April 18, 1967 N. E. LLOYD ETAL 3,314,840

PROCESS AND APPARATUS FOR PRODUCING A NON-WOVEN FABRIC

Filed Aug. 1, 1961

2 Sheets-Sheet 1

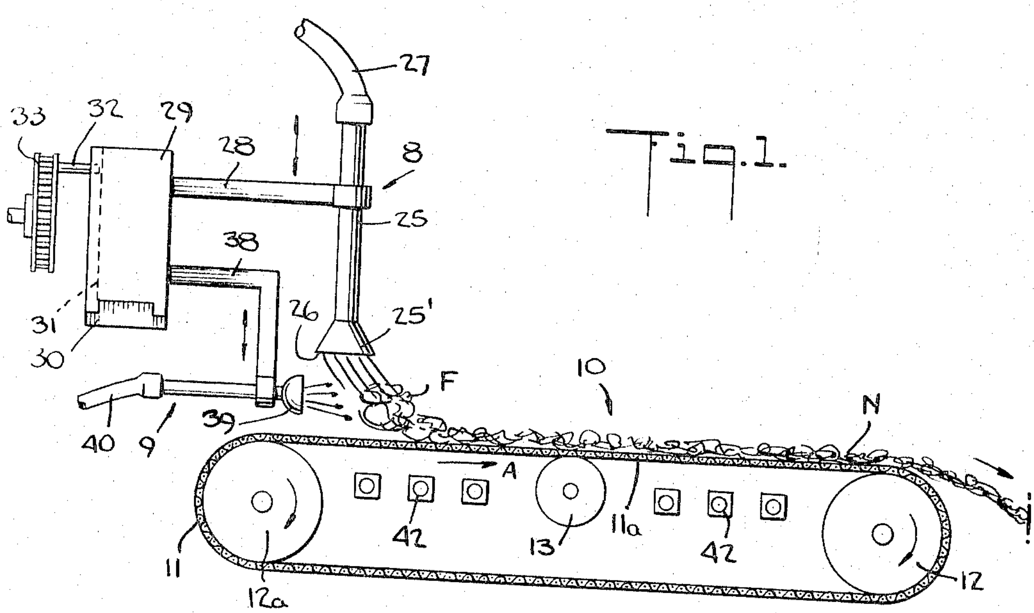

Fig. 1.

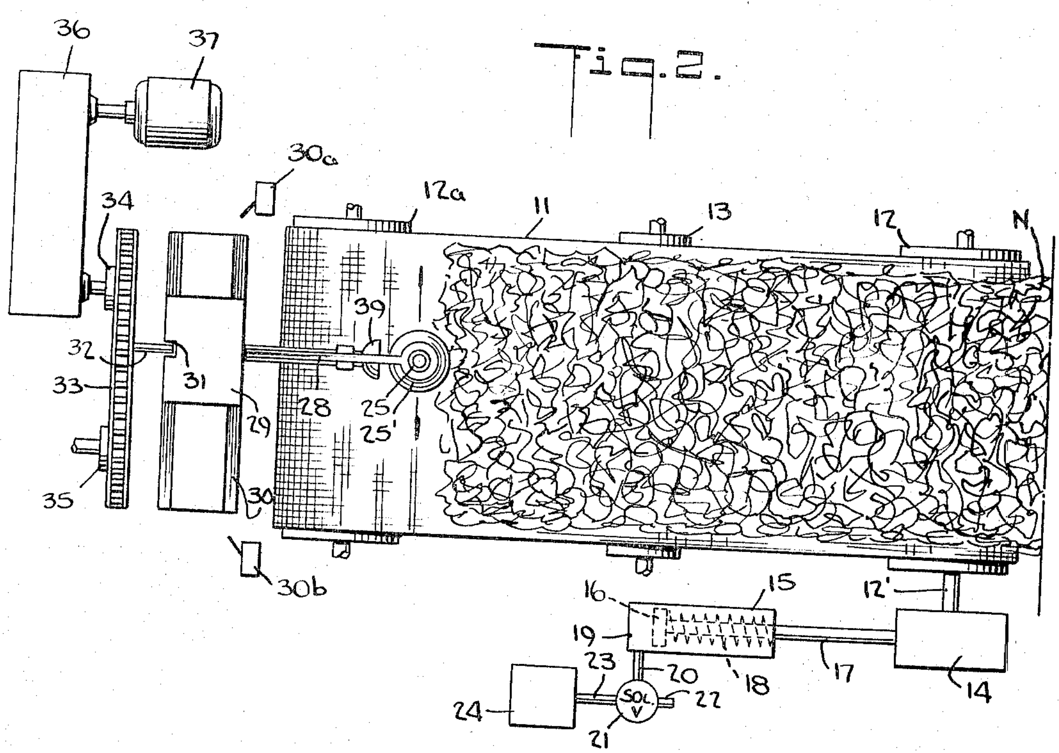

Fig. 2.

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2 Sheets-Sheet 2

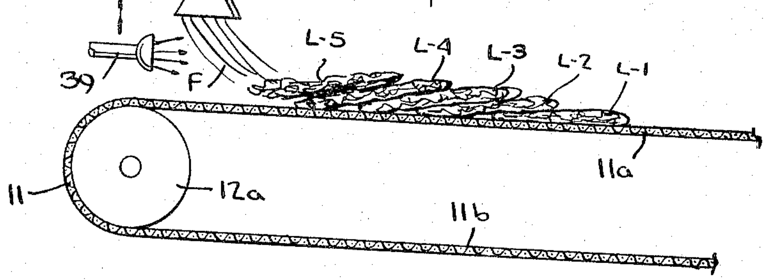

Fig. 3.

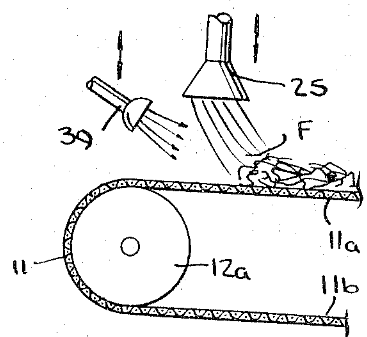

Fig. 4

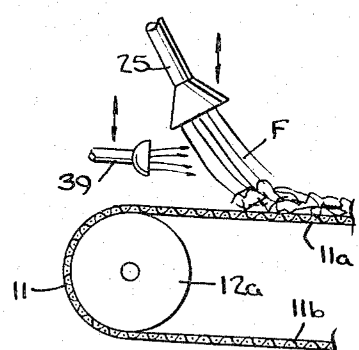

Fig. 5.

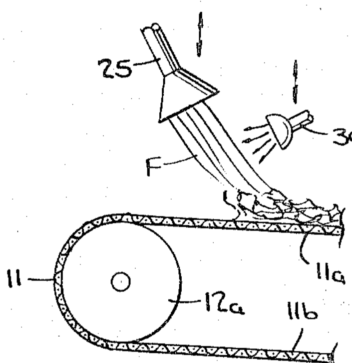

Fig. 6.

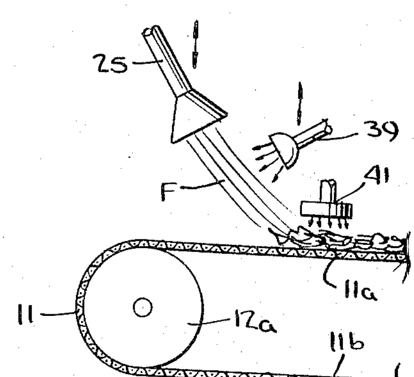

Fig. 7.

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PROCESS AND APPARATUS FOR PRODUCING A NON-WOVEN FABRIC

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24 Claims. (Cl. 156—167)

This invention relates to non-woven fabrics, and in particular to processes of and apparatus for producing such fabrics from synthetic fibers in continuous filament form.

In the heretofore known methods of producing non-woven fabrics for use in the manufacture of filters, clothing and a great number of other products, staple fibers are generally employed as the raw material. If these staple fibers are synthetically produced by extrusion processes and then formed into a finish-coated towline by the fiber manufacturer, the towline must be cut into appropriate lengths which are then baled and shipped to a producer of non-woven fabrics. The latter must then unbale the staple, open it, make it into a flat batting for addition of a plasticizer or binder, and finally subject it to a baking and calendering treatment so as to obtain the fabric in the final form thereof.

The cheapest grades of non-wovens presently available on the market are usually made of natural staple fibers, principally, of course, for reasons of economy. Wherever a higher grade non-woven fabric is desired, i.e. one which is possessed of a number of special properties which are unattainable in a natural fiber non-woven, for example, greater toughness, elasticity, dimensional stability, etc., synthetic fibers are added. Synthetic fibers, however, are relatively expensive to produce, and thus their use as components of the non-wovens considerably increases the cost thereof, a result which is even more evident if the non-wovens are produced entirely from synthetic staple fibers or continuous filaments.

It is, therefore, an important object of the present invention to provide novel and highly efficient processes of and apparatus for producing non-woven fabrics from continuous filament synthetic fibers in such a manner as to avoid the disadvantages and drawbacks inherent in the known non-woven production techniques.

It is another object of the present invention to provide processes of an apparatus for producing high grade non-wovens from continuous filament synthetic fibers in a manner sufficiently inexpensive to render the finished products highly competitive with all known types of non-woven products.

It is also an object of the present invention to provide processes and apparatus as aforesaid by means of which the production of the non-woven fabrics can be made a direct adjunct of the filament extrusion operation at the metier so as to eliminate all need for the heretofore unavoidable handling of the filaments after their extrusion and prior to the formation of the non-woven fabrics.

More specifically, the objectives of the present invention are attained by the positioning of an extrusion jet or spinnerette of the metier directly above one end of a flat, substantially horizontal, movable take-up surface onto which the synthetic filaments are to be deposited. The extrusion jet is mounted for linear reciprocal movement in a direction transverse to the direction of movement of the take-up surface and is associated with an air jet which directs a stream of compressed air at the array of extruded filaments leaving the jet so as to cause the filaments to be whipped about and interlaced or mingled to a considerable extent in a completely random manner prior to the depositing of the filaments on to the take-up surface.

In accordance with one aspect of the present invention, the take-up surface is constituted by an endless wire

mesh screen belt the width of which may range from about 10 to 260 inches and which is supported by and driven over a pair of cylindrical rolls disposed at the points of reversal of the belt movement. One of these rolls is preferably a driven roll and is connected to a suitable intermittent drive or indexing mechanism, such as a ratchet and pawl system, a Geneva movement or a pneumatically operated kicker which is arranged for manual or automatic actuation, so as to enable the belt to be moved by predetermined increments which may range from ¼ inch to as much as 2 feet. If desired, brake means may be associated with the belt-supporting rolls to bring the same to a sudden stop at the termination of each indexing or "kicking" of the belt.

In lieu of the aforesaid indexing mechanisms, it is possible to employ an electrically driven jogging motor with an electronic speed control system to advance the belt intermittently. Such a control system would however, have to be equipped with a dynamic braking circuit to prevent the jogging motor from causing any coasting of the belt at the end of each incremental movement or stroke thereof.

The extrusion jet or spinnerette is preferably of a conventional type having an orifice plate about 1¾ inches in diameter and provided with from about 30 to 3,000 substantially circular or slit openings, although the openings may have other shapes such as circles, triangles, crescents, etc. The basic diameters of these openings may range from about 0.020 to 0.220 mm. The face of the extrusion jet may be located at distances ranging from 2 to 40 inches above the moving belt or take-up surface, while the air jet may be so arranged that the stream of air emanating therefrom strikes the filaments issuing from the extrusion jet at a point located at distances ranging from 1 to 35 inches above the belt. The extrusion jet further may be so oriented that the initial direction of movement of the filaments issuing from the jet may range from being parallel with to being perpendicular to the plane of the take-up belt, while the air jet may be so oriented that the stream of air impringes against the filaments issuing from the extrusion jet at angles ranging from 30 degrees or less to 90 degrees relative to the direction of movement of said filaments toward the surface of the take-up belt. It is contemplated by the present invention that the air jet may be located behind, in front of, or beside the mass of filaments issuing from the extrusion jet, as seen in the direction of travel of the said belt. The extrusion jet and its associated air jet are preferably supported for vertical adjustment on a carriage or slide structure arranged for horizontal movement transverse to the direction of movement of the belt. The carriage is mounted on a rail or slide bar system constituting a part of a suitable rigid framework and is connected with an endless sprocket chain of a variable speed chain drive so as to be capable of being reciprocated or traversed back and forth across the belt at linear speeds ranging from about 16 to 150 feet per minute. Means are preferably provided, for example in the form of pneumatic limit switches or the like at the opposite ends of the aforesaid rail or slide bar system, for ensuring actuation of the intermittent belt drive mechanism only when the jet-moving carriage is stationary at the reversal points of the movement thereof.

More than one set of one extrusion jet and one air jet may, of course, be employed. It is also possible to utilize one or more stationary air jets which are not movable with the associated extrusion jet or jets, in which event it is necessary, however, that the stream of filament-agitating air be coextensive in width with the take-up belt, as by being blown through an elongated slot, so that the filaments are subjected to the air stream at all times irrespective of the positions of the extrusion jet or jets.

Examples of filament forming materials which can be used in implementing the principles of the present invention are organic derivatives of cellulose such as ethers and/or esters thereof, e.g. ethyl cellulose, cellulose acetate, cellulose propionate, cellulose butyrate, cellulose acetate, formate, cellulose acetate propionate, cellulose acetate, butyrate, etc., which esters may be ripened so as to modify their solubility characteristics or may be unripened, i.e. containing fewer than about 0.29 free hydroxyl groups per anhydroglucose unit, such as cellulose triacetate. While other filament forming materials such as polyamides, e.g. nylon 6 or 66, linear polyesters such as polyethylene terephthalate, acrylonitrile polymers and copolymers, olefinic polymers such as polyethylene, polypropyene, polyvinyl chloride, polyvinyl acetate, polyvinyl chloride-vinyl acetate, polyvinylidene chloride, and the like, can be employed, organic acid esters of cellulose, such as cellulose acetate, are preferred and these are advantageously extruded as a solution into a heated evaporative atmosphere.

The mass of filament forming material in the metier is generally heated to temperatures ranging from 50° to 150° and is extruded from the spinnerette, which it may reach via any suitable conduit arrangement such as a flexible, high pressure, brass hose operated in conjunction with a 90° swivel joint, at pressures ranging from 250 to 2,000 p.s.i.g. The filaments issuing from the face of the spinnerette or extrusion jet are preferably moving at velocities ranging from 500 to 3,500 meters per minute. The air issuing from the air jet is preferably maintained under pressures ranging from 3 to 25 p.s.i.g. From 2 to 20 cubic feet per minute of "free air," i.e. air at standard conditions of 70° F. and atmospheric pressure, are required for proper operation of each set of one extrusion jet and one air jet.

As a consequence of the operation of the belt and associated extrusion and air jets under the stated conditions, there is formed on the belt a continuous body or matted web of randomly convoluted, intersecting and interlaced continuous filaments, the web being composed of a plurality of parallel sections which overlap one another by virtue of the fact that each of these sections as it is laid onto the belt is moved away from the region of the spinnerette by an amount less than the width of each section of filaments deposited on the belt. As will be clear to those skilled in the art, the filaments extruded from the spinnerette are still in a semi-plastic condition when they reach the belt, and they will, therefore, tend to coalesce and adhere to one another at their points of intersection or contact. The entire web thus becomes a coherent fabric entity having considerable mechanical strength. It will be understood that by suitably varying the lengths of the increments of movement of the belt, the individual filament layers or sections deposited on the belt by the spinnerette can be overlapped to any desired greater or lesser extent so as to bring about the formation of multi-layer non-woven fabrics of correspondingly different predetermined thicknesses.

The entire web-forming apparatus, comprising the spinnerette or spinnerettes constituting the filament extruding means, the air jets or jets constituting the filament agitating means, and the belt constituting the take-up means are usually enclosed in a suitable housing or cabinet, the atmosphere and temperature conditions in the interior of which may be controlled in accordance with the composition of the filamentary material being extruded and with the manner in which it is extruded into filament form, i.e. by means of a wet, dry, or melt spinning process. Thus, if the filaments are formed from a dope comprising a solution of cellulose acetate (or the like) in acetone there are provided in the cabinet, preferably between the upper and lower reaches of the take-up belt, finned copped tube heating coils through which saturated steam at a pressure of about 150 p.s.i.g. is coursed to maintain the air or atmosphere in the cabinet at a temperature between about 80 and 300° F. This air is preferably introduced into the cabinet by means of compressors or small blowers and may, if desired, be preheated before entering the cabinet. In this manner, it is possible to effect a controlled rate of evaporation and eduction of the acetone or other residual solvents from the solidifying non-woven mat of filaments. Suitable means for exhausting the acetone-laden air from the cabinet are also provided. On the other hand, if the filaments are formed from a melt of the filament forming material, the provision of the heating coils and even of the cabinet itself may be dispensed with.

Other objects, characteristics and advantages of the present invention will be more clearly realized from the following description thereof when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a diagrammatic and schematic side elevational view of one embodiment of an apparatus for producing non-wovens in accordance with the present invention;

FIG. 2 is a top plan view of the apparatus shown in FIG. 1 and illustrates in addition the drive means for the extrusion jet and for the take-up belt;

FIG. 3 is a fragmentary view, on an enlarged scale, of the structure shown in FIG. 1 and illustrates in detail but schematically the formation and the structure of the fabric;

FIGS. 4, 5 and 6 are schematic illustrations of some possible modifications of the relationship between the extrusion and air jets of the apparatus shown in FIGS. 1 and 2; and

FIG. 7 is a view similar to FIG. 6 and illustrates a further modification of the apparatus.

Referring now more particularly to FIGS. 1 and 2 of the drawings, it will be seen that the apparatus according to the present invention essentially comprises filament forming or extruding means **8**, filament agitating means **9**, and take-up means **10** on which the filaments are deposited to form the desired non-woven fabric. The entire system is arranged in a cabinet or housing (not shown).

The take-up means **10** preferably comprises an endless belt **11** made of wire mesh screen and supported at its opposite ends by a pair of rolls or drums **12** and **12*a***. The upper reach **11*a*** of the belt **11** passes over one or more idler rolls **13** positioned between the rolls **12** and **12*a*** which enables the upper reach of the belt to be kept substantially horizontal during its travel from the roll **12*a*** to the roll **12**. The rolls **12**, **12*a*** and **13** are all journaled in suitable bearings (not shown) supported on a rigid steel framework (not shown) arranged in the aforesaid cabinet or housing.

Connected to the axle **12′** of the roll **12** in any desired manner, not explicitly illustrated herein, is a unidirectional intermittent drive or indexing mechanism **14** which may be a ratchet and pawl device, a Geneva movement, a pneumatically operated "kicker" or the like capable of effecting an intermittent or step by step rotation of the roll **12** in a clockwise direction as seen in FIG. 1. The actuating means for the indexing mechanism **14**, which will hereinafter be referred to as the kicker, may be of any suitable type and either manually or automatically operable. Merely by way of example, in the illustrated embodiment of the invention, this actuating means comprises a single-acting pneumatic cylinder **15** having a reciprocal piston **16** therein which is drivingly connected with the kicker **14** by means of a piston rod **17** and is biased toward its retracted or inactive position by a compression spring **18**. The space **19** of the cylinder **15** behind the piston **16** is connected with one port **20** of a solenoid-operated three-way valve **21** which has a second port **22** opening to the atmosphere and a third port **23** connected with a source **24** of air under pressure. It will be understood, therefore, that each time the solenoid valve **21** is actuated to establish communication between the pressure source **24** and the cylinder space **19**, the piston **16** is displaced against the force of the spring **18** to actuate the kicker **14**, which causes the belt **11** to be advanced a predetermined distance in the direction of the arrow A (see FIG. 1), while upon deactuation of the valve **21** communication is established between the ports **20** and **22** thereof to vent the cylinder space **19** to the atmosphere and permit retraction of the piston **16** by the spring **18** unaccompanied by any reverse or forward operation of the kicker **14**.

The filament forming means **8** comprises, in addition to the usual spinning cabinet or metier (not shown), a spinnerette or extrusion jet **25** positioned above one end of the upper reach **11a** of the belt **11** and adjacent the roll **12a**. In the illustrated example of the apparatus, the spinnerette **25** has a cup portion **25′** terminating in a circular orifice plate **26** which is about 1¾ inches in diameter and has formed therein a multiplicity of extremely small openings. Merely by way of example, the number of such openings may be about 300, although it may be as small as 30 and as large as 3000, and the diameters of the extrusion openings in the plate may range between about 0.020 mm. and 0.220 mm. Preferably, all the openings are substantially circular, but they may have other shapes. The spinnerette or extrusion jet **25** is connected via a flexible conduit **27**, e.g. a high pressure brass hose available commercially under the trademark "Penflex," with the interior of the metier (not shown). The spinnerette **25** is supported by an arm **28** which extends from a carriage **29** slidably mounted on a rail or slide bar system **30** extending transversely to the longitudinal dimension of the belt **11** and substantially coextensive in length with the roll or drum **12a**. Two pneumatically operated limit switches **30a** and **30b** are arranged at the opposite ends of the rail **30**. The carriage **29** is provided in its surface facing away from the arm **28** with a groove **31** into which extends slidably an elongated pin **32** carried by one of the links of an endless sprocket chain **33** supported at its opposite ends by a pair of sprockets **34** and **35**. The axle of the sprocket **34** is connected to a suitable speed control mechanism, such as an adjustable gear reducer **36** which is connected to a drive motor **37**.

The carriage **29** in addition carries the filament agitating means **9**. To this end, a second arm **38** extends downwardly from the carriage and supports an air jet **39** at a location intermediate the upper reach **11a** of the belt **11** and the orifice plate **26** of the spinnerette **25**. The jet **39** is connected by means of a flexible hose **40** to a source of compressed air (not shown).

As indicated by the double-headed arrows in FIG. 1, both the spinnerette **25** and the air jet **39** are adapted to be adjusted vertically toward and away from the upper reach **11a** of the take-up belt **11**. Such adjustments may be effected in any desired manner, e.g. by shifting the arms **28** and **38** on and relative to the carriage **29** or by shifting the jets **25** and **39** relative to their respective supports **28** and **38**. Moreover, means may be provided for effecting angular adjustments of the jets so as to vary their inclinations relative to one another and relative to the plane of the upper reach **11a** of the take-up belt **11**. By way of illustration, in FIGS. 1 and 2, for example, the face of the orifice plate **26** of the spinnerette **25** is horizontal, and the filament streams F extruded through the plate **26** thus travel toward the belt **11** at an angle of about 90° to the direction of travel of the belt (arrow A), while the air jet **39** blows against the filaments a stream of compressed air in a direction oriented at an angle of 90° relative to he direction of movement of the filaments. As shown in FIGS. 4 and 5, according to further aspects of the present invention vertically descending filaments F may be subjected to the agitating action of an air stream directed at an acute angle to their direction of movement toward the belt, or filaments traveling at an acute angle, for example as small as 30° or less, relative to the direction of movement of the belt may be subjected to the agitating action of a horizontal stream of air. It will be understood, of course, that any desired angular relationship between the air and filament streams may be attained by other relative orientations of the air and extrusion jets, e.g. where neither of the latter is in a horizontal or vertical position. This holds true also where the orifice plate **26** is disposed vertically so that the filaments F leaving the extrusion jet initially travel in a horizontal direction, i.e. parallel to the plane of the take-up belt, before assuming a downward trajectory toward the upper belt reach **11a**. In any of these cases, however, the jets may be vertically adjusted to vary the distance of travel of the filaments from the orifice plate to the belt and to vary the point of incidence of the air stream against the said filaments before the latter reach the take-up belt.

In the hereinbefore described embodiments of the apparatus according to the present invention, it will be noted that the air stream impinges against the filament stream from in front of the latter as seen in the direction of travel of the take-up belt. As shown in FIGS. 6 and 7, however, the air stream emanating from a vertically adjustable and suitably oriented air jet **39** may impinge against a stream of filaments F issuing from a vertically adjustable and suitably oriented extrusion jet **25** from behind the filament stream as seen in the direction of movement of the belt **11**. The carriage **29** and its associated elements would then be positioned to the right of the extrusion jet rather than as shown in FIG. 1. Such an arrangement is found particularly advantageous when it is desired to spray a solvent or plasticizer and/or other additive onto the mat-forming filaments, to which end a spray head or nozzle **41** of any suitable construction may also be disposed behind the filament stream (see FIG. 7). In the illustrated embodiment of the invention, where the spray is directed onto the freshly laid non-woven mat (still to be described), the nozzle **41** may be supported by the carriage **29** for movement therewith. When the spray head or nozzle **41**, positioned behind the filament stream as shown in FIG. 7, is used with an air jet **39** positioned in front of the filament stream as shown in FIGS. 1 to 5, however, steps must be taken to ensure that the air stream does not disturb the plasticizer or solvent spray. This goal is attained by traversing the spray head **41** and air jet **39** over the belt 180° out of phase with one another, for which purpose a second carriage **29** (not shown) and associated elements are provided.

In accordance with an alternative aspect of the present invention, the spray head **41** may be positioned in front of the filament stream (not illustrated) while the air jet is positioned behind the filament stream as shown in FIG. 6. This type of arrangement would be used where it is desired to spray the solvent or plasticizer against the front of the mass of agitated filaments F before the same are deposited on the take-up belt. Here, too, the air jet and spray head must be traversed 180° out of phase with one another. It is to be understood, of course, that the spray head and air jet may both be located in front of the filament stream, but in such a case it is found desirable to dispose the spray head **41** between the air jet and the filament stream so that the air stream can help the solvent or plasticizer to reach the filaments.

In the operation of the herein described apparatus for practicing the method of the present invention, reference being had at this point to FIGS. 1 and 2, when the sprocket chain **33** driven by the motor **37** has that one of its links to which the pin **32** is connected located in the upper reach of the chain, say just above the sprocket **34**, the carriage **29** is moved together with the said upper reach of the chain **33** along the rail **30** from one end of the same (the upper one in FIG. 2) toward the other so as to traverse the extrusion jet **25** and its associated air jet **39** across the belt **11**. During this traverse of the jets, at which time the belt is stationary, filaments F are extruded toward the belt **11** through the orifice plate **26** of the extrusion jet which is disposed at a predetermined distance of from 2 to 40 inches above the belt, all of these filaments being disposed essentially parallel to one another, untwisted, and still somewhat plastic, by virtue of containing residual solvent if spun from a solution of the filament forming material or by virtue of being incompletely solidified if spun from a melt of the filament forming material. At some preselected point between the face of the orifice plate and the upper reach **11***a* of the take-up belt **11**, e.g. from 1 to 35 inches above the latter, the downwardly streaming array of filaments F is subjected to the influence of a stream of high pressure air flowing transversely to the path of travel of the filaments at an angle ranging from 30 degrees or less to 90 degrees, and preferably at an angle ranging from 45 to 90 degrees, to the direction of movement of the stream or array of filaments. The latter are, thus, violently agitated and whipped about in a completely random manner and are, accordingly, substantially deformed out of their initial linear state as well as randomly entangled and interlaced with one another.

The resultant non-oriented mass of randomly convoluted and intersecting filaments, upon reaching the take-up belt **11**, is deposited on the upper reach **11***a* of the latter in the form of a relatively narrow entangled layer or web extending across the belt due to the fact that the extrusion jet **25** is traversed over the belt as the filaments are formed. The first such layer in any sequence is designated **L–1** in FIG. 3. As this layer rests on the belt **11**, the still plastic filaments tend to coalesce and become bonded to one another at their points of contact. Where necessary, as in the case of the filaments being spun from a solution of cellulose acetate in acetone, for example, the rate of evaporation of the solvent may be predetermined by controlling the temperature and atmospheric conditions existing within the drying cabinet (not shown) which enclosed the belt **11**, to which end a system of finned copper tube heating coils **42** may be arranged within the said cabinet between the upper and lower reaches **11***a* and **11***b* of the take-up belt **11**.

As the carriage **29** arrives at the other end (the lower one in FIG. 2) of the rail **30**, it actuates the switch **30***b* which causes the solenoid valve **21** to be operated so as to permit actuation of the kicker **14** through the intermediary of the cylinder **15** and the piston **16–17**. The belt **11** is thus shifted a predetermined distance in the direction of the arrow A, preferably less than the width of the layer **L–1**. Concurrently therewith, the pin **32** reaches and moves around the sprocket **35**, whereby it is shifted to the lower reach of the chain **33**. During the passage of the pin **32** about the said sprocket, therefore, the pin slides downwardly along the vertical slot **31** of the carriage **29** so that the latter remains essentially stationary.

The pin **32** now begins to move in the opposite direction, i.e. toward the sprocket **34**, with the lower reach of the chain 33. The carriage **29** and the jets **25** and **39** are thus traversed back to their starting positions, which results in a second layer of filaments being deposited on the upper reach **11***a* of the take-up belt. This layer is designated **L–2** in FIG. 3, and it will be seen that a portion of this layer overlaps and rests on the first layer **L–1**, to an extent determined by the magnitude of the incremental movement of the belt relative to the width of the layer. As the still plastic filaments of which the layer **L–2** is formed solidify, they will not only coalesce with one another at their points of contact, but will also adhere and become bonded to the filaments at the top surface of the previously formed layer **L–1**, which may also still be somewhat plastic, i.e. not fully solidified, so as to make the two layers into one coherent entity.

When the pin **32** reaches the sprocket **34**, the carriage **29** actuates the limit switch **30***a* which causes the kicker **14** to be actuated again to advance the belt another predetermined distance. While this is taking place, the pin is traveling about the sprocket **34** and upwardly along the slot **31** in the carriage **29**, so that the latter is essentially stationary while the belt is moving.

The traverses of the extrusion and air jets as hereinbefore described are thereafter repeated again and again, with each traverse of the extrusion jet **25** and air jet **39** forming another layer of matted and tangled filaments on the stationary take-up belt, as indicated by **L–3**, **L–4** and **L–5** in FIG. 3, and with the successive traverses of the jets alternating with incremental advances of the take-up belt so as to ensure that each layer overlaps at least a part of the preceding layer and possibly also a part of the second preceding layer, as shown in FIG. 3.

In this manner, there is formed continuously and as a direct adjunct to the extrusion of the filaments F from the metier a non-woven fabric N which can be taken up from the end of the belt **11** overlying the roll **12** onto a beam or into a bale or package for storage and/or shipment. Such a fabric, due to the bonding of a great number of randomly oriented continuous filaments to one another at their points of intersection and contact, is possessed of considerable mechanical strength and dimensional stability in any direction of the fabric. By means of the process and apparatus according to the present invention, furthermore, it is possible to provide the non-woven fabrics with a great variety of special physical properties such as weight per unit length, "hand," stiffness, filtration power, insulating value, resiliency, draping ability, etc., to any desired and predetermined degree. Stiffness, for example, can be attained by spraying a solvent or plasticizer such as acetone or dimethyl ethyl phthalate and trichloroethyl phosphate against the front of the agitated filament stream before the same is deposited on the take-up belt or against each layer **L–1**, **L–2**, etc. after it is formed on the belt. Merely by way of illustration, continuous filament non-wovens of the herein disclosed types may be advantageously employed as filters for air heating and conditioning systems, inner shoe soles and shoe interliners, lamp shades, upholstery backing, filters for milk, beer, oil and other liquid processing systems, window dressings, insulation, wall coverings, rug backing, quilting, casket liners, acoustical curtains, pennants and banners, decorative wrapping materials, suit and dress materials, 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 than continuous filament synthetic fibers.

It will be understood that the process and apparatus as herein disclosed are susceptible to being modified in a number of ways, depending on the particular desired physical or other characteristics, e.g. resistance to heat, water or chemicals, of the ultimate non-woven fabric. Moreover, the air stream may impinge on the filaments from the side rather than from the front or rear as shown in the drawings. It is possible to employ more than one extrusion jet, in which case these jets, each associated with a respective air jet, may be traversed across the take-up belt either in or out of phase with one another so as to produce layers of matted filaments which overlap one another both longitudinally and transversely of the fabric. Also, successive layers of the fabric may be formed by different jets traversed across the belt in alternating sequences. These arrangements lend themselves very readily to the creation of special decorative patterns and designs, as where the extrusion solutions or melts are differently pigment-dyed. It is further possible, within the contemplation of the present invention, to utilize a continuous rather than intermittent belt movement. To this end, however, the belt speed must be relatively small as compared to the extrusion jet traverse speed, and at the same time one or more pairs of extrusion jets **25** must be provided with the jets of each pair moving 180° out of phase with one another, to compensate for the sine wave layer effect which would result from the use of only one extrusion jet.

The following example will serve to illustrate the principles of the present invention more clearly.

Example

A cellulose acetate spinning dope containing, by weight, 26.8% cellulose acetate with an acetyl value of 55%, 3.3% water and 69.9% acetone is extruded through a spinnerette **25** having a 1¾ inch diameter jet cup in the orifice plate of which are formed 304 circular openings or holes each having a diameter of 0.032 mm. The dope in the metier is preheated to a temperature of 110° C. and extruded at a pressure of 800 p.s.i.g. The extrusion jet is located in a drying cabinet, to which air at a temperature of approximately 200° F. is supplied, at a distance of 14.5 inches above one end of an endless wire mesh take-up belt and oriented to extrude the filaments at an angle of 90 degrees to the plane and direction of movement of the belt, the rate of extrusion of the filaments being about 2000 meters per minute. The belt is 60 inches in width and is moved intermittently 2 inches at a time. The extrusion jet is traversed across the take-up belt at a rate of 56 feet per minute, and its drive is synchronized with the drive of the belt so that the latter is advanced only when the jet is stationary and is stationary during the traverses of the jet across the belt. The stream of filaments extruded toward the belt is subjected to the agitating action of a stream of air under a pressure of 14 p.s.i.g. oriented at an angle of 45 degrees to the direction of movement of the filaments and impinging against the latter at a spread of 3 to 8 inches above the surface of the take-up belt. Additional heat is supplied to the drying cabinet, for aiding in the evaporation of residual solvent from the tangled filaments deposited on the belt, by passing saturated steam at 150 p.s.i.g. through finned copper heating coils disposed between the upper and lower reaches of the take-up belt. The agitated and entangled filaments are deposited on the belt in transverse layers 54 inches long, and each layer overlaps the preceding layer to the extent of about 80% of the width of the preceding layer. The coherent fabric formed in this manner is, after trimming, 50 inches wide and 3/16 inch thick and weighs 4.5 ounces per yard. It has exceptionally good lateral and longitudinal uniformity and stability, and is found to have a smooth "hand" and high resiliency as well as high filtration power. Such a fabric is particularly suited for use in the manufacture of "Christmas tree snow" batting, when calendered lightly, as backing for carpeting and furniture upholstery materials.

By way of resume, therefore, in accordance with the broadest aspects of the present invention the mass of filament forming material is extruded toward a movable take-up surface through a plurality of orifices to form a stream of substantially parallel continuous filaments. A stream of pressurized air is directed at these filaments at a point spaced from the take-up surface so as to agitate the filaments and cause them to be whipped about and entangled into contact with one another at randomly spaced points prior to their arrival at the take-up surface. The stream of still plastic filaments, while being subjected to the action of the stream of pressurized air, is reciprocally traversed across the take-up surface which is advanced in a direction transverse to the direction of traverse of the filaments. This enables the filaments to be deposited in their entangled state on the take-up surface in the form of an elongated matted web composed of a plurality of laterally contiguous layers and having a coherent structure in all directions resulting from the coalescence of the filaments at their points of contact.

It is to be understood that the foregoing detailed description is merely given by way of illustration and that many variations may be made in the invention without departing from the spirit thereof.

Having described our invention, what we desire to secure by Letters Patent is:

1. The process of producing a non-woven fabric, comprising the steps of extruding a mass of filament forming material in liquid phase downwardly toward a movable, substantially horizontal take-up surface through a plurality of orifices to form a stream of substantially parallel continuous filaments, directing a stream of air under pressure at the still plastic filaments at a point above said take-up surface thereby to agitate said stream of filaments and cause the latter to be whipped about and entangled into contact with one another at randomly spaced points prior to their arrival at said take-up surface, traversing the stream of filaments while still in plastic condition, said stream of filaments being associated with said stream of air back and forth across said take-up surface while the latter is stationary, and advancing said take-up surface in a direction transverse to the direction of traverse of said filaments only when the latter reach the reversal points of their transverse movements, to enable said filaments to be deposited in their entangled state on said take-up surface in the form of an elongated matted web composed of a plurality of substantially parallel, laterally contiguous layers and having a coherent structure in all directions resulting from the coalescence of said filaments at said points of contact.

2. The process of claim 1, wherein the initial path along which said filaments are extruded is oriented at an angle ranging from about 0 to 90 degrees to the direction of movement of said take-up surface, and said stream of air is oriented at an angle ranging from about 30 to 90 degrees to the general path of movement of said filaments toward said take-up surface.

3. The process of claim 2, wherein said stream of air impinges against said stream of filaments from behind the latter as viewed in the direction of movement of said take-up surface.

4. The process of claim 2, wherein said stream of air impinges against said stream of filaments from in front of the latter as viewed in the direction of movement of said take-up surface.

5. The process of claim 1, wherein the length of the path along which said filaments move toward said take-up surface ranges from about 2 to 40 inches, and the distance from the point of incidence of said stream of air against said stream of filaments to said take-up surface ranges from about 1 to 35 inches.

6. The process of claim 5, said path along which said filaments move being oriented at an angle ranging from about 30 to 90 degrees to the direction of movement of said take-up surface, and said stream of air being oriented at angle ranging from about 30 to 90 degrees to the extrusion path of said filaments.

7. The process of claim 1, wherein the speed of traverse of said filaments across said take-up surface varies from 16 to 150 feet per minute.

8. The process of claim 1, wherein the distance over which said take-up surface is moved between successive traverses of said filaments ranges from ¼ inch to 24 inches.

9. The process of claim 1, wherein the distance over which said take-up surface is moved between successive traverses of said filaments is less than the width of each layer of filaments deposited on said surface, whereby each of said layers overlaps a part of at least the next preceding layer.

10. The process of claim 9, wherein said distance is sufficiently short relative to the width of each of said layers that each layer overlaps parts of at least the next two preceding layers.

11. The process of claim 1, wherein said filament forming material is a solution of cellulose acetate in acetone and is extruded at a pressure ranging from about 250

to 2,000 p.s.i.g. and at a temperature ranging from about 50 to 150° C.

12. The process of claim 11, wherein the pressure of said stream of air impinging against said elements varies from 3 to 25 p.s.i.g.

13. The process of producing a non-woven fabric, comprising the steps of extruding a liquid solution of cellulose acetate in acetone downwardly and along a path the length of which ranges from about 2 to 40 inches toward a porous, horizontal, movable take-up surface to form a stream of substantially parallel continuous filaments oriented at an angle ranging from about 30 to 90 degrees to the horizontal, directing a stream of air under pressure at the still plastic filaments at an angle ranging from about 30 to 90 degrees relative to the direction of movement of said filaments and at a point the distance of which from said take-up surface ranges from about 1 to 35 inches thereby to agitate said stream of filaments and cause the latter to be whipped about and entangled into contact with one another at randomly spaced points prior to their coming to rest on said take-up surface, traversing said stream of filaments while the same are still in plastic condition, said stream of filaments being associated with said stream of air back and forth across said take-up surface at velocities varying from about 16 to 150 feet per minute, providing an evaporative atmosphere about said take-up surface under conditions sufficient to cause evaporation of said acetone from said filaments, maintaining said take-up surface stationary during said traverses of said filaments thereacross, and advancing said take-up surface in a direction perpendicular to the direction of traverse of said filaments only when the latter each the reversal points of their traversing movements, to enable said filaments to be deposited in their entangled state on said take-up surface in the form of an elongated matted web of predetermined thickness composed of a plurality of substantially parallel, overlapping, laterally contiguous layers and having a coherent structure in all directions resulting from the coalescence of said filaments at said points of contact.

14. The process of claim **13**, further comprising the step of spraying acetone against said layers from above substantially as the same are formed on said take-up surface to fuse some of said filaments making up said layers and thus impart a predetermined degree of stiffness to the ultimate non-woven fabric.

15. The process of claim **13**, further comprising the step of spraying acetone against said stream of filaments in their entangled condition from in front of said filaments as seen in the direction of movement of said take-up surface and during the traversing of said filaments across said take-up surface, thereby to engender a fusion of those of said filaments constituting the bottoms of said layers, whereby the ultimate non-woven fabric has a relatively stiff bottom surface.

16. Apparatus for producing a non-waven fabric, comprising an endless movable belt the upper reach of which defines a take-up surface, an extrusion jet provided with an orifice plate for extruding a stream of substantially parallel filaments toward said take-up surface adjacent one end of said belt, an air jet for directing a stream of air under pressure at the still plastic filaments at a point intermediate said orifice plate and said upper reach of said belt to agitate said stream of filaments and cause them to be whipped about and entangled into contact with one another at randomly spaced points prior to their arrival at said belt, support means for said extrusion jet and said air jet, first drive means operatively connected with said belt for advancing the latter intermittently, second drive means for traversing said support means and thus the agitated filaments back and forth across said belt, and means responsive to arrival of said support means at the reversal points of the traverse path thereof for actuating said first drive means only upon said support means being effectively stationary, whereby said filaments are deposited in their entangled state on said take-up surface of said belt in the form of an elongated matted web composed of a plurality of substantially parallel, overlapping, laterally contiguous layers and having a coherent structure in all directions resulting from the coalescence of said filaments at said points of contact.

17. Apparatus according to claim **16**, further comprising a spray head positioned above said belt for directing against said layers, substantially as the same are formed, a plasticizer for fusing some of said filaments making up said layers so as to impart a pre-determined degree of stiffness to the ultimate non-woven fabric.

18. Apparatus according to claim **16**, further comprising a spray head carried by said support means for directing against said entangled filaments at the front surface thereof, as viewed in the direction of movement of said upper reach of said belt, a plasticizer for fusing those of said filaments at said rear surface so as to impart a predetermined degree of stiffness to the ultimate non-woven fabric.

19. Apparatus according to claim **16**, further comprising brake means operatively connected with said belt for ensuring a substantially instantaneous stopping thereof upon deactuation of said drive means.

20. Apparatus according to claim **16**, said support means being provided with means for adjusting said jets vertically and angularly relative to said belt and relative to one another, to permit said orifice plate to be disposed at a distance ranging from 2 to 40 inches above said take-up surface and to orient said stream of filaments at the place of extrusion at an angle ranging from 0 to 90 degrees relative to the direction of movement of said belt, and to permit said air stream to impinge against said filaments at a distance ranging from 1 to 35 inches above said take-up surface.

21. Apparatus according to claim **20**, said air jet being disposed behind said stream of filaments as viewed in the direction of movment of said upper reach of said belt.

22. Apparatus according to claim **20**, said air jet being disposed in front of said stream of filaments as viewed in the direction of movement of said upper reach of said belt.

23. Apparatus according to claim **20**, said first drive means being preset to move said belt and thus said take-up surface, at each actuation of said first drive means, a distance less than the width of each of said layers deposited on said take-up surface.

24. Apparatus according to claim **20**, further comprising a cabinet enclosing said belt, said extrusion jet and said air jet and providing an atmosphere for drying and solidifying said filaments in said layers.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,314,840 April 18, 1967

Neil E. Lloyd et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 41, for "impringes" read -- impinges --; column 5, line 68, for "he" read -- the --; column 10, line 54, after "at" insert -- an --; column 11, line 33, for "each" read -- reach --; line 56, for "non-waven" read -- non-woven --.

Signed and sealed this 14th day of November 1967.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents