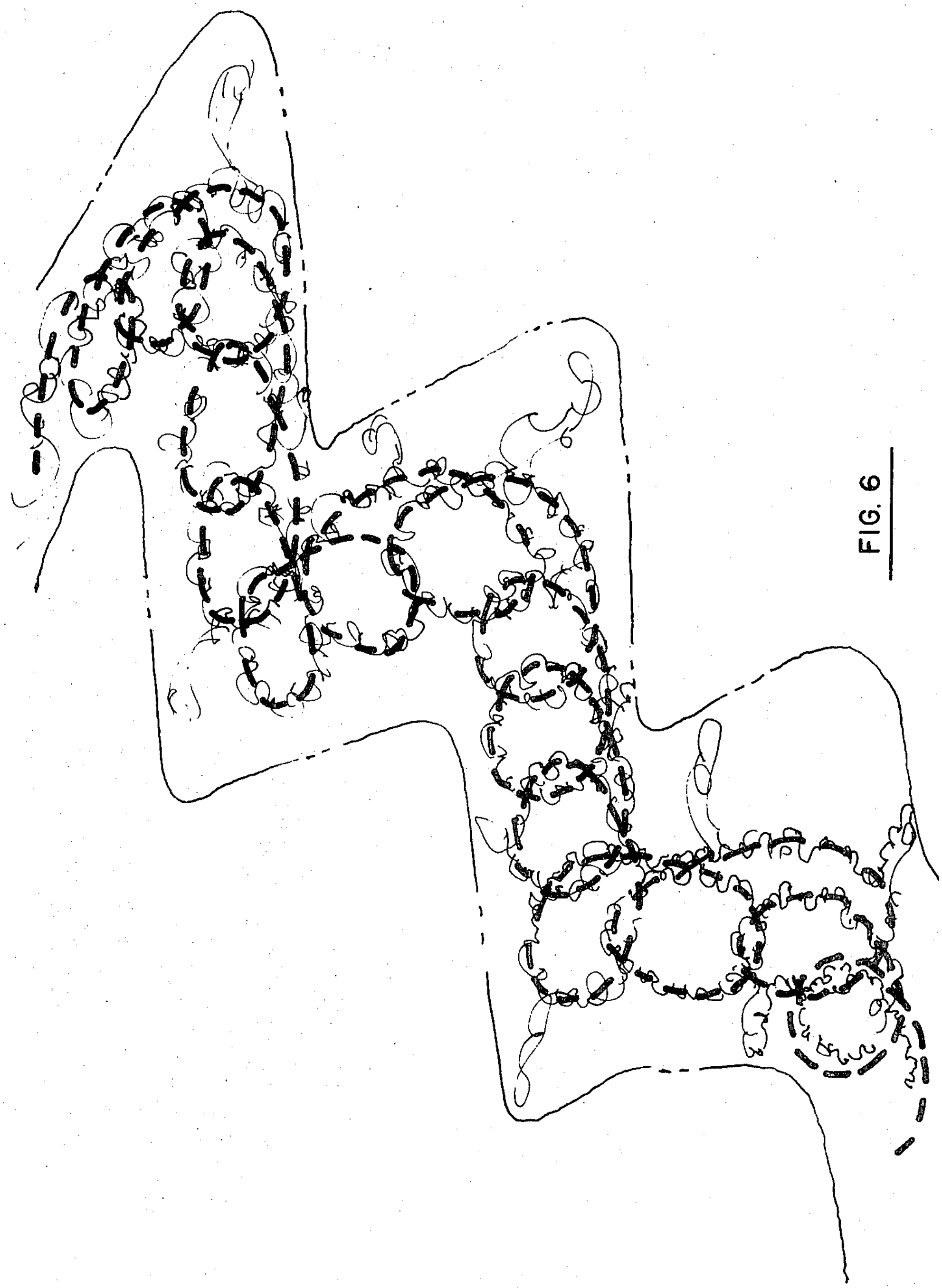

FIG. 6

INVENTORS
Walter P. Lipscomb
Garland L. Turner

United States Patent Office 3,776,796
Patented Dec. 4, 1973

1

3,776,796
PROCESS AND APPARATUS FOR PRODUCTION OF A NONWOVEN WEB

Walter Peter Lipscomb and Garland L. Turner, Chesterfield, Va., assignors to Allied Chemical Corporation, New York, N.Y.

Filed Sept. 28, 1971, Ser. No. 184,542
Int. Cl. D04h *3/05*
U.S. Cl. 156—181 28 Claims

ABSTRACT OF THE DISCLOSURE

Method and apparatus for producing a nonwoven web. Continuous polymer filament is melt spun, treated with a substantially permanent anti-static agent, drawn uniformly about a slowly rotating draw pin, and splayed onto a conveyor by reciprocation of a series of air jet aspirators, each employing an aspirating medium which is introduced into each aspirator and flows through each aspirator in a direction substantially parallel with the aspirator axis, to form a nonwoven web, which is thereafter fusion-bonded between rolls. Filaments having different properties may be used.

BACKGROUND OF THE INVENTION

This invention relates to a process and an apparatus for production of nonwoven webs. The invention is especially adapted for use in production, from continuous thermoplastic polymeric fibrous filaments, of nonwoven webs having uniformly drawn filaments and uniform thickness and of broad width.

The production of nonwoven webs of fibrous elements is an activity of growing commercial importance. These webs permit attainment not only of textile structures having considerably lower costs than and properties equivalent to previously known fabrics of the woven types but also of hitherto unattainable structures having desirable properties and combinations of properties in terms of end use function and aesthetics. It is desirable to produce such nonwoven webs from a random placement of a multiplicity of continuous filaments of synthetic organic polymeric materials, thereby taking advantage of the reduced manufacturing costs inherent in such a procedure as well as producing structures of greatly increased strength and having other useful and distinctive properties.

Many techniques have heretofore been used in the production of nonwoven webs. It has been the exprience of those skilled in the art that achieving a given nonwoven structure requires controlling a large number of variables. Furthermore, it has been found that the controlling variables in their desirable ranges are often mutually exclusive, i.e. achieving one object completely often seems to necessitate missing another object completely. As a result, the nonwoven structures known in the present state of the art are the result of prudent compromises in balancing one set of objects against another.

For example, it has been proposed to separate bundles of filaments by repulsion effects produced when electrostatic charges of similar polarity are induced on the filaments. Processes which involve the use of electrostatic charges are adversely affected by costs of maintaining the charge, problems in controlling electrostatic-charge-producing devices, changes in atmosphere, and changes in the condition of the surfaces over which the filaments pass. Accordingly, difficulties arise in achieving consistent control. This particularly applies when, in the interests of economic operation, large bundles of filaments are to be separated and deposited to form a web, since it is difficult to charge a fast-moving bundle uniformly as the number of filaments is increased.

2

It has also been proposed to use an electric-powered electrostatic eliminator to remove, subsequent to spinning of the fiber-forming filaments, substantially all electrostatic charge induced on the filaments. Processes which involve the use of such substantially one-point electrostatic-charge removal do not ensure permanent protection against the future buildup of electrostatic charge on the filaments prior to formation of the nonwoven web or on the web itself subsequent to its formation. This failure to prevent buildup of static charge reduces the range of utility of nonwoven products formed in such processes.

It has further been proposed that solutions of high polymers be sprayed through nozzles employing a high velocity air stream, whereupon fibrous materials are formed. Generally, these processes have not achieved their potential of widespread industrial usage because the fibers produced and hence the nonwoven fabrics made frequently do not possess sufficient uniformity or strength. This is probably due mainly to the poor molecular orientation of the molecular chains in the fibers manufactured via such spray nozzles.

It has long been known that uniformity of laydown of uniform individual fiber elements in a web of randomly arrayed elements is a most important variable in reducing nonuniformity of physical properties, i.e. strength, in the final web. It also has been long known that the better the uniformity level of a given web, the more economical it is to employ that web in an end product. For if strength in all directions is the desired property in any given web, the average strength selected must be such that the minimum strength in each direction is at least as the required average strength. Attaining this highly desirable strength through uniformity of laydown of uniform fiber elements, however, has more often than not been achieved only at great expense, thereby precluding economical production of the nonwoven product. Furthermore, attaining a highly desirable degree of uniformity of the individual fiber elements themselves with conventional filament-drawing methods or apparatus has been reached, in many instances, at the expense of fine and complex control of numerous variables. For instance, in the utilization of static draw pins to orient fiber filaments subsequent to their formation after spinning, achievement of suitably drawn, uniform fiber elements is highly dependent on the type and nature of the polymer from which the filaments are spun and on a critical relationship between time and temperature.

These problems are particularly difficult when forming webs of substantially broad widths, i.e., exceeding 36 inches. There exists, in fact, considerable demand for wide webs in sizes exceeding 15 feet. The problem of laying down a wide web largely results from the fact that the types of devices employed to produce the fibrous elements are of such a nature that a web of large width requires the combining of a plurality of such devices. It is of common knowledge in the art to unite a plurality of separate filament producing devices, i.e. spinnerettes, and to attempt to combine the filaments produced by such spinnerettes in a manner such that there is the least disturbance of the final product. For instance, producing a web having a width of several feet normally requires utilization of several fixed aspirators, each having individual spinnerettes and each often restricted to a small web laydown area normally not exceeding eight inches. Even where a single spinnerette and a single aspirator capable of producing a sufficient multiplicity of fibrous elements to lay down such a wide web has been constructed, it has been found that, with the vastly increased dimensions of such a spinnerette-aspirator combination, the uniformity of fibrous element distribution in the web has declined some-what, thus substantially devaluating the purpose of constructing such a combination.

SUMMARY OF THE INVENTION

In view of the above, it is a primary object of the invention to provide a mechanically simple, inexpensive and reliable process and apparatus for producing a nonwoven web of randomly disposed filaments which are substantially uniformly distributed throughout said web. Further, it is an object to provide such a process and apparatus characterized by the use of a minimum of difficult-to-control devices. Additionally, it is an object to provide an improved process and apparatus for so producing a web of filaments from a fiber-forming polymer, these webs being resistant to subsequent buildup of electrostatic charge at least for a time sufficient to produce a nonwoven web product. It is still a further object to provide an aspirating apparatus for laying down a nonwoven web of fiber-forming polymeric filaments arrayed in random nonparallel arrangement, which filaments undergo a minimum of twisting, knotting, entanglement and turbulence within such aspirating apparatus. It is still a further object to provide a drawing apparatus which significantly increases the degree of orientation and hence the degree of uniformity of the filaments within the nonwoven web. Further objects and advantages of the present invention will become apparent from the description of the invention which follows.

The above and other objects are achieved according to the present invention which involves a process for forming a nonwoven web which includes the steps of: (a) treating filaments with an effective, compatible anti-static agent; (b) feeding a series of bundles of such filaments to each of a series of aspirators and through the aspirators, each of the bundles having substantially no significant electrostatic charge thereon; (c) splaying each of such bundles from the exit of each aspirator in a pattern such that filaments from a given jet overlap those from the next adjacent jet by substantially less than 100 percent when each of the aspirators is spatially stationary, preferably overlapping from 8 to 25 percent, while traversing each aspirator in a reciprocating motion; (d) depositing said filaments onto a substantially horizontal conveyor moving in the direction generally transversely of the direction of traverse of said aspirating jets, so as to form a web of randomly disposed filaments substantially uniformly distributed throughout said web. Preferably, the filaments are deposited on the conveyor in an arrangement characterized by a random pattern within a swirl pattern within a zig-zag pattern.

In a preferred embodiment, each of said aspirators in an aspirator jet which comprises a hollow nozzle portion for receiving an aspirating medium, a hollow collar portion for receiving a bundle of filaments and for contacting the bundle with the aspirating medium, and a hollow diffuser portion for aspirating the filament bundle with the aspirating medium. The nozzle, the collar, and the diffuser are concentric with respect to one another. Each such jet is characterized by the use of an aspirating medium which is introduced into the jet in a direction substantially parallel with the axis of the jet and flows through the jet in the same parallel direction, so as to minimize twisting, or entanglement of the filaments. The filaments enter the jet through the collar at an angle to that of the jet axis. The diameter of the passageway of the nozzle ranges preferably from 5 percent to 40 percent, more preferably from 20 percent to 33 percent, of the length of the nozzle passageway. The cross-sectional area of the nozzle passageway ranges preferably from 10 percent to 50 percent, more preferably from 25 percent to 35 percent of the cross-sectional area of the passageway of the diffuser. The diffuser passageway diameter ranges preferably from 1 percent to 15 percent, more preferably from 2 percent to 10 percent, of the length of the diffuser passageway. The cross-sectional area of the diffuser passageway occupied by the filaments in the diffuser passageway ranges preferably from 0.1 percent to 5 percent, more preferably from 0.2 percent to 1.5 percent, of the total cross-sectional area of the diffuser passageway.

In another preferred embodiment of this invention, continuous filaments may be drawn uniformly prior to feeding onto each aspirator jet by means of at least one slowly rotating draw pin over which the filaments pass or contact. It is essential that the temperature of the filaments prior to contacting the draw pin be less than the glass transition temperature of such filaments and that such filaments not make a complete 360 degrees wrap around any such pin. The draw pin is positioned spatially so as to provide a predetermined extent, less than 360 degrees of surface contact of the filaments over the circumference of the draw pin such that the velocity of the filaments on the surface of the draw pin is less than the filament velocity at future entry into the aspirator. Preferably, the draw pin is used in combination with a high-speed driven roll placed after the draw pin in the process. The high-speed driven roll is positioned and driven at a surface speed of rotation such that linear filament velocity at the initial point of contact of such filaments on the high-speed driven roll is greater than, more preferably from 1.2 to 4 times greater than, the linear filament velocity at the substantially central point of contact of the filaments on the surface of the draw pin. Through the utilization of the slowly rotating draw pin, fabrics of slightly greater elongation-at-break, greater tear strength, and lower boiling water shrinkage are produced with this slowly rotating draw pin than by conventional drawing methods.

An unbonded web produced according to the process of this invention may be subjected to bonding, such as by passing the web between heated rolls. At the same time, the web may also be subjected to further processing, such as embossing or similar working treatments, to impart additional aesthetic properties thereto. The properties of the final product are dependent on the filament properties and the nature of bonding and embossing treatments.

It is only through the use of an effective, compatible anti-static agent and the use of both a plurality of aspirator jets as described herein and a reciprocating mechanism to reciprocate the jets at a predetermined stroke length and rate in a direction generally transversely of the direction of movement of a conveyor receiving the splayed filaments that the primary advantages of the process of this invention can be obtained. The use of such an anti-static agent permits the filaments to be substantially static-free at least for a time to manufacture a nonwoven web product according to the process of this invention. The use of the plurality of aspirator jets in combination with the reciprocating mechanism provides a quick and effective means for forming a randomly disposed but substantially uniformly distributed nonwoven web of great width and of uniform thickness.

The invention will be more clearly understood and additional 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 of an apparatus for carrying out the invention;

FIG. 2 is an elevational view in cross-section of an aspirating jet of the invention, with an optional splaying device attached to the exit end thereof;

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

FIG. 4 is a large scale perspective view of three aspirator jets, each with splaying devices;

FIG. 5 is a schematic perspective view of a reciprocating mechanism used in the invention; and

FIG. 6 is a schematic view showing the pattern formed by a given filament making up part of the web.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a bundle of filaments **12** is melt spun from a spinnerette **13** through a cross-flow quench stack **14** and is passed to a finish roll **15**. Finish roll **15** is continuously coated with a uniform layer of a liquid anti-static wetting agent by the submersion of a minor portion of the roll **15** in reservoir **11** which contains the anti-static agent. Anti-static agent in reservoir **11** is maintained at a level such that a minor portion of the finish roll **15** always contacts the agent. In general, anti-static agent suitable for use in this invention is any one which effectively dissipates or effectively prevents the buildup of electrostatic charge on the filaments for a time which is at least as great as the time it takes to manufacture a nonwoven web product, which is not otherwise incompatible chemically or physically with the filaments, which treats each filament substantially uniformly, and which is not a deterrent to surface bonding. Such effective, compatible anti-static agents may coat the filaments externally as a liquid overfinish subsequent to filament formation via spinning so as to maintain such filaments sufficiently static-free during their manipulation in processing to a final product. Alternately, such anti-static agent may be introduced into the fibrous filament-forming polymer at about the time of spinning sometimes also into the filament-forming polymer during its formation, so that the resulting filaments are at once antistatic and remain so substantially during their subsequent use. Effective, compatible anti-static agents exhibiting these properties have been found. Accordingly, an anti-static agent having utility in the present proces is selected from the group consisting of sulfonated esters of petroleum derivatives, ethoxylated alkyl amines, surface-active quaternary ammonium derivatives, active polyoxyethylated derivatives, active oxyethylated synthetic fatty amine derivatives, polyethylene glycol acrylates, piperazine compounds, poly-(alkylene ether) containing only the elements carbon, hydrogen, and oxygen and having a molecular weight greater than 600, copolymers of polypropylene oxide and polyethylene oxide polymerized onto ethylene diamine, and condensation products of a fatty acid with glycerine previously condensed with ethylene oxide. Preferred active quaternary ammonium compounds include those containing a pentavalent nitrogen atom to which there is attached one ionizable group such as halogen or sulphate; e.g. stearamido-propyl-dimethyl nonyl-ethenoxy ammonium chloride. A preferred poly(alkylene ether) includes polyethylene ether glycol and generally those such ethers having a hydroxyl group at one end and a nonyl-, decyl-, naphthyl-, or other similar phenyl group at the other end. A more detailed list of anti-static agents suitable for use in this invention may be found in Textile Finishing by A. J. Hall (Haywood Books, London, 1966). Most preferred antistatic agents for this invention include ethyoxylated alkyl amines or sulfonated glycerol trioleate, a sulfonated ester of a petroleum derivative. To any of these most preferred anti-static agents may be added an inert lubricant and a consonant nonionic emulsifier so as to impart superior finishes to the fibrous filaments after melt spinning. In addition, the finish comprising the most preferred anti-static agent, the inert lubricant and the nonionic emulsifier may also function as an aqueous emulsion film on the fibrous filaments and thereby quench, hydrate and generally fix the crystalline structure of such filaments. Use of such suitable anti-static agents allows producers of nonwoven webs greater freedom in varying web fabric properties.

From finish roll **15**, the coated filament bundle **12** having a temperature less than its glass transition temperature is passed over, but not completely around, slowly rotating draw pin **16** and thence around high-speed driven roll **10** and undriven separator roll **17**. The draw pin **16** rotates via variable speed motor **9** at a slow speed, preferably from 5 to 15 r.p.m., and has a small diameter, preferably from approximately 0.5 inch to approximately 2 inches. Generally, the diameter of the draw pin **16** is dependent on the frictional properties of the filament bundle over pin **16**. The effect of the combination of the slowly rotating draw pin **16** with the high-speed driven roll **10** is to uniformly attenuate and thereby to uniformly orient substantially all filaments of bundle **12**. Driven draw roll **10** and separator roll **17** are rotated in the direction shown. Surprisingly, draw pin **16** may be rotated in either direction. Filament bundle **12** is passed around driven roll **10** and separator roll **17** for a number of times which is sufficient to assure attainment of uniform drawing. From rolls **10** and **17**, filament bundle **12** is passed to feed rolls **18**. From each of rolls **18**, the filaments are fed into each of a plurality of aspirator jets **19**. Filament bundles having a broad range of denier, i.e. 30 to 3400 total denier, may be used in each aspirator jet **19**. Preferably, each filament bundle **12** entering each jet **19** consists of from 10 to 500 filaments, and preferably has a denier per filament of from 3 to 20. The enumerated ranges for filaments per bundle and denier per filament are not limiting and are disclosed as indicative of suitable filament bundle size for effective utilization in suitable aspirator jets hereinafter more fully described. The filament bundle **12** passes through each jet **19** at a linear speed which is preferably at least three times, more preferably from 10 to 500 times, the linear speed of the horizontal conveyor **21**. The conveyor **21** is powered by variable speed motor **58**. With linear filament speeds less than three times horizontal conveyor speed, degree and randomness of filament spreading tends to be minimal. With filament speeds greater than 500 times conveyor speed, the filaments tend to rebound too rapidly and extensively from the conveyor as a result of interplay of momentum forces, thereby drastically limiting overlapping of deposited filaments. Practical conveyor speeds range from 2 to 100 feet per minute, preferably from 3 to 60 feet per minute.

Shaped baffles may be added to the sides of conveyor **21** along the laydown area so as to eliminate trimming waste loss and to allow superior web side formation. Splaying device **22** may be connected to the exit end of aspirator jet **19**. These splaying devices are designated to augment the opening out or spreading of the filament bundles prior to deposition of the filaments onto horizontal conveyor **21**. The conveyor surface is placed below the aspirator jet exit at a distance such that efficiency of random, wide dispersal of filaments on the conveyor in a uniform manner is achieved. Consequently, a distance from the exit of the aspirator jet **19**, or of the splaying device **22** that may be attached to the aspirator jet, to the conveyor **21** in the range of approximately 10 inches to 36 inches gives satisfactory operability. Distances less than 10 inches are not satisfactory because normal velocities of the aspirating medium, i.e. air, are sufficient to disturb and disrupt the laydown pattern even with the use of suction devices under the conveyor. With distances greater than 36 inches, filament control becomes poor and laydown becomes erratic because of low air velocities.

To increase the degree of uniform, wide, random deposition of the individual filaments onto the conveyor **21**, aspirator jets **19** are mounted on a reciprocating yoke **23**. Yoke **23** and aspirator jets **19** attached thereto reciprocate in a manner generally transversely of the direction of movement of the conveyor **21**. In this manner, the filaments are enabled to be deposited onto the conveyor **21** in a randomly disposed but substantially uniformly distributed manner. Yoke **23** is mounted for reciprocation on bearings (not shown) and is actuated by any conventional reciprocating mechanism **38** capable of providing reciprocating motion. As depicted in FIG. 5, the presently preferred actuator **38** is a spiral cam **32** mounted on bearing **31** and follower **33** which are operated via gear train **5** by variable speed motor **34**. The cycles per minute of reciprocation can be varied by changing the speed of the motor **34**. The nature of the reciprocation and length of stroke can be varied by changing cam **32**. A suction chamber **36** is provided beneath that portion of conveyor **21** on which the filaments are being laid down. Vacuum pump **37** is the source of suction for chamber **36**. Suction chamber **36** withdraws the aspirating medium that exits from the jet and that may interfere with filament deposition on the conveyor and thereby facilitates uniform distribution of a randomly disposed web on the conveyor.

At the end of conveyor **21** the unbonded web **25** is passed between patterned heated fusion rolls **26** and smooth unheated rolls **29** so as to bond and emboss the web **25**. Subsequent to fusion, the web is passed under tension between a chilled roll **27** and a smooth unchilled roll **30** so as to prevent unequal shrinkage upon cooling. The chilled roll **27** which is cooled by means such as internal circulation of cool water is also of considerable value in making the web more readily handleable. Upon passing from the chilled roll **27**, the fusion-bonded web **35** is passed across moving receiving surface **59** and is wound up on a mandrel **28** for shipment to the processor.

The process of this invention can be used to make webs or sheets from any fiber filament-forming thermoplastic polymer from which filaments can be obtained. Such polymers include: polyamides, e.g. poly(epsilon-caprolactam) (hereinafter nylon 6), 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 filament-forming thermoplastic polymers include nylon 6, nylon 66 and polyethylene terephthalate. It is further possible, practicable and, in some cases, desirable to utilize polymers of different chemical compositions of the process of this invention. Thus, while the description of the process of this invention set forth above has indicated that all of the filaments may have the same composition and thus produce a nonwoven web product having a substantially uniform composition, there may be circumstances where it is desirable to provide, as part of the nonwoven web products, filaments of a different chemical composition than the chemical composition of other filaments of the web product. These multi-polymer webs can be produced in this invention, for example, by providing multi-feeds to one or more aspirating jets, each new polymer feed formed from a separate spinning, finishing and drawing device. Thus, products may be produced which have one, two, or many more different chemical compositions of fibers in the web product. These different compositions may be distributed uniformly in the product or may be disposed in particularly limited areas of the product in order to produce a desired pattern thereon.

Referring to FIG. 2, the preferred aspirator jet of this invention comprises: (a) a hollow air nozzle **49** which is externally threaded at each end and which has an air inlet conduit **35** attached to its upper end; (b) a hollow collar **55** which is internally threaded at each end so as to connect and hold in alignment air nozzle **49** and diffuser **56** and which has an annular inlet aperture **57** for receiving filament bundle **12**; and (c) a hollow diffuser **56** which is externally threaded at its upper end and through which the filaments and high velocity air are propelled to splaying device **22** and thereafter onto a receiving surface. The inlet aperture **57** is arranged to direct the filaments entering therein downwards, i.e. in the direction of air flow. We have found that the diameter of nozzle passageway **51** ranges from less than 40 percent, preferably from 5 percent to 40 percent, more preferably from 20 percent to 30 percent, of the length of nozzle passageway **51**, so as to minimize turbulence and air diffusion within the nozzle. Further, the cross-sectional area of the nozzle passageway **51** ranges preferably from 10 percent to 50 percent, more preferably from 25 percent to 35 percent, of the cross-sectional area of the diffuser passageway **54**. With values of nozzle area less than 10 percent of the diffuser area, the filament bundle exiting the aspirator jet tends to exhibit poor or inadequate spreading. With values of nozzle area greater than 50 percent of diffuser area, the aspirator tends to exhibit poor pull and poor aspiration, i.e. overload. Also, the diameter of diffuser passageway **54** is preferably from 1 percent to 15 percent, more preferably from 2 percent to 10 percent, of the length thereof. With values of diffuser diameter less than 1 percent of diffuser length, diffuser construction via drilling becomes extremely intricate without corresponding comparable improvements in aspirator jet operation being achieved. With values of diffuser diameter greater than 15 percent of diffuser length, aspiration and spreading of filaments tends to become relatively hampered. Still further, the diffuser entrance chamber **53**, is designed so as to facilitate flow of the filament bundle from the collar **55**. Accordingly, the maximum diameter of diffuser chamber **53** is preferably from 2 to 3 times the diameter of diffuser passageway **54**, and the chamber is preferably conical in shape. For example, a suitable diffuser entrance passageway has a maximum diameter of approximately 2.5 times the diameter of diffuser passageway **54** and has a shape of a 60° cone. Still further, it is preferred that a small flat annular ring **32** surrounds diffuser passageway exit **31** and have a conical taper which sweeps back from exit **31** to the outer wall of diffuser **56** at an angle ranging from 30° to 50°. Finally, the cross-sectional area of diffuser passageway **54** is designed to be such that the cross-sectional area occupied by the filaments during passage therein is less than 5 percent, preferably from 0.1 percent to 5 percent, and more preferably from 0.2 percent to 1.5 percent, of the total cross-sectional area. With values of diffuser cross-sectional area occupied by the filaments being greater than 5 percent, the filament bundle tends to be thrown and impacted rather than to be spread widely and uniformly randomly from the jet exit. With values of less than 0.1 percent, economics of aspirator construction are not realized. The respective lengths and diameters of air nozzle entrance chamber **50** and of collar passageway chamber **52** are not critical. However, such dimensions should be used as are practical; i.e. compatible with the overall operation of the present invention. The dimensions of inlet aperture **57** and of collar chamber **52** are adjusted to suit the effective diameter of the filament bundle **12** entering therein.

An aspirator jet design of the above or similar type in which the aspirating medium, i.e. air, is introduced as a coherent column parallel with the jet axis is believed to be an improvement over conventional aspirating means. Conventional aspirator jets which introduce high velocity air at an angle to that of the aspirating jet axis produce an undesirable vortex action therein which twists, knots, or entangles the filaments. In such conventional jets, local pockets of turbulence which cause filaments to entangle are produced. Aspirating jet **19** as described above, keeps the filaments from any substantial twisting, knotting or entanglement. In operating aspirator jet **19**, the aspirating media, which is a pressurized fluid such as air, is introduced from a supply source **12**, not shown, into chamber **50** at a pressure which is sufficient to forward the filaments from the jet at high velocity but which is not so high as to enhance turbulence. Such aspirating media pressure preferably ranges from 15 p.s.i.g. to 120 p.s.i.g., more preferably from 30 p.s.i.g. to 100 p.si.g The aspirating media enters and flows through nozzle passageway **51** and exits therefrom as a high velocity stream. The extract pressurized state of the aspirating media is contingent upon several conditions and thus may be varied to suit the specific circumstances. Factors which influence operating pressures are aspirating jet design; pressure of aspirating media consumed, type and properties of filament-forming polymer, degree of orientation to which filaments have been subjected, and resulting properties of the nonwoven product. The high velocity stream which exits nozzle passageway **51** engages filaments **12** after entering aperture **30** with sufficient energy to propel the filaments through collar chamber **52** into diffuser chamber **53** through diffuser passageway **54** and out of aspirating jet **19**.

Although we have found that the aspirator jet heretofore described is most preferred for use in the process of this invention, the invention is not limited to such an aspirator jet. In general, suitable aspirator jets are constructed so as to forward the filaments at high velocity, to generate sufficient pull therein, to maintain the filaments under minimum tension, and to open and separate the filament bundle during exit from the aspirator jet. Furthermore, the jet should be designed to avoid turbulent flow which leads to entanglement and bunched filaments therein and consequently to nonuniform webs. Depending on design preferences when using the present invention, the filaments from a single spinneret may supply several aspirator jets. Alternatively, the filaments from more than one spinnerette may supply a single jet.

In a preferred embodiment of the present invention, referring to FIGS. 2 and 3, a splaying device **22** is attached securely to the bottom portion of aspirator jet diffuser **56** by a suitable means such as welding or screwing. Splaying device **22** is patterned so as to make use of the Coanda principle of aerodynamics. Splaying device **22** involves a modification and utilization of this principle to obtain a new and useful result. Essentially, the filament bundle **12** as it issues from the aspirator jet diffuser passageway **54** begins to splay or spread. With improved Coanda splaying device **22** attached to the exit of jet **19** in a manner such that the distance along the center-line or axis of the jet from jet exit **31** to lines of greatest convergence **39** is of a magnitude which is designed to enhance filament spreading, the slightly splayed filament bundle **12** contacts splaying device **22** and spreads out in a pattern which exceeds the width of a fully splayed filament bundle at a corresponding distance from the aspirator jet exit when using the aspirator jet alone. Such center-line distance should neither be so small as to have little effect on spreading of filaments that exit from the aspirator jet as a very narrow diameter, high velocity stream for short distances nor so large as to also have little effect on spreading of filaments that have insufficient viscosities at great distances from the aspirator in order to change the filament flow pattern substantially. Preferred is a center-line distance from jet exit **31** to greatest convergence lines **39** ranging from approximately 4 to approximately 10 times the diameter of jet exit **31**. Experience has shown that the minimum distance between maximum convergence lines **39** for effective filament spreading is at least as great as the diameter of aspirator exit passageway **54**.

Improved Coanda splaying devices suitable for use in this invention may include any device having continuous smooth, preferably symmetrical, opposing surfaces of curvature in accordance with Coanda's principle. Such opposing surfaces exhibit a converging to diverging pattern as the surfaces proceed in distance from the exit **31** of the aspirator jet **19**. 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** in vertical distance to a line (shown as point **39**) of maximum convergence and thereafter to a line (shown as point **40**) of maximum divergence. More preferably, the lines of maximum convergence and the lines of maximum divergence are perpendicular in reference to the center-line of aspirator exit passageway **54**, so as to enhance symmetrical splaying patterns. The use of splaying device **22** in combination with aspirator jet **19** not only broadens the width of filamentary web deposited on the conveyor but also, surprisingly, deposits the individual filaments in a more random pattern.

In FIG. 4 is illustrated the physical relationship of the aspirator jets with the reciprocating mechanism and the horizontal conveyor within the process of this invention. "Y" represents the length of stroke of reciprocating mechanism in inches and the linear speed of the mechanism in cycles per second. "R" represents the center-line distance between adjacent aspirator jets. "X" represents the distance from the exit of the aspirator jet, or splaying device if applicable, to the conveyor **21**. "Z" represents the linear speed of conveyor **21** in a direction which is substantially transverse to the direction of reciprocation of the reciprocating yoke **23**. At predetermined operable filament speeds from aspirator jet exit, air velocities, cross-sectional areas of aspirator exit passageway occupied by filaments, and aspirator conveyor distances, it has been found that, with judicious choice of R, Y and Z, a superior uniform web of a specified width and thickness can be obtained. By overlapping the splayed filament section deposited by one jet with the section deposited by an adjacent jet and so on for each jet, a uniform web may be obtained. The range of operable values of R, Y and Z in this invention are designed to be such that the filaments do not become bunched or entangled and thereby the webs do not become nonuniform. At suitable values of R, Y and Z, the filaments exit from each aspirator in a unique arrangement which is characterized by a randomness within a swirl pattern within a zig-zag pattern, so as to assure a superior wide and random degree of filament dispersal uniformly distributed on the laydown area. In order to properly utilize aerodynamics effects and to attain efficient and effective filament dispersal, there should be substantially less than 100 percent overlap of filaments splayed from adjacent jets when the jets are stationary prior to reciprocation. The preferred range of filament overlap from adjacent jets found in practice varies from 8 percent to 25 percent overlap in order to yield the best uniformity and greatest width consistent with the smallest amount of edge waste. To obtain suitable degrees of overlapping, values of R in the range of 40 percent to 145 percent of stroke length, stroke of reciprocator in the range of approximately 1.5 to 18 inches, and linear reciprocating speed of the reciprocator compatible with stroke length and conveyor speed, preferably in the range of 5 to 150 cycles per minute, are generally practical and economically feasible for use in this invention. Faster, shorter strokes provide greater randomness of filament distribution. Preferably, in the operation of the process of this invention, each jet is parallel to and at the same distance apart from each adjacent jet and is reciprocated at the same stroke length and reciprocating speed. Alternately, but at a sacrifice to a symmetrical laydown pattern, the jets may be positioned at small angles to adjacent jets or may be at different distances apart or may have different stroke lengths so long as reciprocating speed of each jet is substantially the same.

We recognize that these exact dimensions and speeds and their enumerated ranges disclosed herein are not limiting and depend on a complex relationship among length of stroke of reciprocating mechanisms, speed of stroke of reciprocator mechanism, center-line distances between adjacent aspirator jets, jet-conveyor distances, conveyor speed, filament speed through jets, air velocity at the jet exit, cross-sectional jet through area occupied by filaments, etc. We have found that a wise choice of these dimensions and speeds subject to the general limitations herein discussed within the scope of our invention assures production of a superior uniform nonwoven web of a thickness per pass and width which are generally greater than those of webs produced by processes utilizing a comparable volume of fiber filament laydown equipment. Thus, economies of this invention are realized.

Referring to FIG. 6, it can be seen that the claimed process lays down the individual filaments into a pattern characterized by a filament pattern comprising a random pattern within a swirl pattern both of which patterns are within a zig-zag pattern. This pattern for each individual filament tends to enhance the uniformity of properties obtained in the web formed by the instant process.

Attainment of highly uniform drawn filaments may also be achieved in the process of this invention. To accomplish this, an improved drawing step and apparatus may be added subsequent to filament spinning and prior to filament splaying from the aspirator onto the conveyor. Superior nonwoven webs having uniformly drawn filaments may be produced in the process of our invention by using at least one slowly rotating draw pin over which the filaments pass. The primary function of such a draw pin is to effect a highly uniform draw which results in highly uniform filaments rather than to effect a substantially greater degree of draw. It is essential for effective drawing that the temperature of the filaments prior to contacting the draw pin be lower than the glass transition temperature of the filaments so as to prevent sticking of the filaments to each other and process equipment, and to enhance uniform drawing of the filaments. It is further preferred that the filaments not make a complete 360° wrap around the draw pin so as to substantially eliminate slipping or uneven filament flow which commonly occurs on conventional drawing apparatus. The slowly rotating draw pin resists rise of filament temperature caused by friction which normally occurs in conventional drawing apparatus upon contact of the filaments with static or stationary draw pins or rolls. Such drawing having minimal friction is accomplished by placing the slowly rotating draw pin spatially so as to provide a predetermined extent, less than 360°, of surface contact of the filaments over the circumference of the draw pin in a manner such that the velocity of the filaments at the substantially central point of contact of the filaments on the surface of the draw pin is less than the filament velocity at future entry into the aspirator. The surface of the draw pin is constructed preferably of a relatively high friction, but smooth material, e.g. from 2 to 40 root-mean-square, having high surface hardness, and high abrasion resistance. A preferred surface material is hardened ceramic. While the filaments preferably do not make a 360° wrap around the draw pin, there may be instances where a wrap in excess of 360° is acceptable or even preferred.

Preferably, the draw pin is used in conjunction with a high-speed driven roll placed at a point subsequent to the draw pin in the process. The high-speed driven roll is positioned and operated at a surface speed of rotation such that filament velocity at the initial point of contact of the filaments on the high-speed driven roll is greater than, more preferably from 1.2 to 4 times greater than, the filament velocity at the substantially central point of contact of the filaments on the surface of the draw pin. Ratios of filament velocity on high-speed roll to filament velocity on slowly rotating roll must be greater than 1 so as to effect drawing. Effective and efficient drawing occurs when such ratio is from 1.2 to 4. The respective exact lengths, diameters, and rotational speeds of the draw pin and the high speed driven roll should be practical, i.e. compatible with the overall economic operation of the present process.

If the draw pin is rotated at a slow speed, preferably from 5 r.p.m. to 15 r.p.m. so as to minimize loss of mechanical energy in operating the pin, friction variations are smoothed out and highly uniform filaments are produced. When drawing with the slowly rotating draw pin, rate of drawdown is reduced so as to augment the degree of uniformity of each filament in the bundle. For instance, drawdown may range from 2–1 to 3.5–1 via the slowly rotating draw pin in cases wherein conventional drawing apparatus has drawdown of 6–1. Such high rates of drawdown present in conventional drawing apparatus restrict the degree of filament uniformity which can be attained due to draw roll friction and variable orientation of the filaments. Further, uniform drawing with the slowly rotating draw pin is achieved without addition of heat to the drawing step; hence, unexpectedly lower bonding temperatures are required. This drawing arrangement with the slowly rotating pin is believed to be an improvement over existing means of drawing since uniform drawing can be accomplished without fine and complex control of critical time and temperature variables and at substantially lower speeds. Thus, the arrangement effects an over-all reduction of mechanical energy requirements and of the amount and sophistication of drawing equipment required, without significantly sacrificing drawn yarn properties, i.e. tenacity, tensile modulus and shrinkage. In fact, the following enumerated nonwoven web properties may be obtained: denier per filament in the range from 0.5 to 35, tenacity exceeding 5 grams per denier, elongation in the range from 29 to 160 percent, tensile modulus in the range from 5 to 20 grams per denier and shrinkage in the range from 2 percent to 8 percent. It is well known that oriented nonwoven webs such as oriented nylon generally have boiling water shrinkages above 10 percent; in fact, shrinkages ranging from 12 percent to 16 percent are normal. Reduction of this shrinkage from 6 percent to 8 percent requires heat setting by lengthy inefficient techniques, which generally are inoperable at low filament speeds. However, nonwoven webs which are drawn using the slowly rotating draw pin of this invention exhibit low shrinkages, often in the range from 2 to 6 percent, and no separate heat setting step is required.

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

Example I

Using the apparatus shown in FIG. 1, nylon 6 having a relative formic acid viscosity of 55 is spun at a temperature of 260° C. through a spinnerette **13** with 32 holes, each hole being approximately 0.016 diameter by 0.04 inch length, at a rate of 40 grams per minute. Directly below spinnerette **13**, the nylon filaments formed in the spinnerette are quenched in a 6-inch diameter quench stack **14** using a cocurrent air flow of 50 feet per minute. The top of the quench stack touches against the bottom of the spinnerette to minimize the effect of air flow on the spinnerette temperature. Below the quench chimney, the filaments in bundle **12** are passed around finish roll **15**. On roll **15** each filament in bundle **12** is substantially uniformly coated with sulfonated glycerol trioleate, a liquid anti-static agent, which is housed in reservoir **11** and which continuously contacts roll **15**.

The filament bundle **12** then passes at a one-half wrap over a 3-inch long, ⅝-inch diameter draw pin **16** which is roating counterclockwise at a speed of 10 r.p.m. Thereafter, the bundle **12** passes around high-speed driven roll **10** and undriven separator roll **17**. Filament velocity at the central point of contact of the filaments on the surface of the draw pin **16** is 200 feet per minute. Filament velocity at the substantially initial point of contact of the filaments on the high-speed driven roll is 710 feet per minute. High-speed driven roll **10** has a diameter of 6.3 inches. After five passes around driven roll **10** and separator roll **17**, the filaments are passed to feed rolls **18**, one roll located adjacent each of two aspirator jets **19**, each being parallel to the other and at a 12.5-inch centerline distance apart. A bundle of filaments converges at the inlet aperture **57** of each aspirator jet of the type described with reference to FIG. 2. The dimensions of the aspirating jet are as follows: nozzle entrance chamber **50** has a diameter of ⅛-inch and a length of 1$\frac{1}{16}$-inches; nozzle passageway **51** has a diameter of .042 inch and a length of $\frac{3}{16}$ inch; diameter of diffuser entrance chamber **53**, a 60° truncated cone, is $\frac{3}{16}$ inch; diffuser passageway **54** has a diameter of .076 inch and a length of 1¾ inches; and the diffuser passageway cross-sectional area occupied by filaments is approximately 0.5 percent of the total cross-sectional area. Air at ambient temperature and a constant pressure of 70 p.s.i.g. is used as the fluid. Filament speed through the jet was approximately 710 feet per minute. The two jets **19**, each providing a 17 percent overlap were mounted on yoke travelling at a 12-inch stroke length and 60 cycles per minute. Upon passage through the jets, the filaments were splayed from the jet exits onto a horizontal conveyor **21** moving at 16 feet per minute. The distance from diffuser passageway exit **31** of the aspirator jet **19** to the surface of conveyor **22** is 14 inches. The conveyor **21** is comprised of a 36-inch wide, 6-feet long belt composed of 20 mesh square weave stainless steel. Beneath that portion of the conveyor **22** on which the filaments were splayed was a suction chamber **36** which evacuated by means of a vacuum pump **37**. The web formed in this manner is coherent, even without bonding. A web of 3.0 to 3.5 grams per square yard is obtained. At the end of conveyor **21** the unbonded web is fusion-bonded at 187° C. at a nip pressure of 2000 p.s.i.g., cooled and wound up for storage.

The nonwoven web produced is characterized by having a random filament distribution throughout. The appearance of the web is uniform and is essentially free from filament aggregates. A web of 22 inches wide is obtained. The tensile breaking strength is 9 pounds per inch width per ounce per square yard. Weight of web is 5.7 ounces per square yard. Extensibility at break is 64 percent. Boiling water shrinkage before bonding is 5 percent. Tongue tear strength is 3.7 pounds per ounce per square yard.

As alternate methods of processing the unbonded web formed by a procedure similar to that described in this example, the unbonded unwoven web at the end of conveyor **22** may be bound with adhesives in emulsion form, adhesives or thermoplastics in dry powdered form, or plastisols. Alternatively, the web may be laminated to sheet thermoplastics. For instance, an unbonded nonwoven web may be impregnated with emulsion of vinyl acetate-acrylic adhesive and then dried; a tongue tear strength of 28 pounds for a 3.5 ounce per square yard web may be obtained.

Example II

A nonwoven web is prepared in a similar manner as in Example I, except that a splaying device which is essentially the same as that described in FIG. 2 is attached to the end of each aspirator jet. Results similar to Example I are obtained, with the exception that the nonwoven web produced has a uniform width which is substantially greater than that of web of Example I.

The nonwoven web or sheet prepared in accordance with this invention may serve a variety of useful purposes. It is possible to provide the nonwoven web fabric with a great variety of special physical properties such as broad width, weight per unit length, tuftability, stiffness, surface softening, filtration power, resiliency, insulating value, etc. to any desired and predetermined degree. Broad widths exceeding 12 feet, for example, can be attained by increasing the number of aspirator jets on the reciprocating mechanism. Tuftability, for example, can be attained by applying additional finish to the bonded web subsequent to passing it through the chilled roll. Surface softening of the nonwoven web, for example, can be achieved by applying a spin finish of zinc chloride to the filaments prior to their passage to the aspirator jets. Stiffness, for example, can be attained by impregnating the web with a solvent or plasticizer after the web is formed on the conveyor. With suitable coats and/or laminations, these nonwoven webs may serve in industrial applications in the place of conventional woven materials. By incorporation of a suitable binder, with or without an additional embossing operation, cloth-like articles are produced. The nonwoven webs prepared via this invention can serve as interlining or interfacing materials useful in imparting shape and/or stiffness to garments or other articles. All

of the above-mentioned articles which are based on such nonwoven webs are strong in resistance to tear, have good tensile properties, are dimensionally stable, are esssentially static-free, resist shrinkage, and some are significantly soft. Merely by way of illustration, continuous filament nonwoven webs of the herein disclosed types may be advantageously employed as backing for carpets, backing for upholstery, floor coverings, filters, coating substrates, interfacings, interliners for shoes, insulation, coverings for walls, fabric applications and the like. Many of these products can now, by following the teachings of the present invention, be manufactured so as to be priced competitively with comparable products heretofore manufactured from cheaper materials.

The practice of this invention is advantageous in several respects. It permits rapid and continuous preparation of useful filaments. It also results in high rates of production of the nonwoven webs therefrom. Such nonwoven webs may be composed of drawn and/or undrawn filaments or filaments having different properties. Static-free nonwoven webs exhibiting a broad range of thicknesses and/or widths can be readily and continuously formed into useful structures assuming a wide variety of form. Furthermore, formation of these nonwoven webs can be accomplished through a minimal amount of adjustment of the devices which will be used in the process of this invention. Hence, this invention exhibits a high degree of flexibility and is inexpensive and reliable.

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 limitation in the appended claims.

What is claimed is:

1. A process for the production of a nonwoven filamentary web comprising the steps of:

(a) treating filaments with an effective, compatible anti-static agent;

(b) substantially simultaneously feeding each of a series of bundles of said filaments through each of a plurality of aspirators, each of said bundles having substantially no electrostatic charge contained thereon;

(c) splaying said filaments of said bundles from the exit of each of said aspirators in a pattern such that the filaments from a given aspirator overlap the filaments from the next adjacent aspirator while traversing said aspirators in a reciprocating motion having a predetermined stroke length and linear reciprocating speed wherein said filaments from said given aspirator overlap said filaments from said next adjacent aspirator by from 8 percent to 25 percent when each of said aspirators is spatially stationary;

(d) depositing said filaments onto a substantially horizontal conveyor moving in a direction generally transversely of the direction of traverse of said aspirators,

so that said filaments are deposited on said conveyor in a path characterized by a random pattern within a swirl pattern both of which patterns are within a zig-zag pattern, said arrangement being in a direction substantially the same as the direction of forward motion of said conveyor so as to form a web of randomly disposed filaments substantially uniformly distributed throughout said web.

2. The process of claim **1** including splaying said filaments from the exit end of each of said aspirators into a Coanda splaying device, so as to effectively increase the area of filament deposition on said conveyor.

3. The process of claim **1** wherein said stroke length ranges from 1.5 inches to 18 inches and said linear reciprocating speed is compatible with said stroke length and the linear speed of said moving horizontal conveyor.

4. The process of claim **3** wherein the center-line distance between adjacent aspirators ranges from 40 percent to 145 percent of said stroke length.

5. The process of claim 4 wherein the linear speed of said filaments within each of said aspirators ranges from 10 times to 500 times said linear speed of said horizontal conveyor.

6. The process of claim 5 wherein the distance from the exit of said aspirator to the surface of said conveyor ranges from 10 inches to 36 inches.

7. The process of claim 6 wherein said effective, compatible anti-static agent is selected from the group consisting of ethoxylated alkyl amines and sulfonated esters of petroleum derivatives.

8. The process of claim 7 wherein said effective, compatible anti-static agent is sulfonated glycerol trioleate.

9. A process for the production of a nonwoven filamentary web comprising the steps of:

(a) treating filaments with an effective, compatible anti-static agent;

(b) drawing said filaments by passing said filaments over a slowly rotating draw pin at less than a 360° pass, said filaments having a temperature prior to contacting said draw pin of less than the glass transition temperature of said filaments, of surface contact of said filaments over the circumference of said draw pin in a manner such that the velocity of said filaments at the substantially central point of contact of said filaments on the surface of said draw pin is less than the filament velocity at future entry into an aspirator in said process;

(c) feeding a series of bundles of said filaments to each of a series of aspirators and through said aspirators, each of said bundles having substantially no electrostatic charge contained thereon;

(d) splaying said filaments of said bundles from the exit of each of said aspirators in a pattern such that the filaments from a given aspirator overlap the filaments from the next adjacent aspirator while traversing said aspirators in a reciprocating motion having a predetermined stroke length and linear reciprocating speed wherein said filaments from said given aspirator overlap said filaments from said next adjacent aspirator by from 8 percent to 25 percent when each of said aspirators is spatially stationary; and

(e) depositing said filaments onto a substantially horizontal conveyor moving in a direction generally transversely of the direction of traverse of said aspirators

to form a web of randomly disposed filaments substantially uniformly distributed throughout said web.

10. The process of claim 9 including the step of utilizing a high-speed driven roll after said slowly rotating draw pin, said high-speed driven roll being rotated at a surface speed of rotation such that the initial filament velocity at the initial point of contact of said filaments on said high-speed driven roll is greater than the subsequent filament velocity at the substantially central point of contact of said filaments on the surface of said draw pin.

11. The process of claim 10 wherein said initial filament velocity ranges from 1.2 times to 4 times greater than said subsequent velocity.

12. The process of claim 11 wherein said slowly rotating draw pin rotates at a surface speed ranging from 5 r.p.m. to 15 r.p.m.

13. The process of claim 8 wherein, subsequent to said treating step and prior to said feeding step, said filaments are drawn by passage over a slowly rotating draw pin and around a high-speed driven roll placed after said draw pin, said filaments having a temperature prior to contacting said draw pin of less than the glass transition temperature of said filaments, said filaments making less than a 360° pass over said draw pin, said high-speed driven roll being rotated at a surface speed of rotation such that filament velocity at the initial point of contact of said filaments on said high-speed driven roll ranges from 1.2 times to 4 times greater than the filament velocity at the substantially central point of contact of said filaments on the surface of said draw pin.

14. An apparatus for producing a nonwoven web of randomly disposed filaments substantially uniformly distributed throughout said web, said apparatus comprising, in combination, treating means for treating filaments with an effective, compatible antistatic agent; aspirating means comprising a plurality of aspirators through each of which a bundle of said filaments is fed; each of said aspirators is an aspirator jet comprising a hollow nozzle portion for receiving the aspirating medium, a hollow collar portion for receiving said bundle of filaments and for receiving said apsirating medium from said nozzle, and a hollow diffuser portion for aspirating said bundle of filaments with said aspirating medium, said aspirating medium being introduced into said jet in a direction substantially parallel with the axis of said jet and flowing through said jet in said parallel direction so as to minimize twisting or entangling of said filaments which enter said jet at an angle to said axis, said nozzle, said collar and said diffuser being concentric with respect to each other; reciprocating means aligned with, cooperating with and traversing said aspirating means for splaying the filaments of said bundles from the exit of each of said aspirators in a pattern such that the filaments from a given aspirator overlap the filaments from the next adjacent aspirator by substantially less than 100 percent when all of said aspirators are spatially stationary, said reciprocating means having a predetermined stroke amplitude and linear reciprocating speed which significantly augment said overlap; and substantially horizontal receiving surface for receiving and collecting the dispersed filaments to form said web, said surface moving in a direction generally transversely of the direction of traverse of said aspirating means.

15. The apparatus of claim 14 wherein said aspirator jet is further characterized by having a diameter of the passageway of said nozzle ranging from 5 percent to 40 percent of the length of said nozzle passageway, a cross-sectional area of said nozzle passageway ranging from 10 percent to 50 percent of a cross-sectional area of the passageway of said diffuser, a diameter of said diffuser passageway ranging from 1 percent to 15 percent of a length of said diffuser passageway, a cross-sectional area of said diffuser passageway occupied by said filaments ranging from 0.1 percent to 5 percent of said diffuser passageway cross-sectional area, said aspirating medium being introduced into said nozzle at a pressure ranging from 15 p.s.i.g. to 120 p.s.i.g.

16. The apparatus of claim 15 wherein said aspirator jet has said nozzle passageway diameter ranging from 20 percent to 33 percent of said nozzle passageway length, said nozzle passageway cross-sectional area ranging from 25 percent to 35 percent of said diffuser passageway cross-sectional area, said diffuser passageway diameter ranging from 2 percent to 10 percent of said diffuser passageway length, and said diffuser passageway cross-sectional area occupied by filaments ranging from 0.2 percent to 1.5 percent of said diffuser passageway cross-sectional area and wherein said collar portion has an aperture on the side thereof to initially receive said filament bundle in a direction transverse to said axis of said jet.

17. The apparatus of claim 15 wherein an improved Coanda splaying adapter is affixed to the exit end of each of said aspirator jets, said splaying adapter having continuously smooth, symmetrical, opposing surfaces of curvature, said opposing surfaces exhibiting a converging to diverging pattern as said surfaces proceed in distance from the exit of said aspirator jet such that the area of filament deposition on said conveyor is effectively increased.

18. The apparatus of claim 17 wherein each of said opposing surfaces develops as a line from near the exit of said aspirator jet to a line of maximum convergence and thereafter to a line of maximum divergence, each of

said lines being in a direction substantially perpendicular to the center-line of said diffuser passageway.

19. The apparatus of claim 18 wherein the minimum distance between the two lines of maximum convergence is at least as great as said diffuser passageway diameter.

20. The apparatus of claim 18 wherein said aspirator jets are spaced apart a distance such that said filaments exiting from a given aspirator jet overlap the filaments from said next adjacent aspirator jet by from 8 percent to 25 percent when each of said aspirator jets is spatially stationary.

21. The apparatus of claim 20 wherein said given aspirator jet is substantially parallel to said next adjacent aspirator jet and the center-line distance between said adjacent aspirator jets ranges from 40 percent to 145 percent of said stroke length.

22. The apparatus of claim 21 wherein the linear speed of said filaments within each of said aspirator jets ranges from 10 times to 500 times the linear speed of said horizontal conveyor.

23. The apparatus of claim 22 wherein the minimum distance from the exit of said aspirator to the surface of said conveyor ranges from 10 inches to 36 inches.

24. An apparatus for producing a nonwoven web of randomly disposed filaments substantially uniformly distributed throughous said web, said apparaatus comprising, in combination, treating means for treating filaments with an effective, compatible antistatic agent; drawing means for orienting and attenuating said filaments, said drawing means comprising a slowly rotating draw pin, said draw pin being positioned spatially so as to provide a predetermined extent, less than 360°, of surface contact of said filaments on the circumference of said draw pin in a manner such that the velocity of said filaments at the substantially central point of contact of said filaments on the surface of said draw pin is less than the filament velocity during future entry into an aspirating means of said apparatus and such that said filaments pass over said draw pin at a filament temperature less than the glass transition temperature of said filaments and at a less than 360° pass; aspirating means comprising a plurality of aspirators through each of which a bundle of said filaments is fed, each of said bundles having substantially no electrostatic charge contained thereon and each of said aspirators is an aspirator jet comprising a hollow nozzle portion for receiving the aspirating medium, a hollow collar portion for receiving said bundle of filaments and for receiving said aspirating medium from said nozzle, and a hollow diffuser portion for aspirating said bundle of filaments with said aspirating medium, said aspirating medium being introduced into said jet in a direction substantially parallel with the axis of said jet and flowing through said jet in said parallel direction so as to minimize twisting or entangling of said filaments which enter said jet at an angle to said axis, said nozzle, said collar and said diffuser being concentric with respect to each other; reciprocating means aligned with, cooperating with and traversing said aspirating means for splaying the filaments of said bundles from the exit of each of said aspirators in a pattern such that the filaments from a given aspirator overlap the filaments from the next adjacent aspirator by substantially less than 100 percent when all of said aspirators are spatially stationary; said reciprocating means having a predetermined stroke amplitude and a liner reciprocating speed which significantly augment said overlap; and substantially horizontal surface for receiving and collecting the dispersed filaments to form said web, said surface moving in a direction generally transversely of the direction of traverse of said aspirating means.

25. The apparatus of claim 24 wherein said drawing means comprises, in combination, said slowly rotating draw pin and a high-speed driven roll placed after said draw pin, said high-speed driven roll having a surface speed driven roll is greater than subsequent filament velocinitial point of contact of said filaments on said high-speed driven roll is greater than subsequent filament velocity at the substantially central point of contact of said filaments on the surface of said draw pin.

26. The apparatus of claim 25 wherein the initial filament velocity ranges from 1.2 times to 4 times greater than the subsequent filament velocity.

27. The apparatus of claim 26 wherein said slowly rotating draw pin rotates at a speed ranging from 5 r.p.m. to 15 r.p.m.

28. The apparatus of claim 23 including, subsequent to said treating means and prior to said feeding means, a drawing means for orienting and attenuating said filaments, said drawing means comprising, in combination, a slowly rotating draw pin and a high-speed driven roll placed after said draw pin, said filaments passing over said draw pin at a filment temperature less than the glass transition temperature of said filament and at a less than 360° pass, said high-speed driven roll having a surface speed of rotation such that filament velocity at the initial point of contact of said filaments on said high-speed driven roll ranges from 1.2 times to 4 times greater than filament velocity at the substantially central point of contact of said filaments on the surface of said draw pin.

References Cited

UNITED STATES PATENTS

3,692,618	9/1972	Dorschner et al.	156—181
3,687,721	8/1972	Dardoufas	117—139.5
3,649,535	5/1972	Clark et al.	117—139.5
3,293,718	12/1966	Sheets	28—1
3,600,775	8/1971	Shuijters	28—1.4
3,040,412	6/1962	Russel	28—72.2
2,052,869	9/1936	Coanda	239—418
3,341,394	9/1967	Kinney	156—167
3,259,954	7/1966	Dyer	28—1.4

DANIEL J. FRITSCH, Primary Examiner

U.S. Cl. X.R.

28—15 M; 156—167, 229, 306, 390, 433, 441, 494, 425—83