Jan. 21, 1969 M. R. LIVINGSTON ET AL 3,422,510

APPARATUS AND METHOD FOR PRODUCING A NON-WOVEN FABRIC

Filed Dec. 30, 1964 Sheet 1 of 4

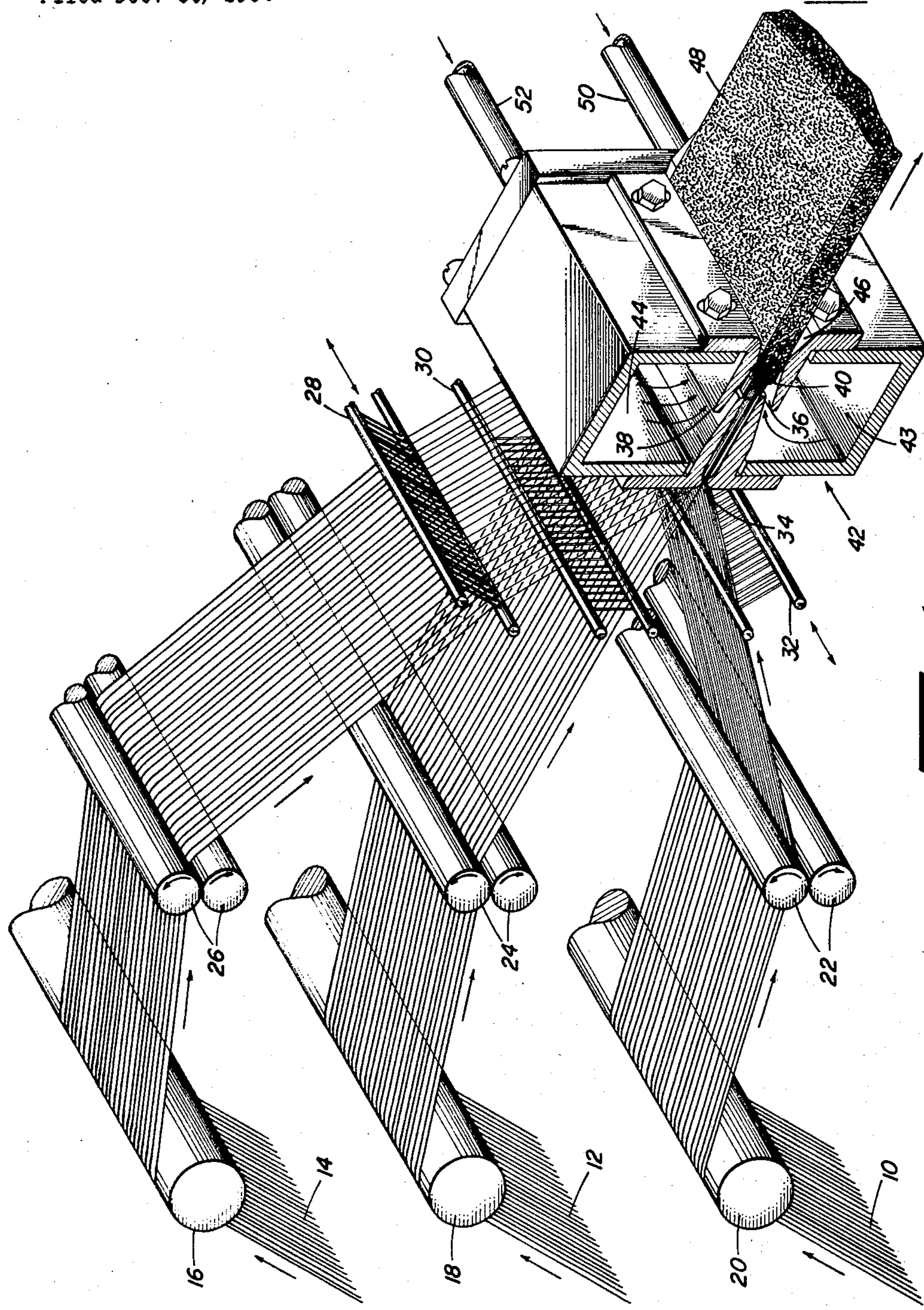

FIG. 1

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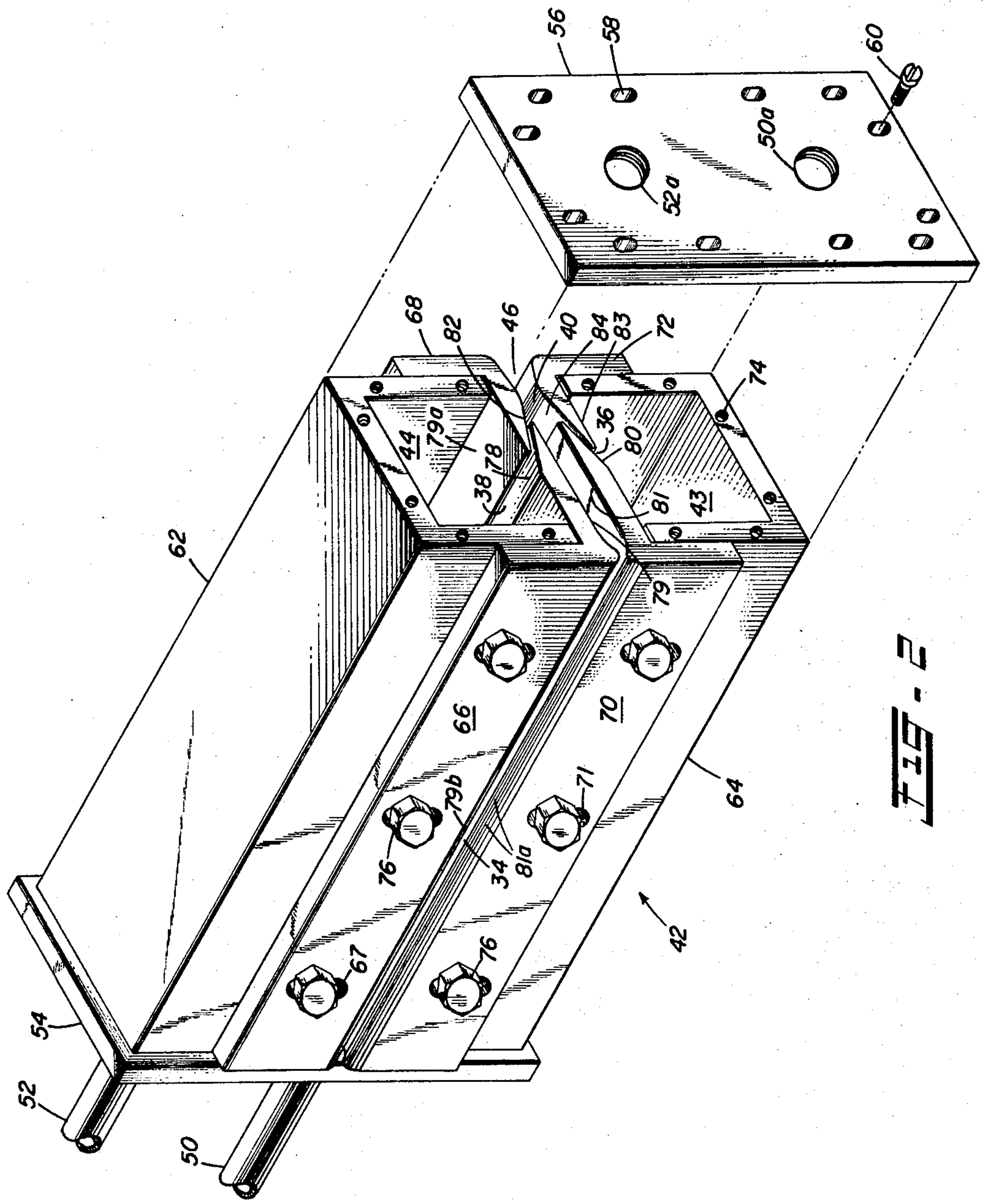

FIG-2

APPARATUS AND METHOD FOR PRODUCING A NON-WOVEN FABRIC

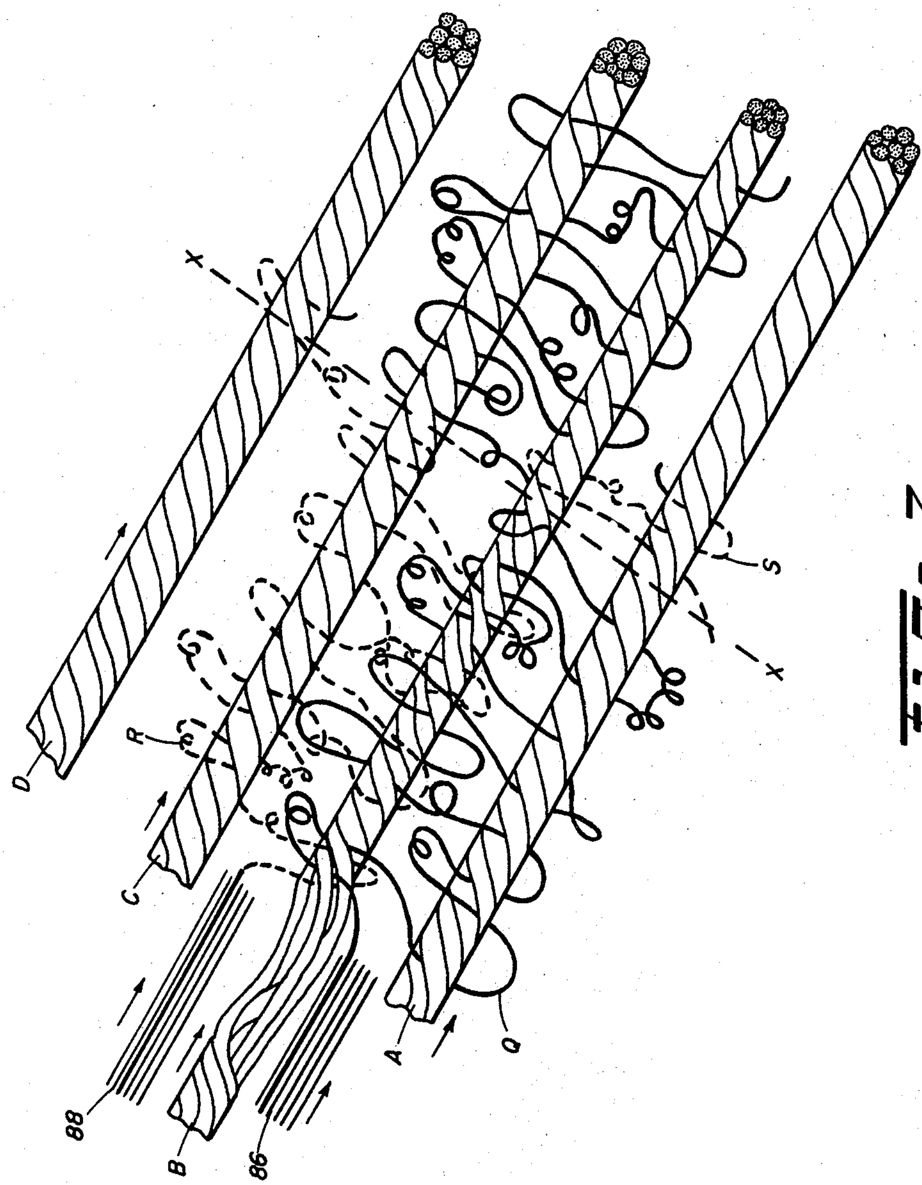

FIG. 3

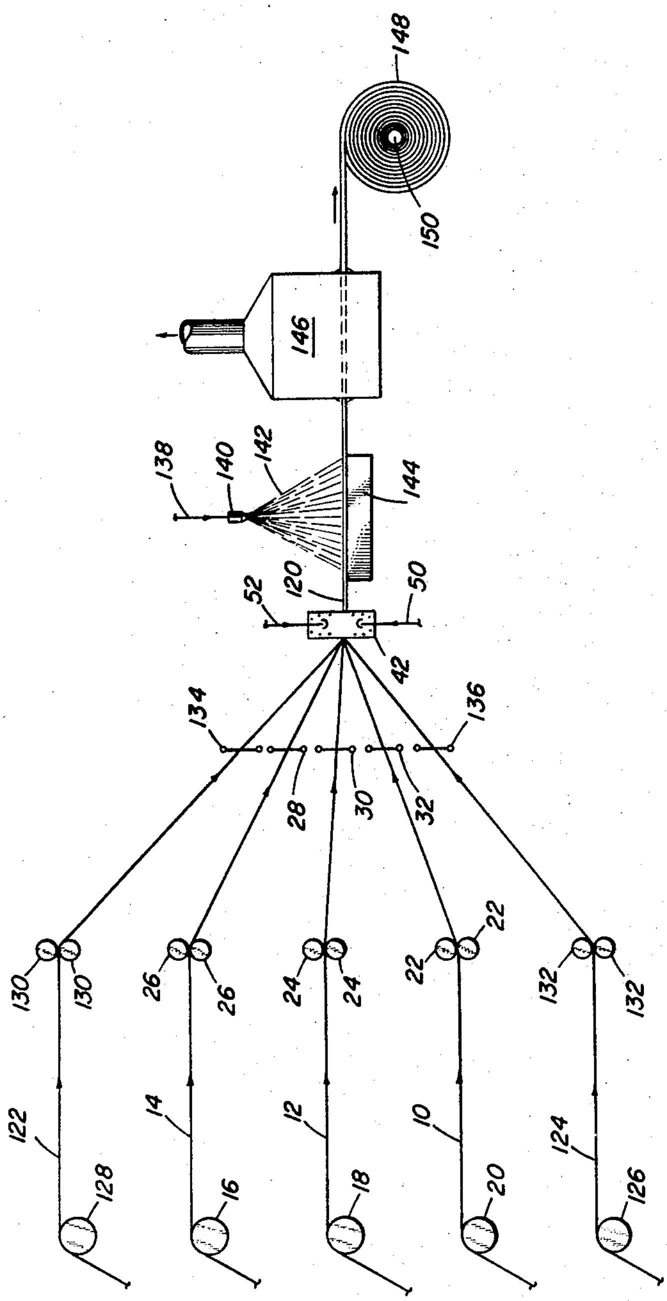
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FIG-4

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APPARATUS AND METHOD FOR PRODUCING A NON-WOVEN FABRIC

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Int. Cl. D02g *1/16;* D04h *17/00;* D03d *3/04*

ABSTRACT OF THE DISCLOSURE

Apparatus and method for producing a non-woven fabric, said method comprising feeding at a low overfeed a first sheet of warp yarns to the inlet slit of a bulking zone; simultaneously feeding to the inlet slit at an angle to the feed of the first sheet at least one other sheet of warp yarns at a higher feed rate than the first, said sheets being in at least partially superimposed relationship; oscillating the other sheet with respect to the first sheet prior to entry into the inlet slit; bulking the combined warp yarns in the bulking zone with a fluid medium under pressure whereby adjacent yarns are entangled to form a non-woven fabric; and withdrawing the resulting fabric from the outlet slit of the bulking zone.

This invention relates broadly to apparatus and method for producing a non-woven fabric. The scope of the invention also includes the non-woven fabric itself, which is unique in that it is made solely from warp yarns. In this new fabric, entangled warp yarns and/or filaments thereof serve as a substitute for the normal filling.

In accordance with the present invention a plurality (e.g., 2, 3, 5, 7 or any desired number) of sheets of warp yarns of any flexible filamentary material such as any of the available textile filaments, or blends or combinations thereof, are bulked to produce a continuous sheet of non-woven fabric in any desired width. As a result, the invention provides a low-cost, high-speed technique for producing fabrics that are similar to those which are knitted or woven from bulk or spun yarns.

It was known prior to the present invention that continuous filament yarns could be bulked (see, for example, U.S. Patents 2,783,609; 2,829,420; 2,852,906; and 2,884,756), which is also true of staple yarns as illustrated by U.S. Patent 2,869,967. Filamentary or fibrous mat materials are likewise known, as exemplified by U.S. Patents 2,736,676; 2,859,506; and 2,875,503. Jet devices for use in connection with the processing of filamentary materials are also known (see, for instance, U.S. Patent 2,924,868 and the patents referred to therein; also, U.S. Patent 3,055,080).

To the best of our knowledge and belief, however, it was not known or suggested prior to our invention to produce a bulked non-woven fabric from two or more warps of yarns as briefly described in the first two paragraphs of this specification and more fully hereafter.

It is a primary object of the present invention to provide a new and improved method of making a non-woven bulky fabric that simulates a woven or knitted fabric at a low cost and a high production speed.

Another object of the invention is to provide apparatus, including a component thereof (more particularly a slit-jet device), by the utilization of which the method features of the invention can be practiced.

Still another object of the invention is to provide a new non-woven fabric, more particularly a non-woven bulky fabric, that contains no filling (as do knitted and woven fabrics), and which can be produced at a relatively low

cost and high production speed, e.g., at from 25 to 50 yards or more per minute, and in any desired width.

Other objects of the invention will be apparent to those skilled in the art from the following more detailed description and from the accompanying drawing which is illustrative of a preferred embodiment of the invention.

The novel features of the invention are set forth in the appended claims. The invention itself, however, will be more readily understood from the following description taken in connection with the accompanying drawing, which is illustrative of the invention, and wherein

FIGURE 1 is an isometric, somewhat schematic, view illustrating the main process features of the invention, and shows warps of yarn from which the non-woven fabric is made; and also, guide or directional change rolls, feed rolls, means (specifically weaving reeds) for keeping the warp yarns in approximately parallel relationship, and a slit-jet device (with one end exposed for purpose of clarity) wherein the combined sheets of approximately parallel warp yarns of continuous length are entangled (more particularly mechanically, or physically entangled), as hereafter more fully described, to form a bulky or bulked fabric, and wherein, also for purpose of clarity, the thickness of the fabric emerging from the slit-jet device has been exaggerated;

FIGURE 2 is an isometric view of the slit-jet device of FIGURE 1 with one end plate illustrated as being in an exploded position in order to show more clearly the details of the device;

FIGURE 3 is a greatly enlarged view, partly isometric and partly plan, that illustrates in simple form the mode of entanglement that occurs between individual, adjacent, warp yarns when only two sheets or warps are used in the process; and

FIGURE 4 shows in flow-sheet form a modification of the process illustrated in FIGURE 1 by including two additional warps of yarn in the feed to the slit-jet device and showing means for imparting additional transverse strength to the finished fabric as desired or as conditions may require.

The present invention provides a new, unobvious and economical method of making a relatively inexpensive non-woven fabric. Briefly described, the method comprises feeding at a relatively low overfeed a first sheet or "core warp" of approximately parallel warp yarns to the inlet slit of the slit-jet device comprising a bulking zone having inlet and outlet slits. Simultaneously (i.e., along with the core sheet or warp) there is fed to the inlet slit at least one other sheet or warp (e.g., 2, 3, 4, 5, 6, 7, 8 or any desired higher number of sheets depending, for example, upon the particular apparatus employed, the particular warp yarns used, and the particular type or kind of non-woven fabric wanted) of approximately parallel warp yarns at a higher feed rate than that of the first sheet.

Some slight degree of overfeed of the core warp is necessary in order to provide sufficient slackness to permit the filaments to open in the turbulent or bulking zone to which the core warp and other sheet(s) or warp(s) subsequently pass. Otherwise, the loops formed in, or derived from, filaments of yarns of the adacent "other" sheet(s), sometimes herein designated as "effect" sheet(s) or warp(s), of higher overfeed than the core warp cannot penetrate and become entangled in, or interlaced with, the core warp yarns and/or the filaments thereof. The overfeed of the core warp may range, for example, from 0.5 to 10%, but preferably is within the range of from about 3% to about 8%. A core-warp overfeed substantially outside the aforementioned range of 0.5–10% generally produces a non-woven fabric that is less suited for the usual textile applications but may be suitable for other purposes.

The overfeed of the effect warp(s) ordinarily is at least 10% in excess of the overfeed of the core warp. So far as is known there is no upper limit on the overfeed of the effect warp(s) with respect to that of the core warp other than the influence that the percentage overfeed has upon the strength and weight of the finished fabric. A preferred range of the overfeed of the effect warp(s) is from 20% to 1000% in excess of the overfeed of the core warp, since within this range there can be produced fabrics having, in general, the widest appeal to the buyer.

The chosen overfeed of the effect warp(s) is greatly dependent upon the particular fabric construction employed and the characteristics desired in the finished fabric. For example, a core warp of 200 denier yarn can be bound together by a second warp of 100 denier fed at only 20% overfeed (i.e., 20% in excess of the feed rate of the core warp), and the resulting fabric might be designated as having about 320 denier/end. Conversely, a 100 denier core warp can be bound together by a 30 denier second warp fed at 600% overfeed to give about 310 denier/end. The fabrics have about the same weight, but their appearance, hand and strength vary greatly.

The sheet or sheets being fed at a higher feed rate to the inlet slit of the bulking zone are oscillated with respect to the first sheet prior to entry into the aforesaid inlet slit, e.g., by means of an oscillating weaving reed, or an oscillating comb such as those used on beamers or slashers. Other means of oscillating the effect sheet(s) of warp yarns include heddles such as are used on looms; hooked needles that provide criss-cross oscillation (some needles moving left as others move right, etc.); air currents directed by movable vanes; and threaded rolls in which the threads, while being parallel, progress first in one direction and then either reverse or "wander" over the surface in random manner. The oscillating means is advantageously one, such as an oscillating weaving reed or an oscillating comb, that also maintains the warp yarns in approximately parallel relationship. A suitable device or devices, e.g., one or more stationary weaving reeds or stationary combs, also is employed to maintain the warp yarns of the first sheet approximately parallel to each other.

Other examples of oscillating means will be apparent to those skilled in the art from the foregoing illustrative examples.

Ordinarily, in practicing the method features of this invention at least one (or at least two) angularly-fed sheet of substantially parallel warp yarns is fed from above and at least one (or at least two) angularly-fed sheet of substantially parallel warp yarns is fed from below the said first sheet at a higher rate than the said first sheet.

The oscillation of certain of the feed sheets to which reference previously has been made may be carried out in various ways. For example, one angularly-feed sheet approaching the inlet slit of the bulking zone may be oscillated in phase but in reverse order with at least one other angularly-feed sheet approaching the said slit; or, at least one angularly-fed sheet approaching the inlet slit may be oscillated out of phase with at least one angularly-fed sheet approaching the aforesaid inlet slit. Other variations in the movements of the high overfeed effect sheets have been suggested or indicated in an earlier paragraph describing various devices or means for effecting oscillation of said sheets.

The combined warp yarns are bulked in the bulking zone of a slit-jet device after entry therein through the aforesaid inlet-slit, more particularly in contact with a fluid medium, specifically a gaseous fluid medium, under pressure, e.g., high velocity air, nitrogen, argon, helium, carbon dioxide, flue gases, etc. In some cases, wet (saturated) or high-pressure (superheated) steam may be used. The only restriction on the use of steam is that its temperature should not be so high as to cause the yarns in the warps being processed to melt or to fuse together. Preferably air is used as the bulking medium.

By practicing the method of this invention including bulking in the aforementioned slit-jet device there is obtained a non-woven fabric, comprising sheet material consisting essentially (or consisting solely) of warp yarns, i.e., multifilamentary warp yarns, of continuous length wherein yarns of the warp that are in close proximity to each other are at least partly, if not almost or substantially completely, entangled together by loops formed in individual filaments of other close-proximity warp yarns. These loops are created during formation, and specifically during bulking, of the non-woven fabric.

As is illustrated more clearly in FIGURE 3, and in the production of which will be described more fully hereafter with particular reference to that figure, the invention provides a non-woven fabric comprising sheet material consisting essentially of warp yarns of continuous length wherein adjacent yarns thereof are opened up and penetrated in at least some of the openings by loops in individual filaments of other adacent warp yarns, whereby the said loops become entangled in, and more particularly interlaced with, the various adjacent warp yarns and hold the said yarns together. It will be understood, of course, by those skilled in the art that a more specific embodiment of such a non-woven fabric is a bulky non-woven fabric wherein at least some of the aforementioned "adjacent" warp yarns are those wherein the warp yarns are next to each other.

As will be further noted from a consideration of FIGURE 3 and the following more detailed description, the invention also provides a non-woven fabric material wherein the filamentary component consists essentially or solely of warp yarns of continuous length, and at least some (if not a major number or almost all or substantially all) of the individual yarns of the warp are connected to warp yarns adjacent thereto by cross-overs in the form of loops derived from individual filaments of warp yarns interposed between the said cross-overs. A preferred fabric of the invention is a bulky non-woven fabric comprised of organic filamentary material (examples of which will be given later herein) consisting of warps of the same or different organic yarns in continuous length and wherein adjacent yarns of the warp are at least partly (if not mostly or substantially completely) entangled together by loops derived from filaments of other adjacent warp yarns.

The invention also provides (see FIGURE 4 and the description hereafter given with reference to that figure) a bulky non-woven fabric comprising (1) sheet material consisting essentially or solely of warp yarns of continuous length and wherein yarns of the warp that are in close proximity to each other are at least partly entangled together by loops in (or derived from) individual filaments of other close-proximity yarns; and (2) a bonding agent that further bonds or holds together the said warp yarns and thereby imparts additional transverse strength to the said sheet material. It will be understood, of course, by those skilled in the art that a bonding agent may be used, if desired, in conjunction with any of the unbonded, non-woven fabrics of the invention in order to increase the transverse strength of the fabric.

After the combined warp yarns have been bulked in the bulking zone of the slit-jet device to yield a non-woven fabric having the above-described characteristics, the said fabric is withdrawn from the outlet slit of the bulking zone, and either passed to further processing steps (as illustrated in FIGURE 4, for example) or taken up on a suitable fabric take-up device.

The present invention also provides apparatus for producing a non-woven fabric comprising:

A. a slit jet having inlet and outlet slits leading to a bulking zone;
B. means including guide rolls and driven feed rolls adapted for feeding at a low overfeed a first sheet of approximately parallel warp yarns to the inlet slit of the said slit jet;
C. means including guide rolls and driven feed rolls adapted for feeding, simultaneously with the said first

sheet, to the inlet slit of the said slit jet at least one other sheet of approximately parallel warp yarns at a higher rate than that of the said first sheet;

D. oscillating means adapted to oscillate the said other sheet or sheets with respect to the first sheet prior to entry in the said inlet slit;

E. means for introducing a fluid bulking medium under pressure to the bulking zone of the said slit jet; and

F. means for withdrawing a non-woven fabric wherein adjacent yarns are intertwined with each other from the outlet slit of the said slit jet.

As previously indicated, the above-described apparatus advantageously additionally includes stationary means, e.g., a stationary weaving reed or reeds, for maintaining in approximately parallel relationship the warp yarns of which the aforesaid first or core sheet or warp is constituted prior to entry thereof in the inlet slit of the slit jet. Advantageously, too, the oscillating means additionally includes means, e.g., an oscillating weaving reed or reeds, for maintaining in approximately parallel relationship the warp yarns of which the angularly-fed sheet or sheets are constituted prior to entry thereof in the inlet slit of the aforesaid slit jet.

Of particular importance as a component of the apparatus of this invention and for use in practicing the method features of the invention to obtain a bulked, non-woven fabric is the aforementioned slit-jet device. In a preferred embodiment of the invention this device comprises:

(A) an inverted channel having downwardly extending side walls;

(B) an angle-shaped quarter-inlet jet member removably attached to one side wall and an angle-shaped quarter-outlet jet member removably attached to the opposite side wall of the said inverted channel, the bases of the said jet members abutting the lower edges of the said side walls and extending inwardly to form a slotted bottom wall for the said inverted channel, the vase of the said quarter-inlet jet member having an outer surface and a machined plane inner surface that slopes downwardly towards its inwardly-extending edge and the base of the quarter-outlet jet member having a plane inner surface and a machined plane outer surface that slopes upwardly toward its inwardly-extending edge, and the aforesaid jet members in their fixed operating positions providing means for entrance of a bulking fluid to a bulking zone, and the elements of (A) and (B) together forming a first chamber adapted to receive a bulking fluid;

(C) a channel having upwardly extending side walls;

(D) an angle-shaped quarter-inlet jet member removably attached to one side wall and an angle-shaped quarter-outlet jet member removably attached to the opposite side wall of the said channel, the bases of the said jet members abutting the upper edges of the said side walls and extending inwardly to form a slotted upper wall for the said channel, the base of the said quarter-inlet jet member having an outer surface and a machined plane inner surface that slopes upwardly toward its inwardly-extending edge and the base of the quarter-outlet jet member having a plane inner surface and a machined plane outer surface that slopes downwardly toward its inwardly-extending edge, and the aforesaid jet members in their fixed operating positions providing means for entrance of a bulking fluid to a bulking zone, and the elements of (C) and (D) together forming a second chamber adapted to receive a bulking fluid, said first and second chambers being spaced apart to provide an inlet slit adapted to receive sheet material consisting of warp yarns and an outlet slit adapted for the withdrawal of a sheet of non-woven fabric;

(E) removably attached end closure plates for closing the ends of the aforesaid first and second chambers and the end space between the two chambers; and

(F) means for introducing a bulking fluid into each of the aforesaid first and second chambers.

Preferably the means of (F), supra, are means for introducing high-velocity air into each end of the aforesaid first and second chambers. Alternatively, the air may be introduced (although less satisfactorily) into the top and into the bottom of the aforesaid first and second chambers. The point of supply of the fluid is not important so long as sufficient fluid is delivered to each member to maintain constant pressure from end to end of each.

Referring now to the accompanying drawing and, more particularly, to FIGURE 1 thereof, it is there shown by way of illustration that sheets of warp yarns **10**, **12** and **14** of any desired filamentary material (numerous examples of which are hereafter given) are fed over guide or directional change rolls **16**, **18** and **20**. The aforementioned warps are then fed to pairs of driven feed rolls **22**, **24** and **26** (drive not shown). Each pair of feed rolls is controlled by a variable speed drive so that the overfeed of the warps can be adjusted to meet the specific properties required in the finished fabric. The path of the warps passes through means for maintaining the warps in approximately equally-spaced, parallel relationship with each other, e.g., weaving reeds **28**, **30** and **32** or other similar devices. Weaving reed **30** is of the stationary type while reeds **28** and **32** are of the oscillating type with respect to center or core warp **12**.

The sheets or warps **10**, **12** and **14** are introduced into the yarn-inlet side **34** of the slit-jet device **42**. The physical make-up of the layers or sheets of yarn in these three warps is comparable to a sandwich. Warp **12** is the middle layer while warp **10** is below and warp **14** above it. A bulking medium, e.g., compressed air, is introduced to the lower (or second) air chamber **43** and the upper (or first) air chamber **44** of the slit-jet device **42** through conduits **50** and **62**, respectively, which pass through openings in end-closure plates **54** and **56**, respectively (FIGURE 2).

The bulking fluid, specifically air, from the air chambers **43** and **44** passes through slit-jet passages **36** and **38**, and encounters the three warps in the bulking zone **40**. In this zone, core sheet or warp **12** is bulked by filamentary and yarn entanglement, as briefly described above and more fully hereafter, with yarn from warps **10** and **14** and, specifically by loops in the individual filaments thereof. Warp **12** is used as the skeletal or sheet upon which all the bulking is done.

A major factor in obtaining the aforementioned results is the adjustment of the overfeed rates of the other two warps, viz., **10** and **14**, by means of feed rolls **22** and **26**. Warp or sheet **12** is fed at a relatively low overfeed rate while warps **10** and **14** are fed at considerably higher overfeed rates, thereby causing the warps **10** and **14** to be bulked over warp **12**. Details of the overfeed rates of the core and other warps and a discussion thereof have been given hereinbefore.

With regard to the degree of twist in the yarn, it may be mentioned that twists up to about 5 t.p.i. in the low overfeed or core warp **12** and twists up to the point of considerable liveliness (e.g., from 10 to 20 t.p.i.) in the high overfeed warps **10** and **14** can be used. However, if yarns twisted above about 1 t.p.i. in low overfeed warp **12** and above about 0.5 t.p.i. in high overfeed warps **10** and **14** are used, cross-entanglement is restricted due to limited movement of the filaments in the turbulent zone, as a consequence of which the resulting non-woven fabric has a low transverse strength and poor cover. Hence, it is desirable and advantageous that yarns in the low overfeed or core warp have a twist not exceeding about 1 t.p.i. and the yarns in the high overfeed warps **10** and **14** have zero or very low twist (preferably not exceeding about 0.5 t.p.i.) in order to obtain the best results.

The bulked or finished non-woven fabric **48** leaves the bulking zone **40** through the outlet slit **46**, which also serves as the outlet for the air from the slit-jet device **42**. The bulked or finished non-woven fabric, upon being withdrawn from the slit-jet device **42** by suitable driven rollers (not shown) can then be taken up over rollers or otherwise handled in any manner that is well known in the textile art.

Referring now more particularly to FIGURE 2, the slit-jet device **42** there shown may be made, for example, entirely (or at least the important functional elements thereof) of stainless steel or of chromium- or nickel-plated steel. It comprises an inverted channel **62** having removably attached lengthwise to the side walls thereof by means of machine screws **76** the angle-shaped quarter-inlet jet member **66** and the angle-shaped quarter-outlet jet member **68**. The base of the quarter-inlet jet member **66** has an outer surface **79** and a machined plane inner surface **78** that slopes downwardly toward its inwardly extending edge while the base of the quarter-outlet jet member **68** has a plane inner surface **79***a* and a machined plane outer surface **82** that slopes upwardly toward its inwardly-extending edge. The angles of both of the above-indicated slopes are, for example, about 15° to about 25° from the horizontal, more particularly about 20°. The two quarter jet members **66** and **68**, in their fixed operating positions, form the air passage **38** to the bulking zone **40**. In other words, the bases of the said jet members abut the lower edges of the side walls of the inverted channel **62** and extend inwardly to form a slotted bottom wall for the said channel.

The other half of the slit-jet device comprises a channel **64** having removably attached lengthwise to the side walls thereof by means of machine screws **76** the angle-shaped quarter-inlet jet member **70** and the angle-shaped quarter-outlet jet member **72**. The base of the quarter-inlet jet member **70** has an outer surface **81** and a machined plane inner surface **80** that slopes upwardly toward its inwardly-extending edge and the base of the quarter-outlet jet member having a plane inner surface **83** and a machined plane outer surface **84** that slopes downwardly toward its inwardly-extending edge. The angles of both of these above-indicated slopes are, for example, about 15° to about 25°, more particularly about 20°, and correspond to the angles of slopes mentioned in the preceding paragraph with reference to quarter-inlet and -outlet jet members **66** and **68**, respectively. The two quarter jet members **70** and **72**, in their fixed operating positions, form the air passage **36** to the bulking zone **40**. In other words, the bases of the said jet members abut the upper edges of the side walls of the channel **64** and extend inwardly to form a top wall for the said channel.

The dimensions of the air passages **36** and **38** are critical, but are dependent primarily upon the deniers and degree of overfeed of the warp yarns being processed. Therefore, the spacings between the surfaces **78** and **82** of the upper section and between surfaces **80** and **84** of lower section must be adjustable. The required degree of adjustment can be provided by using elongated holes **67** in member **66** through which pass the screws **76**. Due to the wide variations that are possible in warp yarns and overfeed rates, no rules can be established concerning the dimensions of passages **36** and **38**. However, they may vary from less than 0.005 inch, perhaps 0.004 or even as little as 0.0035 inch, for fine or extremely fine denier warps with low overfeeds up to 0.050 inch and more, perhaps 0.060 or even as much as 0.070 inch for heavy or very heavy denier warps and high overfeed rates. Each fabric construction requires optimizing the slits at the beginning of the run.

The volume of bulking fluid, e.g., compressed air or other gaseous fluid medium, used by the jet depends mainly upon the dimensions of the passages **36** and **38** and the pressure used. It may vary, for example, from about 25 cu. ft./in. of jet at 30 p.s.i.g. to about 100 cu. ft./in. at 70 p.s.i.g. with wider jet openings.

Yarn-inlet passage **34** and fabric-outlet passage **46** are formed by attaching end-cover plates **54** and **56** to the end of the above-described half-jet assemblies, which also may be described as being first and second chambers. The aforesaid end cover plates are screwed to the said first and second chambers by means of machine screws **60** passing through slotted holes **58** into the tapped holes **74**. The slotted holes **58** provide means for adjusting the height of the yarn-inlet passage **34** and fabric outlet passage **46**. The height of the passages **34** and **46** should be sufficient to accommodate, without friction, the sheets of warps used; and, also, should be sufficient to prevent a back-flow of the bulking medium, e.g., air.

If ridges **79***b* and **81***a* are used on the entering edges of outer surfaces **79** and **81**, respectively (see FIGURE 2), to make the slit jet self-threading, the spacing between the ridges may vary, for example, from 0.01 to 0.05 inch. If these ridges are so formed that they extend, for instance, about 0.03 inch above the surfaces **79** and **81**, the spacing between the flat portions of these surfaces may then vary, for example, from about 0.07 to about 0.11 inch. The ridges **79***b* and **81***a* are made, of course, by suitably machining the frontal or outward-extending edges of outer surfaces **79** and **81**, respectively.

Space **46**, the exit port, may vary at its narrowest portion from, for instance, 0.05 inch to 0.10 inch. The slope of the walls of the exit port may range, for example, from 5° to 10°, the preferred angle being about 5°. Difficulty is encountered in maintaining turbulence in the bulking zone if this slope is substantially more than 10°.

End-cover plates **54** and **56** are provided with two conduits **50** and **52** which are screwed into drilled and tapped holes **50***a* and **52***a*. A bulking medium, more particularly a fluid medium and specifically a gaseous medium (commonly air), is piped under pressure to both ends of the jet **42** in order to maintain equilibrium of air pressure in both lower air chamber **43** and upper air chamber **44**. In this way an even flow of gaseous bulking medium, e.g., air, is assured across the entire face of the slit-jet device through passages **36** and **38**. Any gaseous bulking media that have no deleterious effect upon the particular filaments may be employed, numerous examples of which have been mentioned hereinbefore.

The use of liquid bulking media, e.g., water, is not precluded but no advantages appear to reside in the use of such media. Furthermore, there are known disadvantages. For example, the volume and flow rates required would necessitate the use of very large and costly pumping equipment, while the removal of liquid from the finished fabric would require the expenditure of large quantities of heat.

Instead of having the bulking medium enter the chambers **43** and **44** through the ends of said chambers, it may be introduced into each of said chambers through one, two or more conduits entering the top, and the same number entering the bottom of each of said chambers. To furnish the required quantities of air, in some cases it may be necessary to use very large headers connected to chambers **43** and **44** at closely spaced intervals. Air or other gaseous fluid medium should be available at pressures ranging, for instance, from 20 p.s.i.g. to 100 p.s.i.g. The pressure and flow rates must be adjustable because no prediction of the optimum value of each for any given fabric construction can be made.

FIGURE 3 illustrates the bulking pattern that is produced when practicing the present invention. A pattern (or artificial weave or knit) results from the present invention that is believed to have been unknown heretobefore in the art of bulking fabrics.

In FIGURE 3, A, B, C and D represent individual yarns from the low overfeed or core warp **12**. As previously mentioned, twist in these core-warp yarns should not exceed about 1 t.p.i. for best operation. Yarns from warp **10** are designated **86** and **88**, and only one filament from each of these is shown tracing its way through a portion of the fabric. As also has been mentioned previously, the yarns in the high overfeed warp **10** should have zero or very low twist, preferably not exceeding 0.5 t.p.i. for best results.

Filament Q from yarn **86**, under the influence of the turbulent bulking medium, is whipped about rapidly with the result that many loops are formed therein. The yarns A, B, C and D are also whipped about by the turbulence, but movement of the individual filaments is restricted by the low overfeed to a simple opening up of the yarn structure. This permits some of the loops formed in Q and its fellow filaments from yarn **86** to penetrate the yarns A and B which are in close proximity. These loops become entangled into yarns A and B and serve to bind them together.

For the purpose of clarity and simplicity only the movement of filament Q is shown, but each of the filaments of yarn **86** follows a path similar to that shown for Q. The result is that a multitude of cross-over filaments binds yarns A and B together simply by being entangled therein at intervals.

Filaments of yarn **88** undergo entanglement between yarns B and C, similar to that just described with reference to filaments of yarn **86**, following paths in the manner illustrated by way of example for filament R of yarn **88**.

The oscillation of warp **10** causes yarn **86** to move into the space between yarns B and C as at X—X, so that filament Q and its fellow filaments are interlaced between B and C. This movement of whole yarns adds transverse strength to the fabric. At the same time, yarn **88** moves into the space between C and D as shown by the path of filament R, and another yarn (not shown) moves into the space between A and B, the filaments then interlacing these two yarns as illustrated by the path of filament S.

From the foregoing description it will be readily seen that if each yarn **86**, **88** is composed of, for example, 40 filaments, the interlacing between the yarns A, B, C and D of core warp **12** will become quite intense, resulting in a strong structure with good cover. The use of additional high overfeed warps further strengthens the total structure, and many loops protrude from the surface to give a soft, spun-yarn type of hand.

FIGURE 4 illustrates an embodiment of the invention wherein two additional sheets or warps of yarns **122** and **124** have been added with their corresponding directional change rolls **126** and **128**. Driven feed rolls **130** and **132** plus the oscillating weaving reeds **134** and **136** make up the forward half of this embodiment of the invention.

After passage of the five warps of yarns **122, 14, 12, 10** and **124** through the slit-jet device **42**, a very bulky, non-woven fabric **120** emerges. Suitable means are provided to give the non-woven fabric **120** additional transverse strength if needed or desired. To this end bonding and/or plasticizing agents may be fed through conduit **138** into spray nozzle **140** where the spray **142** of bonding and/or plasticizing agents is directed onto and into the non-woven fabric **120**. Any drippings are caught in the catch tray **144**.

Illustrative examples of bonding and/or plasticizing agents that may be used as described hereinbefore are solutions or dispersions in organic solvents or water, i.e., latices of binders such as natural or synthetic rubber, polyvinyl acetate, copolymers of vinyl acetate and vinyl chloride, phenol-, urea-, melamine-aldehyde (specifically -formaldehyde) resins separately or in various combinations or modifications; acrylic resins; epoxy resins; insolubilized starches; and the like. The chosen binder depends to a large extent upon the particular use of the end product.

Various plasticizers and other effect agents may be applied to the fabric, the chosen plasticizer depending, for example, upon such influencing factors as the chemical constitution of the filamentary material and the particular use of the finished fabric.

Examples of plasticizers that may be used are diethyl and dibutyl phthalates, diethyl, dibutyl and diamyl tartrates, ethyl citrate, benzyl alcohol, benzyl benzoate, di-(methoxyethyl) phthalate, the methyl and ethyl ethers of ethylene glycol, monoethyl-p-toluenesulfonamide, monomethylxylenesulfonamide, triacetin, formic acid, acetic acid, trichloroethyl phosphate, triphenyl phosphate, triethyl phosphate, glyceryl diacetate, glyceryl triacetate, diacetone alcohol, ethoxyethyl acetate, methoxyethyl acetate, butoxyethyl acetate, butoxyethanol, butoxyethoxyethanol, ethyl lactate, acetyl triethyl citrate, ethylene chlorhydrin, butyrolactone, triethanolamine, etc.

Referring again to FIGURE 4, the non-woven fabric **120** is shown as being pulled along by a driven wind-up mandrel **150** (drive not shown), and the spray-treated fabric is passed into a curing or drying oven **146** depending upon the type of agent or agents that have been sprayed or otherwise applied to the fabric **120**. Upon leaving the oven **146**, the finished fabric is wound into rolls **148** on the wind-up mandrel **150**.

Although the latter portion of this embodiment of the invention has been described with particular reference to a non-woven fabric made from five sheets of warp yarns, the same technique for applying bonding and/or plasticizing agents may be used, of course, in treating non-woven fabrics made from three sheets of warp yarns as illustrated in FIGURE 1, or from a plurality of any other number of such sheets.

The filamentary materials of which the warp yarns used in practicing this invention are comprised or composed may be of inorganic origin, e.g., glass filaments, or of organic origin, but preferably are organic. Examples of the latter are thermoplastic filaments such as nylon, polyesters such as polyethylene, terephthalate, polyurethanes, polycarbonates, acrylonitrile polymers and copolymers, polyester amides, polyethylenes, polypropylenes, ethers of cellulose, organic esters of cellulose and the like. Thus the filaments may be lower alkanoic esters of cellulose such as cellulose propionate, cellulose butyrate, cellulose acetatebutyrate, and the like, and especially cellulose acetate. The cellulose acetate may be conventional cellulose acetate having an acetyl value of about 55% by weight (calculated as acetic acid) or it may be cellulose triaceate having an acetyl value in excess of about 59%. Other and more specific examples of organic filamentary material are those comprised of fluorinated ethylene polymers and copolymers such as poly(monochlorotrifluoroethylene), polyhexamethylene adipamide, polycaproamide, and the like.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of producing a non-woven fabric which comprises feeding at a low overfeed a first sheet of approximately parallel warp yarns to the inlet slit of a bulking zone having inlet and outlet slits; simultaneously feeding to the inlet of the said slit at an angle to the feed of said first sheet at least one other sheet of approximately parallel warp yarns at a higher feed rate than that of the said first sheet, said sheets being in at least partially superimposed relationship; oscillating the said other sheet or sheets with respect to the said first sheet just prior to entry into the said inlet slit; bulking the combined warp yarns in the said bulking zone by contacting said yarns with a fluid medium under pressure whereby adjacent yarns are entangled with each other thereby to form a non-woven fabric; and withdrawing the resulting non-woven fabric from the outlet slit of the said bulking zone.

2. A method as in claim **1** wherein the first sheet is fed to the inlet slit of the bulking zone at an overfeed not exceeding about 10%.

3. A method of producing a non-woven fabric which comprises feeding, at from about 2% to about 10% overfeed, a first sheet of approximately parallel warp yarns to the inlet slit of a bulking zone having inlet and outlet slits; simultaneously feeding to the said inlet slit, at an angle to the feed of the first sheet, at least two other sheets of approximately parallel warp yarns at a higher feed rate than that of the said first sheet, said sheets being in at least partially superimposed relationship; oscillating the said other sheets with respect to the said first sheet just prior to entry into the said inlet slit; bulking the combined warp yarns in the said bulking zone in contact with a fluid medium under pressure whereby adjacent yarns are intertwined with each other to form a non-woven fabric; and withdrawing the resulting non-woven fabric through the outlet slit of the said bulking zone.

4. A method as in claim **3** wherein the fluid medium with which the warp yarns are contacted in the bulking zone is a gaseous fluid medium under pressure.

5. A method as in claim **4** wherein the gaseous fluid medium under pressure is air under pressure.

6. A method as in claim **3** wherein at least one angularly-fed sheet of substantially parallel warp yarns is fed from below the said first sheet at a higher rate than the said first sheet.

7. A method as in claim **6** wherein at least one angularly-fed sheet approaching the inlet slit of the bulking zone is oscillated in phase but in reverse order with at least one other angularly-fed sheet approaching the said slit.

8. A method as in claim **6** wherein at least one angularly-fed sheet approaching the inlet slit is oscillated out of phase with at least one angularly-fed sheet approaching the said slit.

9. A method as in claim **3** wherein at least two angularly-fed sheets of substantially parallel warp yarns are fed from above and at least two other angularly-fed sheets of substantially parallel warp yarns are fed from below the first said sheet at a higher rate than the said first sheet.

10. Apparatus for producing a non-woven fabric comprising:

A. a slit jet having inlet and outlet slits leading to a bulking zone;
B. means including guide rolls and driven feed rolls adapted for feeding at a low overfeed a first sheet of approximately parallel warp yarns to the inlet slit of the said slit jet;
C. means including guide rolls and driven feed rolls adapted for feeding, simultaneously with the said first sheet, to the inlet slit of the said slit jet at least one other sheet of approximately parallel warp yarns at a higher rate than that of the said first sheet;
D. said means of B and C including means feeding said sheets to said slit jets in angular at least partially superimposed relationship;
E. oscillating means adapted to oscillate the said other sheets or sheets with respect to the first sheet just prior to entry in the said inlet slit;
F. means for introducing a fluid bulking medium under pressure to the bulking zone of the said slit jet; and
G. means for withdrawing a non-woven fabric wherein adjacent yarns are entangled with each other from the outlet slit of the said slit jet.

11. Apparatus as in claim **10** which additionally includes stationary means for maintaining in approximately parallel relationship the warp yarns of which the said first sheet is constituted prior to entry thereof in the inlet slit of the said slit jet.

12. Apparatus as in claim **10** wherein the oscillating means additionally includes means for maintaining in approximately parallel relationship the warp yarns of which the said other sheet or sheets are constituted prior to entry thereof in the inlet slit of the said slit jet.

13. Apparatus as in claim **12** wherein the oscillating means is at least one oscillating weaving reed through which pass the warp yarns of which the said other sheet or sheets are constituted prior to entry thereof in the inlet slit of the said slit jet.

14. A slit-jet device adapted for use in producing a bulked non-woven fabric, said device comprising:

A. an inverted channel having downwardly extending side walls;
B. an angle-shaped quarter-inlet jet member removably attached to one side wall and an angle-shaped quarter-outlet jet member removably attached to the opposite side wall of the said inverted channel, the bases of the said jet members abutting the lower edges of the said side walls and extending inwardly to form a slotted bottom wall for the said inverted channel, the base of the said quarter-inlet jet member having an outer surface and a machined plane inner surface that slopes downwardly towards its inwardly-extending edge and the base of the quarter-outlet jet member having a plane inner surface and a mechanical plane outer surface that slopes upwardly toward its inwardly-extending edge, and the aforesaid jet members in their fixed operating positions providing means for entrance of a bulking fluid to a bulking zone, and
 the elements of A and B together forming a first chamber adapted to receive a bulking fluid;
C. a channel having upwardly extending side walls;
D. an angle-shaped quarter-inlet jet member removably attached to one side wall and an angle-shaped quarter-outlet jet member removably attached to the opposite side wall of the said channel, the bases of the said jet members abutting the upper edges of the said side walls and extending inwardly to form a slotted upper wall for the said channel, the base of the said quarter-inlet jet member having an outer surface and a machined plane inner surface that slopes upwardly toward its inwardly-extending edge, and the aforesaid jet members in their fixed operating positions providing means for entrance of a bulking fluid to a bulking zone, and
 the elements of C and D together forming a second chamber adapted to receive a bulking fluid, said first and second chambers being spaced apart to provide an inlet slit adapted to receive sheet material consisting of warp yarns and an outlet slit adapted for the withdrawal of a sheet of non-woven fabric;
E. removably attached end closure plates for closing the ends of the aforesaid first and second chambers and the end space between the two chambers; and
F. means for introducing a bulking fluid into each of the aforesaid first and second chambers.

15. A slit-jet device as in claim **14** wherein the means of F are means for introducing high-velocity air into each end of the aforesaid first and second chambers.

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