Feb. 16, 1971 C. V. EDWARDS 3,563,838

CONTINUOUS FILAMENT NONWOVEN WEB

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FIG. 1

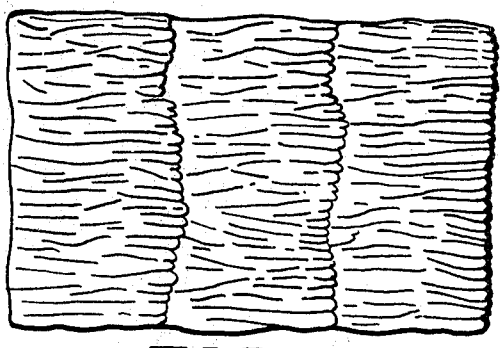


FIG. 2

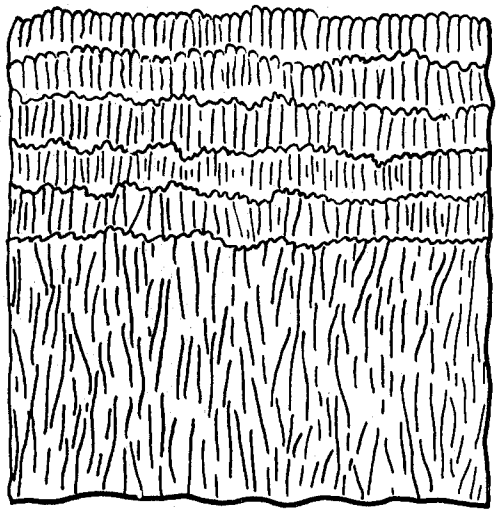


FIG. 6

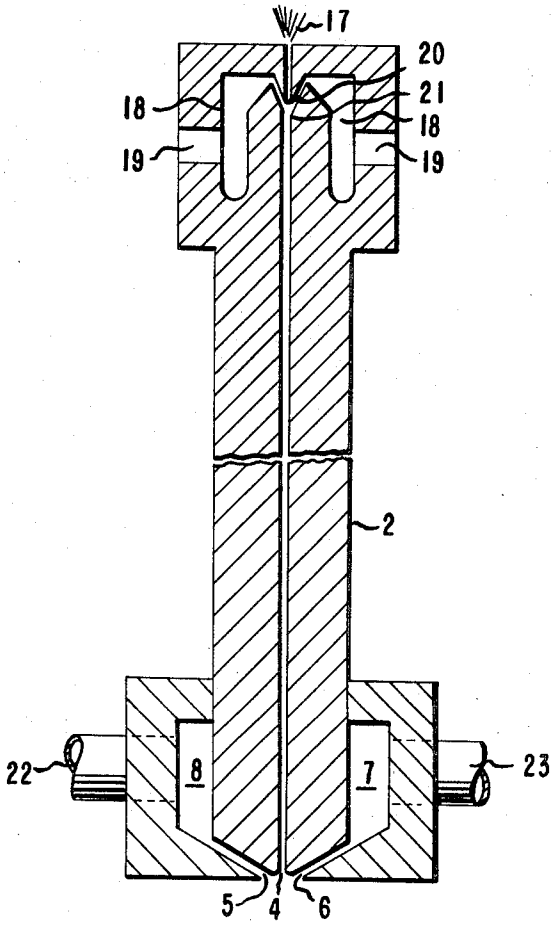


FIG. 4

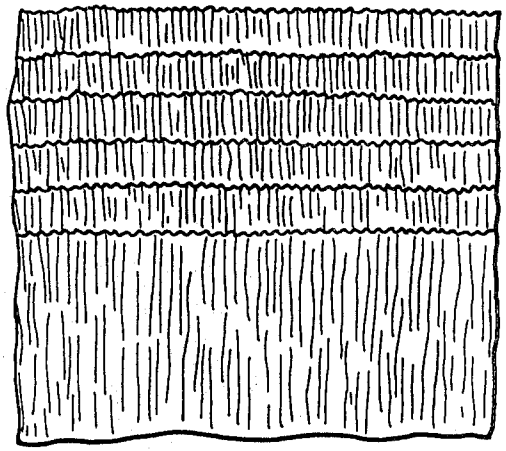
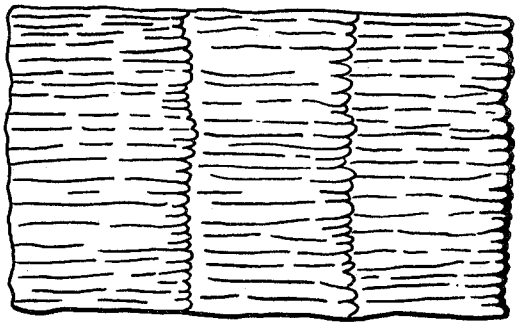


FIG. 3



INVENTOR
CLIFTON VEDANTUS EDWARDS

BY Sol Schwartz

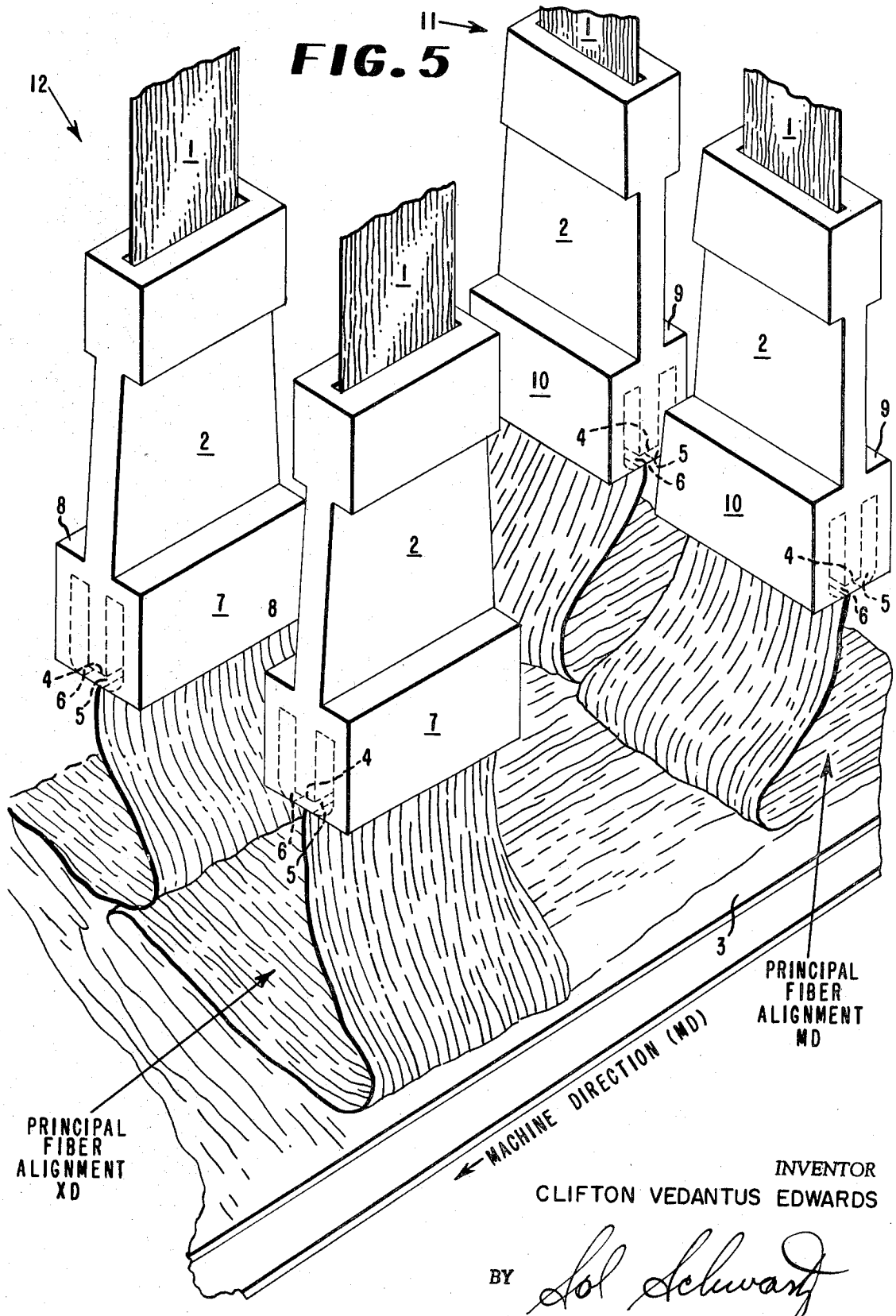
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FIG. 5



INVENTOR
CLIFTON VEDANTUS EDWARDS

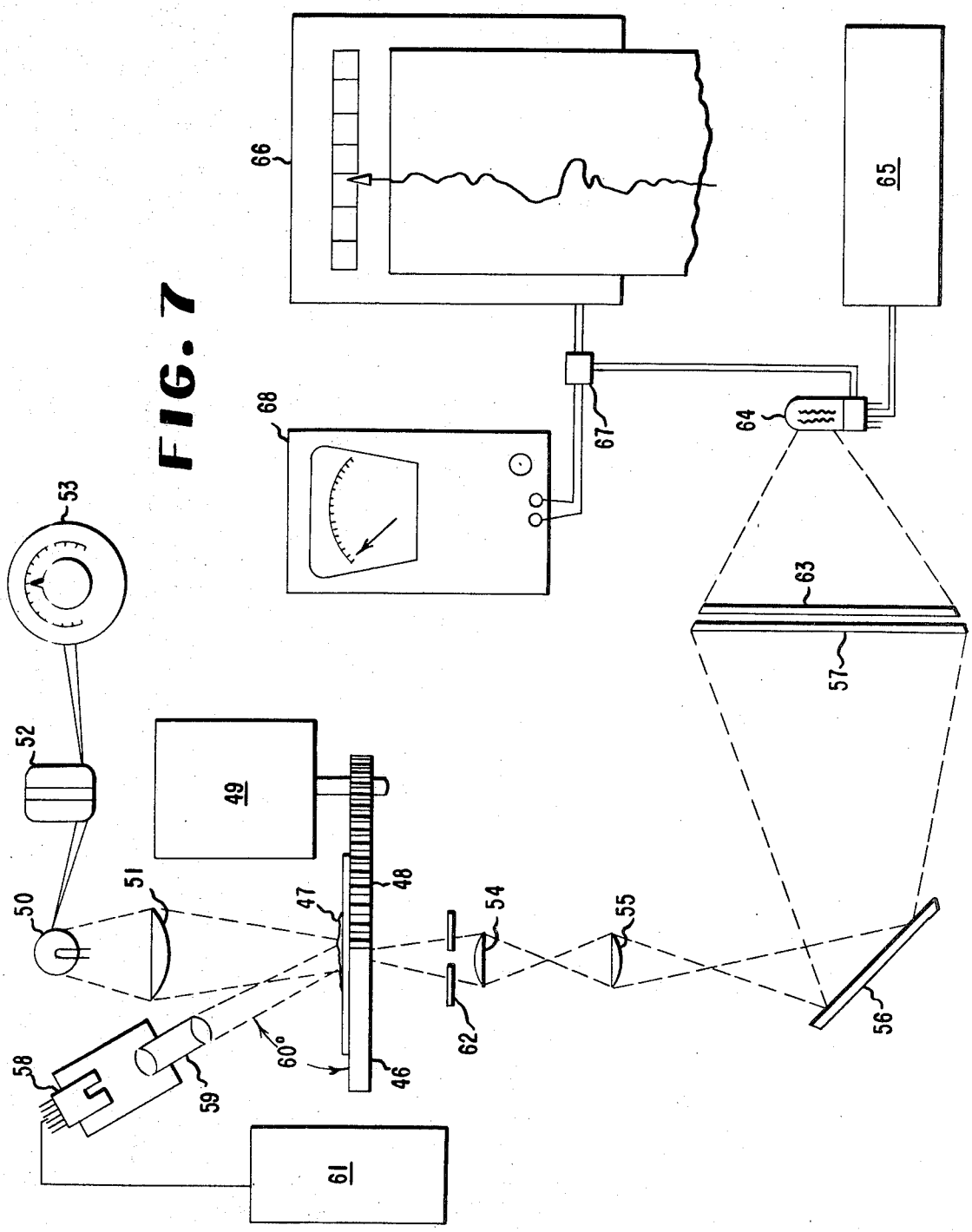
BY Sol Schwartz
ATTORNEY

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FIG. 7



INVENTOR
CLIFTON VEDANTUS EDWARDS

BY Sol Schwartz
ATTORNEY

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FIG. 8

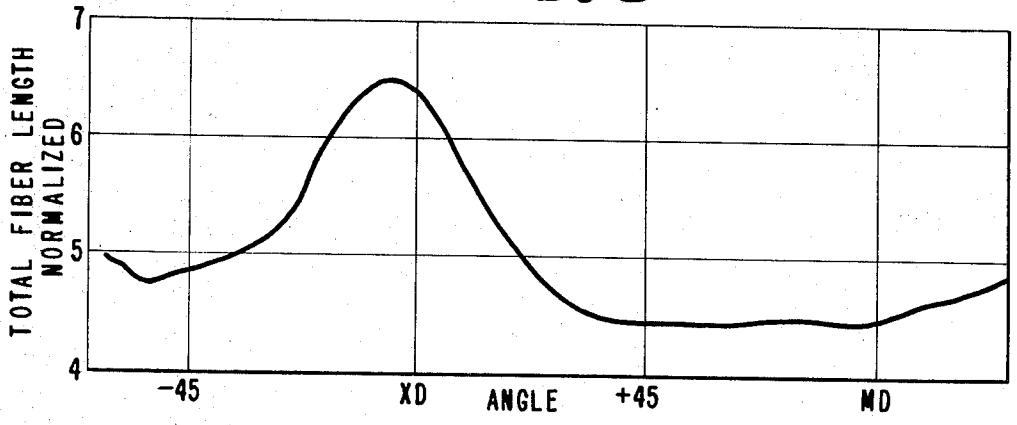
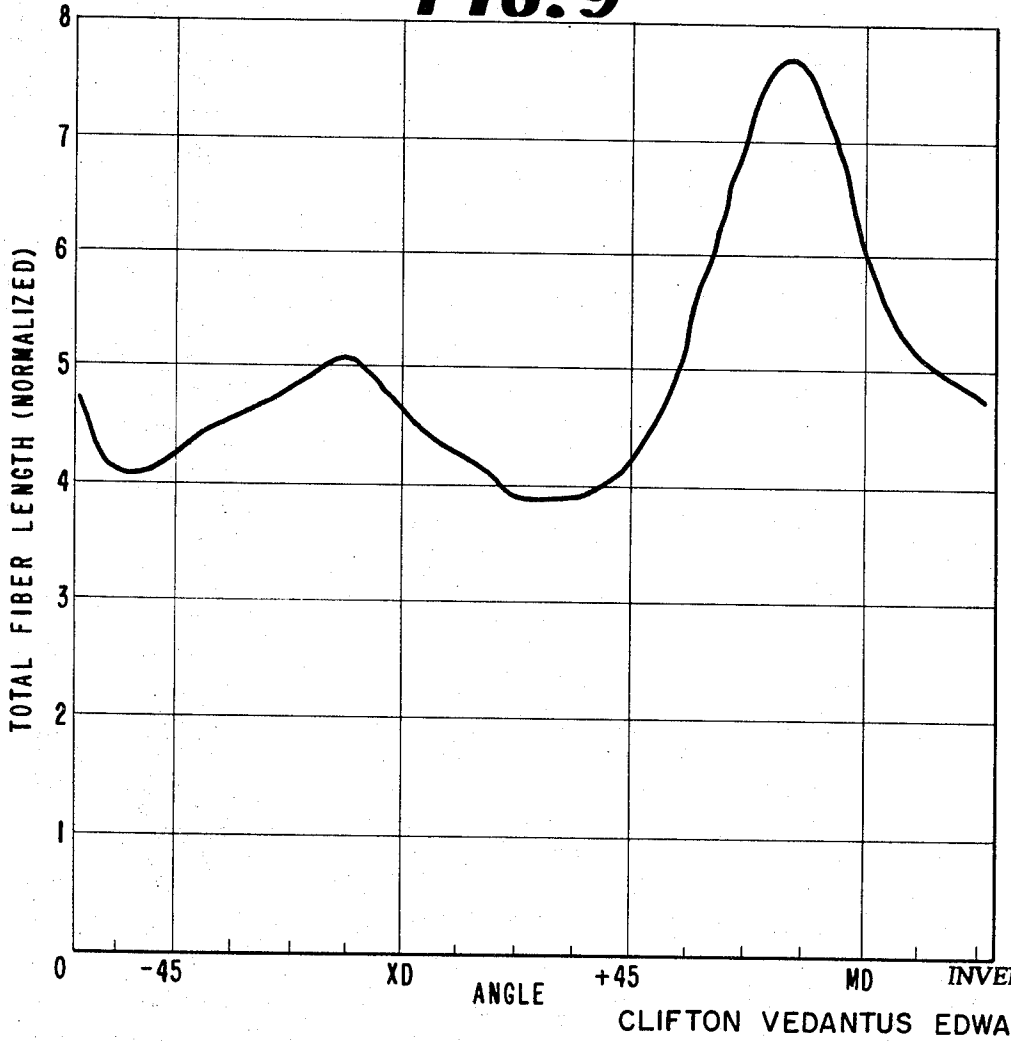


FIG. 9



INVENTOR
CLIFTON VEDANTUS EDWARDS
BY Sol Schwartz
ATTORNEY

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FIG. 10

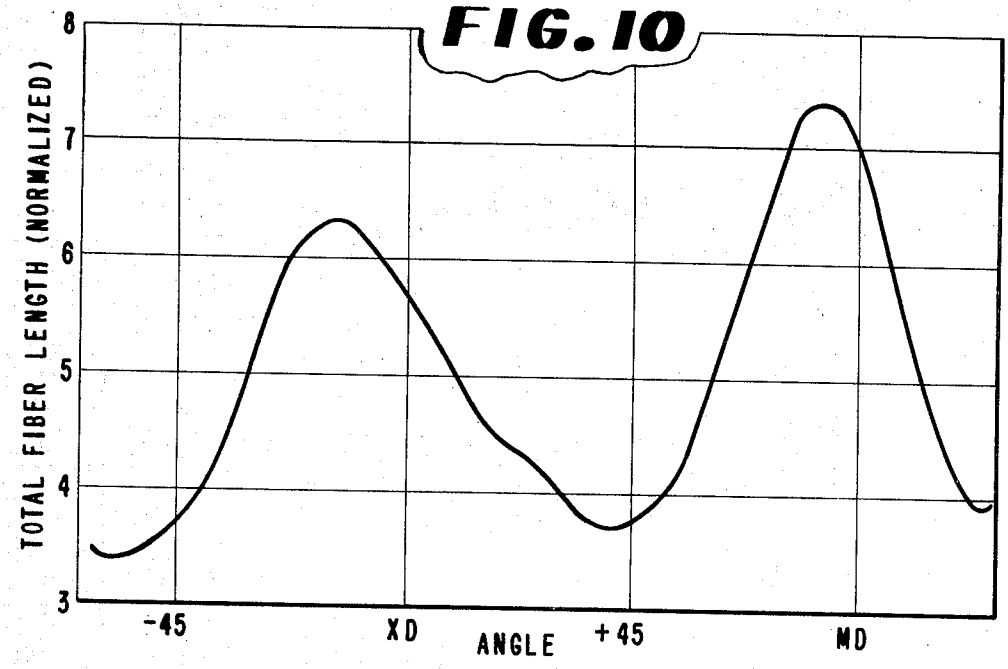
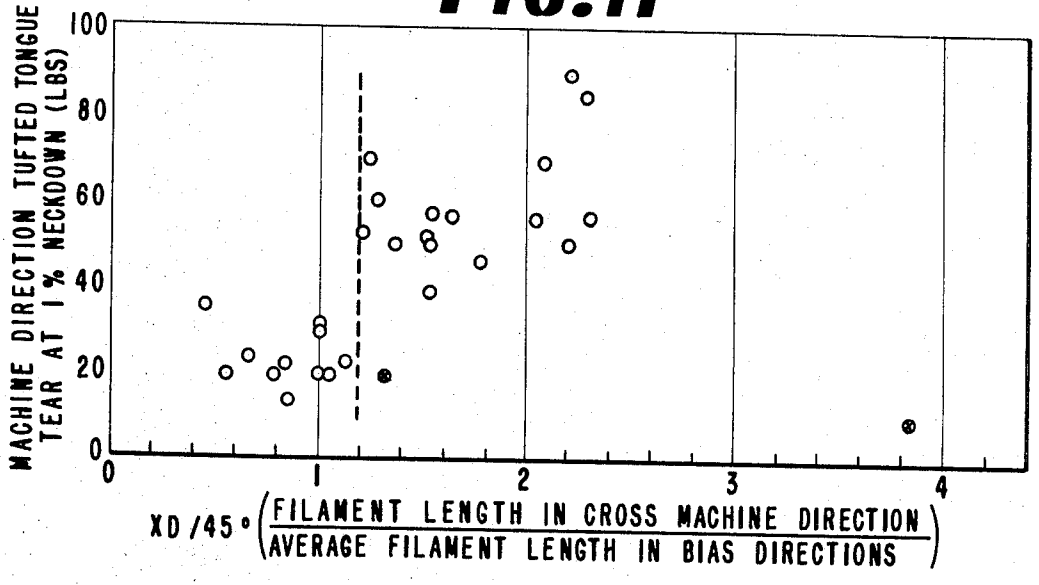


FIG. 11



INVENTOR
CLIFTON VEDANTUS EDWARDS
BY Sol Schwartz
ATTORNEY

FIG. 12

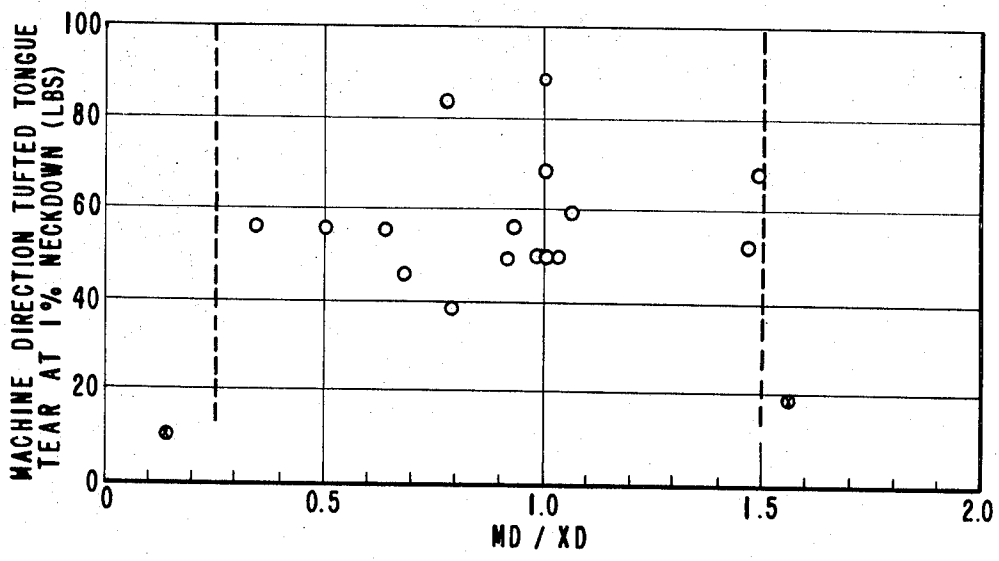
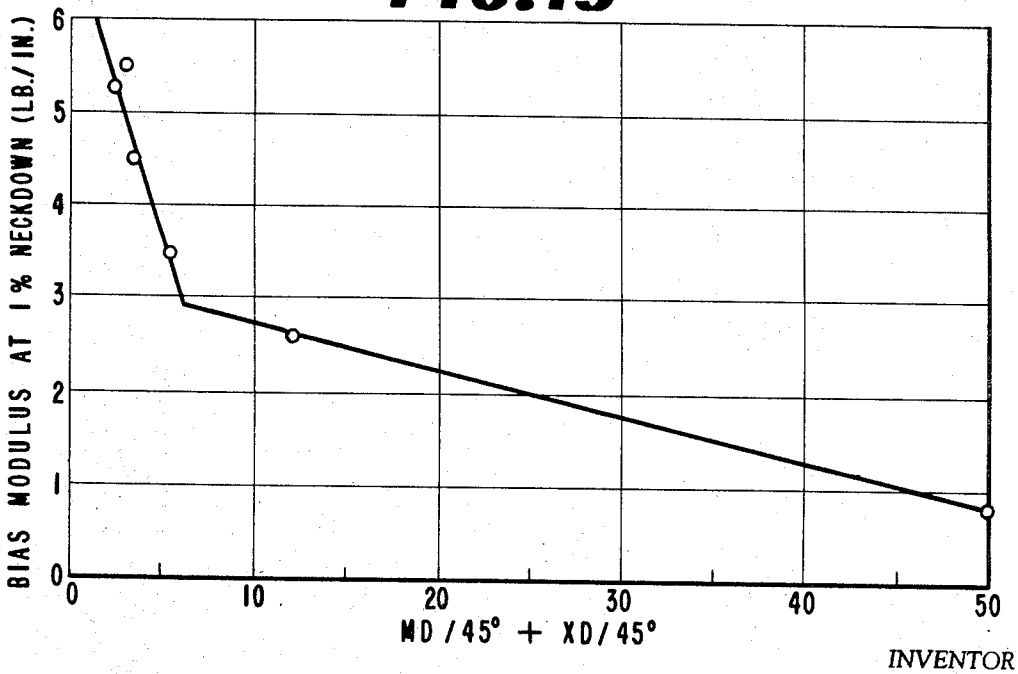


FIG. 13



INVENTOR
CLIFTON VEDANTUS EDWARDS
BY Sol Schwartz
ATTORNEY

United States Patent Office 3,563,838 Patented Feb. 16, 1971

3,563,838

CONTINUOUS FILAMENT NONWOVEN WEB

Clifton Vedantus Edwards, Nashville, Tenn., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware

Continuation-in-part of application Ser. No. 651,799, July 7, 1967. This application July 9, 1968, Ser. No. 743,516

Int. Cl. D04h 3/02

U.S. Cl. 161—57 12 Claims

ABSTRACT OF THE DISCLOSURE

The invention relates to continuous filament nonwoven webs having a specified filament directionality. The continuous synthetic filaments are preferentially aligned in directions approximately parallel or perpendicular to the fabric length direction, and extend for a distance greater than 7 inches in that direction. Such webs are particularly useful as primary backings for tufted carpets since they offer exceptionally high resistance to width loss on stretching coupled with high tear strength.

This application is a continuation-in-part of my earlier filed application Ser. No. 651,799 filed July 7, 1967, now abandoned.

DESCRIPTION OF THE INVENTION

A recently developed process for preparing "continuous filament" nonwoven fabrics in which the filaments are well separated and randomly disposed is described in Kinney U.S. 3,338,992. In this process an electrostatically charged multifilament strand of continuous filaments is forwarded under tension by means of a jet device toward a laydown zone. As the tension on the filaments is released at the exit of the jet device, the filaments separate due to the repelling effect of the charge on each filament, and while thus separated, are collected as a nonwoven web. The nonwoven webs produced in the above described process contain well separated, randomly disposed filaments. These webs may be bonded by known methods to produce fabrics with properties that are substantially independent of direction.

Primary carpet backings for the manufacture of tufted carpets require resistance to width loss on stretching, coupled with high tear strength. During processing in carpet mills, tufted primary carpet backings are subjected to considerable longitudinal stress which not only may lengthen the carpet in the "machine direction," but also may cause a narrowing or "necking down" of the tufted carpet backing in the "cross-machine direction." Such dimensional changes are highly undesirable since, unless corrected, they may cause changes in the carpet tufting pattern and may provide a tufted carpet of narrower width than is commercially acceptable.

Nonwoven webs from staple-length fibers in which the fibers are preferentially aligned in one or more directions, are known in the art. Such webs can be prepared, for example, by carding the fibers using conventional equipment to produce webs having fibers predominantly oriented in the machine direction. Where such equipment is provided with a cross-lapping device, it is also known to produce staple fiber webs having the fibers predominantly oriented in the cross-machine direction. Nonwoven webs from staple fibers having the fibers predominantly oriented in the machine and cross-machine directions can be produced by combining and bonding the two types of webs described above. These webs have been found to lack adequate tear strength after tufting when the webs have been bonded to a sufficient degree

to obtain acceptable resistance to "neck-down" in the cross-machine direction.

Woven fabrics have been traditionally used as primary backings in the manufacture of carpets. They provide high resistance to stretch in the warp and weft directions by virtue of the fact that all of the fibers are oriented in these two directions. However, woven carpet backings are expensive to produce except in coarse weaves from relatively cheap fibers such as jute. Coarse weaves cause the tufting needles to move aside in the carpet making process which prevents the preparation of precisely defined tufting patterns. Woven primary backings also have low resistance to deformation in the bias directions. In a tufted carpet, this results in undesirable "bowing" or "skewing" of the tufting pattern. By "bowing" is meant an advance or retardation of the tufting pattern across the width of the carpets and by "skewing" an advance of the tufting pattern along one edge of tufted carpet with respect to the other edge. Jute carpet backings possess the additional disadvantage of staining the tufted yarns during some dyeing processes.

A method for preparing nonwoven structures containing highly "directionalized" filaments is described in Selby U.S. 3,197,351. The method comprises passing a warp of untwisted filaments to a spreading zone, electrostatically spreading the individual filaments, applying a binder composition to the uniformly spread warp of filaments and setting the binder to retain the spaced relationship, thus forming a nonwoven structure in which the filaments are essentially parallel and aligned in the machine direction. Nonwoven webs with filaments oriented in the machine and cross-machine directions can be prepared from the above structures by the laborious method of cutting lengths of these structures, rotating them through 90°, combining them with lentghs of webs having machine direction filament alignment and subjecting the composite webs to an additional bonding step. These nonwoven fabrics, while providing high resistance to stretch in the machine and cross-machine direction, still suffer from the disadvantage of having low resistance to deformation in the bias directions, thus giving rise to bowing and skewing of the tufting pattern when used as primary backings for the manufacture of tufted carpets.

The present invention provides bonded nonwoven webs having high resistance to deformation in the machine, cross-machine and bias directions. Such webs are particularly useful as primary backings in the manufacture of carpets or other tufted articles. After tufting, the bonded webs of the invention have an improved combination of machine direction tear strength, resistance to "neckdown" in the cross-machine direction and resistance to deformation in the bias directions.

SUMMARY OF THE INVENTION

The improved product is attained by providing a substantially continuous length of bonded nonwoven fabric comprising non-randomly disposed synthetic "continuous filaments" wherein:

(a) $XD/45°$ is at least about 1.2 preferably below about 2.4;
(b) MD/XD is in the range of about 0.25–1.5;
(c) $(MD/45°+XD/45°)$ is less than about 6 preferably above about 2.4.

The term "$XD/45°$" is a measure of the total filament length in the cross-machine direction divided by the average of the total filament length in the bias directions. The term "$MD/45°$" is a measure of the total filament length in the machine direction divided by the average of the total filament length in the bias directions. The term "MD/XD" is a measure of the ratio of filament length in the machine direction to that in the cross-machine direc-

tion. Stated differently, XD is a measure of the total filament length in the direction perpendicular to the fabric length direction, MD is a measure of the total filament length in the fabric length direction, and 45° is the average of the measures of the total filament length in the directions at 45° to the fabric length direction, wherein said XD, MD and 45° are measures determined by the hereinafter described randometer method.

The term (MD) is a value on the randometer chart described in detail below, occuring within 15° of the continuous fabric length direction. The term (XD) is a value on the randometer chart occuring within 15° of the direction perpendicular to the continuous fabric length direction and the term (45°) is the average of the values on the randometer chart occurring at 45° to the continuous fabric length direction.

The filaments of the fabric of the invention lying approximately parallel to the direction perpendicular to the continuous fabric length direction extend for a distance greater than about 7 inches in such direction.

It has been found that continuous filament nonwoven fabrics having a preferred combination of filament alignment in the machine and cross-machine directions but with not less than a certain minimum of the filaments aligned in the non-preferred directions (for example, the bias direction) have, when suitably bonded and tufted with carpet yarns, improved machine direction tear strength, cross-machine direction tensile strength and high resistance to deformation in the bias directions. These properties are particularly important in bonded nonwoven fabrics to be used as backings for tufted carpets. Preferential alignment of fibers in accordance with the invention allows bonding of the nonwoven fabrics without reduction of machine direction tear strength to an unacceptable level and increases the resistance of the bonded nonwoven fabrics to width loss under stress such as that encountered during processing of tufted carpets.

This invention provides nonwoven webs of uniform fabric weight in which the filaments are preferentially aligned in a given direction and yet also provide strength in the other directions. In the preferred method for accomplishing this result, a primary fluid stream containing a plurality of electrostatically charged continuous filaments is forwarded toward a laydown zone on a receiver surface moving away from the laydown zone (fabric length direction). A secondary fluid stream is periodically impinged on one side of said primary fluid stream thereby deflecting said primary fluid stream in a direction transverse to the original direction of the primary fluid stream. Preferably two secondary fluid streams are alternately impinged on opposite sides of said primary fluid stream thereby deflecting said primary fluid stream alternately in opposite directions transverse to the original direction of the primary fluid stream. The filaments in the primary stream are thereby laid down in swaths on the receiver, aligned in the direction of deflection. Adjacent swaths deflected in the cross-machine direction, XD, overlap or abut at the extreme of each traverse where the direction is reversed. Adjacent swaths deflected in the machine direction abut or overlap along the sides of the swaths. The kinetic energy of each secondary fluid stream is varied cyclically and the deflection distance varies accordingly. By "deflection distance" is meant the distance from the point that the band of filaments or swath is laying down on the receiver to the point where the undeflected band of filaments lay down. Thus, the pressure of each opposing pair of secondary fluid streams will increase from substantially no pressure, i.e., one having no deflecting effect, to a maximum at the filament reversal points. The deflection frequency and the distance between filament reversal points are such as to provide a deflection speed that is at least equal to one third the filament speed, preferably substantially equal to the filament speed at the jet device exit. The "deflection speed" is the speed at which the swath traverses the laydown receiver.

The angle of filament deflection, i.e., the angle that the primary fluid stream is deflected from its original undeflected direction, is dependent on the kinetic energy of the secondary fluid stream, which is in turn dependent on the deflection plenum pressure. The greater the kinetic energy of the secondary fluid stream, the greater will be the deflection. Since it is desired that the "continuous filaments" be disposed in the nonwoven webs in a well-separated condition, filament entanglement should be minimized by limiting the angle of filament deflection through use of a secondary fluid stream of relatively low kinetic energy.

Preferably the process is used in conjunction with a process for the preparation of nonwoven webs as described in Kinney, U.S. 3,338,992. A corona charging device as described in U.S. Pat. 3,163,753, may be employed. A plurality of filament-containing fluid streams are used to prepare wide continuous nonwoven webs of substantially uniform fabric weight.

For the commercial production of nonwoven fabrics, a plurality of filament deflecting devices can be used and these devices may be disposed so as to provide filament deflection in both the machine and cross-machine directions. Additional bias filament directionality may be introduced by deflecting some of the filaments in one or both directions 45° to the machine and cross-machine directions. The distance between filament reversal points in the cross-machine direction and the swath width in the machine direction are such that several filament de-direction of filament deflection and thus provide a nonwoven web. At the extreme position of filament deflection, the filaments form loops before beginning their traverse in the opposite direction. These looped filaments provide nonwoven fabric strength in directions other than the direction of filament deflection and thus provide a nonwoven web which also has strength or stability in the non-preferred directions. Cyclical deflection of filament-containing primary fluid streams greatly facilitates blending of these streams to produce wide width nonwoven webs of uniform fabric weight. In order for one jet device to lay down a swath with nearly constant fabric weight center and gradually tapering edges desirable for multi-swath blending, the filaments should traverse the laydown receiver with a substantially constant deflection speed, and should be well separated at the reversal points so that the edges taper gradually.

Well separated filaments may be achieved by electrostatic charging of the filaments before they reach the jet device, and constant rate of traverse may be achieved by desired regulation of the pressure in the deflection plenums.

The "directional" web prepared as above will ordinarily be carried on the laydown receiver to a second laydown zone where a similar web with filaments aligned about 90° to the alignment of the filaments in the first web is deposited thereon in a similar manner. While two laydown zones may be used in preparing the products of this invention, greater resistance to delamination during tearing particularly for highly directional webs, is obtained when more than two laydown zones are used or if "interleaving" (as hereinafter described in Example IX) is used.

Thus, a plurality of uniformly spaced moving fluid streams (e.g. air streams) each carrying and advancing a plurality of electrostatically charged "continuous filaments" at a velocity of at least 200 yards per minute is prepared and directed in parallel initial lines of direction at a plurality of laterally aligned first positions. Each of said streams is then simultaneously laterally oscillated pneumatically from its initial line of direction in regular periodic laterally diverging patterns and the filaments of each moving stream are deposited as swaths of filaments constituting a web in a laydown zone on a moving belt. The path of each swath of filaments as it is laid down, traverses the receiver surface for a given distance and then reverses direction. Traverse occurs at a substantially

uniform velocity of at least one third the filament velocity at the first positions and said traversal paths are in a direction substantially transverse to the stream direction at said first positions. Adjacent swaths generally overlap or abut to form a unitary "directional" web.

For the purpose of preparing a primary carpet backing with a highly desirable balance of physical properties, it is preferred that the filaments be comprised of isotactic polypropylene of mixed orientation. It is further preferred that the polypropylene filaments be comprised of highly oriented and relatively unoriented zones spaced along the lengths of the filaments. It is still further preferred that the filaments be deflected in the machine and cross-machine directions and that the distance between swath reversal points be greater than about 7 inches (17.8 cm.). Nonwoven webs prepared according to this invention using isotactic polypropylene filaments comprising highly oriented and relatively unoriented zones spaced along the length of the filaments and having the bond strength distribution characteristics and bearing a lubricant of the class disclosed in Jung U.S. 3,322,607 provide a strong, dimensionally stable nonwoven fabric eminently suitable as a backing for tufted carpets.

DESCRIPTION OF THE DRAWINGS

The nonwoven fabrics of this invention are described further by reference to the following figures in which:

FIG. 1 is a schematic of a nonwoven fabric of this invention in which the surface layer comprises filaments with preferential alignment in the cross-machine direction.

FIG. 2 is a schematic of a nonwoven fabric of this invention in which the surface layer comprises filaments with preferential alignment in the machine direction.

FIG. 3 is a schematic of a nonwoven fabric of this invention in which the surface layer comprises filaments aligned in the cross-machine direction to a greater degree than in FIG. 1.

FIG. 4 is a schematic of a nonwoven fabric of this invention in which the surface layer comprises filaments aligned in the machine direction to a greater degree than in FIG. 2.

FIG. 5 is a schematic of the process and apparatus used to prepare the products of this invention. Only two deflection devices operating in each of the machine and cross-machine directions are shown and transfer lines supplying jet and deflection air have been omitted.

FIG. 6 is a cross sectional view of a modified "slot jet device" suitable for making the products of this invention.

FIG. 7 illustrates an apparatus hereinafter termed "randometer" for obtaining a measure of the total filament length aligned in a given direction.

FIGS. 8, 9 and 10 are graphs obtained by the randometer technique from nonwoven webs having filaments preferentially aligned in the cross-machine direction (FIG. 8), in both the machine and cross-machine directions (FIG. 9), and in both directions (FIG. 10) to a greater degree than in FIG. 9.

FIGS. 11 and 12 are graphs showing the relationship between the tear strength at 1% "neckdown" of tufted bonded webs and *XD*/45° (FIG. 11 and *MD*/*XD* (FIG. 12) ratios respectively.

FIG. 13 is a graph showing the relationship between the bias modulus at 1% "neckdown" of tufted bonded webs and (*MD*/45°+*XD*/45°).

In FIG. 1, the position of filaments on the surface of a nonwoven web is shown in which the filaments were deflected in the cross-machine direction at a deflection speed less than the filament speed. The filament reversal point is in approximately the same place throughout the thickness of the cross-machine direction layer. The layers of filaments from a given jet device are interleaved in the cross-machine direction with layers of filaments from adjacent jet devices and shingled in the machine direction by machine direction motion of the laydown receiver. The filaments are not straight between reversal points.

In FIG. 2, the position of filaments on the surface of a nonwoven web is shown in which the filaments were deflected in the machine direction at a deflection speed less than the filament speed. The filament reversal points are staggered throughout the thickness of the web by the machine direction motion of the laydown receiver. Layers of filaments from adjacent jets abut or overlap each other and blend together. The filaments are not straight between the turn-around points.

In FIG. 3, the position of filaments on the surface of a nonwoven web is shown in which the filaments were deflected in the cross-machine direction at a deflection speed nearly equal to the filament speed. The filament reversal point is in approximately the same place throughout the thickness of the cross-machine direction layer. The layers of filaments from a given jet are interleaved in the cross-machine direction with layers of filaments from adjacent jets and shingled in the machine direction by machine direction motion of the laydown receiver. The filaments are essentially straight between the turn-around points.

In FIG. 4, the position of filaments on the surface of a nonwoven web is shown in which the filaments were deflected in the machine direction at a deflection speed nearly equal to the filament speed. The filament reversal points are staggered throughout the thickness of the web by the machine direction motion of the laydown receiver. Layers of filaments from adjacent jets abut or overlap each other and blend together. The filaments are essentially straight between turn-around points.

In FIG. 5, ribbons of electrostatically charged continuous filaments **1** are forwarded by means of slot jet devices **2**, toward a flexible pervious belt **3**, covering a suction means (not shown). As the tension on the filaments is released at the exit **4**, of the slot jet device **2**, the filaments are deflected alternately by opposed air streams issuing from filament deflection gaps **5**, **6**, supplied alternately by plenums **7**, **8**, **9**, and **10**. Plenums **7**, **9**, **8** and **10** are connected through manifolds and transfer lines (not shown) to compressed air supplies governed by rotary valves having variable speed drives (not shown), that alternately provide air to the opposing plenums. In this figure, a first "bank" or row **11** of two jets is used for "machine direction" deflection and a second "bank" **12** of two jets is used for "cross-machine direction" deflection.

In FIG. 6, a ribbon of electrostatically charged continuous filaments is pulled into orifice **17** of slot jet **2**, by flow of compressed air from a source (not shown) through entrance **19**, and jet plenums **18**, through entrance orifices **20**, through effuser throat **21**, to slot jet exit **4**. Compressed air is supplied alternately through air inlets **22** and **23** to the deflection plenums **7** and **8** and then through the respective "deflection gaps" **5** and **6** to impinge on the filament containing air stream emanating from exit **4**, of slot jet **2**.

In FIG. 11 the machine direction "tufted tear strength" is plotted against *XD*/45°, as measured by the randometer test, for nonwoven webs which have been bonded to a level such that the "neckdown" of a tufted sample at 3.3 lb./in. (0.59 kg./cm.) longitudinal stress is 1%. High tufted tear strength results when the value of *XD*/45° falls to the right of the dotted line, i.e., *XD*/45° is greater than about 1.2, a requirement which must be satisfied to obtain the nonwoven webs of the present invention. Two points (denoted by ⊗) are seen in the figure where the tear strength is low even though *XD*/45° is greater than 1.2. This is because other requirements of the invention are not satisfied (see FIG. 12).

In FIG. 12, the machine direction "tufted tear strength" is plotted against *MD*/*XD* as measured by the randometer test, for nonwoven webs bonded to a level

such that the "neckdown" of a tufted sample at 3.3 lb./in. (0.59 kg./cm.) longitudinal stress is 1%. The graph indicates that high values of tear strength are obtained when the ratio *MD/XD* is in the approximate range 0.25–1.5. This defines another requirement which must be satisfied to obtain the nonwoven webs of the present invention.

In FIG. 13, the "bias modulus of tufted webs bonded to a level such that the "neckdown" at 3.3 lb./in. (0.59 kg./cm.) longitudinal stress is 1%, is plotted against (*MD*/45°+*XD*/45°). "Bias modulus" has been found to correlate inversely with the amount of "bowing" of the tufting pattern during processing of 12–15 ft. (3.66–4.57 m.) wide tufting substrates. A typical tufting substrate such as 9 oz./yd.^{2} (302 g./m.^{2}) jute has a "bias modulus" after tufting of about 0.5 lb./in. (0.0895 kg./cm.) and gives rise to a high degree of "bowing" of the tufting pattern. In order that the amount of bowing be reduced to an acceptable level, the "bias modulus" should be about 3 lb./in. (0.535 kg./cm.). The figure shows that this occurs when (*MD*/45°+*XD*/45°) is less than about 6 and this constitutes another requirement which must be met to obtain the products of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred filaments for use in the nonwoven fabrics of this invention comprise continuous isotactic polypropylene filaments "segmentally drawn" along the length of the filaments by passage over a heated roll such as the steam-heated roll described in Edwards U.S. 3,302,698, adapted with an axially slotted surface to heat seven-inch (17.8 cm.) segments of the filaments with one inch (2.54 cm.) separations followed by passage over unheated draw rolls. While these filaments are preferred, other continuous filaments also may be used in the products of this invention. For example, polypropylene continuous filaments drawn at a single draw ratio or at two or more different draw ratios may be used. Nonwoven webs prepared from these polypropylene filaments may be self-bonded by suitable heat treatments.

Continuous filaments of other polyolefins and other polymers such as polyesters, polyamides, polyethers, polyurethanes, polyacrylics, etc. may also be used in the products of this invention.

The nonwoven fabrics of this invention may be bonded by methods known in the art but are preferably self-bonded by heating in saturated steam to the level described in Jung, U.S. 3,322,607 in a bonder of the type described in Wyeth U.S. Pat. 3,313,002. Unless indicated to the contrary in the examples which follow, the bonding was accomplished in this manner.

A measurement of "filament directionality" can be obtained by the hereinafter described "randometer" test and has the advantage that it is universally applicable to straight, curved, or crimed fibers.

The "randometer" method is based on the principle that only the incident light rays which are perpendicular to the filament axis of a filament are reflected as light rays which are perpendicular to the filament axis. Hence, by focusing a beam of parallel light rays on a nonwoven sheet at an incident angle less than 90°, e.g. 60°, the light which is emitted perpendicular to the plane of the sheet comes only from filaments having an orientation within the plane of the sheet which is perpendicular to the incident light rays. By collecting and measuring photoelectrically the intensity of the light, a measure of the total length of the filament segments perpendicular to the light rays, therefore, parallel to each other, can be determined. By rotating the sheet, the parallel filament segments for any given direction can be measured and from this measurement, an analysis of the filament alignment can be made.

An apparatus suitable for this measurement is shown schematically in FIG. 7 and will hereinafter be referred to as a randometer. A detailed description of the components, the method of operation, and the method for standardizing the characterizations are given below.

As shown in FIG. 7, the apparatus has a revolving stage **46** on which the sample **47** to be examined is placed. Stage **46** is modified by gear **48** which has half the teeth removed so that when driven by synchronous motor **49**, it rotates only 180°. Stage **46** rotates at ¼ r.p.m., thus the time for rotation of the sample through 180° is 2 minutes. Lamp **50** is located directly over the sample and in line with magnifying lens system **51**. Lamp **50** is a 6-volt lamp and its intensity is controlled through 6-volt transformer **52** and variable-voltage transformer **53**. The light from lamp **50** is focused by lens system **51** onto the bottom of the sample, and when projected through objective lens **54**, eyepiece **55** and reflected from mirror **56**, gives a shadow of the sample on ground-glass screen **57** at a magnification of 36×. Screen **57** is circular and has a diameter of 6.9 inches (17.5 cm.).

A second lamp **58** is mounted in a housing with projection lens **59** to focus the light on the sample at an angle of 60°. Lamp **58** is a 25-watt, concentrated arc lamp receiving its power from power supply **61** which is modified to eliminate the A.C. ripple. The filaments or segments of filaments which are perpendicular to the light from lamp **58** reflect the light into the magnifying lens and mirror system to screen **57** for measurement. Optical slit **62** is located between the objective lens **54** and stage **46** and serves to control the limits of the light reflected from the sample. The slit is 1/16 in. (0.159 cm.) x ⅜ in. (0.954 cm.) and is mounted with its long axis parallel to an imaginary line which is perpendicular to the light from lamp **58** and within the plane of the sample.

The light from the screen is focused by Fresnel lens **63** onto photomultiplier tube **64** (RCA type 1P21) having a 2500 volt DC power supply **65**. The screen, Fresnel lens, and photomultiplier tube are contained in a single light-tight unit, which can, however, be opened for visual observation of the screen. The output from the photomultiplier tube is fed into a microampere recorder **66** having a chart speed of 5 in. (12.7 cm.)/min. and a chart 9.5 in. (24.13 cm.) wide. The chart records the light reflected from the parallel filaments at each direction as the sample is rotated through 180°. The sensitivity of recorder **66** should be adjusted so that a current of 6 microamperes gives 100% pen deflection.

A two-way switch **67** is in the line from the photomultiplier tube to the recorder so that the signal can be measured on a sensitive microampere meter **68**, if desired. This meter can also be used in conjunction with a 6-volt lamp of fixed intensity to measure the fiber density of the sample so that, if desirable, all samples can be compared on the same basis.

Samples of the nonwoven sheet to be examined should permit clear viewing on the randometer of all the filaments through the thickness of the samples. Samples in excess of about 2.0 oz./yd.^{2} (67.5 g./m.^{2}) should be delaminated to fall within the range stated below, but care should be exercised to avoid disturbing filament "directionality" during delamination.

The delaminated samples are placed between two microscope slides which are then taped together. The slide is placed on the revolving stage so that the light from lamp **58** shows on the sample. The background lamp **50** is then turned on and the filaments are focused as sharply as possible by moving revolving stage **46** up or down, while they are viewed on the screen. Lamp **50** is then turned off. Stage **46**, lamp **58** and projection lens **59** are enclosed in a light-tight unit. The voltage of power supply **65** is adjusted so that the pen will remain on scale in the direction of maximum filament alignment and the intensity of the reflected light is recorded on the microampere recorder chart as the sample is rotated through 180°.

Two methods can be used to obtain a measurement of the filament directionality and these give comparable results. In the first method, the heights of the intensity-

orientation curve so obtained are measured in inches from the zero line of the chart at 80° equally spaced orientations and the arithmetic mean of these heights is determined. To standardize the randometer characterization, each of the 80 readings is multiplied by the factor

$$\frac{5}{\text{arithmetic mean}}$$

to shift the curve to a standard mean of (5 in.) (12.7 cm.) pen deflection. When obtaining measurements on nonwoven webs with preferentially oriented fibers of about 8 denier/filament, the samples are delaminated into layers having fabric weights between 0.75 and 2.0 oz./yd.^{2} (25.4–67.5 g./m.^{2}), and measurements are taken on each layer. To improve the precision several measurements may be made on each layer. For each layer, the standardized readings at each angle are averaged to obtain a curve for that layer. Then a curve for the entire sample is reconstructed by averaging the readings at each angle for the different layers in proportion to the fabric weight of these layers. This method was used to obtain the data plotted in FIGS. 8, 9 and 10.

"XD" is the maximum value on the randometer chart occurring within 15° of the direction perpendicular to the continuous fabric length direction and is used in the calculation of *XD*/45° and *MD*/*XD*. "MD" is the peak value occurring within 15° of the continuous fabric length direction and is used in the calculation of *MD*/45° and *MD*/*XD*. If no peak occurs, the chart reading at the continuous fabric length direction is used. "45°" is the average of the two values on the randometer chart occurring at 45° to the continuous fabric length direction and is used in the calculation of *MD*/45° and *XD*/45°.

A measurement of the filament directionality of the nonwoven is obtained by calculating the ratio of MD or XD to the average chart values in the bias directions. For example, in FIG. 10, the peak heights corresponding to the MD and XD are 7.4 and 6.4 respectively while the filament length values corresponding to the two bias directions are each 3.7. The measurements of filament directionality are therefore given by *MD*/45°=7.4/3.7=2, and *XD*/45°=6.4/3.7=1.73.

The second method is more rapid since it does not require the standardization of the readings, however, all the readings on the various layers of a given nonwoven web must be made at the same setting of the voltage of power supply **65**. After delaminating the sample into layers of appropriate fabric weight, a voltage setting is chosen which will insure that the pen will remain on scale for all samples. The values of intensity MD, XD and the two bias directions, are read off the charts for each layer, then all the MD values are added and divided by ½ the sum of all the bias values. A similar measurement is obtained with the XD values. This method was used to obtain the data in the following examples.

The Melt Flow Rate (MFR) of the resins used in the examples was measured by the procedure of ASTM–D 1238–62T using a load of 2,160 gm. and a temperature of 230° C. The MFR=weight in grams extruded over a period of 10 minutes.

The "neckdown" on longitudinal stress of tufted nonwoven fabrics may be measured in the following manner: A nonwoven fabric tufted as in Example II is cut into a sample 5.5 inches (14 cm.) wide (cross-machine direction, across tufting rows) and 14 inches (35.6 cm.) long (machine direction, along tufting rows). The sample is marked in the width direction with lines 4.0 inches (10.2 cm.) and 8.0 inches (20.3 cm.) from one end and 2.0 inches (5.1 cm.) from the other end. Metal staples are placed on the 8.0 inch (20.3 cm.) line 0.197 inch (0.5 cm.) from each edge of the sample. The distance between the staples is measured to the nearest 0.01 inch (.0254 cm.) and recorded. The sample is mounted in 1 inch (2.54 cm.) by 8 inch (20.3 cm.) "Instron" clamps so that the clamps are to and touching the 4.0 inch and 2.0 inch lines on the sample and the sample is centered in the clamps. The sample is mounted in an "Instron" tester with a clamp separation of 8 inches (20.3 cm.). The sample is extended using a full scale load of 50 lbs. (22.7 kg.), a crosshead speed of 10 inches (25.4 cm.) per minute and a chart speed of 20 inches (50.8 cm.) per minute. The "Instron" is set to stop when the load reaches 18 lbs. (8.17 kg.) (3.3 lbs. [1.5 kg.] per inch of sample width). The "Instron" is started. When the "Instron" stops, the distance between staples is measured to the nearest 0.01 inch (0.0254 cm.) while the sample is still under stress. The percent neckdown is equal to the difference of the original distance between staples and the distance between staples while under stress divided by the original distance between staples and multiplied by 100.

The machine direction "tongue tear strength" of a tufted nonwoven fabric may be measured in the following manner. A nonwoven fabric tufted as in Example II is cut into a sample 6 inches (15.2 cm.) wide (cross-machine direction, across tufting rows) and 8 inches (20.3 cm.) long (machine direction, along tufting rows). The sample is cut in the center of the width 4 inches (10.2 cm.) in the machine (tufting) direction. The sample is mounted in an "Instron" tester using 1.5 inch (3.7 cm.) by 2 inch (5.1 cm.) serrated clamps. With a jaw separation of 3 inches (7.6 cm.), one side of the sample cut is mounted in the upper jaw and the other side of the sample cut is mounted in the lower jaw. The sample is uniformly spaced between the jaws. The full scale load is adjusted to a value greater than the tear strength expected for the sample. Using a crosshead speed of 12 inches (30.5 cm.) per minute and a chart speed of 10 inches (25.4 cm.) per minute, the "Instron" is started and the sample is torn. An average of the three highest stresses (one hundred units=full scale deflection) during tearing is taken. If it is not possible to obtain three peaks, the average of the peaks obtained is taken. The tongue tear strength in pounds is the average highest stress divided by 100 and multiplied by the full scale load.

The "bias modulus" of a nonwoven fabric may be measured in the following manner. A nonwoven fabric tufted as in Example II is cut into samples 4 inches (10.2 cm.) wide by 6 inches (15.2 cm.) long in the bias directions. The sample is mounted in an Instron using a 1 in. (2.54 cm.) by 3 inches (7.6 cm.) clamp on the back side and a one inch (2.54 cm.) square clamp on the front side and a jaw separation of 3 in. (7.6 cm.). The sample is mounted for extension in the bias direction. At a crosshead speed of 5 inches (12.7 cm.) per minute, the load at 10% elongation is measured and divided by the sample width of 4 inches (10.2 cm.). The results are reported in pounds per inch.

The "tufted grab tensile" of a nonwoven fabric may be measured in the following manner. A sample tufted as in Example II is cut into samples 4 inches (10.2 cm.) wide by 6 inches (15.2 cm.) long in the testing direction. The sample is mounted in an "Instron" using a 1 inch (2.54 cm.) by 2 inch (5.08 cm.) clamp on the back side and a 1 inch (2.54 cm.) square clamp in the front side at a jaw separation of 3 inches (7.6 cm.). A crosshead speed of 12 inches (30.48 cm.) per minute is used. The peak of the "Instron" curve is read and reported as pounds breaking strength.

The method for measuring the bond strength distribution is described in Jung U.S. 3,322,607 (column 9, lines 10–75 and column 10, lines 1–7). With the nonwovens of the present invention, the strips are cut in the bias directions to minimize double clamping of filaments between the "Instron" clamps. The preferred products of this invention are bonded to a level such that (1) the average bond strength ($\bar{S}$) is at least 0.9 gram and less than the filament breaking strength; (2) the distribution of the bond strengths is such that the variance (σ^2) is

greater than 4; (3) the number of bonds is such that the product ($N_b\bar{S}$) of the number of bonds per cubic centimeter (N_b) and the average bond strength is greater than 5×10^4 g./cm.^{3} and (4) this product divided by the filament breaking strength is less than 9×10^3/cm.^{3}.

The distance that filaments extend in a given direction is measured on a test sample of sufficient size that it is at least twice the length in the test direction as the estimated distance between filament reversal points. It is often convenient to use an approximately square sample for this test. The surface of the sheet near the center of the sample is examined either visually or under conditions of low magnification (1.5–5×) and a filament is selected, said filament being aligned in the sheet approximately parallel to the direction in which it is desired to determine the distance between filament reversal points. The selected filament is then carefully teased out of the web with the aid of dissecting tools, for example, tweezers, scalpels, probes, the path of the filament being marked as teasing progresses. Any technique applicable may be used to mark the path of the filament during the test. A convenient technique is to spray the sheet with a light coat of a flat contrasting paint which, on drying, easily flakes from the surface of the sheet. When a filament is teased from this painted sheet, unpainted surface is exposed which marks the filament path. The teasing operation is continued in both directions until the path of the filament clearly reverses itself twice or until the path length is greater than about 7 inches (17.8 cm.). If the filament breaks during the teasing operation, another one is chosen. For the products of this invention, the filaments aligned in the sheet approximately perpendicular to the fabric length direction proceed in such direction for a distance greater than about 7 inches. Preferably the filaments aligned in the sheet approximately parallel to the fabric length direction will also extend at least 7 inches in such direction. Measurements on about five filaments in each direction are sufficient to make this determination.

When the nonwoven fabrics of this invention are comprised of more than one layer, the various layers may be comprised of the same quantity and type of fibers or the layers may differ in quantity, fiber type or both. For example, the fibers in the different layers may differ in degree of fiber orientation, denier, crimp, and polymer type. When separate "binder filaments" are included in the nonwoven webs, the amount of such binder filaments may differ from layer to layer. Improved surface stability of the nonwoven fabrics of this invention can be gained by providing increased "binder" quantity in the surface layers.

The following examples are intended to demonstrate this invention and are not intended to be limitative in any way.

EXAMPLE I

Web A.—An approximately 1 oz./yd.^{2} (33.9 g./m.^{2}) nonwoven web containing continuous filaments of isotactic polypropylene is prepared from polymer having a MFR of 8.5. The polypropylene filaments are extruded at a temperature of 255° C. through a spinneret having 500 orifices of size .015 inch (.038 cm.) diameter at a throughput of 0.45 gm./min./hole and are segmentally drawn along the length of the filaments by passage successively over unheated feed rolls operating at peripheral speeds of 191, 211 and 221 y.p.m. (175, 193 and 202 m./min.), followed by passage over a steam-heated roll such as that described in Edwards U.S. 3,302,698 operated at a peripheral speed of 249 yards (228 m.) per minute and heated at 130° C. but adapted with an axially slotted surface to heat seven inch (17.8 cm.) segments of the filaments with one inch (2.54 cm.) separations followed by passage over two unheated draw rolls operating at a peripheral speed of 594 yards (542 m.) per minute. The ribbon of continuous filaments thus formed is given a negative electrostatic charge by passage across the target bar of a corona charging device such as that described in DiSabato et al. U.S. 3,163,753. Stripping of the ribbon of continuous filaments from the draw roll is accomplished by a single slot jet of the type shown in FIG. 6 using a jet plenum pressure of 20 p.s.i.g. (1.407 kg./cm.^{2}) but with no deflection air supplied to the deflection plenums. The nonwoven web was collected on a suction receiver and then lightly bonded by heating in saturated steam at 65 p.s.i.a. (4.57 kg./cm.^{2}).

Web B.—A nonwoven web approximately 1 oz./yd.^{2} (33.9 g./m.^{2}) containing continuous filaments of isotactic polypropylene is prepared as above except the three unheated feed rolls are operated at peripheral speeds of 169, 186 and 194 y.p.m. (154, 170 and 177 m./min.) and the heated, axially slotted feed roll is operated at a peripheral speed of 209 y.p.m. (191 m./min.).

Web C.—An approximately 1 oz./yd.^{2} (33.9 g./m.^{2}) nonwoven web is prepared but with cross-machine direction filament alignment using drawing conditions as in preparing the second random web above. Deflection air is supplied to the deflection plenums alternately. The oscillation frequency (both plenums going through a complete cycle) is 5.5 cycles/second. Deflection plenum pressure varied from zero to a peak of 4 p.s.i.g. (.281 kg./cm.^{2}) which gives a distance between swath reversal points of 25 inches (63.5 cm.) and the lateral swath deflection speed is 0.77 times the filament speed and is kept constant between reversals. This web was lightly bonded as above except a saturated steam pressure of 78 p.s.i.a. (5.48 kg./cm.^{2}) was used.

EXAMPLE II

Web C is combined with two layers of Web A and one layer of Web B all prepared as above. The layers are arranged from top to bottom in the order Webs A, B, C, A and bonded in saturated steam at 97 p.s.i.a. (6.82 kg./cm.^{2}) to give a composite web of 4 oz./yd.^{2} (135.6 g./m.^{2}). Using the procedure described in U.S. 3,322,607 the average bond strength $\bar{S}$ in the bonded nonwoven fabric is found to be 1.74 g., the product of the number of bonds/cc. and the average bond strength ($N_b\bar{S}$) is 18.9×10^4 g./cm.^{3}, the variance is 8.7 and the ratio of N_bS to fiber strength is 7.3×10^3/cm.^{3}.

The filament directionality by the randometer technique gave: $MD/45°=1.20$ and $XD/45°=1.53$.

The bonded nonwoven fabric is submerged in a 4% aqueous dispersion of a methyl-hydrogen-polysiloxane which contains 0.4% of a surface active agent (sodium alkylarylsulfonate). The fabric is then squeezed between two rolls with a nip pressure of 50 p.s.i.g. (3.5 kg./cm.^{2}) at a speed of 1.5 yd./min. (1.4 m./min.) and dried in a circulating air oven at 93° C. for 45 minutes. About 2% by weight of polysiloxane is added by this treatment. The fabric is tufted under the following conditions:

Gauge (distance between needles)	0.188 in. (0.48 cm.).
Speed	400 tufts/min., 7 tufts/in. (2.8 tufts/cm.).
Pile yarn	3700 denier nylon continuous filament.
Tuft height	0.438 in. (1.11 cm.).
Type pile	Loop.

The tufted nonwoven fabric has a machine direction "tongue tear strength" of 40 lbs. (18.1 kg.) and a cross-machine direction grab tensile strength of 86 lbs. (36.2 kg.). On loading 3.3 lbs. per inch (0.59 kg./cm.) in the machine direction the nonwoven fabric decreases in width 1.2%. This product has directionality values within the limits of the present invention and exhibits good tufted tear strength and low neckdown.

EXAMPLE III

Two layers of each of Webs A and B are combined from top to bottom in order A, B, B, A and bonded at

100 p.s.i.a. (7.04 kg./cm.^{2}) saturated steam to give a composite web of 4 oz./yd.^{2} (135.6 g./m.^{2}) containing randomly disposed filaments. Using the procedure described in U.S. 3,322,607, the average bond strength in the bonded nonwoven fabric is found to be 1.65 g., $N_b\overline{S}$ is 18×10^4 g./cm.^{3}, the variance is 9.1 and the ratio of $N_b\overline{S}$ to fiber strength is 7.06×10^3/cm.^{3}.

Filament directionality by randometer measurement showed $MD/45°=1.32$ and $XD/45°=1.05$.

After tufting as in Example II the nonwoven fabric has a machine direction "tongue tear strength" of 21.3 lbs. (9.66 kg.) and a cross-machine direction grab tensile strength of 54.3 lbs. (24.6 kg.). On loading 3.3 lbs. per inch (0.59 kg. per cm.) in the machine direction the nonwoven fabric decreases in width 1.6%. In this product, the value of $XD/45°$ is too low and an acceptable combination of tear strength and resistance to neckdown is not obtained.

EXAMPLE IV

Continuous polypropylene filaments, prepared from a polymer having $MFR=8.5$ and segmentally drawn along their length are cut into 4.5 inch (11.4 cm.) staple and formed into nonwoven webs with the fibers preferentially aligned in the cross-machine direction by garnetting and cross-lapping. This web is cross-lapped to form a composite nonwoven web of 4 oz./yd.^{2} (135.6 g./m.^{2}) with fibers preferentially aligned in the machine and cross-machine directions and bonded at 85 p.s.i.a. (5.98 kg./cm.^{2}) in saturated steam. The randometer measurements gave $MD/45°=0.96$ and $XD/45°=1.08$.

After tufting as in Example II the bonded nonwoven fabric has a machine direction "tongue tear strength" of 22 lbs. (9.98 kg.) and a cross-machine direction grab tensile strength of 62 lbs. (28.1 kg.). On loading 3.3 lbs. per inch (0.589 kg. per cm.) in the machine direction the nonwoven fabric decreases in width 2.5%. The results indicate that an acceptable combination of tear strength and resistance to neckdown is not obtained.

EXAMPLE V

A 4 oz./yd.^{2} (135.6 g./m.^{2}) nonwoven web is prepared from polymer having $MFR=8.5$ using an arrangement similar to that illustrated in FIG. 5 except only one jet is used for each direction of deflection. Polypropylene filaments are extruded at 255° C. from a spinneret having 500 orifices of size 0.015 in. (.038 cm.) diameter at a throughput of 0.45 gm./min./hole and are passed successively over unheated rolls operating at peripheral speeds of 187, 195 and 200 y.p.m. (171, 178 and 183 m./min.), respectively, and then over a steam heated roll such as that described in Edwards, U.S. 3,302,698, operated at 120° C. and at a peripheral speed of 200 y.p.m. (183 m./min.), and fitted with an axially slotted surface to heat seven inch (17.8 cm.) segments with one inch (2.54 cm.) separations. The filaments are then passed over two draw rolls both operating at a peripheral speed of 650 y.p.m. (594 m./min.). The continuous filaments thus formed are separated into two ribbons of 250 filaments each which are given a negative electrostatic charge by passage across the target bars of corona charging devices such as are described in DiSabato et al., U.S. 3,163,753. Stripping of the ribbons of continuous filaments is accomplished by slot jets of the type shown in FIG. 6 using a jet plenum pressure of 40 p.s.i.g. (4.88 kg./cm.^{2}). Deflection air is supplied to both jets at 9 cycles/sec. and a peak deflection pressure of 20 p.s.i.g. (244 kg./cm.^{2}). The distance between swath reversal points is 20 inches (50.8 cm.). The nonwoven web is collected on a suction receiver and bonded in saturated steam at 88 p.s.i.a. (6.18 kg./cm.^{2}). Using the procedure described in U.S. 3,322,607, the average bond strength in the bonded nonwoven fabric is found to be 1.51 g., $N_b\overline{S}$ is 4.63×10^4 g./cm.^{3}, the variance is 7.3 and the ratio of $N_b\overline{S}$ to fiber strength is 1.63×10^3/cm.^{3}. The nonwoven fabric has a weight of 4 oz./yd.^{2} (135.6 g./m.^{2}). Filament alignment in the nonwoven fabric is obtained by randometer measurement and shows $MD/45°=2.15$ and $XD/45°=2.20$.

After tufting as in Example II, the tufted nonwoven fabric has a machine direction tufted "tongue tear strength" of 54 lbs. (24.5 kg.) and a cross-machine direction grab tensile strength of 73.3 lbs. (33.2 kg.). On loading 3.3 lbs. per inch (0.59 kg./cm.) in the machine direction the nonwoven fabric decreases in width 1.2%.

EXAMPLE VI

A nonwoven web is produced from polypropylene polymer with a MFR=8.5 using an arrangement similar to that shown in FIG. 5 except that three jets are used for cross-machine direction deflection and one jet is used for machine direction deflection. The edges of the web amounting to half the distance between swath reversal points of the two outside cross-machine direction deflecting jets are discarded. The polypropylene filaments are spun and segmentally drawn along the length of the filaments by passage successively over three unheated feed rolls operating at peripheral speeds of 192, 198 and 204 y.p.m. (175, 181 and 186 m./min.) and then over a heated roll of the type described in Edwards U.S. 3,302,698 operating at a peripheral speed of 209 y.p.m. (191 m./min.) and heated at 130° C. but adapted with an axially slotted surface to heat seven inch (17.8 cm.) segments of the filaments with one inch (2.54 cm.) separations and then passed over two draw rolls operating at 593 y.p.m. (542 m./min.). The ribbons of continuous filaments thus formed are given a negative electrostatic charge by passage across the target bars of corona charging devices such as those described in DiSabato et al. U.S. 3,163,753. Stripping of the ribbons of continuous filaments from the draw rolls is accomplished with slot jets of the type shown in FIG. 6 using 20 p.s.i.g. (1.410 kg./cm.^{2}) jet plenum pressure for the cross-machine direction deflecting jets and 30 p.s.i.g. (2.110 kg./cm.^{2}) jet plenum pressure for the machine direction deflecting jet. The output of each jet is deflected so that the distance between filament reversal is about 7 inchs (17.8 cm.) at a deflection frequency of 18 cycles per second (deflection speed=0.79 filament speed). A nonwoven web of 3.9 oz./yd.^{2} (132 gm./m.^{2}) was collected and bonded at 72, 77, 82 and 87 p.s.i.a. (5.06, 5.41, 5.76 and 6.11 kg./cm.^{2}) steam pressure. The bonded webs were tufted as in Example II and a plot was made of machine direction tufted tongue tear against neckdown of the tufted sample at 3.3 lb./in. (0.59 kg./cm.) longitudinal stress. The tear strength at 1% neckdown was normalized to a 4 oz./yd.^{2} (135.5 gm./m.^{2}) structure giving 53 lbs. (24.1 kg.). The randometer showed $MD/45°=1.77$ and $XD/45°=1.20$.

EXAMPLE VII

A nonwoven web is prepared as in Example VI except three jets deflecting in the machine direction and three jets deflecting in the cross-machine direction are used and the output of each jet is deflected so that the distance between swath reversal points is 14 inches (35.6 cm.) at a deflection frequency of 9 cycles/sec. (deflection speed=0.79 filament speed) using a peak deflection plenum pressure of 2 p.s.i.g. (0.1406 kg./cm.^{2}).

A nonwoven web of 3.2 oz./yd.^{2} (108 gm./m.^{2}) is collected and bonded in saturated steam at 72, 77, 82 and 87 p.s.i.a. (5.06, 5.41, 5.76 and 6.11 kg./cm.^{2}). The procedure of Example VI was repeated and the tufted tear strength at 1% neckdown for a 4 oz./yd.^{2} (135.5 gm./m.^{2}) web was calculated to be 57 lbs. (25.9 kg.). The randometer measurements on this sample showed $MD/45°=1.43$ and $XD/45°=1.54$.

EXAMPLE VIII

A nonwoven web is prepared as in Example VI except three jets deflecting in the machine direction and two jets deflecting in the cross-machine direction are used and the output of each jet is deflected so that the distance between

swath reversal points is 28 inches (74 cm.) at a deflection frequency of 4.5 cycles/sec. (deflection speed=0.79 filament speed) using a peak deflection plenum pressure of 6 p.s.i.g. (422 g./cm.^{2}).

A nonwoven web of 3.6 oz./yd.^{2} (122 gm./m.^{2}) is collected and bonded in saturated steam at 72, 77, 82 and 87 p.s.i.a. (5.06, 5.41, 5.76 and 6.11 kg./cm.^{2}). The procedure of Example VI was repeated, and the tufted tongue tear at 1% neckdown for a 4 oz./yd.^{2} (135.5 gm./m.^{2}) web was calculated to be 50 lbs. (22.7 kg.). The randometer measurements showed $MD/45°=1.40$ and $XD/45°=1.37$.

EXAMPLE IX

An interleaved nonwoven web is prepared as in Example VI from polypropylene polymer having MFR=8.5 except one jet deflecting in the machine direction and two jets deflecting in the cross-machine direction are used. Looking down on the jet devices and receiver which is moving from East to West, the center of the machine direction deflecting jet device is taken as a reference point. The center of one cross-machine deflecting jet device is located 7 inches (17.8 cm.) West and 8 inches (20.3 cm.) North of the reference point and the center of the other cross-machine deflecting jet is 7 inches (17.8 cm.) East and 8 inches (20.3 cm.) South of the reference point. The unheated feed rolls are operated at peripheral speeds of 169, 186 and 195 y.p.m. (154, 170 and 178 m./min.) and the heated roll is operated at a peripheral speed of 209 y.p.m. (191 m./min.). Jet plenum pressure of 30 p.s.i.g. (2.110 kg./cm.^{2}) is used for all jets. The output of each jet is deflected so that the distance between swath reversal points is 28 inches (71 cm.) at a deflection frequency of 4 cycles/sec. (deflection speed=0.7 filaments speed) using a peak deflection plenum pressure of 5 p.s.i.g. (0.351 kg./cm.^{2}). Direction of deflection is controlled so that the jets do not interfere one with another. The edges of the web not covered by the machine direction deflection are discarded. Fabric weight is 4.8 oz./yd.^{2} (162.5 g./m.^{2}). The web is bonded in saturated steam at 84 p.s.i.a. (5.9 kg./cm.^{2}). Filament alignment in this nonwoven fabric obtained by randometer measurement showed $MD/45°=1.36$ and $XD/45°=1.28$.

After tufting as in Example II, the nonwoven fabric had a machine direction tongue tear strength of 75 lbs. (34.0 kg.), a cross-machine direction tensile strength of 142 lbs. (64.2 kg.) and a "neckdown" of 1.4% when subjected to a longitudinal stress of 3.3 lbs./in. (0.59 kg./cm.).

EXAMPLE X

Polypropylene filaments are prepared from polymer of MFR=8.5 and segmentally drawn along the length of the filaments by passage successively over an unheated feed roll operated at 170 y.p.m. (155 m./min.) followed by passage over a steam heated roll such as that described in Edwards U.S. 3,302,698 operated at a peripheral speed of 180 y.p.m. (165 m./min.) heated at 126° C. but adapted with an axially slotted surface to heat seven inch (17.8 cm.) segments of the filaments with one inch (2.54 cm.) separations followed by passage over two unheated draw rolls operating at a peripheral speed of 595 y.p.m. (544 m./min.) and then wound on bobbins.

A random web from undrewn polypropylene filaments is prepared using the process disclosed in U.S. 3,338,992. Polypropylene polymer of the same MFR as above is extruded through a spinneret containing 5 holes of diameter of 0.015 inch (0.038 cm.) at a throughput of 3 g./min. After quenching, the filaments are passed around a feed roll operating at 230 y.p.m. (210 m./min.) then over the target bar of a corona charging device and into a round laydown jet which reciprocated slowly across a laydown receiver. The speed of the receiver was adjusted to give a fabric weight of about 0.25 oz./yd.^{2} (8.48 g./m.) and the web so formed was lightly bonded in saturated steam at 55 p.s.i.a. (3.86 kg./cm.^{2}) using a bonder of the type described in Huffman U.S. 3,192,560.

The continuous filaments prepared above were formed into a nonwoven web with highly directionalized filaments, using a procedure similar to that described in Selby U.S. 3,197,351. A warp of untwisted filaments was passed into a spreading zone and the individual filaments were electrostatically spread and deposited onto the lightweight random web prepared as above which acted as a binder. The assembly was lightly bonded as above in saturated steam at 70 p.s.i.a. (4.92 kg./cm.^{2})(Web D) and had a fabric weight of about 1 oz./yd.^{2} (33.9 g./m.^{2}).

Several composite nonwoven webs were prepared using 2 layers of Web D combined with two layers of Web D rotated 90°. The layers were combined from top to bottom in the order Web D, Web D (90°), Web D, Web D (90°) and bonded in saturated steam using a bonder of the type described in Huffman U.S. 3,192,560 at the steam pressures indicated in Table I. The bonded nonwoven fabrics were tufted as in Example II.

TABLE I

Bonding pressure		Bias modulus		Machine direction tufted tongue tear		Neckdown, percent
P.s.i.a.	(Kg./cm.^{2})	Lbs./in.	(Kg./cm.)	Lbs.	(Kg.)	
80	(5.62)	0.45	(.0805)	20	(9.1)	2.2
85	(5.97)	0.86	(1.56)	17	(7.21)	0.4
90	(6.32)	0.86	(.156)	51	(23.2)	0.4

Bias modulus of each of the above samples was plotted against "neckdown" and from the resulting curve a value for bias modulus at 1% "neckdown" was obtained.

Filament alignment in these nonwovens obtained by the randometer method showed $MD/45°=25.1$ and $XD/45°=25.1$. In these webs, the filament alignment in the machine and cross-machine direction is too high resulting in unacceptably low bias modulus.

EXAMPLE XI

A highly directional 1.7 oz./yd.^{2} (57.6 g./m.^{2}) web with filament alignment in the cross-machine direction was prepared from filaments spun as in Example I(Web A), except the first four rolls were operated at peripheral speeds of 180, 197, 205 and 220 y.p.m. (165, 180, 187.5 and 201 m./min.). These filaments were charged and stripped off the draw rolls with a slot device of the type shown in FIG. 6 at a jet plenum pressure of 20 p.s.i.g. (1.406 kg./cm.^{2}) and were then passed to a second jet operated at a jet plenum pressure of 25 p.s.i.g. (1.758 kg./cm.^{2}). The second jet was mechanically oscillated at 2 cycles/second. Filaments emerging from this second jet were blown across the laydown receiver so that the distance between swath reversal points was 60 inches (152 cm.). The resultant web was lightly bonded at 52 p.s.i.a. (3.66 kg./cm.^{2}) using a bonder as described in Wyeth, U.S. 3,313,002.

A composite structure was prepared using two layers of this lightly bonded web, one as layed down and the other rotated 90°. The composite structure was bonded in saturated steam as above at the pressures indicated in Table II. The samples were tufted as in Example II.

TABLE II

Bonding pressure		Bias modulus		Machine direction tufted tongue tear		Neck down percen
P.s.i.a.	(Kg./cm.^{2})	Lbs./in.	(Kg./cm.)	Lbs.	(Kg.)	
83	(5.85)	1.9	(0.34)	49	(22.3)	2.1
86	(6.06)	2.6	(0.465)	57	(25.9)	0.9

Bias modulus of the above samples was plotted against percent "neckdown" at 3.3 lb./in. (0.59 kg./cm.) longi-

tudinal stress and from the resulting line a value for bias modulus at 1% "neckdown" was obtained.

Filament alignment in these nonwovens was obtained by the randometer technique which showed *MD*/45°=5.95 and *XD*/45°=5.95. This nonwoven web is less directional than that described in Example X, however, its filament directionality is still too high in the MD and XD to provide adequate resistance to deformation in the bias directions.

EXAMPLE XII

A nonwoven web is prepared with an apparatus similar to that shown in FIG. 5 except that 14 slot jets are used for cross-machine direction deflection and 14 slot jets for machine direction deflection. Using polypropylene polymer of MFR=2.5, 500 polypropylene filaments at each position are extruded through capillaries 15 x 90 mils (.038 x .23 cm.) at a throughput of 30 lbs. (13.65 kg.) per position per hour at a temperature of about 275° C. and are segmentally drawn by successive passage over three unheated feed rolls operating at peripheral speeds of 214, 220, and 226 y.p.m. (196, 201, and 206 m./min.) and then over a heated roll of the type described in Edwards, U.S. 3,302,698 operating at a peripheral speed of 234 y.p.m. (214 m./min.) heated to 140° C. and adapted with an axially slotted surface to heat seven inches (17.8 cm.) segments of the fibers with 1 inch (2.54 cm.) separations, and then over two draw rolls operating at a peripheral speed of 600 y.p.m. (549 m./min.). The ribbons of filaments are given a negative electrostatic charge by passage through a corona charging device of the type hereinbefore described and are led to a first bank of slot jets of the type shown in FIG. 6 which oscillate the ribbons in the cross-machine direction so that the distance between swath reversal points is 26 inches (66 cm.) at a deflection frequency of 5.5 cycles per second.

500 filaments per position are fed to a second bank of slot jets after passage over three unheated feed rolls operating at peripheral speeds of 234, 240 and 247 y.p.m. (214, 220 and 226 m./min.), an axially slotted roll heated to 140° C. and operating at 254 y.p.m. (234 m./min.), two draw rolls operating at peripheral speeds of 600 y.p.m. (549 m./min). and a corona charging device. This second bank of jets oscillates the threadline in the machine direction at a deflection frequency of nine cycles per second, so that the distance between swath reversal points is 13 inches (33 cm.). The nonwoven web is collected on a suction laydown receiver moving at 12.0 y.p.m. (11 m./min.) and bonded in saturated steam at a range of pressure given in Table III, to give nonwovens having fabric weights ofabout 4 oz./yd.^{2} (136 g./m.^{2}). The randometer measurements showed *MD*/45°=1.21 and *XD*/45°=1.78.

The bonded nonwoven webs are lubricated with about 1% of a methyl-hydrogen-polysiloxane. Some samples are tufted so that the tufting needles penetrate the side of the nonwoven webs having cross-machine direction filament alignment, and other samples are tufted so that the needles penetrate the side of the nonwoven webs having machine direction filament alignment. The tufting conditons are as follows:

Gauge: 1/10 inch (0.254 cm.).
Pitch: 12 stitches per inch (4.74 stitches/cm.).
Yarn: 2600 denier continuous filament nylon.
Pile height: 3/8 inch (0.952 cm.).

A carboxylated styrene-butadiene latex with a styrene to butadiene ratio of about 40:60, compounded with 300 parts of filler, is applied to the back of the tufted material to lock the tufts into the backing and machine direction tear strength is determined on the samples. The results, listed in Table III, indicate that the samples tufted so that the needles penetrate the side of the product having machine direction filament alignment have considerably higher tear strength than those tufted into the side having cross-machine filament alignment.

TABLE III

Sample	Bonding pressure P.s.i.a.	Bonding pressure (Kg./cm.^{2})	Tufted into—	Machine direction tufted tongue tear Lbs.	Machine direction tufted tongue tear (Kg.)
13-A	90	(6.33)	[a]	43	(19.5)
13-A	90	(6.33)	[b]	22	(10)
13-B	95	(6.57)	[a]	43	(19.5)
13-B	95	(6.57)	[b]	21	(9.55)
13-C	100	(7.03)	[a]	42	(19.1)
13-C	100	(7.03)	[b]	21	(9.55)
13-D	105	(7.38)	[a]	30	(13.62)
13-D	105	(7.38)	[b]	20	(9.1)

[a]Side with machine direction filament alignment.
[b]Side with cross-machine direction filament alignment.

EXAMPLE XIII

The web samples described in Example XII and bonded at the same conditions were tufted as before so that the tufting needles penetrated the side with machine direction filament alignment. The "tufted tongue tear strength" and the "neckdown" at 3.3 lb./in. (0.59 kg./cm.) longitudinal stress were measured with no latex applied. The results are given in Table IV indicating that there is an acceptable balance of tear strength and resistance to "neckdown."

TABLE IV

Bonding pressure P.s.i.a.	Bonding pressure (Kg./cm.^{2})	Machine direction tufted tongue tear Lbs.	Machine direction tufted tongue tear (Kg.)	Neckdown at 3.3 lb./in. (0.59 kg./cm.) stress, percent
90	(6.33)	99	(45)	1.5
95	(6.57)	82	(37.3)	1.6
100	(7.03)	69	(31.4)	1.3
105	(7.38)	48	(21.8)	1.1

EXAMPLE XIV

Approximately 1 oz./yd.^{2} (33.9 gm./m.^{2}) nonwoven webs containing continuous filaments of isotactic polypropylene aligned in the machine direction are prepared as in Example I, except that the three unheated rolls were operated at peripheral speeds of 187, 194 and 200 y.p.m. respectively (171, 178 and 183 m./min.), the axially slotted roll was heated to about 120° C. and operated at a peripheral speed of 208 y.p.m. (190 m./min.), and the draw rolls were operated at peripheral speeds of 654 y.p.m. (598 m./min.). The oscillating conditions and the distances between reversal points are listed in Table V. The three webs 14–A, 14–B and 14–C so prepared were lightly bonded at 65 p.s.i.a. (4.58 kg./cm.^{2}) steam pressure, using a bonder of the type described in Wyeth, U.S. 3,313,002. These webs were then used to prepare composite samples as described in the following examples.

TABLE V

Web	Oscillation frequency, c.p.s.	Reversal distance Inches	Reversal distance (Cm.)	Oscillation plenum pressure P.s.i.g.	Oscillation plenum pressure (Kg./cm.^{2})
14-A	2	15	(38.1)	1	(0.0703)
14-B	4	15	(38.1)	2	(0.141)
14-C	9	15	(38.1)	5	(0.352)

EXAMPLE XV

Web 14–A from Example XIV was used to prepare all of the following composite structures.

Composite 15–1.—Four layers of the web were placed on top of one another so that the filaments in each case were aligned in the long or machine direction. Samples of these four layer composites were then bonded at each of the following saturated steam pressures in a bonder as described before: 76, 84, 92 and 100 p.s.i.a. (5.35, 5.9, 6.46 and 7.03 kg./cm.^{2}).

Composite 15–2.—The procedure described above was repeated except that the four layers were rotated through 90° so that the direction of filament alignment was the cross-machine direction.

Composite 15–3.—The above procedure was again repeated except that the first layer was rotated so that the direction of filament alignment was +45°, the second layer −45°, the third layer +45°, and the fourth layer −45°.

Composite 15–4.—In this composite, the first layer was rotated so that the direction of filament alignment was +45°, the second layer had machine direction filament alignment, the third layer was rotated 90° so that the direction of filament alignment was the cross-machine direction, and the fourth layer was rotated so that the direction of filament alignment was the −45° direction.

Composite 15–5.—In this composite, the first layer had filaments aligned in the machine direction, the second layer in the cross-machine direction, the third layer in the machine direction and the fourth layer in the cross-machine direction.

The fiber directionality of these composites was determined by the randometer test, the composites bonded at the various steam pressures were then lubricated and tufted as described before. The properties of these composite structures are listed in Table VI.

EXAMPLE XVI

Composites 16–1 through 16–5 were prepared as in Example XV except that web 14–B from Example XIV was used. The randometer and the tufted properties of these composites are listed in Table VII.

EXAMPLE XVII

Composites 17–1 through 17–5 were prepared as in Example XV except that web 14–C from Example XIV was used. The randometer and the tufted properties are listed in Table VIII.

EXAMPLE XVIII

Webs having filaments aligned in the machine and cross-machine directions were prepared using the same conditions as in Example XIV. 500 polypropylene filaments, after being segmentally drawn, were divided into three bundles of 125, 250 and 125 filaments respectively. The first 125 filaments were led into a jet which oscillated the filaments in the machine direction. The next 250 filaments were led into a second jet downstream from the first one which deposited a web with cross-machine direction filament alignment on top of the first web. The last 125 filaments were led into a third jet which deposited a web with machine direction filament alignment on top of the other two webs. Composite webs were produced at different oscillating conditions and were bonded over a range of bonding pressures. The speed of the laydown belt was adjusted in each case to obtain webs of about 4 oz./yd.^{2} (135.6 g./m.^{2}). The bonded webs were lubricated and tufted as before and directionality measurements were made by the randometer test. The properties of these structures are listed in Table IX.

TABLE VI

Composite	Randometer MD/45°	Randometer XD/45°	Bonding pressure P.s.i.a.	Bonding pressure (Kg./cm.^{2})	Machine direction tufted tongue tear Lbs.	Machine direction tufted tongue tear (Kg.)	Neckdown at 3.3 lb./in. (0.59 kg./cm.) stress, percent	Cross-machine direction tufted grab tensile Lbs.	Cross-machine direction tufted grab tensile (Kg.)
15–1	1.64	0.82	76	(5.35)	56	(25.4)	4.8	93	(42.3)
			84	(5.9)	37	(16.8)	3.4	79	(35.9)
			92	(6.46)	20	(9.1)	1.6	64	(29.1)
			100	(7.03)	9	(4.09)	0.6	48	(21.8)
15–2	0.82	1.64	76	(5.35)	79	(35.9)	6.6	>200	(>91)
			84	(5.9)	65	(29.6)	3.1	>200	(>91)
			92	(6.46)	57	(25.9)	1.2	159	(72.1)
			100	(7.03)	8	(3.64)	0.6	136	(61.9)
15–3	0.82	0.82	76	(5.35)	80	(36.4)	6.5	180	(81.8)
			84	(5.9)	61	(27.7)	4.8	162	(73.6)
			92	(6.46)	37	(16.8)	2.6	121	(55)
			100	(7.03)	19	(8.64)	0.7	89	(40.5)
15–4	1.0	1.0	76	(5.35)	79	(35.9)	4.5	186	(84.5)
			84	(5.9)	63	(28.6)	2.9	151	(68.6)
			92	(6.46)	35	(15.9)	2.3	97	(44.1)
			100	(7.03)	13	(5.9)	0.7	61	(27.7)
15–5	1.23	1.23	76	(5.35)	144	(65.5)	6.3	176	(80)
			84	(5.9)	114	(51.9)	4.2	182	(82.6)
			92	(6.46)	113	(51.4)	2.6	140	(63.6)
			100	(7.03)	65	(29.6)	0.8	72	(32.8)

TABLE VII

Composite	Randometer MD/45°	Randometer XD/45°	Bonding pressure P.s.i.a.	Bonding pressure (Kg./cm.^{2})	Machine direction tufted tongue tear Lbs.	Machine direction tufted tongue tear (Kg.)	Neckdown at 3.3 lb./in. (0.59 kg./cm.) stress, percent	Cross-machine direction tufted grab tensile Lbs.	Cross-machine direction tufted grab tensile (Kg.)
16–1	2.30	0.79	76	(5.35)	51	(23.2)	4.5	107	(48.6)
			84	(5.9)	36	(16.35)	2.6	68	(30.9)
			92	(6.46)	21	(9.55)	1.3	60	(27.3)
			100	(7.03)	15	(6.82)	0.6	44	(20)
16–2	0.79	2.30	76	(5.35)	98	(44.5)	7.2	>200	(>91)
			84	(5.9)	47	(21.35)	5.3	181	(82.2)
			92	(6.46)	55	(25)	0.9	173	(78.6)
			100	(7.03)	19	(8.64)	0.6	137	(62.3)
16–3	0.65	0.65	76	(5.35)	86	(29.1)	6.7	168	(76.4)
			84	(5.9)	71	(32.3)	5.3	165	(75)
			92	(6.46)	42	(19.1)	2.6	130	(59)
			100	(7.03)	21	(9.53)	0.8	80	(36.4)
16–4	1.0	1.0	76	(5.35)	82	(37.3)	4.9	175	(79.5)
			84	(5.9)	73	(33.2)	2.7	174	(79)
			92	(6.46)	52	(23.3)	2.2	124	(56.4)
			100	(7.03)	21	(9.55)	0.5	84	(38.2)
16–5	1.55	1.55	76	(5.35)	84	(38.2)	5.4	162	(73.6)
			84	(5.9)	135	(61.4)	3.9	164	(74.5)
			92	(6.46)	46	(20.9)	2.1	109	(49.5)
			100	(7.03)	59	(26.8)	0.6	63	(28.6)

TABLE VIII

Composite	Randometer MD/45°	Randometer XD/45°	Bonding pressure P.s.i.a.	Bonding pressure (Kg./cm.²)	Machine direction tufted tongue tear Lbs.	Machine direction tufted tongue tear (Kg.)	Neckdown at 3.3 lb./in. (0.59 kg./cm.) stress, percent	Cross-machine direction tufted grab tensile Lbs.	Cross-machine direction tufted grab tensile (Kg.)
17-1	3.84	0.56	76	(5.35)	51	(23.2)	2.6	67	(30.5)
			84	(5.9)	36	(16.4)	2.1	68	(30.9)
			92	(6.46)	21	(9.55)	0.4	43	(19.6)
			100	(7.03)	15	(6.81)	0.9	48	(21.8)
17-2	0.56	3.84	76	(5.35)	45	(20.4)	8.0	>200	(>91)
			84	(5.9)	37	(16.8)	3.5	>200	(>91)
			92	(6.46)	19	(8.63)	1.6	>200	(>91)
			100	(7.03)	11	(5.0)	1.5	125	(56.8)
17-3	0.45	0.45	76	(5.35)	93	(42.3)	7.3	136	(61.8)
			84	(5.9)	84	(38.2)	4.6	188	(85.5)
			92	(6.46)	69	(31.4)	4.2	137	(62.3)
			100	(7.03)	35	(15.9)	1.0	132	(60)
17-4	1.0	1.0	76	(5.39)	110	(50)	3.4	200	(91)
			84	(5.9)	91	(41.4)	2.5	155	(70.5)
			92	(6.46)	48	(21.8)	2.1	127	(57.7)
			100	(7.03)	33	(15)	0.8	89	(40.4)
17-5	2.20	2.20	76	(5.35)	120	(54.5)	1.6	113	(51.8)
			84	(5.9)	87	(39.5)	0.9	102	(46.3)
			92	(6.46)	73	(33.2)	0.8	91	(41.4)
			100	(7.03)	68	(30.9)	0.3	72	(32.7)

EXAMPLE XIX

3 oz./yd.² (101.7 g./m.²) webs were prepared from polypropylene filaments produced as in Example I except that a polymer of MFR=2.5 was used at a spinning temperature of 275° C. and a throughput of 0.69 g./min./hole. Segmental drawing of the filaments was carried out using speeds of 167, 179, 185, 192 and 500 y.p.m. (153, 164, 169, 176 and 457 m./min.) respectively. The 500 filaments were divided into three bundles of 125, 250 and 125 filaments and deposited through the respective jets as described in Example XVIII. The webs were bonded, lubricated and tufted as before and the properties are summarized in Table X. The randometer test showed $MD/45°=3.1$ and $XD/45°=2.08$.

test. After bonding over a range of steam pressures, samples are tufted and the tufted tear strength is plotted against the neckdown of 3.3 lb./in. (0.59 kg./cm.) stress. From this plot, the tufted tear strength at 1% neckdown is found to be 19 lbs. (8.65 kg.).

The same webs are rotated 90° and then tufted, i.e., $MD/45°$ is now 1.31 and $XD/45°$ is 2.04. It is found that the machine direction tufted tongue tear at 1% neckdown is 56 lbs. (21.5 kg.).

EXAMPLE XXI

The data in the preceding examples were used to determine the machine direction tufted tear strength and the bias modulus when the neckdown at 3.3 lb./in. (0.59

TABLE IX

Composite	Oscillation frequency, cycles/second	Oscillation plenum p.s.i.g.	Oscillation plenum (Kg./cm.²)	Distance between swath reversal points In.	Distance between swath reversal points (Cm.)	Randometer MD/45°	Randometer XD/45°	Bonding pressure P.s.i.a.	Bonding pressure (Kg./cm.²)	Machine direction tufted tongue tear Lbs.	Machine direction tufted tongue tear (Kg.)	Neckdown at 3.3 lb./in. (0.59 kg./cm.) stress, percent	Bias modulus Lb./in.	Bias modulus (Kg./cm.)
18-1	2	1	(.0703)	15	(38.1)	1.18	1.14	70	(4.82)	78	(35.4)	5.4		
								75	(5.26)	66	(30)	4.1		
								80	(5.62)	48	(21.8)	3.4	3.2	(0.573)
								85	(5.97)	39	(17.7)	2.2	4.2	(0.75)
								90	(6.32)	24	(10.9)	1.2	5.2	(0.93)
								95	(6.67)	15	(6.81)	0.5		
18-2	4	2	(.1406)	15	(38.1)	1.40	1.52	65	(4.56)	92	(41.8)	5.0		
								70	(4.82)	82	(37.2)	2.8		
								75	(5.26)	84	(38.2)	3.2		
								80	(5.62)	71	(32.3)	1.0	3.2	(0.573)
								85	(5.97)	52	(23.6)	0.9		
								90	(6.32)	46	(20.9)	1.3	5.5	(0.985)
								95	(6.67)	22	(10)	1.1		
18-3	9	5	(0.351)	15	(38.1)	1.77	2.28	70	(4.82)	74	(33.6)	1.7		
								75	(5.26)	111	(50.4)	1.5		
								80	(5.62)	99	(45)	1.5	3.1	(0.555)
								85	(5.97)	90	(40.8)	1.0		
								90	(6.32)	73	(33.2)	0.1		
								95	(6.67)	57	(25.9)	0.1	5.9	(1.075)

TABLE X

Bonding pressure P.s.i.a.	Bonding pressure (Kg./cm.²)	Machine direction tufted tongue tear Lbs.	Machine direction tufted tongue tear (Kg.)	Neckdown at 3.3 lb./in. (0.59 kg./cm.) stress, percent	Bias modulus Lb./in.	Bias modulus (Kg./cm.)
76	(5.35)	75	(34)	1.4	3.3	(0.59)
84	(5.90)	66	(30)	0.8	3.5	(0.626)
88	(6.19)	44	(20)	0.2	4.0	(0.716)

EXAMPLE XX

4 oz./yd.² (135.5 gm./m.²) nonwoven webs are prepared as in Example V except that the filaments are separated into two ribbons of 375 filaments and 125 filaments respectively, the 375 filament ribbon being led to a jet deflecting in the machine direction and the 125 filament ribbon to a jet deflecting in the cross-machine direction. The non-woven webs so collected are found to have $MD/45°=2.04$ and $XD/45°=1.31$ by the randometer

kg./cm.) stress was equal to 1%. Where properties were available at more than one bonding condition, this was done by plotting tufted tear strength and bias modulus against percent neckdown and graphically determining the values when the neckdown was 1%. Where only properties at one bonding condition were available, the values of machine direction tufted "tongue tear" and of bias modulus at 1% "neckdown" were estimated. These values are given in Table XI and were used to plot the graphs in FIGS. 11–13.

EXAMPLE XXII

A nonwoven web is prepared as follows. Isotactic polypropylene filaments are melt spun at 245° C. from 12.5 MFR polymer through 726 capillaries of size 0.015 x 0.090 inch at a rate of 0.63 gm./min./hole. These filaments are radially quenched, and pass over feed rolls operating at peripheral speeds of 257 and 283 y.p.m., and then over two draw rolls operating at a peripheral speed of 850 y.p.m. The feed rolls are heated to 100° C. and 114° C. respectively, and the second feed roll has a slotted surface 1 inch which heats 7 inch segments of the filaments with 1 inch separations. The ribbon of continuous filaments thus formed was given a negative electrostatic charge by a corona charging device as described in Di Sabato et al. U.S. 3,163,753. The filaments were stripped off the draw rolls by tension applied with a slot jet.

TABLE XI

Example	Randometer			Machine direction tufted tongue tear at 1% neckdown		Bias modulus at 1% neckdown	
	MD/45	XD/45	MD/XD	Lbs.	(Kg.)	Lb./in.	(Kg./cm.)
II	1.2	1.53	0.79	38	(17.8)		
III	1.32	1.05	1.26	18	(8.18)		
V	2.15	2.20	0.98	50	(22.7)		
VI	1.77	1.20	1.47	53	(24.1)		
VII	1.43	1.54	0.93	57	(25.9)		
VIII	1.40	1.37	1.03	50	(22.7)		
IX	1.36	1.28	1.06	60	(27.3)		
X	25.1	25.1	1.00	51	(23.2)	0.8	(0.143)
XI	5.95	5.95	1.00	57	(25.9)	2.6	(0.465)
XIII	1.21	1.78	0.68	46	(20.5)		
XV-1	1.64	0.82	2.00	13	(5.9)		
XV-2	0.82	1.64	0.50	56	(25.5)		
XV-3	0.82	0.82	1.00	21	(9.55)		
XV-4	1.00	1.00	1.00	19	(8.63)		
XV-5	1.23	1.23	1.00	70	(31.8)		
XVI-1	2.30	0.79	2.91	19	(8.63)		
XVI-2	0.79	2.30	0.34	56	(25.5)		
XVI-3	0.65	0.65	1.00	23	(10.5)		
XVI-4	1.00	1.00	1.00	29	(13.2)		
XVI-5	1.55	1.55	1.00	50	(22.7)		
XVII-1	3.84	0.56	6.85	19	(8.63)		
XVII-2	0.56	3.84	0.14	10	(4.54)		
XVII-3	0.45	0.45	1.00	35	(15.9)		
XVII-4	1.00	1.00	1.00	30	(13.6)		
XVII-5	2.20	2.20	1.00	90	(40.9)		
XVIII-1	1.18	1.14	1.03	22	(10)	5.3	(0.95)
XVIII-2	1.40	1.52	0.92	51	(23.2)	5.5	(0.985)
XVIII-3	1.77	2.28	0.78	85	(38.6)	4.5	(0.805)
XIX	3.10	2.08	1.49	69	(31.4)	3.5	(0.626)
XX—as is	2.04	1.31	1.56	19	(8.63)		
XX—rotated 90°	1.31	2.04	0.64	56	(25.5)		

The filaments emerging from this jet were deflected in the cross machine direction by alternate displacement of the enveloping exit air stream through coanda effect. The resultant web was bonded in saturated steam at 86 p.s.i.a. A nonwoven fabric with basis weight of 4.1 oz./yd.^{2} is obtained. Filament alignment measured by the randometer technique was $MD/45°=.82$, $XD/45°=2.2$.

The above examples illustrate bonded nonwoven fabrics of 3 to 5 oz./yd. basis weight which have after lubrication per Jung 3,322,607 and tufting an acceptable balance of properties i.e., a tear strength of about 40 lbs. (18.2 kg.) or greater coupled with a neckdown under longitudinal stress of about 1% or less and a bias modulus of about 3 lb./in. (0.536 kg./cm.) or more. Nonwoven fabrics of higher or lower basis weight having filament directionality within the hereinbefore described limits will also show an improvement in properties over controls which do not meet the filament directionality requirements of the instant invention.

While the above examples describe the preparation of highly desirable embodiments of the present invention, it is obvious that suitable modifications can be made without departing from the spirit of the invention. For example, other methods of bonding may be used such as the application of a thermoplastic powder, or the use of a heating fluid other than steam. If desired, the edges of the nonwoven fabric can be stabilized as described in Sands U.S. 3,360,421.

While the products of this invention are particularly suitable for use as primary carpet backings, they can also be used in the manufacture of other tufted articles including chenille bed spreads, pile linings, upholstery materials and imitation furs.

What is claimed is:

1. A length of bonded nonwoven fabric having continuous synthetic filaments that are preferentially aligned approximately perpendicular to the fabric length direction and extend for a distance greater than about 7 inches, the filaments of said fabric being disposed in such manner to provide the following filament directionality values:

(a) $XD/45°$ at least 1.2;
(b) MD/XD between about 0.25 and 1.5; and
(c) $(MD/45°+XD/45°)$ less than about 6,

wherein XD is a measure of the total filament length in the direction perpendicular to the fabric length direction, MD is a measure of the total filament length in the fabric length direction and 45° is the average of the measures of the total filament length in the directions at 45° to the fabric length direction, wherein XD, MD and 45° are measures determined by the randometer method.

2. The fabric of claim **1** having other filaments that are preferentially aligned approximately parallel to the fabric length direction and extend for a distance greater than about 7 inches.

3. The fabric of claim **1** wherein $XD/45°$ is below about 2.4 and the sum of $MD/45°+XD/45°$ is above about 2.4.

4. The fabric of claim **2** wherein $XD/45°$ is below about 2.4 and the sum of $MD/45°+XD/45°$ is above about 2.4.

5. The fabric of claim **1** wherein the filaments are polypropylene.

6. The fabric of claim **2** wherein the filaments are polypropylene.

7. The fabric of claim **1** bonded to a level such that (1) the average bond strength ($\overline{S}$) is at least 0.9 gram and less than the filament breaking strength: (2) the distribution of bond strengths is such that the variance (σ^2) is greater than 4; (3) the number of bonds is such that the product ($N_b\overline{S}$) of the number of bonds per cubic centimeter (N_b) and the average bond strength is greater than 5×10^4 g./cm.^{3} and (4) this product divided by the filament breaking strength is less than 9×10^3/cm.^{3}.

8. The fabric of claim 2 bonded to a level such that (1) the average bond strength ($\overline{S}$) is at least 0.9 gram and less than the filament breaking strength; (2) the distribution of bond strengths is such that the variance (σ^2) is greater than 4; (3) the number of bonds is such that the product ($N_b\overline{S}$) of the number of bonds per cubic centimeter (N_b) and the average bond strength is greater than 5×10^4 g./cm.^{3} and (4) this product divided by the filament breaking strength is less than 9×10^3/cm.^{3}.

9. The fabric of claim 7 bearing a lubricant.

10. The fabric of claim 8 bearing a lubricant.

11. The fabric of claim 1 wherein the filaments lying approximately perpendicular to the fabric length direction, reverse direction in a periodic manner, with a distance between filament reversal points of at least seven inches.

12. The fabric of claim 11 wherein $XD/45°$ is below about 2.4 and the sum of $MD/45°+XD/45°$ is above about 2.4.

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ROBERT F. BURNETT, Primary Examiner

R. O. LINKER, JR., Assistant Examiner

U.S. Cl. X.R.

156—181; 161—60, 150, 170

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,563,838 Dated February 16, 1971

Inventor(s) Clifton Vedantus Edwards

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 35, "lentghs" should read -- lengths --.

Column 4, line 28, insert after "de-" -- flecting device are used across the width of the nonwoven web. --

Column 4, delete line 29 in its entirety through line 30 ending with "woven web."

Column 7, line 8, " "bias modulus " should read -- "bias modulus" --.

Column 7, line 55, "crimed" should read -- crimped --.

Column 9, line 2, "80°" should read -- 80 --.

Column 14, line 40, "inchs" should read -- inches --.

Column 15, line 33, "filaments" should read -- filament

Column 15, line 64, "undrewn" should read -- undrawn --

Column 16, line 28, "1.56" should read -- .156 --.

Column 16, line 70, "percen" should read -- percent --.

Column 17, line 50, "ofabout" should read -- of about --

Signed and sealed this 29th day of June 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER
Commissioner of Pat