Oct. 1, 1968 L. O. DWORJANYN 3,403,862

APPARATUS FOR PREPARING TANGLELACED NON-WOVEN FABRICS BY LIQUID STREAM JETS

Filed Jan. 6, 1967 2 Sheets-Sheet 1

FIG. 1

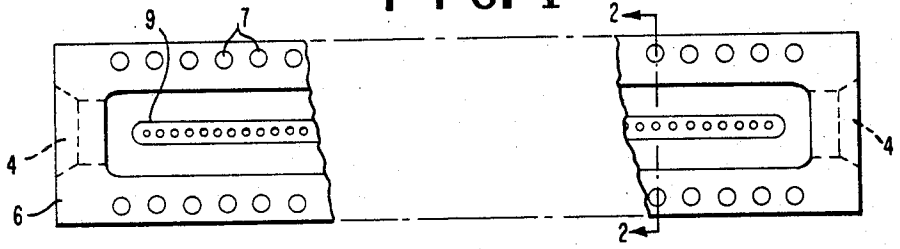


FIG. 2

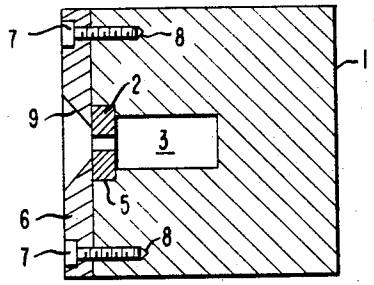


FIG. 7

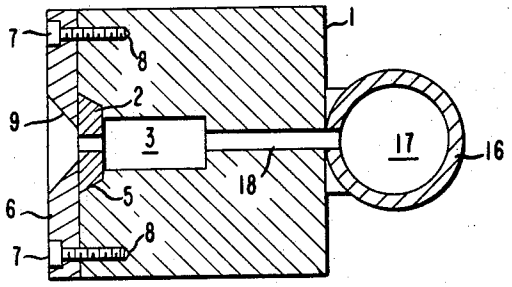


FIG. 6

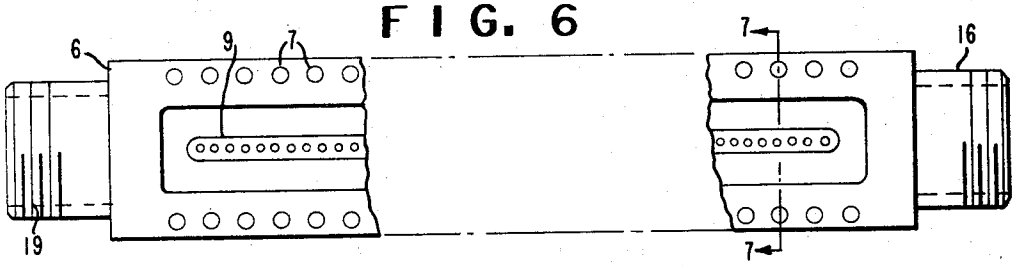


FIG. 3

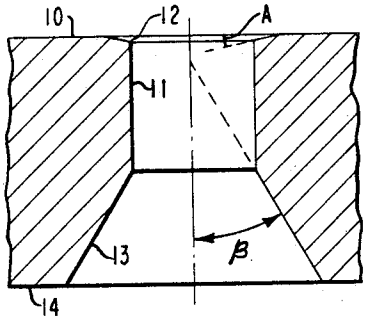


FIG. 4

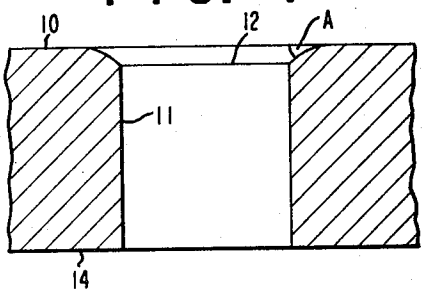
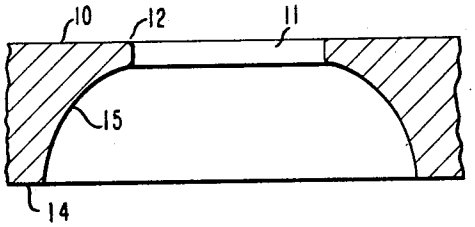


FIG. 5



INVENTOR
LEE O. DWORJANYN

BY Norris E. Buchanan
ATTORNEY

Oct. 1, 1968 L. O. DWORJANYN 3,403,862
APPARATUS FOR PREPARING TANGLELACED NON-WOVEN FABRICS BY LIQUID STREAM JETS
Filed Jan. 6, 1967 2 Sheets-Sheet 2

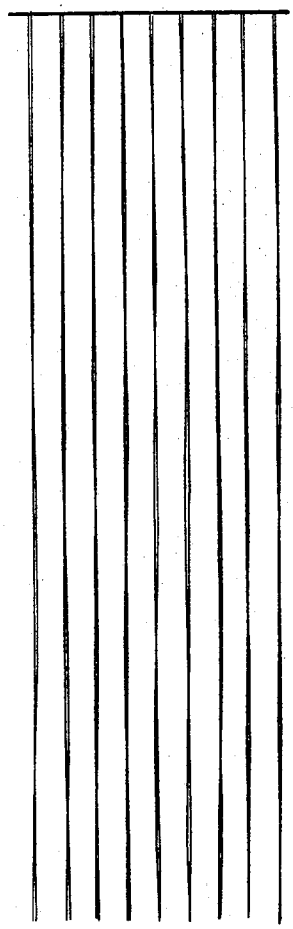
FIG. 8



FIG. 9



FIG. 10



INVENTOR
LEE O. DWORJANYN

BY Nonie E. Reichman
ATTORNEY

United States Patent Office

3,403,862

Patented Oct. 1, 1968

3,403,862

APPARATUS FOR PREPARING TANGLELACED NON-WOVEN FABRICS BY LIQUID STREAM JETS

Lee O. Dworjanyn, Wilmington, Del., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

Filed Jan. 6, 1967, Ser. No. 607,698
3 Claims. (Cl. 239—566)

ABSTRACT OF THE DISCLOSURE

Apparatus is described for preparing tanglelaced nonwoven fabrics by jetting liquid streams into a layer of fibrous material to entangle the fibers. Liquid is jetted at 200 to 5000 pounds per square inch from a line of orifices 2 to 30 mils in diameter to form high energy streams. Improvements in jet manifolds are disclosed to provide more effective liquid streams.

The invention relates to jet equipment for treating fibrous material with high pressure streams of liquid, and is more particularly concerned with the jet devices used for preparing tanglelaced nonwoven products.

Methods are known for rearranging fibers of a loose layer into a pattern by treatment with low pressure sprays of water directed through apertures of a patterning plate. Patterned structures prepared in that way require adhesive or binder to bond the individual fibers together. It has recently been found that the highly concentrated energy of fine streams of liquid jetted from orifices at pressures of 200 to 5000 p.s.i. can securely entangle fibers to provide strong, durable nonwoven fabrics without using any adhesive or binder. In this process a layer of fibrous material on a suitable support is passed under high pressure streams from a row of small diameter orifices in a jet manifold until the fibrous material has received sufficient treatment energy to produce the required fiber entanglement. Products in which the fibers are securely entangled are designated tanglelaced fabrics. By supporting the fibrous material on suitable patterning members during treatment, tanglelaced fabrics can be produced which resemble conventional woven fabrics in appearance and properties.

The energy of the stream is proportional to the pressure at which the stream is formed and to the volumetric flow rate. The concentration of this energy is inversely proportional to the cross-sectional area of the stream when it reaches the layer of fibrous material. The flow rate through a circular sharp-edged orifice is commonly stated to be

$$0.61\left(\frac{\pi}{4}D^2\right)\sqrt{2gh}$$

where 0.61 is the discharge coefficient, D is the orifice diameter, g is the acceleration due to gravity, and h is the head of liquid. Prior art studies of the use of relatively large orifices for measuring or regulating flow rates have not been concerned with maintaining the energy of the stream concentrated after the stream has been formed at the orifice. Previous small diameter orifices have been found to produce streams which rapidly increase in cross-sectional area as they travel away from the point of initial formation in the orifice. Within a short distance, the density of such a stream becomes so low that the stream disintegrates into separate drops of liquid.

The jet device of the present invention provides streams having substantially the initial cross-sectional area for a considerable distance from the orifice, so that the stream remains at relatively high density at treatment distances.

Improved orifices make possible the treatment of fibers with streams which have a remarkably high concentration of energy and are much more effective than previous streams for producing tanglelaced fabrics. Less water consumption is required, and the orifices can be more closely spaced to provide more uniform treatment. These relatively high density, unbroken streams will be designated coherent liquid streams.

The present invention is an improvement in jet equipment for treating a layer of fibrous material with streams of liquid, jetted against the layer from orifices arranged in a row in a manifold supplied with liquid at high pressure wherein the improvement comprises a manifold wall having a surface finish around the orifice entrances of less than 40 microinches surface roughness, as measused by A.S.A. Standard No. B–46.1–1962, an orifice entrance bevel of less than 10° extending a mean distance of less than 100 microinches into the orifice throat, the variation from said mean not exceeding ±20 microinches around the perimeter, and a peak to valley deviation along the orifice entrance edge of less than 0.04 D., where D. is the mean orifice diameter. The cross-sectional configuration of the hole must be such that the stream does not contact the wall.

The orifices can be formed by methods used for spinnerets, but the manifold surface must be carefully finished to avoid the excessive rounding of the orifice entrance which is characteristic of spinnerets. Thus, the orifices can be drilled from the entrance surface, smoothed with a broach, and the manifold wall polished around the orifice entrances, provided that special precautions are taken to work within the specified limits. Experience indicates that this cannot be accomplished by drilling from the outside of a manifold. Therefore, the orifices are preferably prepared in a metal strip which is subsequently with a previous manifold.

In the drawings, which illustrate specific embodiments of the invention and the streams obtained in comparison with a previous manifold.

FIGURE 1 is a bottom view of a jet manifold,

FIGURE 2 is a sectional end view taken on line 2—2 of FIGURE 1,

FIGURE 3 is an enlarged sectional view of a preferred form of orifice, the cross-section being taken along the axis of the orifice,

FIGURE 4 is a corresponding view of a previous form of orifice,

FIGURE 5 is a corresponding view of a second preferred form of orifice,

FIGURE 6 is a bottom view of an alternate jet manifold arrangement,

FIGURE 7 is a sectional end view taken on line 7—7 of FIGURE 6, and

FIGURES 8, 9 and 10 are enlarged views of water streams jetted at 1000 p.s.i. from 5 mil orifices in manifolds, the first 1.5 inches of the stream flow being shown in each figure and the orifices differing as follows:

FIGURE 8 (not in accordance with this invention) drilled opposite to the direction of flow, as described in the comparison portion of Example 1;

FIGURE 9, drilled and finished in accordance with this invention as described in Example 1; and

FIGURE 10, drilled and finished in accordance with further improvements described in Example 2.

Referring now to FIGURES 1 and 2, there is shown a manifold body **1** into which the orifice strip **2** is sealed. The manifold body has a rectangular chamber **3** into which liquid, under a pressure of 200–2000 p.s.i.g. or greater, is admitted through a pair of inlet passageways **4**. The orifice strip rests in a groove **5** and is sealed in place by a slotted retaining plate **6**. The retaining plate is

secured to the body by a plurality of bolts **7** which engage threaded holes **8** in the holder.

In this embodiment the body of the manifold is preferably formed from a rectangular block of Type 304 or 316 stainless steel which measures 1.5 inches (3.8 cm.) wide and 1.5 inches (3.8 cm) high, and is of a length determined by the width of fabric to be treated. A chamber **3**, 0.25 inch (0.64 cm.) wide and 0.5 inch (1.3 cm.) deep, is machined into the block. The liquid inlets **4** are drilled from both ends of the block and penetrate the end walls of the chamber.

Two rows of threaded holes **8** are formed to receive the bolts **7** which secure the orifice strip and retaining plate to the holder. A shallow groove **5** is machined in the base of the block to receive the orifice strip **2**. The retaining plate is of stainless steel and measures 1.5 inches (3.8 cm.) wide and 0.625 inch (1.59 cm.) thick. A tapered slot **9**, of a length greater than the row of orifices, is machined through the thickness of the strip, diverging in the direction of stream flow from a width of 0.063 inch (0.160 cm.) to 0.5 inch (1.27 cm.). The slot exposes the row of holes in the perforated strip, and diverges so as to support the maximum area of the perforated strip without interfering with stream flow. In this preferred embodiment the orifice strip is formed from stainless steel and the dimensions approximate those of the groove **5** in which it rests.

The configuration of the holes in the orifice strip **2** is critical to the production of coherent and parallel nondiverging streams. One preferred hole configuration, comprising three sections of different contours, is illustrated in FIGURE 3. The upstream surface **10** of the orifice strip intersects the cylindrical hole-throat **11** to form a substantially right-angle entrance edge **12**. Downstream from the hole-throat **11** the bore diverges to form a frusto-conical exit section **13**. For purposes of convenience in machining, the angle of divergence (β), measured with respect to the hole axis, is preferably 30°, but any angle above 5° will help to avoid interference with the stream formed by the orifice.

A hole contour of this type may be formed by first drilling a hole completely through the strip, the diameter of this hole being about 30% less than the final hole diameter but not more than about 0.002 inch (0.005 cm.) less than the final hole diameter. The exit section is then formed using a conical drill, after which the hole-throat and entrance edge are smoothed by the broach as it enlarges the hole from the upstream side. The upstream surface of the strip around the inlet edge **12** is then polished to have less than 40 microinches surface roughness, as measured by A.S.A. Standard No. B–46.1–1962. Great care is taken to avoid rounding the orifice entrance edge **12**. A slight bevel appears to be inevitable but the angle A of departure from the plane of the upstream surface **10** must be less than 10°, and the bevel must extend less than a mean distance of 100 microinches into the orifice throat, measured perpendicular to the plane of the upstream surface. The resulting orifice entrance edge **12** must have less than 0.04 D roughness height, i.e., peak to valley deviation, where D is the mean orifice diameter in inches. This value can be measured by microscopy-observation and comparison with the measured value of the adjacent upstream surface.

FIGURE 4 ilustrates an orifice which is not in accordance with this invention because of imperfections, e.g. excessive rounding or burrs or nicks, at the entrance edge. When an orifice is drilled from the downstream surface **14**, the edge breaks away or forms burrs at the upstream surface to an extent which has made finishing to the required limits impossible. The angle A exceeds 10° and the entrance bevel extends more than 100 microinches into the orifice throat. A similar rounding of the entrance edge is found when an orifice strip, although drilled from the upstream surface, is merely polished to have less than 40 microinches surface roughness without observing the precautions detailed above.

FIGURE 5 illustrates an orifice produced by etching instead of drilling. The procedure described in Mears et al. U.S. Patent No. 2,536,383 of Jan. 2, 1951, is used to etch a hole from the downstream face **14**. A brief etching from the upstream face is then used to provide an orifice throat **11** of the required diameter. A relatively short throat-length of 0.0005 inch (0.0013 cm.) or less can be provided in this way. Downstream from the throat, the hole diverges to a frusto-paraboloidal exit portion **15**. The finished orifice must conform to the limits defined previously. In addition, care is preferably taken to obtain an approximately cylindrical orifice throat. Although the roundness obtained by drilling is not essential provided that the orifice is satisfactory in other respects, and non-circular orifices are within the scope of this invention, any out-of-roundness preferably should not exceed ±5 to 10% of the average throat diameter for maximum effectiveness.

Either of the drilling or etching procedures described can be used to prepare orifices of 0.002-inch diameter, or less, or of 0.060-inch diameter, or more. For the purposes of the present invention, diameters of 0.003 to 0.030 inch are preferable. The spacing of the orifices, produced by the above or other methods, should be sufficient to avoid interaction between adjacent streams. The preferred center-to-center spacing is from 3 to 10 times the diameter. For orifices of more than one diameter the larger diameter is used in determining a suitable spacing.

FIGURES 6 and 7 illustrate a type of orifice manifold which is desirable when there is a long line of orifices. The flow rate required to supply the large number of streams results in high inlet velocities, and associated turbulence, which interfere with formation of uniform streams and may disrupt coherent flow from many orifices. In order to overcome this problem, a distribution conduit **16** is welded onto manifold body **1**. The chamber **17** of the conduit is interconnected with the rectangular chamber **3** of the manifold body through a plurality of passages **18** drilled through the body and conduit. The liquid is introduced through the ends **19** of the conduit and is uniformly divided among the different passages **18**, each of which may supply only 10 to 40 orifices. Turbulence and uneven flow can be further reduced by mounting a coil of wire, a fine mesh screen, or a perforated plate in the chamber **3** so that it is spaced from the orifice strip **2**. The orifice strip and the groove **5** are beveled to provide a better seal. In other respects this embodiment is similar to the one shown in FIGURES 1 and 2, described previously.

The improved jet equipment of this invention is particularly useful for preparing patterned, tanglelaced fabrics. The process involves supporting a layer of fibrous material on an apertured patterning member and traversing the supported layer with liquid streams, jetted at high pressure and having a high concentration of energy, for a sufficient amount of treatment to securely entangle the fibers in a pattern determined by the supporting member. The starting layer may be any web, mat or batt of loose fibers prepared by carding, random laydown, air or slurry deposition. The patterning member may be a perforated plate, or a woven wire screen of 3 to 80 or more wires per inch (1 to 31 wires/cm.) having wire diameters ranging from 0.005 to 0.025 inch (0.013 to 0.064 cm.) and having 10% to 75% open area.

The liquid streams are jetted at a pressure of at least 200 p.s.i. and preferably at 1000 to 2000 p.s.i. or higher. For best results the energy of the streams should be highly concentrated. The energy flux EF of the streams will depend upon the jet device used, the pressure of the liquid supplied to the jet orifice, and the orifice-to-web spacing during treatment. The liquid initially forms a "solid" stream, i.e. an unbroken, homogeneous liquid stream. The initial energy flux, in foot-poundals per square inch per second, is readily calculated by the formula,

$$EF_1=77\,PG/a$$

where:

P=the liquid pressure in p.s.i.

G=the volumetric flow of the stream in cu. ft./minute, and

A=the initial cross-sectional area of the stream in square inches.

The value of G for use in the above formula can be obtained by measuring the flow rate of the stream. The initial cross-sectional area a, which is inside the jet device, can be determined by measuring the actual orifice area and multiplying by the discharge coefficient (usually 0.61), or it can be calculated from measured flow rates. Since the area a corresponds to solid stream flow, the above formula gives the maximum value of energy flux which can be obtained at the pressure and flow rate used. The energy flux of streams from previous orifices has decreased rapidly as the streams travel away from the orifice, even when using carefully drilled orifices. The stream diverges to an area A just prior to impact against the web and the kinetic energy of the stream is spread over this larger area. The cross-sectional area A can be estimated from photographs of the stream with the web removed, or can be measured with micrometer probes. The energy flux is then equal to the initial energy flux times the stream density ratio (a/A). Therefore, the formula for energy flux at the web being treated is

$$EF_W=77\,PG/A \text{ ft.-poundals/in.}^2 \text{ sec.}$$

The preferred jet devices of this invention provide streams which, with very few exceptions, have substantially constant cross-sectional areas for a distance of at least 3 or 4 inches from the orifices. Since the value of a/A is approximately unity, the energy flux at the web being treated is aproximated by the formula for the initial energy flux, $EF=77PG/a$. On the other hand, with previous jet devices having orifices prepared by drilling a tube from the outside or downstream surface, the value of A increases rapidly with distance from the orifices and the energy flux at the web-treatment distance is greatly reduced, as shown in Example 2.

The web must be treated with a sufficient amount of energy to provide the desired fiber entanglement. Adequate treatment will provide tanglelaced fabrics which, without the use of binder or other additional treatment, are so strong and durable that they can withstand repeated use and laundering without appreciable loss of strength or surface pilling and fuzzing. The amount of treatment is measured by the energy expended per pound of treated fabric. The amount of energy E_1 expended during one passage under a manifold, in horsepower-hours per pound of fabric, may be calculated from the formula:

$$E_1=0.125\ (YPG/sb)$$

where:

Y=number ofg orifices per linear inch of manifold,

P=presure of liquid in the manifold in p.s.i.g.,

G=volumetric flow in cu. ft./min./orifice,

s=speed of passage of the web under the streams, in ft./min., and

b=the weight of the fabric produced, in oz./yd.^{2}.

The total amount of energy expended in treating the web is the sum of the individual energy values for each pass under each manifold, if there is more than one.

When treating fibrous material with streams of water impinged on the material at an energy flux EF of at least 23,000 ft.-poundals/in.^{2} sec., patterned, tanglelaced nonwoven fabrics can be prepared at expenditures of energy of at least about 0.2 HP hr./lb. of fabric. At any given set of processing conditions, surface stability of the non-woven fabric obtained (i.e., the resistance of the fabric to surface pilling and fuzzing) can be improved by increasing the total amount of energy E used in preparing the fabric. For products with sufficient surface stability to withstand repeated launderings, such as might be required for certain apparel and other uses, an energy flux EF of at least 100,000 ft. poundals/in.$_2$ sec. and an energy E greater than 1 HP hr./lb. of fabric are preferred.

The jet devices of this invention are highly efficient for producing such tanglelaced fabrics, as shown in Example 3. The previous jet devices are much less effective, not only because the energy is less concentrated, but because of the large amount of air associated with the low density streams. The entrapped air interferes with the action of the liquid on the fibers and may cause gross non-uniformities in the pattern of the fabric. The air prevents satisfactory tack-down of the web in initial operations. The fibers must be secured on the patterning support so that the web will retain coherency and uniformity when exposed to the high energy flux streams used in the primary treatment. With the previous jet devices this involves restraining the web under a coarse mesh screen or perforated plate until the fibers are fixed in position, and/or starting the treatment with low-pressure streams, but this initial treatment decreases the efficiency by increasing the amount of liquid and horsepower-hours of energy required to produce a pound of fabric.

In contrast to the above, loose fibrous webs can be exposed directly to high energy flux streams from the jet devices of this invention without requiring prior treatment with low pressure streams, which are ineffective for entangling, or the use of special devices which restrain movement of the fibers. The efficiency in terms of water consumption and horsepower-hours of energy is greatly improved. The more concentrated energy of the streams also accomplishes better patterning and entangling of fibers, so that superior tanglelaced fabrics and finer patterns can be produced.

The following examples illustrate preferred embodiments and advantages of the invention but are not intended to limit the scope of invention.

EXAMPLE 1

(a) A flat surface, parallel to a tangent, is machined axially along a 6 inch (15 cm.) section of the outer wall of a stainless steel tube having an orginal outside diameter of 0.5 inch (1.3 cm.). The original wall thickness of 0.1 inch (0.25 cm.) is reduced to 0.019 inch (0.048 cm.) at the flat surface. The tube is cut lengthwise on each side of the flat portion and a row of 0.0048 inch (0.012 cm.) diameter orifices, evenly spaced at 40 holes per inch, are drilled into the 0.019 inch thick wall. The holes are drilled from the inside surface of the tube with the axes parallel to each other and perpendicular to the flat surface. The drilled portion of the tube is polished with 600 grit paper to remove drilling burrs. The holes are smoothed by pushing a 0.0050 inch (0.013 cm.) diameter broach through from the inside surface of the tube. The drilled tube wall is then carefully polished. The inner surface of the wall has a finish of 12 microinches (0.30 micron) surface roughness around the orifice entrances with orifice entrance bevels of less than 10° extending from 10 to 20 microinches into the orifice throat. Along the orifice entrance edges the peak to valley deviation from the mean orifice diameter is less than ±1.5% (±0.0015 D). The sections of the tube are rejoined by welding after the above drilling and polishing operations.

(b) For comparison a drilled tube manifold was prepared without cutting the tube apart for drilling and polishing. The orifices were drilled from the outside with a cylindrical wooden rod inserted in the tube. The wooden rod, in which burrs resulting from the drilling operation were imbedded, was removed. The inside of the tube was polished as well as possible, using a piece of 600 grit paper on the end of a metal rod. The holes were then reopened with a 0.0050 inch diameter broach, and the inside of the tube was again polished with 600 grit paper. The two ends of the tube were connected to a water supply at 1000 p.s.i. FIGURE 8 illustrates the streams formed with this tube; they diverged immediately on leaving the orifice and

broke up as they receded. Within the 1.5 inch distance shown, the streams had disintegrated into separate drops of liquid. The tube was then cut open for evaluation. The surface roughness was greater than 100 microinches on the inside of the tube around the holes and on the orifice entrance edge. There was an irregular entrance edge bevel slope of greater than 10°.

FIGURE 9 illustrates the improved streams obtained at 1000 p.s.i. with a tube drilled from the inside surface and finished in accordance with this invention as described in paragraph (a) of the example. The streams remain coherent for a much greater distance and do not begin to break up until they have traveled most of the 1.5 inch distance illustrated in the figure.

EXAMPLE 2

This example illustrates a further improvement in jet manifolds.

A perforated strip is prepared from a stainless steel strip 0.012 inch (0.031 cm.) thick and 0.500 inch (1.3 cm.) wide. Holes 0.005 inch (0.013 cm.) in diameter are drilled at an even spacing of 20 per inch along the center line of the strip. The strip is carefully polished on both sides with 600 grit paper and the holes are smoothed by passing a 0.0051 inch broach through the holes in the direction of drilling. The strip is then cleaned in an ultrasonic bath and mounted in a manifold of the type illustrated in FIGURES 1 and 2. The strip is arranged so that the directions of drilling and fluid flow are the same.

The surface of the upstream face of the strip around the orifices has a finish roughness of 4 microinches (0.1 micron). The bevel slope is less than 5° and extends into the hole for a maximum distance of 8 microinches. The maximum peak to valley deviation along the orifice entrance edges is ±0.01 D. FIGURE 10 illustrates the improved stream stability obtained when jetting water supplied at 1000 p.s.i. The streams remain columnar, nondivergent and coherent for the entire 1.5 inch distance of travel shown.

The following tables show the great improvement in stream density and energy flux of the above streams over those obtained with drilled tube orifices prepared by drilling a tube from the outside as described in paragraph (b) of Example 1. The values are compared at three pressures for three distances below the orifices in the tube or strip jet device.

DENSITY AND ENERGY FLUX AT VARIOUS PRESSURES

	Distance below orifice		
	⅛ inch	¾ inch	1.5 inch
At 200 p.s.i.:			
Drilled tube orifices:			
Stream density	0.241	0.103	0.0785
Energy flux	270,000	115,000	88,000
Preforated strip of Ex. 2:			
Stream density	1.0	1.0	1.0
Energy flux	1,120,000	1,120,000	1,120,000
At 500 p.s.i.:			
Drilled tube orifices:			
Stream density	0.214	0.0763	0.0565
Energy	930,000	330,000	250,000
Perforated strip of Ex. 2:			
Stream density	1.0	1.0	1.0
Energy flux	4,360,000	4,360,000	4,360,000
At 1,000 p.s.i.:			
Drilled tube orifices:			
Stream density	0.190	0.0595	0.0108
Energy flux	2,340,000	730,000	130,000
Perforated strip of Ex. 2:			
Stream density	1.0	1.0	1.0
Energy flux	12,330,000	12,330,000	12,330,000

EXAMPLE 3

This example compares the effectiveness, in producing surface-stable, tanglelaced nonwoven fabrics, of liquid streams of the types illustrated in FIGURES 8 and 10.

(a) A driller-strip jet manifold is prepared as described in Example 2, but having orifices 0.007 inch in diameter. The manifold is supplied with water at 1500 p.s.i. A random web weighting 2.5 oz./yd.^{2} is prepared by air deposition of blended staple fibers. The web contains 50% by weight 1.5 denier per filament, 1.5 inch acrylic staple fibers and 50% by weight of 1.5 denier per filament, 0.25 inch rayon staple fibers.

The web is supported on a 15 mesh plain weave screen having 15% open area and made from wires having a diameter of 0.041 inch. The supported web is passed under the water streams from the manifold, at a distance of 1.0 inch from the orifices and at a rate of 1.6 yard per minute. A preliminary tack-down treatment is unnecessary with this jet device, but is used in order to provide more nearly comparable conditions for the different manifolds to be evaluated. This pretreatment consisted of one pass at 500 p.s.i. water pressure and one at 1500 p.s.i. with a 68% open area screen placed on top to hold the web in place, and one pass at 500 p.s.i., without the top screen. The pretreated web on the supporting screen is next passed several times under 1500 p.s.i. streams, without the top screen. Samples are taken for evaluation after 1, 2, 4 and 8 passes.

The samples are subjected to 25 cycles of washing and drying, using a conventional household combination machine, and are then evaluated for surface stability. A rating of 5 indicates no evidence of pilling or fuzzing on either face, 4 indicates good surface stability and 3 indicates acceptable stability in this respect. A rating of 1 indicates excessive pilling and a 0 rating indicates that the surface pattern is destroyed beyond recognition. The results are given in the table.

(b) An etched-strip jet manifold is prepared as described in connection with FIGURE 5. The orifices prepared by etching are approximately 0.006 inch in diameter and evenly spaced to give about the same rate of flow, in gallons per minute per inch length of orifice row, as for the previous drilled-strip jet. Example 1(*a*) is then repeated without change except for the use of this etched-strip jet manifold. The results are given in the table.

(c) A drilled-tube jet manifold is prepared as described in paragraph (b) of Example 1. The orifices are prepared by drilling from the outside of the tube and do not conform to this invention. They are 0.005 inch in diameter and evenly spaced to give about the same flow rate (within 15%) in g.p.m./in. of orifices as the previous drilled-strip jet. Example 1(*a*) is then repeated without change except for the use of this drilled-tube manifold. The results are given in the table.

SURFACE STABILITY RATINGS OF FABRIC AFTER THE INDICATED NUMBER OF PASSES

Manifold	Number of 1,500 p.s.i. passes after pretreatment			
	1	2	4	8
(a)	4.0	4.0	4.5	5.0
(b)	4.5	4.8	5.0	5.0
(c)	0	0	0	2.5

From the above and similar experiments it is concluded that at least 8 times as much water consumption at 1500 p.s.i. is required to provide a pill rating of 4.0 to 5.0 when the fabric is prepared with the drilled-tube jet manifold instead of one of the jet manifolds of this invention.

The invention has been illustrated for a single straight line of circular orifices, but the invention is also useful for other orifice arrangements and non-circular orifice shapes. The orifices can be arranged in two or more rows, or in other configurations. Highly coherent streams are produced by oblong-shaped orifices, e.g., orifices 0.004 inch by 0.010 inch, which embody the improvements of this invention.

Since many different embodiments of the invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not limited by the specific illustrations except to the extent defined in the following claims.

I claim:

1. In apparatus for preparing tanglelaced nonwoven fabrics having means for supporting fibrous material for

treatment, means including an orifice manifold for jetting liquid supplied at pressures of at least 200 pounds per square inch to form streams having over 23,000 energy flux in foot-poundals per square inch per second at the treatment distance, and means for traversing the supported fibrous material with the streams; the improvement in the orifice manifold which comprises an orifice wall in the manifold, a row of orifices in the wall for jetting the liquid, a finish on the surface of the wall of less than 40 microinches roughness around entrances to said orifices as measured by A.S.A. Standard No. B–46.1–1962, an orifice entrance bevel of less than 10° extending a mean distance of less than 100 microinches into the orifice throat, the variation from said means not exceeding ±20 microinches around the perimeter, and a peak to valley deviation along the orifice entrance edge of less than 0.04 D, where D is the mean orifice diameter.

2. Apparatus as defined in claim 1 wherein said orifices are arranged in a straight line at a center-to-center spacing of 3 D to 10 D.

3. Apparatus as defined in claim 1 wherein said orifice wall is a metal strip which is sealed in place in said manifold.

References Cited

UNITED STATES PATENTS

2,925,224	2/1960	Cunningham	239—566
2,968,126	1/1961	Richardson	239—566

EVERETT W. KIRBY, *Primary Examiner.*