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TEXTILE-LIKE NONWOVEN FABRIC

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ABSTRACT OF THE DISCLOSURE

Nonwoven textile fabrics having closely-spaced parallel regions of fiber entanglement are produced by treating fibrous sheet materials with streams of water or other suitable liquid. A layer of randomly disposed fibers is supported on a smooth surface and fibers are entangled along closely-spaced parallel lines with streams of liquid jetted under high pressure to form a structure of interlocking fibers which has adequate strength and durability without bonding agents for uses of woven textile fabrics.

REFERENCES TO RELATED APPLICATIONS

This is a continuation-in-part of our copending applications Ser. No. 834,788 filed June 19, 1969 and now Pat. No. 3,508,308, and Ser. No. 712,070 filed Mar. 11, 1968 and now Pat. No. 3,493,462, which are continuations-in-part of our abandoned applications Ser. No. 711,718 filed Mar. 8, 1968, Ser. No. 584,627 filed Sept. 22, 1966, and Ser. No. 208,136 filed July 6, 1962.

FIELD OF THE INVENTION

This invention relates to novel textile products. It is more particularly concerned with nonwoven textile fabrics obtained by entangling a random array of fibers along closely-spaced parallel lines.

SUMMARY OF THE INVENTION

The products of this invention are substantially uniformly dense textile-like nonwoven fabrics composed of a random array of fibers entangled along closely-spaced parallel lines to provide an unbonded fiber structure characterized by a strip tensile strength of at least 2 lbs./inch per oz./yd.^{2} of fabric weight, a fiber-interlock value of at least 10 and an internal bond value of at least 0.2 foot-pound. The fabric has at least 10 discrete parallel regions of three-dimensional fiber interentanglement per inch.

The substantially uniformly dense fabrics do not have a pattern of apertures or holes. At low basis weights there may be some random voids between parallel regions of fiber interentanglement, but the fabrics have excellent covering power. By "three-dimensional fiber interentanglement" is meant that individual fibers wind, twist back-and-forth and pass about one another in all directions of said regions so as to be virtually inseparable. The fibers are randomly entangled in said regions and the orientation of fiber portions between the parallel regions of entanglement is generally random.

The fabric is readily prepared by a process which is particularly useful for fabrics weighing less than 6 ounces per square yard, and preferably weighing 0.5 to 3 oz./yd.^{2}.

PROCESS

The products of the invention may be made by traversing a layer of fibrous material, on a smooth (non-

patterning) supporting member, along parallel paths with essentially columnar streams of liquid jetted from orifices arranged in line at a frequency of at least 10 orifices per inch to produce at least 10 discrete regions of interentangled fibers per inch.

Suitable apparatus and details of the process are disclosed in our process patent (allowed Ser. No. 834,788) which is relied upon to supplement the present disclosure. Although the patent illustrates that orifice spacings as low as 5 per inch can be used, the orifice spacing is preferably 20 to 40 or more per inch.

Preferred orifices are shown in U.S. Pat. 3,403,862 to Dworjanyn. Orifice diameters of 5 and 7 mils are especially preferred.

During treatment, the layer of fibrous material is supported by a member which does not influence the arrangement of the fibers into a pattern dependent on the supporting surface. This type of member will be simply called a "smooth supporting member" hereinafter, and it may be a solid plate, bar, roll or the like, or it may be a relatively smooth screen of sufficiently fine mesh so that the fibers are not rearranged into any pattern dependent on the screen pattern. Preferably a smooth, plain-woven screen of 80 x 80 mesh per inch or finer is used in conjunction with the preferred orifices disclosed in the Dworjanyn patent.

In order to obtain the high-strength nonwoven fabrics, it is essential that the initial material be subjected to the action of streams of a noncompressible fluid at sufficiently high energy flux and for a sufficient amount of treatment to entangle the fibers thereof. 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:

$$EF_i=77\ PG/a$$

where:

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

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-section area a, which is inside the jet device, can be determined by measuring the actual orifice area and multiplying by the discharge coefficient (usually 0.64), or it can be calculated from measuring 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 will usually decrease rapidly as the stream travels away from the orifice, even when using carefully shaped 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 value of A increases with the orifice-to-web spacing and, at a given treatment distance, the value depends upon the jet device and the liquid supply pressure used.

A pressure of 200 p.s.i.g. can provide sufficient energy flux for several inches when using a highly efficient jet device, e.g., as in Examples 1 to 5. With other jet devices, the energy flux of a stream may become too low in a relatively short distance even when using higher pressures, due to the stream breaking up and losing its columnar form. When this occurs, there is a sudden increase in the value of A and the energy flux drops rapidly. Since the stream may become less stable when higher pressures are used, the energy flux at a given treatment distance may actually decrease when the jet orifice pressure is increased to provide a higher initial energy flux (PG/a).

By "essentially columnar" is meant that the streams have a total divergence angle of not greater than about 5 degrees. Particularly, strong and surface-stable fabrics are obtained with high-pressure liquid streams having an angle of divergence of less than about 3 degrees.

The amount of treatment must be sufficient and is measured by energy expended per pound of fabric produced. The energy E_1 expended during one passage under a manifold in the preparation of a given nonwoven fabric, in horsepower-hours per pound of fabric, may be calculated from the formula:

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

where:

Y=number of orifices per linear inch of manifold,
P=pressure 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.

It has been observed that the entanglement of the fibers is related to the product of the energy E of the treatment and the impact force I (in pounds) of the water stream.

$$I=PAK$$

where P is the pressure on the orifice in p.s.i. gauge, A is the area of a single orifice in square inches and K is the orifice discharge coefficient (approximately 0.64).

The process of the present invention may be used to produce entangled nonwoven fabrics from any type of loose fibrous web, batt, or sheet. The ease with which a given web can be entangled is dependent upon many factors, and process conditions may be chosen accordingly. Fiber mobility also has a bearing on the ease with which a web can be processed. Factors which influence fiber mobility include, for example, the density, modulus stiffness, surface-friction properties, denier, crimp and/or length of the fibers in the web. In general, fibers which are highly wettable, or have a high degree of crimp, or have a low modulus or low denier, can also be processed more readily.

Suitable fibrous material includes all manner of textile fibers and combinations of textile fibers and papermaking fibers such as wood pulp, cotton linters and the like. The textile fibers can be of any convenient length ranging from short staple (e.g., 0.25 inch) to continuous lengths. Deniers of from 1 to 3 are readily processed but smaller and larger deniers can be used. The fibers can be straight or crimped. Blends of various fibers can be used and the fibrous layer can contain layers of different composition.

Papermarking fibers can be present in the initial layer as a paper sheet, a layer of loose fibers or an intimate blend with the textile fibers. The fibrous material should contain at least about 20% of textile fibers to obtain a product having the desired integrity of a nonwoven fabric.

Nonwoven fabrics having particularly high levels of drape and conformability may be obtained by using crimpable, shrinkable, spontaneously elongatable, or elastic fibers as one of the components of the fibrous sheet material and developing the latent properties of the fiber after formation of the nonwoven fabric.

The products of this invention are termed "textile-like nonwoven fabrics" as they compare favorably in strength, appearance and handle with conventional textile fabrics. An elongation at the break of between 20 and about 100% in both major directions is readily provided.

TESTS FOR EVALUATING PHYSICAL PROPERTIES

The tensile properties are measured on an Instron tester at 70° F. and 65% relative humidity. Strip tensile strength and break strength is determined for a sample 0.5-inch wide (1.0-inch wide for Examples 5 and 6), using a 2-inch gauge length and elongating at 50% per minute.

Initial modulus is determined by measuring the initial slope of the stress-strain curve. The 5% secant modulus is defined by American Society for Testing and Materials Standards E6–61, part 10, page 1836. It is determined by reading, from the stress-strain curve used to measure strip tensile strength, the stress at 5% elongation and multiplying this by 20.

Drape flex (or bending length) is determined by using a sample 1 inch wide and 6 inches long and moving it slowly in a direction parallel to its long dimension so that its end projects from the edge of a horizontal surface. The length of the overhang is measured when the tip of the sample is depressed under its own weight to the point where the line joining the tip to the edge of the platform makes an angle of 41.5° with the horizontal. One-half of this length is the drape flex of the specimen, reported in centimeters.

Surface stability is determined by washing the samples 25 cycles in an automatic washer-dryer machine at cotton settings. The samples are then rated subjectively for surface stability on a scale of 5 (surface stability unaltered by the washing treatment) to 1 (sample falling apart or showing extremely bad pilling).

FIBER-INTERLOCK TEST

The fiber-interlock value is the maximum force in grams per unit fabric weight needed to pull apart a given sample between two hooks.

Samples are cut 0.5 inch x 1.0 inch and weighed, and each sample is marked with two points 0.5 inch apart symmetrically along the midline of the fabric so that each point is 0.25 inch from the sides near an end of the fabric.

The eye end of a hook (Carlisle-6 fish hook with the barb ground off or a hook of similar wire diameter and size) is mounted on the upper jaw of an Instron tester so that the hook hangs vertically from the jaw. This hook is inserted through one marked point on the fabric sample.

A second hook is inserted through the other marked point on the sample, and the eye end of the hook is clamped in the lower jaw of the Instron. The two hooks are now opposed but in line, and hold the sample at 0.5-inch interhook distances.

The "Instron" tester is set to elongate the sample at 0.5 inch per minute (100% elongation/minute) and the force in grams to pull the sample apart is recorded. The maximum load in grams divided by the fabric weight in grams per square meter is the single fiber interlock value. The average of 3 determinations in the machine direction and 3 in the cross direction (or of samples cut in directions at 90° to each other) is reported to two significant figures as the fiber interlock value.

INTERNAL BOND VALUE TEST

It has been found that the following "internal bond" test is a measure of the extent of three-dimensional entanglement. It is believed that this test measures the ability of the fibers that penetrate the entangled fiber regions at substantial angles to the plane of the fabric to prevent delamination in the test.

(A) The internal bond value of the nonwoven fabric is determined by a procedure described in Technical Association of the Pulp and Paper Industry (TAPPI) "RC–308 Test for Interfiber Bond Using the Internal Bond Tester." Further information regarding this procedure, particularly about the equipment used, is disclosed by Blockman and Wikstrand, TAPPI, March 1958, volume 41, number 3, pages 190A to 194A, "Interfiber Bond Strength of Paper." The faces of the steel anvils, striking bar, samples of nonwoven fabric and double-faced pressure-sensitive tape are each one inch square. The samples are mounted at 200 p.s.i. for one second. Five samples are tested in the machine direction of the fabric and five in the cross direction, and the average value is reported in foot-pounds.

Routine Control Method RC–308 specifies the use of "Scotch Brand type 400 double-faced pressure sensitive tape" in the test. In case such a commercial product is not available, its characteristics are as follows: Double-faced pressure-sensitive tape, 1-inch wide with combined thickness of adhesive layers of 0.0015±0.0005 inch (measured under about 1 p.s.i. pressure) and with an adhesion to steel within 35±5 ounces/inch (measured according to Federal Specification UU–T–91C of May 10, 1961).

It should be a routine practice to check the tape each day by running the test on two layers of tape between the bottom steel anvil and the aluminum angle pressed together at 200 p.s.i. These tests should give a value of at least 0.5 foot-pound. If they do not, some tape is stripped off the roll and the tape calibration is repeated with fresh tape until proper values are obtained. It is obvious that, since the test is designed to measure internal bond values as high as 0.5, the adhesion of the tape to the anvil and angle must be at least 0.5 foot-pound. This fact could be overlooked by an operator that might be accustomed to obtaining values below 0.5.

The tape-contacting surfaces of the anvil and angle must be clean. Preferably they should be cleaned with a minimum of acetone and dried between each set of determinations.

Meaningful results may not be obtained by the above Method (A) on (1) net-like products having an open area of more than about 15% or (2) very thin fabrics having a fabric weight of less than 1.0 oz./yd.^{2}, due to adhesion of the two layers of tape to each other. For these products the following Method (B) should be used:

(B) The sample is fastened to the lower fixed steel plate with the tape. This assembly is then pressed (sample face down) into a thin, flat bed of aluminum oxide (grade 400 "Lionite Floated Flour" made by General Abrasive Co., Inc., of Little Rock, Ark.) at a pressure of 100 p.s.i. The assembly is removed from the bed and the bottom of the steel plate held firmly against the vertical shaft of a laboratory vibrator (providing an amplitude of 0.5 mm. at a frequency of 60 cycles per second) for 30 seconds. This treatment effectively removes the aluminum oxide from the fabric but not from any tape face exposed through openings in the fabric.

If the sample is vibrated face up, then it should be gently blown by mouth after the vibration treatment to remove any loose aluminum oxide from the sample, and aluminum oxide remaining on the steel surfaces of the anvil should be removed with a brush to avoid contaminating the apparatus.

The assembly is replaced in the mounting jig and fastened to the upper striking bar with tape at 200 p.s.i. and tested as in Method A.

Although the instrument has a dual range, all measurements in the application were made on the high range of from 0.100–0.500 ft.-lb.

The open area of a fabric can be estimated by measuring the size of the openings and counting for a given area.

It is observed that Method B gives substantially the same results as Method A on fabrics of low open area and weights greater than 1 oz./yd.^{2}.

ENTANGLEMENT FREQUENCY AND COMPLETENESS TEST

In these tests, nonwoven fabrics are characterized according to the frequency and the completeness of the fiber entanglement in non-bonded fabric, as determined from strip tensile breaking data using an "Instron" tester.

Entanglement frequency is a measure of the frequency of occurrence of entanglement sites along individual lengths of fiber in the nonwoven fabric. The higher the value of entanglement frequency the greater is the surface stability of the fabric, i.e., the resistance of the fabric to the development of pilling and fuzzing upon repeated laundering.

Entanglement completeness is a measure of the proportion of fibers that break (rather than slip out) when a long and wide strip is tested. It is related to the development of fabric strength.

Durable non-bonded products have an entanglement frequency of at least 20 per inch and an entanglement completeness of at least 0.5.

Entanglement frequency and completeness are calculated from strip tensile breaking data, using strips of the following sizes:

Strip width symbol	Strip width (in.)	"Instron" gauge length (in.)	Elongation rate (in./min.)
w_0	0.8	0	0.5
w_1	0.3	1.5	5
w_2	1.9	1.5	5

In cutting the strips from fabrics having a repeating pattern of ridges or lines of high and low basis weight, integral numbers of repeating units are included in the strip width, always cutting through the low basis weight portion and attempting in each case to approximate the desired widths (w_0, w_1, w_2) closely. Ten or more specimens are tested at w_1, and five or more at w_2 and w_0 using an "Instron" tester with standard rubber coated, flat jaw faces and the gauge lengths and elongation rates listed above. Average tensile breaking forces for each width (w_0, w_1 and w_2) are correspondingly reported as T_0, T_1, and T_2. It is observed that:

$$\frac{T_1}{w_1} < \frac{T_2}{w_2} < \frac{T_0}{w_0}$$

It is postulated that the above inequalities occur because:

(1) There is a border zone of width D at the cut edges of the long gauge length specimens, which zone is ineffective in carrying stress; and

(2) With zero gauge length, fibers are clamped jaw-to-jaw and ideally all fibers carry stress up to the breaking point, while with long gauge length, some poorly-entangled fibers slip out without breaking. A measure of the proportion of stress-carrying fibers is called *c*.

Provided that D is less than ½ w_1, then:

$$\frac{T_1}{w_1-2D} = \frac{T_2}{w_2-2D} = c\,\frac{T_0}{w_0}$$

and D and *c* are:

$$D = \frac{w_1 T_2 - w_2 T_1}{2(T_2 - T_1)} \quad c = \frac{T_2 - T_1}{w_2 - w_1} \cdot \frac{w_0}{T_0}$$

In certain cases D may be nearly zero and even a small experimental error can result in the measured D being negative. For patterned fabrics, strips are cut in two directions: (a) in the direction of pattern ridges or lines of highest basis weight (i.e., weight per unit area), and (b) in the direction at 90° to the direction specified in (a). In unpatterned fabrics any two directions at 90° will suffice. *c* and D are determined separately for each direction and the arithmetic means of the values for both directions, $\bar{c}$ and $\bar{D}$, are calculated. $\bar{c}$ is called the *entanglement completeness.*

When $\bar{c}$ is greater than 0.5, $\bar{D}$ is a measure of the average distance required for fibers in the fabric to become completely entangled so that they cannot be separated without breaking. When $\bar{c}$ is less than 0.5, it has been found that $\bar{D}$ may be influenced by factors other than entanglement. Accordingly when $\bar{c}$ is less than 0.5, calculation of $\bar{D}$ as described above may not be meaningful.

From testing various samples, it is observed that the surface stability of a fabric increases with increasing product of $1/\bar{D}$ a nd the square root of fiber denier d. Since 1.5 denier fibers are frequently used, all deniers are normalized with respect to 1.5 and *entanglement frequency* $\bar{f}$ per inch is defined as

$$\bar{f}=1/D\sqrt{d/1.5}$$

If the fabric contains fibers of more than one denier, the effective denier d is taken as the weighted average of the deniers.

If the measured $\bar{D}$ turns out to be zero or negative, it is proper to assume that the actual $\bar{D}$ is less than 0.01 inch and $\bar{f}$ therefore greater than $100\sqrt{d/1.5}$ per inch.

EXAMPLE 1

A series of samples is prepared using a web of continuous, polyethylene terephthalate filaments having a filament denier of 1.3 and a filament tenacity of 3.6 grams per denier. The web is placed on an 80 x 80 mesh-per-inch smooth screen (30% open area) which serves merely to support the web during treatment. The supported web is passed under essentially columnar streams of water from sharp-edged orifices arranged in line in a manifold. The orifices used for items A and B have diameters of 2.5 mils and are spaced 40/inch. The orifices used for items C and D have diameters of 7 mils and are spaced 20/inch.

Each product is given one treatment at 500 p.s.i.g. using a 16 x 18 mesh, 71% area screen on top of the web; the sample turned over and given one treatment at 2000 p.s.i.g. without a screen over the web.

The presence of lines of entanglement at these frequencies, i.e., 20 or 40 per inch, provides good strength and coherence as may be seen from properties in Table I.

TABLE I

Sample	Belt speed (yds./min.)	Energy (HP.-hrs./lb.)	Entanglement completeness ($\bar{c}$)	Entanglement frequency ($\bar{f}$)	Web weight (oz./yd.^{2})	Strip tensile strtngth (MD)/(XD)* (lb./in.)/(oz./yd.)^2
A	2.82	0.31	1.0	16	2.7	7.7/7.0
B	0.71	1.47	0.85	17	2.4	6.0/6.8
C	11.4	0.31	0.90	24	2.7	7.8/6.3
D	2.86	1.17	0.94	39	2.9	8.4/8.5

* MD tested in direction of lines of entanglement. XD tested 90° to MD.

EXAMPLE 2

This example illustrates preparation of a nonwoven fabric having 20 lines of entanglement per inch, using a flat bar to support the web during treatment.

The initial material is a web of randomly-disposed fibers prepared by a random web air-laying technique. The web contains 50% by weight of 1.5 inch, 1.5 denier acrylic fibers and 50% of 0.25 inch, 1.5 denier acrylic fibers, and weighs about 3 oz./yd.^{2}. The web is treated with essentially columnar streams of water issuing from 0.007-inch diameter orifices, drilled in a line in a manifold at a frequency of 20 orifices/inch. The web is held against the flat surface of a one-inch wide metal bar, which is held stationary during treatment. The web is spaced one inch from the orifices during treatment and is moved over the bar at a speed of 2 yards per minute. The streams of water strike the web and then the flat surface of the bar at about 90° to the flat surface. The web is passed under the streams once using a water pressure of 500 p.s.i.g. and once using 1000 p.s.i.g. It is then turned over and passed once more under the streams, at 1000 p.s.i.g. while held against the flat bar. Energy flux of the streams at 1000 p.s.i.g. is 12×10^6 ft. poundals/in.^{2} second and total energy expended in the treatment is 1.4 HP.-hr./lb. All passes are done in one major direction of the web and the resulting nonwoven fabric has 20 lines of entanglement per inch in one fabric direction, corresponding to the number of orifices per inch. This provides good strength and stability as can be seen from the following properties:

Strip tensile strength (lb./in.)/(oz./yd.^{2})	MD 4.6, XD 3.4
Elongation (percent)	MD 65, XD 76
5% secant modulus (lb./in.)/(oz./yd.^{2})	MD 0.4, XD 0.4
Entanglement completeness ($\bar{c}$)	0.98
Entanglement frequency ($\bar{f}$)	22
Surface stability:	
Top face	3.8
Bottom face	4.5

NOTE: MD: Tested in direction of lines of entanglement. XD: Tested at 90° to MD.

EXAMPLE 3

This example illustrates the preparation of nonwoven fabrics from a variety of staple textile fibers.

Webs containing a random array of fibers are made by air deposition of fibers or blends of fibers as shown in Table II, items 1–9.

All polyester P fibers are of poly(ethylene terephthalate). Items 6 and 7 are a blend of polyester fibers and (1) a low melting 3.0 d.p.f. fiber from a polymer of vinyl chloride (Vinyon HH® by American Viscose Division of FMC) and (2) 1.8 d.p.f. polypropylene fibers, respectively, both present as a potential binder and shrinking agent. All fibers are 1.5 d.p.f. unless noted otherwise above.

The webs are placed on a smooth, plain-weave screen (about 30 to 40% open area) and passed under a row of substantially columnar, unbroken vertical jet streams of water. The streams are produced by a row of orifices spaced 40 per inch located in a manifold. The water enters the cylindrical portion of the orifice (5 mils diameter by about 1 mil long) and exits as a stream from the frusto-conical portion (about 15 mils diameter at edge of cone by about 11 mils long). A 150-mesh screen and a speed of 6 y.p.m. is used for all items except 3 and 4 which use a 100-mesh screen and a speed of 3.6 y.p.m.

The smooth supporting member is located on the face of a drum which revolves under 4 rows of the water streams. Items 1 and 5–9 are given one passage under the water streams under the condition shown. Items 2, 3 and 4 are given one passage, the nonwoven fabric turned over and given a second treatment on the opposite face. Exact alignment of rows of water streams when using multiple manifolds or exact registration between fabric and water streams when using multiple passes is not essential to obtaining distinct lines of entanglement. Generally, the orifice spacing of the last, or, in general, the highest pressure jet, determines the structure in the final product.

The use of 7-mil diameter orifices spaced 20 per inch at the same pressures as used above with the web on a smooth 80 x 80 mesh screen (31% open area) gives products of similar properties except that the lines of entanglement are spaced 20/inch when the speed is increased to give the same value of energy times impact force (EI).

Properties of the products are given as items 1–9 in Table III.

TABLE II

Item	Fiber: Type *	Fiber: Length (in.)	Pressure, p.s.i.: 1	2	3	4	Energy, HP.-hr./lb.	EI×10³
1	P	0.75	150	250	900	1,500	1.4	22.3
2	P	0.75	200	900	1,100	1,500	1.4	21.6
			50	250	900	1,500	1.0	15.9
3**	P	1.5	50	300	700	1,200	2.3	28.4
4**	P	1.5	50	300	700	1,200	3.4	42.8
5	P/R (9/1)	0.75/0.75	200	600	1,100	1,500	1.8	27.1
6	P/V (9/1)	0.75/0.25	50	200	900	1,500	1.4	22.2
7	P/PP (9/1)	0.75/1.25	50	200	900	1,500	1.4	22.2
8	R	0.75	300	700	1,100		0.9	10.9
9	N	1.5	200	900	1,200	1,500	2.0	32.1
10	P/WP (67/33)	1.5	500	800			0.11	0.9
11	P/WP (5/5)	1.5	350	600			0.05	0.3
12	P/WP (4/6)	1.5	800	800	800		0.5	6.0
13	P/WP (37/63)	1.5	300	400	500		0.25	1.3
14	P/WP (25/75)	1.5	350	600			0.05	0.3
15	R/WP (5/5)	1.56	350	600			0.05	0.3

*Fiber type: N=66 nylon; P=polyester; PP=polypropylene; V=Vinyon; R=rayon; WP=wood pulp.

**After the indicated treatment the fabric is flipped and the treatment is repeated.

TABLE III

Item	Basis weight (oz./yd.²)	Break strength (lb./in.)	Average tensile (lb./in.)/(oz./yd.²)	F.I.V.	I.B.V.	$\bar{c}$	$\bar{f}$	Percent elongation (MD/XD)
1	1.1	4.2/3.7	3.7	24	.31	.74	17	64/85
2	1.4	9.6/6.7	5.8	29	.31	.71	20	61/86
3	1.7	11.5/10.1	6.6	33	>.49	.81	20	57/77
4	1.1	7.6/4.4	5.3	32	>.47	.63	12	
5	1.0	3.2/2.5	2.9	19	.45	.35	14	51/81
6	1.0	6.5/3.2	4.9	23	.49	.52	22	59/84
7	1.0	5.1/2.8	3.9	23	.38	.54	13	62/90
8	1.2	3.9/2.8	2.8	18	.27	.64	14	27/48
9	0.9	9.3/4.8	7.8	81	>.49	.76	15	75/102
10	1.4	5.3/6.3	4.1	20	.22	.53	20	58/57
11	1.8	5.7/7.5	3.6	17	.23	.53	24	46/51
12	1.8	9.7/5.8	4.3	17	.53	.63	27	37/74
13	1.5	3.6/4.3	2.6	11	.29	.42	17	34/88
14	2.0	3.9/5.1	2.2	12	.25	.48	22	25/48
15	1.9	5.3/5.9	3.0	11	.29	.65	53	34/44

EXAMPLE 4

This example illustrates the preparation of nonwoven fabrics from staple textile fibers and papermaking cellulosic fibers.

For items 10 to 15 the starting web consists of one or more layers of a random array of poly(ethylene terephthalate) or rayon fibers (both 1.5 d.p.f.) facing the screen and covered by one or more layers of a tissue grade paper.

The paper used for items 10, 11, 14 and 15 (Herty SG kraft 8708–1) is made from Weyerhaeuser SG bleached kraft pulp (a sulphate pulp) from 100% western red cedar on a Fourdrinier paper machine. No beating or refining is done on the furnish which has a headbox Canadian Standard Freeness of 565 at a consistency of 0.182%. The wet paper is pressed a minimum and then dried under mild conditions to give a bulky (3.75 cc./g.) porous paper. The paper has a weight of 0.59/0.45 oz./yd.², break strength of 2.5/0.98 lb./in. and elongation at the break of 1.6/5.9% for the machine and cross-directions (MD/XD) and a fiber interlock value of 3.9. This paper is preferred for making products of this type.

The paper used for items 12 and 13 (Herty/Dryden 861–6) is made in a similar manner from a fully bleached kraft softwood pulp from 50% spruce and 50% northern jack pine. The furnish in the headbox has a Canadian Standard Freeness of 660 at a consistency of 0.087%. The paper has a bulk of 3.58 cc./g. (TAPPI Standard). The paper has a weight of 0.64/0.64 oz./yd.², a breaking strength of 5.08/1.44 lb./in., and elongation at the break of 1.7/2.4% and a fiber interlock value of 3.5.

Each composite of fiber web and paper covering on a smooth 80 x 80 mesh, plain woven screen (31% open area) is passed under multiple rows of water streams from the orifices of Example 3 (items 12 and 13) or given separate passes under a single row of water streams from the same type orifices (items 10, 11, 14 and 15) using the pressure (gauge) and speed as given in Table II. Improved results are obtained with the use of a vacuum box under the screen to remove water. A speed of 20 y.p.m. is used for items 10, 11, 14 and 15; a speed of 6 y.p.m. is used for items 12 and 13.

Properties of the nonwoven fabrics are given in Table III. The products are integral and the fibers and wood pulp substantially blended together so they do not have a definite paper side and a fiber side. At higher total weights such as 2.5 oz./yd.² or more the products have a more definite two-sided appearance.

The products of this example are fabric-like in nature rather than paper-like, as is especially shown by the elongations. However, the products are somewhat stiffer than products containing no wood pulp. They can be softened by passing between longitudinally meshed grooved rolls and a set of circumferentially meshed grooved rolls.

The products of this example can be treated with fabric softeners, water repellants and/or flame retardants. The use of colored papers affords colored products. Any designs or pattern printed on the original paper can be retained essentially intact on the final entangled product.

EXAMPLE 5

This example illustrates the preparation of nonwoven fabrics from a web containing an intimate blend of stable textile fibers and papermaking cellulosic fibers.

A paper made from a bleached kraft pulp from western red cedar is broken up into fiber form on a hammermill and then further dispersed by passage through an air deposition web former. Weighed amounts of the dry paper web and poly(ethylene terephthalate) staple fibers of 1.5 d.p.f. and 1.5 inch length are blended by hand and the blend

TABLE V

	Percent wood pulp	Basis weight (oz./yd.^{2})	Break strength (lb./in.)	Average tensile (lb./in.)/ (oz./yd.^{2})	F.I.V.	I.B.V.	$\bar{c}$	$\bar{f}$	Percent elongation MD/XD
Item:									
a	5	2.6	9.4/11	3.9	19	0.22	0.56	16	69/66
b	10	1.6	7.3/4.1	3.6	23	0.26	0.57	15	76/59
c	10	2.6	14/16	5.6	33	0.22	0.66	19	69/63
d	15	0.86	1.4/2.4	2.1	14	0.32	0.26	9	91/85
e	15	1.6	8.7/15	7.4	24	0.27	0.56	15	79/68
f	15	2.3	13/25	8.4	26	0.22	0.61	20	76/70
g	30	1.0	2.7/3.6	3.3	12	0.30	0.54	12	76/67
h	30	1.9	9.1/19	7.3	26	0.28	0.68	24	65/62
i	30	2.9	17/36	8.9	25	0.26	0.74	35	66/58

passed three times through a commercial random web former.

One or more layers of the above random fiber web (each layer having a nominal weight of 1 oz./yd.^{2}) is placed on an 80 x 80 mesh, smooth woven screen (31% open area) and passed at 20 yards/minute under a row of water streams from 5-mil diameter orifices spaced 40/inch (of of the same type as Example 3). A vacuum box (15 inches of water) is located under the screen. The screen is then passed back under the water streams following the same path for as many times as is desired. The compositions of the web and the gauge pressures used for each pass are given in Table IV.

The properties of the dried products are given in Table V. All of the nonwoven fabrics have lines of entanglement of 40/inch, with elongations at break ranging from 65 to 91 and 56 to 85% for the machine and cross-directions, respectively.

TABLE IV

Item	Percent wood pulp	Pressure, p.s.i.g. 1	2	3	4	Energy, HP.-hr./lb.	EI×10^3
a	5	600	1,200	1,300	1,500	.252	4.05
b	10	600	1,200	1,400		.256	3.91
c	10	600	1,200	1,300	1,500	.252	4.05
d	15	500	1,200			0.25	3.3
e	15	600	1,200	1,400		0.26	3.9
f	15	600	1,200	1,300	1,500	0.25	4.0
g	30	500	1,200			0.25	3.3
h	30	600	1,200	1,400		0.25	3.9
i	30	600	1,200	1,300	1,500	0.25	4.0

NOTE.—All items run at 20 y.p.m. on an 80×80 mesh screen.

We claim:

1. A substantially uniformly dense textile-like nonwoven fabric composed of a random array of fibers entangled along closely-spaced parallel lines to provide an unbonded fiber structure characterized by a strip tensile strength of at least 2 lbs./inch per oz./yd.^{2} of fabric weight, a fiber-interlock value of at least 10 and an internal bond value of at least 0.2 foot-pound, the fabric having at least 10 discrete parallel regions of three-dimensional fiber interentanglement per inch wherein individual fibers wind, twist back-and-forth, and pass about one another in all directions so as to be virtually inseparable.

2. A fabric as defined in claim **1** and weighing 0.5 to 3 ounces per square yard.

References Cited

UNITED STATES PATENTS

2,774,129	12/1956	Secrist	161—169X
2,862,251	12/1958	Kalwaites	161—169X
2,881,505	4/1959	Hoffman	28—72.2
2,893,105	7/1959	Lauterbach	28—72.2
2,958,113	11/1960	Lauterbach	28—79
3,033,721	5/1962	Kalwaites	161—109X
3,214,819	11/1965	Guerin	28—72.2

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