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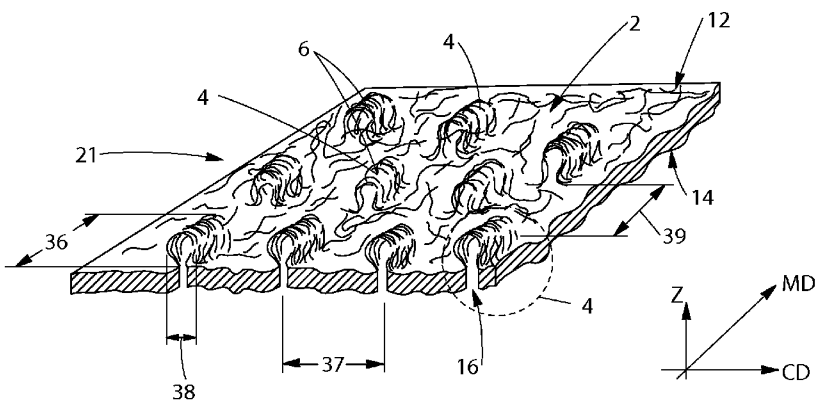

Fig. 3

(57) Abstract: The present invention is directed to a fluid permeable structured fibrous web comprising thermally stable, fibers that are thermally bonded together using heat producing a base substrate that is thermally stable. The base substrate is textured via mechanical treatment producing a structured fibrous web having an aged caliper of less than 1.5 mm, a vertical wicking height of at least 5 mm, a permeability of at least 10,000 cm^2/(Pa-s) and a specific volume of at least 5 cm^3/g. The structured fibrous web provides optimal fluid wicking and the fluid acquisition capabilities and is directed toward fluid management applications.

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FLUID PERMEABLE STRUCTURED FIBROUS WEB

FIELD OF THE INVENTION

The present invention is related to fluid permeable fibrous webs, particularly fluid permeable fibrous webs providing optimal fluid acquisition and distribution capabilities.

BACKGROUND OF THE INVENTION

Commercial woven and nonwoven fabrics typically comprise synthetic polymers formed into fibers. These fabrics are typically produced with solid fibers that have a high inherent overall density, typically 0.9 g/cm^3 to 1.4 g/cm^3. The overall weight or basis weight of the fabric is often dictated by a desired opacity, mechanical properties, softness/cushiness, or a specific fluid interaction of the fabric to promote an acceptable thickness or caliper, strength and protection perception. Often, these properties are needed in combination to achieve the desired level of performance.

A key aspect of using synthetic fiber nonwovens is their functionality. For many fabrics and nonwovens, its function is to provide a desired feel to a product; to make it softer or make it feel more natural. For other fabrics or nonwovens, the functionality is important to improve the direct performance of the product. For instance, a disposable absorbent article typically includes a nonwoven topsheet, a backsheet and an absorbent core therebetween. The nonwoven topsheet is permeable to allow fluids to pass through to the absorbent core. In order to control leakage and rewet due to gushing, a fluid acquisition layer that typically comprises at least one nonwoven layer is disposed between the topsheet and the absorbent core. The nonwoven acquisition layer has capacity to take in fluid and transport it to the absorbent core. The effectiveness of the acquisition layer in performing this function is largely dependent upon the thickness of the layer and the properties of the fibers used to form it. However, thickness leads to bulkiness which is undesirable to the consumer. Therefore, the optimal thickness or caliper of the acquisition layer is often a compromise between thickness for fluid handling and thinness for comfort. As the fluid acquisition layer decreases in thickness, its capacity to take in fluids is reduced; therefore, necessitating an enhancement in the material's ability to quickly distribute fluids in the plane of the layer away from the point of intake. Material properties related to fluid distribution performance include wicking and permeability.

Thus, a fluid acquisition layer is desired exhibiting a thickness for fluid acquisition and thinness for comfort while providing permeability and fluid wicking capabilities necessary for enhanced fluid distribution. What's more, caliper or thickness is difficult to maintain due to compressive forces induced during material handling, storage and normal use. Thus, it is also desired to provide a nonwoven exhibiting a robust caliper that is sustainable during normal handling, packaging and use. Further, a process for enhancing the caliper of a nonwoven material close to its end use is desired in order to minimize the impact of such compressive forces induced during material handling and converting.

SUMMARY OF THE INVENTION

The present invention is directed to a fluid permeable structured fibrous web comprising thermoplastic fibers. The structured fibrous web has an aged caliper of less than 1.5 mm, a vertical wicking height of at least 5 mm, a permeability of at least 10,000 $cm^2/(Pa{\cdot}s)$ and a specific volume of at least 5 cm^3/g. The thermoplastic fibers are preferably thermally stable and non extendable so that they break in the plane of the web during mechanical treatment as described below, and stiff to withstand compressive forces during use. The fibers preferably have a modulus of at least 0.5 GPa and are thermally bonded together using heat producing a fibrous web base substrate that is thermally stable. Although fiber shapes include solid round and hollow round fibers, other shapes include trilobal, delta or any other multi-lobal fiber shape that increases fiber surface area to increase vertical wicking capability.

The fibrous web base substrate includes a first surface and a second surface that are mechanically treated to impart localized out of plane thickness to the base substrate forming a structured fibrous web. The structured fibrous web comprises a first region and a plurality of discrete second regions disposed throughout the first region. The second regions form discontinuities on the second surface of the fibrous web and displaced fibers on the first surface. The displaced fibers are fixed along a first side of the second region and separated proximate to the first surface along a second side of the second region opposite the first side forming loose ends extending away from the first surface of the fibrous fabric. At least 50% and less than 100% of the displaced fibers have loose ends providing free volume for collecting fluid.

In one embodiment the fluid permeable structured fibrous web includes a plurality of overbonded regions disposed throughout the first region in between the second regions. The overbonded regions can continuously extend between the second regions forming depressions which provide additional void volume for fluid acquisition and channels providing fluid distribution which enhances permeability.

The fluid permeable structured fibrous web is directed toward fluid management applications desiring optimal fluid acquisition and distribution capabilities. Such fluid management applications include cleaning applications such as wipes for cleaning up spills and disposable absorbent articles such as diapers, feminine protection products, wound dressings, bibs, and adult incontinence products.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings where:

FIG. 1 is a schematic representation of an apparatus for making a web according present invention.

FIG. 1A is a schematic representation of an alternate apparatus for making a laminate web according to the present invention.

FIG. 2 is an enlarged view of a portion of the apparatus shown in FIG. 1.

FIG. 3 is a partial perspective view of a structured substrate.

FIG. 4 is an enlarged portion of the structured substrate shown in FIG. 3.

FIG. 5 is a cross-sectional view of a portion of the structured substrate shown in FIG. 4.

FIG. 6 is a plan view of a portion of the structured substrate shown in FIG. 5.

FIG. 7 is a cross-sectional depiction of a portion of the apparatus shown in FIG. 2.

FIG. 8 is a perspective view of a portion of the apparatus for forming one embodiment the web of the present invention.

FIG. 9 is an enlarged perspective view of a portion of the apparatus for forming the web of the present invention.

FIG. 10 is a partial perspective view of a structured substrate having melt-bonded portions of displaced fibers.

FIG. 11 is an enlarged portion of the structured substrate shown in FIG. 10.

FIG. 12A-12F are plan views of a portion of the structured substrate of the present invention illustrating various patterns of bonded and/or over bond regions.

FIG. 13 is a cross-sectional view of a portion of the structured substrate showing bonded and/or over bond regions.

FIG. 14 is a cross-sectional view of a portion of the structured substrate showing bonded and/or over bond regions on opposing surfaces of the structured substrate.

FIG. 15 is a photomicrograph of a portion of a web of the present invention showing tent-like structures formed at low fiber displacement deformations.

FIG. 16 is a photomicrograph of a portion of a web of the present invention showing substantial fiber breakage resulting from increased fiber displacement deformation.

FIG 17A and 17B are photomicrographs of portions of a web of the present invention showing portions of the structured substrate that are cut in order to determine the number of displaced fibers.

FIG. 18 is a photomicrograph of a portion of a web of the present invention identifying locations along tip bonded displaced fibers of the structured substrate that are cut in order to determine the number of displaced fibers.

FIG. 19A through 19C are cross sections of shaped fiber configurations.

FIG. 20 is a schematic representation of an in plane radial permeability apparatus set up.

FIGs. 21A, 21B and 21C are an alternate views of portions of the in plane radial permeability apparatus set up shown in FIG. 20.

FIG. 22 is a schematic representation of a fluid delivery reservoir for the in plane radial permeability apparatus set up shown in FIG. 20.

DETAILED DESCRIPTION OF THE INVENTION

Definitions:

As used herein and in the claims, the term "comprising" is inclusive or open-ended and does not exclude additional unrecited elements, compositional components, or method steps.

As used herein the term "activation" means any process by which tensile strain produced by intermeshing teeth and grooves causes intermediate web sections to stretch or extend. Such processes have been found useful in the production of many articles including breathable films, stretch composites, apertured materials and textured materials. For nonwoven webs, the stretching can cause fiber reorientation, change in fiber denier and / or cross section, a reduction in basis weight, and/or controlled fiber destruction in the intermediate web sections. For example, a common activation method is the process known in the art as ring rolling.

As used herein "depth of engagement" means the extent to which intermeshing teeth and grooves of opposing activation members extend into one another.

As used herein, the term "nonwoven web" refers to a web having a structure of individual fibers or threads which are interlaid, but not in a repeating pattern as in a woven or knitted fabric, which do not typically have randomly oriented fibers. Nonwoven webs or fabrics have been formed from many processes, such as, for example, meltblowing processes, spunbonding processes, hydroentangling, airlaid, and bonded carded web processes, including carded thermal bonding. The basis weight of nonwoven fabrics is usually expressed in grams per square meter (g/m^2). The basis weight of a laminate web is the combined basis weight of the constituent layers and any other added components. Fiber diameters are usually expressed in microns; fiber size can also be expressed in denier, which is a unit of weight per length of fiber. The basis weight of laminate webs suitable for use in the present invention can range from 6 g/m^2 to 400 g/m^2, depending on the ultimate use of the web. For use as a hand towel, for example, both a first web and a second web can be a nonwoven web having a basis weight of between 18 g/m^2 and 500 g/m^2.

As used herein, "spunbond fibers" refers to relatively small diameter fibers which are formed by extruding molten thermoplastic material as filaments from a plurality of fine, usually circular capillaries of a spinneret with the diameter of the extruded filaments then being rapidly reduced by an externally applied force. Spunbond fibers are generally not tacky when they are deposited on a collecting surface. Spunbond fibers are generally continuous and have average diameters (from a sample of at least 10) larger than 7 microns, and more particularly, between about 10 and 40 microns.

As used herein, the term "meltblowing" refers to a process in which fibers are formed by extruding a molten thermoplastic material through a plurality of fine, usually circular, die capillaries as molten threads or filaments into converging high velocity, usually heated, gas (for example air) streams which attenuate the filaments of molten thermoplastic material to reduce their diameter, which may be to microfiber diameter. Thereafter, the meltblown fibers are carried by the high velocity gas stream and are deposited on a collecting surface, often while still tacky; to form a web of randomly dispersed meltblown fibers. Meltblown fibers are microfibers which may be continuous or discontinuous and are generally smaller than 10 microns in average diameter.

As used herein, the term "polymer" generally includes, but is not limited to, homopolymers, copolymers, such as for example, block, graft, random and alternating copolymers, terpolymers, etc., and blends and modifications thereof. In addition, unless otherwise specifically limited, the term "polymer" includes all possible geometric configurations of the material. The configurations include, but are not limited to, isotactic, atactic, syndiotactic, and random symmetries.

As used herein, the term "monocomponent" fiber refers to a fiber formed from one or more extruders using only one polymer. This is not meant to exclude fibers formed from one polymer to which small amounts of additives have been added for coloration, antistatic properties, lubrication, hydrophilicity, etc. These additives, for example titanium dioxide for coloration, are generally present in an amount less than about 5 weight percent and more typically about 2 weight percent.

As used herein, the term "bicomponent fibers" refers to fibers which have been formed from at least two different polymers extruded from separate extruders but spun together to form one fiber. Bicomponent fibers are also sometimes referred to as conjugate fibers or multicomponent fibers. The polymers are arranged in substantially constantly positioned distinct zones across the cross-section of the bicomponent fibers and extend continuously along the length of the bicomponent fibers. The configuration of such a bicomponent fiber may be, for example, a sheath/core arrangement wherein one polymer is surrounded by another, or may be a side-by-side arrangement, a pie arrangement, or an "islands-in-the-sea" arrangement.

As used herein, the term "biconstituent fibers" refers to fibers which have been formed from at least two polymers extruded from the same extruder as a blend. Biconstituent fibers do not have the various polymer components arranged in relatively constantly positioned distinct zones across the cross sectional area of the fiber and the various polymers are usually not continuous along the entire length of the fiber, instead usually forming fibers which start and end at random. Biconstituent fibers are sometimes also referred to as multiconstituent fibers.

As used herein, the term “non-round fibers” describes fibers having a non-round cross-section, and include “shaped fibers” and “capillary channel fibers.” Such fibers can be solid or hollow, and they can be tri-lobal, delta-shaped, and are preferably fibers having capillary channels on their outer surfaces. The capillary channels can be of various cross-sectional shapes such as “U-shaped”, “H-shaped”, “C-shaped” and “V-shaped”. One preferred capillary channel fiber is T-401, designated as 4DG fiber available from Fiber Innovation Technologies, Johnson City, TN. T-401 fiber is a polyethylene terephthalate (PET polyester).

“Absorbent article" means devices that absorb and/or contain liquid. Wearable absorbent articles are absorbent articles placed against or in proximity to the body of the wearer to absorb and contain various exudates discharged from the body. Nonlimiting examples of wearable absorbent articles include diapers, pant-like or pull-on diapers, training pants, sanitary napkins, tampons, panty liners, incontinence devices, and the like. Additional absorbent articles include wipes and cleaning products.

"Disposed" refers to the placement of one element of an article relative to another element of an article. For example, the elements may be formed (joined and positioned) in a particular place or position as a unitary structure with other elements of the diaper or as a separate element joined to another element of the diaper.

“Extensible nonwoven” is a fibrous nonwoven web that elongates, without rupture or breakage, by at least 50%. For example, an extensible material that has an initial length of 100 mm can elongate at least to 150 mm, when strained at 100% per minute strain rate when tested at 23 ± 2°C and at 50 ± 2% relative humidity. A material may be extensible in one direction (e.g. CD), but non-extensible in another direction (e.g. MD). An extensible nonwoven is generally composed of extensible fibers.

“Highly extensible nonwoven” is a fibrous nonwoven web that elongates, without rupture or breakage, by at least 100%. For example, a highly extensible material that has an initial length of 100 mm can elongate at least to 200 mm, when strained at 100% per minute strain rate when tested at 23 ± 2°C and at 50 ± 2% relative humidity. A material may be highly extensible in one direction (e.g. CD), but non-extensible in another direction (e.g. MD) or extensible in the other direction. A highly extensible nonwoven is generally composed of highly extensible fibers.

“Non-extensible nonwoven” is a fibrous nonwoven web that elongates, with rupture or breakage, before 50% elongation is reached. For example, a non-extensible material that has an initial length of 100 mm cannot elongate more than 50 mm, when strained at 100% per minute strain rate when tested at 23 ± 2°C and at 50 ± 2% relative humidity. A non-extensible nonwoven is non-extensible in both the machine direction (MD) and cross direction (CD).

“Extensible fiber is a fiber that elongates by at least 400% without rupture or breakage, when strained at 100% per minute strain rate when tested at 23 ± 2°C and at 50 ± 2% relative humidity.

“Highly extensible fiber is a fiber that elongates by at least 500% without rupture or breakage, when strained at 100% per minute strain rate when tested at 23 ± 2°C and at 50 ± 2% relative humidity.

“Non extensible fiber is a fiber that elongates by less than 400% without rupture or breakage, when strained at 100% per minute strain rate when tested at 23 ± 2°C and at 50 ± 2% relative humidity.

“Hydrophilic or hydrophilicity” refers to a fiber or nonwoven material in which water or saline rapidly wets out on the surface the fiber or fibrous material. A material that wicks water or saline can be classified as hydrophilic. A way for measuring hydrophilicity is by measuring its vertical wicking capability. For the present invention, a nonwoven material is hydrophilic if it exhibits a vertical wicking capability of at least 5 mm.

"Joined" refers to configurations whereby an element is directly secured to another element by affixing the element directly to the other element, and configurations whereby an element is indirectly secured to another element by affixing the element to intermediate member(s) that in turn are affixed to the other element.

“Laminate” means two or more materials that are bonded to one another by methods known in the art, e.g. adhesive bonding, thermal bonding, ultrasonic bonding.

“Machine direction” or “MD” is the direction parallel to the direction of travel of the web as it moves through the manufacturing process. Directions within ±45 degrees of the MD are considered to be machine directional. The “cross machine direction” or “CD” is the direction substantially perpendicular to the MD and in the plane generally defined by the web. Directions within less than 45 degrees of the cross direction are considered to be cross directional.

“Outboard” and “inboard” refer, respectively, to the location of an element disposed relatively far from or near to the longitudinal centerline of an absorbent article with respect to a second element. For example, if element A is outboard of element B, then element A is farther from the longitudinal centerline than is element B.

“Wicking” refers to the active fluid transport of fluid through the nonwoven via capillary forces. Wicking rate refers to the fluid movement per unit time, or i.e. how far a fluid has traveled in a specified period of time.

“Acquisition rate” refers to the speed in which a material takes-up a defined quantity of fluid or the amount of time it takes for the fluid to pass through the material.

“Permeability” refers to a relative ability of a fluid to flow through a material in the X-Y plane. Materials with high permeability enable higher fluid flow rates than materials with lower permeability.

"Web" means a material capable of being wound into a roll. Webs may be films, nonwovens, laminates, apertured laminates, etc. The face of a web refers to one of its two dimensional surfaces, as opposed to its edge.

“X-Y plane” means the plane defined by the MD and CD of a moving web or the length.

Regarding all numerical ranges disclosed herein, it should be understood that every maximum numerical limitation given throughout this specification includes every lower numerical limitation, as if such lower numerical limitations were expressly written herein. In addition, every minimum numerical limitation given throughout this specification will include every higher numerical limitation, as if such higher numerical limitations were expressly written herein. Further, every numerical range given throughout this specification will include every narrower numerical range that falls within such broader numerical range and will also encompass each individual number within the numerical range, as if such narrower numerical ranges and individual numbers were all expressly written herein.

The present invention provides a structured substrate formed by activation of a suitable base substrate. The activation induces fiber displacement and forms a three dimensional texture which increases the fluid acquisition properties of the base substrate. The surface energy of the base substrate can also be modified to increase its fluid wicking properties. The structured substrate of the present invention will be described with respect to a preferred method and apparatus used for making the structured substrate from the base substrate. A preferred apparatus **150** is shown schematically in FIG. 1 and FIG. 2 and discussed more fully below.

Base Substrate

The base substrate **20** according to the present invention is a fluid permeable fibrous nonwoven web formed from a loose collection of thermally stable fibers. The fibers according to the present invention are non extensible which was previously defined as elongating by less than 300% without rupture or breakage; however, the non extensible fibers forming the base substrate of the present invention preferably elongate by less than 200% without rupture or breakage. The fibers can include staple fibers formed into a web using industry standard carding, airlaid, or wetlaid technologies; however, continuous spunbond fibers forming spunlaid nonwoven webs using industry standard spunbond type technologies is preferred. Fibers and spunlaid processes for producing spunlaid webs are discussed more fully below.

The fibers of the present invention may have various cross sectional shapes that include, but are not limited to; round, elliptical, star shaped, trilobal, multilobal with 3-8 lobes, rectangular, H-shaped, C-shaped, I-shape, U-shaped and other various eccentricities. Hollow fibers can also be used. Preferred shapes are round, trilobal and H-shaped. Round fibers are the least expensive and are therefore preferred from an economic standpoint but trilobal shaped fibers provide increased surface area and are therefore preferred from a functional standpoint. The round and trilobal fiber shapes can also be hollow; however, solid fibers are preferred. Hollow fibers are useful because they have a higher compression resistance at equivalent denier than a solid fiber of the same shape and denier.

Fibers in the present invention tend to be larger than those found in typical spunbond nonwovens. Because the diameter of shaped fibers can be hard to determine, the denier of the fiber is often referenced. Denier is defined as the mass of a fiber in grams at 9000 linear meters of length, expressed as dpf (denier per filament). For the present invention, the preferred denier range is greater than 1 dpf and less than 100 dpf. A more preferred denier range is 1.5 dpf to 50 dpf and a still more preferred range from 2.0 dpf to 20 dpf, and a most preferred range of 4 dpf to 10 dpf.

The loose collection of fibers forming the base substrate of the present invention are bonded in advance of activation and corresponding fiber displacement. A fibrous web can be under bonded so that the fibers have a high level of mobility and tend to pull out from the bond sites under tension or fully bonded with much higher bond site integrity such that the fibers exhibit minimal fiber mobility and tend to break under tension. The non extensible fibers forming the base substrate of the present invention are preferably fully bonded to form a non extensible fibrous web material. As explained more fully below, a non extensible base substrate is preferred for forming the structured substrate via fiber displacement.

Fully bonding of the base substrate can be done in one bonding step, e.g. during manufacturing of the base substrate. Alternatively, there can be more than one bonding step to make the pre-bonded base substrate, e.g. the base substrate can be only lightly bonded or under bonded upon manufacturing to provide sufficient integrity to wind it up. Subsequently, the base substrate may then undergo further bonding steps to obtain a fully bonded web, e.g. immediately prior to subjecting the base substrate to the fiber displacement process of the present invention. Also, there may be bonding steps at any time between base substrate manufacture and fiber displacement. The different bonding steps may also impart different bonding patterns.

Processes for bonding fibers are described in detail in “Nonwovens: Theory, Process, Performance and Testing” by Albin Turbak (Tappi 1997). Typical bonding methods include mechanical entanglement, hydrodynamic entanglement, needle punching, and chemical bonding and/or resin bonding; however, thermal bonding such as thru-air bonding utilizing heat and thermal point bonding utilizing pressure and heat are preferred with thermal point bonding being most preferred.

Thru-air bonding is performed by passing a heated gas through a collection of fibers to produce a consolidated nonwoven web. Thermal point bonding involves applying heat and pressure to discrete locations to form bond sites on the nonwoven web. The actual bond sites include a variety of shapes and sizes; including but not limited to oval, round and four sided geometric shapes. The total overall thermal point bond area is between 2% and 60%, preferably between 4% and 35%, more preferably between 5% and 30% and most preferably between 8% and 20%. A fully bonded base substrate of the present invention has a total overall bond area of from 8% to 70%, preferably from 12% to 50%, and most preferably between 15% and 35%. The thermal point bonding pin density is between 5pins/cm^2 and 100pins/cm^2, preferably between 10pins/cm^2 and 60pins/cm^2 and most preferably between 20pins/cm^2 and 40pins/cm^2. A fully bonded base substrate of the present invention has a bonding pin density of from 10pins/cm^2 to 60 pins/cm^2, preferably from 20 pins/cm^2 to 40 pins/cm^2.

Thermal bonding requires fibers formed from thermally bondable polymers, such as thermoplastic polymers and fiber made therefrom. For the present invention, the fiber composition includes a thermally bondable polymer. The preferred thermally bondable polymer comprises polyester resin, preferably PET resin, more preferably PET resin and coPET resin providing thermally bondable, thermally stable fibers as discussed more fully below. For the present invention, the thermoplastic polymer content is present at a level of greater than about 30%, preferably greater than about 50%, more preferably greater than about 70%, and most preferably greater than about 90% by weight of the fiber.

As a result of bonding, the base substrate has mechanical properties in both the machine direction (MD) and cross machine direction (CD). The MD tensile strength is between 1 N/cm and 200 N/cm, preferably between 5 N/cm and 100 N/cm, more preferably between 10 N/cm and 50 N/cm and most preferably between 20 N/cm and 40 N/cm. The CD tensile strength is between 0.5 N/cm and 50 N/cm, preferably between 2 N/cm and 35 N/cm, and most preferably between 5 N/cm and 25 N/cm. The base substrate should also have a characteristic ratio of MD to CD tensile strength ratio between 1.1 and 10, preferably between 1.5 and 6 and most preferably between 1.8 and 5.

The bonding method also influences the thickness of the base substrate. The base substrate thickness or caliper is also dependent on the number, size and shape of fiber present in a given measured location. The base substrate thickness is between 0.10 mm and 1.3 mm, more preferably between 0.15 mm and 1.0 mm and most preferably between 0.20 mm and 0.7 mm.

The base substrate also has a characteristic opacity. Opacity is a measure of the relative amount of light that passes through the base substrate. Without wishing to be bound by theory, it is believed that the characteristic opacity depends on the number, size, type, morphology, and shape of fibers present in a given measured location. Opacity can be measured using TAPPI Test Method T 425 om-01 "Opacity of Paper (15/d geometry, Illuminant A/2 degrees, 89% Reflectance Backing and Paper Backing)". The opacity is measured as a percentage. For the present invention, the base substrate opacity is greater than 5%, preferably greater than 10%, more preferably greater than 20%, still more preferably greater than 30% and most preferably greater than 40%.

The base substrate has a characteristic basis weight and a characteristic density. Basis weight is defined as a fiber/nonwoven mass per unit area. For the present invention, the basis weight of the base substrate is between 10 g/m^2 and 200 g/m^2. The base substrate density is determined by dividing the base substrate basis weight by the base substrate thickness. For the present invention the density of the base substrate is between 14 kg/m^3 and 200 kg/m^3. The base substrate also has a base substrate specific volume which is an inverse of the base substrate density measured in cubic centimeters per gram.

The base substrate of the present invention can be used to make roof felt, filtration articles, dryer sheets and other consumer products.

Base Substrate Modification

In the present invention, the base substrate can be modified to optimize its fluid dispersion and acquisition properties for use in products where fluid management is important. The fluid dispersion properties can be enhanced by changing the surface energy of the base substrate to increase hydrophilicity and corresponding wicking properties. Modifying the surface energy of the base substrate is optional and is typically performed as the base substrate is made. The fluid acquisition properties can be influenced by modifying the structure of the base substrate by fiber displacement to introduce a 3D texture which increases the thickness or loft and corresponding specific volume of the substrate.

Surface Energy

Hydrophilicity of the base substrate relates to the surface energy. The surface energy of the base substrate can be modified through topical surface treatments, chemical grafting to the surface of the fibers or reactive oxidization of the fiber surfaces via plasma or corona treatments then further chemical bonding from gas reaction addition.

The surface energy of the base substrate can also be influenced by the polymeric material used in producing the fibers of the base substrate. The polymeric material can either have inherent hydrophilicity or it can be rendered hydrophilic through chemical modification of the polymer, fiber surface, and base substrate surface through melt additives or combination of the polymeric material with other materials that induce hydrophilic behavior. Examples of materials used for polypropylene are IRGASURF® HL560 from Ciba and a PET copolymer from Eastman Chemical, EASTONE® family of polymeric materials for PET.

Surface energy can also be influenced through topical treatments of the fibers. Topical treatment of fiber surfaces generally involves surfactants that are added in an emulsion via foam, spray, kiss-roll or other suitable technique in a diluted state and then dried. Polymers that might require a topical treatment are polypropylene or polyester terephthalate based polymer systems. Other polymers include aliphatic polyesteramides; aliphatic polyesters; aromatic polyesters including polyethylene terephthalates and copolymers, polybutylene terephthalates and copolymers; polytrimethylene terephthalates and copolymers; polylactic acid and copolymers. A category of materials referred to as soil release polymers (SRP) are also suitable for topical treatment. Soil release polymers are a family of materials that include low molecular weight polyester polyether, polyester polyether block copolymer and nonionic polyester compounds. Some of these materials can be added as melt additives, but their preferred usage is as topical treatments. Commercial examples of this category of materials are available from Clariant as the Texcare™ family of products.

Structured Substrate

The second modification to the base substrate **20** involves mechanically treating the base substrate to produce a structured fibrous web substrate (the terms “structured fibrous web” and “structured substrate” are used interchangeably herein). The structured substrate is defined as (1) a base substrate permanently deformed through fiber rearrangement and fiber separation and breakage producing permanent fiber dislocation (referred to hereinafter as “fiber displacement”) such that the structured substrate has a thickness value which is higher than that of the base substrate and optionally (2) a base substrate modified by over bonding (referred to hereinafter as “over bonding”) to form a compressed region below the thickness of the base substrate. Fiber displacement processes involve permanent mechanical displacement of fibers via rods, pins, buttons, structured screens or belts or other suitable technology. The permanent fiber dislocation provides additional thickness or caliper compared to the base substrate. The additional thickness increases specific volume of the substrate and also increases fluid permeability of the substrate. The over bonding improves the mechanical properties of the base substrate and can enhance the depth of channels in between displaced fiber regions for fluid management.

Fiber Displacement

The base substrate previously described can be processed using the apparatus **150** shown in FIG.1 to form structured substrate **21**, a portion of which is shown in FIGS. 3-6. As shown in Fig. 3, the structured substrate has a first region **2** in the X-Y plane and a plurality of second regions **4** disposed throughout the first region **2**. The second regions **4** comprise displaced fibers **6** forming discontinuities **16** on the second surface **14** of the structured substrate **21** and displaced fibers **6** having loose ends **18** extending from the first surface **12**. As shown in FIG. 4, the displaced fibers **6** extend from a first side **11** of the second region **4** and are separated and broken forming loose ends **18** along a second side **13** opposite the first side **11** proximate to the first surface **12**. For the present invention, proximate to the first surface **12** means the fiber breakage occurs between the first surface **12** and the peak or distal portion **3** of the displaced fibers, preferably, closer to the first surface **12** than to the distal portion **3** of the displaced fibers **6** .

The location of the fiber separation or breakage is primary attributed to the non extendable fibers forming the base substrate; however, displaced fiber formation and corresponding fiber breakage is also influenced by the extent of bonding used in forming the base substrate. A base substrate comprising fully bonded non extensible fibers provides a structure that due to its fiber strength, fiber stiffness, and bonding strength forms tent like structures at low fiber displacement deformations, as shown in the micrograph in FIG. 15. Once the fiber displacement deformation is extended, substantial fiber breakage is observed, typically concentrated on one side as shown in the micrograph in FIG. 16.

The purpose for creating the displaced fibers **6** having loose ends **18** in FIG. 4 is to increase the structured substrate specific volume over the base substrate specific volume by creating void volume. For the present invention it has been found that creating displaced fibers **6** having at least

50% and less than 100% loose ends in the second regions produces a structured substrate having an increased caliper and corresponding specific volume which is sustainable during use. (See Table 6 examples 1N5 – 1N9 provided below) In certain embodiments described further herein, the loose ends **18** of the displaced fibers **6** can be thermally bonded for improved compression resistance and corresponding sustainability. Displaced fibers **6** having thermally bonded loose ends and a process for producing the same are discussed more fully below.

As shown in FIG. 5, the displaced fibers **6** in second regions **4** exhibit a thickness or caliper which is greater than the thickness **32** of the first region **2** which typically will be the same as the base substrate thickness. The size and shape of the second regions **4** having displaced fibers **6** may vary depending on the technology used. FIG. 5 shows a cross section of the structured substrate **21** illustrating displaced fibers **6** in a second region **4**. Displaced fiber **6** thickness **34** describes the thickness or caliper of the second region **4** of the structured substrate **21** resulting from the displaced fibers **6**. As shown, the displaced fiber thickness **34** is greater than the first region thickness **32**. It is preferred that displaced fiber thickness **34** be at least 110% greater than the first region thickness **32**, more preferably at least 125% greater, and most preferably at least 150% greater than the first region thickness **32**. The aged caliper for displaced fiber thickness **34** is between 0.1 mm and 5 mm, preferably between 0.2 mm and 2 mm and most preferably between 0.5 mm and 1.5 mm.

The number of second regions **4** having displaced fibers **6** per unit area of structured substrate **21** can vary as shown in FIG. 3. In general, the area density need not be uniform across the entire area of structured substrate **21**, but second regions **4** can be limited to certain regions of structured substrate **21**, such as in regions having predetermined shapes, such as lines, stripes, bands, circles, and the like.

As shown in FIG. 3, the total area occupied by the second regions **4** is less than 75%, preferably less than 50% and more preferably less than 25% of the total area, but is at least 10%. The size of the second regions and spacing between second regions **4** can vary. FIG. 3 and FIG. 4 show the length **36**, width **38** and spacing **37** and **39** between second regions **4**. The spacing **39** in the machine direction between the second regions **4** shown in FIG. 3 is preferably between 0.1 mm and 1000 mm, more preferably between 0.5 mm and 100 mm and most preferably between 1 mm and 10 mm. The side to side spacing **37** between the second regions **4** in the cross machine direction is between 0.2 mm and 16 mm, preferably between 0.4 mm and 10 mm, more preferably between 0.8 mm and 7 mm and most preferably between 1 mm and 5.2 mm.

As shown in FIG. 1, structured substrate **21** can be formed from a generally planar, two dimensional nonwoven base substrate **20** supplied from a supply roll **152**. The base substrate **20** moves in the machine direction MD by apparatus **150** to a nip **116** formed by intermeshing rollers **104** and **102A** which form displaced fibers **6** having loose ends **18**. The structured substrate **21** having displaced fibers **6** optionally proceeds to nip **117** formed between roll **104** and bonding roll **156** which bonds the loose ends **18** of the displaced fibers **6.** From there, structured substrate **22** proceeds to optionally intermeshing rolls **102B** and **104** which removes structured substrate **22** from roll **104** and optionally conveys it to nip **119** formed between roll **102B** and bonding roll **158** where over bond regions are formed in structured substrate **23** which is eventually taken up on supply roll **160.** Although FIG. 1 illustrates the sequence of process steps as described, for base substrates which are not yet fully bonded it is desirable to reverse the process so that bonded regions are formed in the base substrate prior to forming displaced fibers **6**. For this embodiment the base substrate **20** would be supplied from a supply roll similar to the take up supply roll **160** shown in FIG. 1 and moved to a nip **119** formed between roll **102B** and bonding roll **158** where the substrate is bonded prior to entering nip **118** formed between intermeshing rolls **102B** and **104** where displaced fibers **6** having loose ends **18** are formed in the second regions **4**.

Although FIG. 1 shows base substrate **20** supplied from supply roll **152**, the base substrate **20** can be supplied from any other supply means, such as festooned webs, as is known in the art. In one embodiment, base substrate **20** can be supplied directly from a web making apparatus, such as a nonwoven web-making production line.

As shown in FIG. 1, first surface **12** corresponds to first side of base substrate **20**, as well as the first side of structured substrate **21**. Second surface **14** corresponds to the second side of base substrate 20, as well as the second side of structured substrate **21**. In general, the term “side” is used herein in the common usage of the term to describe the two major surfaces of generally two-dimensional webs, such as nonwovens. Base substrate **20** is a nonwoven web comprising substantially randomly oriented fibers, that is, randomly oriented at least with respect to the MD and CD. By “substantially randomly oriented” is meant random orientation that, due to processing conditions, may exhibit a higher amount of fibers oriented in the MD than the CD, or vice-versa. For example, in spunbonding and meltblowing processes continuous strands of fibers are deposited on a support moving in the MD. Despite attempts to make the orientation of the fibers of the spunbond or meltblown nonwoven web truly “random,” usually a higher percentage of fibers are oriented in the MD as opposed to the CD.

In some embodiments of the present invention it may be desirable to purposely orient a significant percentage of fibers in a predetermined orientation with respect to the MD in the plane of the web. For example, it may be that, due to tooth spacing and placement on roll **104** (as discussed below), it may be desirable to produce a nonwoven web having a predominant fiber orientation at an angle of, for example, 60 degrees off parallel to the longitudinal axis of the web. Such webs can be produced by processes that combine lapping webs at the desired angle, and, if desired carding the web into a finished web. A web having a high percentage of fibers having a predetermined angle can statistically bias more fibers to be formed into displaced fibers in structured substrate **21**, as discussed more fully below.

Base substrate **20** can be provided either directly from a web making process or indirectly from a supply roll **152**, as shown in FIG. 1. Base substrate **20** can be preheated by means known in the art, such as by heating over oil-heated or electrically heated rollers. For example, roll **154** could be heated to pre-heat the base substrate **20** prior to the fiber displacement process.

As shown in FIG. 1, supply roll **152** rotates in the direction indicated by the arrow as base substrate **20** is moved in the machine direction over roller **154** and to the nip **116** of a first set of counter-rotating intermeshing rolls **102A** and **104**. Rolls **102A** and **104** are the first set of intermeshing rollers of apparatus **150**. The first set of intermeshing rolls **102A** and **104** operate to form displaced fibers and to facilitate fiber breakage in base substrate **20**, to make structured substrate referred to herein after as structured substrate **21**. Intermeshing rolls **102A** and **104** are more clearly shown in FIG. 2.

Referring to FIG. 2, there is shown in more detail the portion of apparatus **150** for making displaced fibers on structured substrate **21** of the present invention. This portion of apparatus **150** is shown as nip rollers **100** in FIG. 2, and comprises a pair of intermeshing rolls **102** and **104** (corresponding to rolls **102A** and **104**, respectively, in FIG. 1), each rotating about an axis **A**, the axes **A** being parallel in the same plane. Although the apparatus **150** is designed such that base substrate **20** remains on roll **104** through a certain angle of rotation, FIG. 2 shows in principle what happens as base substrate **20** goes through nip **116** on apparatus **150** and exits as structured substrate **21** having regions of displaced fibers **6**. The intermeshing rolls can be made from metal or plastic. Non-limiting examples of metal rolls would be aluminum or steel. Non-limiting examples of plastic rolls would be polycarbonate, acrylonitrile butadiene styrene (ABS), and polyphenylene oxide (PPO). The plastics can be filled with metals or inorganic additive materials.

As shown in FIG. 2, roll **102** comprises a plurality of ridges **106** and corresponding grooves **108** which can extend unbroken about the entire circumference of roll **102**. In some embodiments, depending on what kind of pattern is desired in structured substrate **21**, roll **102** (and, likewise, roll **102A**) can comprise ridges **106** wherein portions have been removed, such as by etching, milling or other machining processes, such that some or all of ridges **106** are not circumferentially continuous, but have breaks or gaps. The breaks or gaps can be arranged to form a pattern, including simple geometric patters such as circles or diamonds, but also including complex patterns such as logos and trademarks. In one embodiment, roll **102** can have teeth, similar to the teeth on roll **104**, described more fully below. In this manner, it is possible to have displaced fibers **6** on both sides **12, 14** of structured substrate **21**.

Roll **104** is similar to roll **102**, but rather than having ridges that can extend unbroken about the entire circumference, roll **104** comprises a plurality of rows of circumferentially-extending ridges that have been modified to be rows of circumferentially-spaced teeth **110** that extend in spaced relationship about at least a portion of roll **104**. The individual rows of teeth **110** of roll **104** are separated by corresponding grooves **112**. In operation, rolls **102** and **104** intermesh such that the ridges **106** of roll **102** extend into the grooves **112** of roll **104** and the teeth **110** of roll **104** extend into the grooves **108** of roll **102**. The intermeshing is shown in greater detail in the cross sectional representation of FIG. 7, discussed below. Both or either of rolls **102** and **104** can be heated by means known in the art such as by using hot oil filled rollers or electrically-heated rollers.

As shown in FIG. 3, structured substrate **21** has a first region **2** defined on both sides of structured substrate **21** by the generally planar, two-dimensional configuration of the base substrate **20**, and a plurality of discrete second regions **4** defined by spaced-apart displaced fibers **6** and discontinuities **16** which can result from integral extensions of the fibers of the base substrate **20**.

The structure of second regions **4** is differentiated depending on which side of structured substrate **21** is considered. For the embodiment of structured substrate **21** shown in FIG. 3, on the side of structured substrate **21** associated with first surface **12** of structured substrate **21**, each discrete second region **4** can comprise a plurality of displaced fibers **6** extending outwardly from first surface **12** and having loose ends **18**. Displaced fibers **6** comprise fibers having a significant orientation in the Z-direction, and each displaced fiber **6** has a base **5** disposed along a first side **11** of the second region **4** proximal to the first surface **12**, a loose end **18** separated or broken at a second side **13** of the second region **4** opposite the first side **11** near the first surface **12** and a distal portion **3** at a maximum distance in the Z-direction from the first surface **12**. On the side of structured substrate **21** associated with second surface **14**, second region **4** comprises discontinuities **16** which are defined by fiber orientation discontinuities **16** on the second surface **14** of structured substrate **21**. The discontinuities **16** correspond to the locations where teeth **110** of roll **104** penetrated base substrate **20**.

As used herein, the term "integral" as in "integral extension" when used of the second regions **4** refers to fibers of the second regions **4** having originated from the fibers of the base substrate **20**. Therefore, the broken fibers **8** of displaced fibers **6**, for example, can be plastically deformed and/or extended fibers from the base substrate **20**, and can be, therefore, integral with first regions **2** of structured substrate **21**. In other words, some, but not all of the fibers have been broken, and such fibers had been present in base substrate **20** from the beginning. As used herein, "integral" is to be distinguished from fibers introduced to or added to a separate precursor web for the purpose of making displaced fibers. While some embodiments of structured substrates **21, 22** and **23** of the present invention may utilize such added fibers, in a preferred embodiment, broken fibers **8** of displaced fibers **6** are integral to structured substrate **21**.

It can be appreciated that a suitable base substrate **20** for a structured substrate **21** of the present invention having broken fibers **8** in displaced fibers **6** should comprise fibers having sufficient fiber immobility and/or plastic deformation to break and form loose ends **18**. Such fibers are shown as loose fiber ends **18** in FIGS. 4 and 5. For the present invention, loose fiber ends **18** of displaced fibers **6** are desirable for producing void space or free volume for collecting fluid. In a preferred embodiment at least 50%, more preferably at least 70% and less than 100% of the fibers urged in the Z-direction are broken fibers **8** having loose ends **18**.

The second regions **4** can be shaped to form patterns in both the X-Y plane and the Z-plane to target specific volume distributions that can vary in shape, size and distribution.

Representative second region having displaced fibers **6** for the embodiment of structured substrate **21** shown in FIG. 2 is shown in a further enlarged view in FIGS. 3-6. The representative displaced fibers **6** are of the type formed on an elongated tooth **110** on roll **104**, such that the displaced fibers **6** comprises a plurality of broken fibers **8** that are substantially aligned such that the displaced fibers **6** have a distinct longitudinal orientation and a longitudinal axis **L**. Displaced fibers **6** also have a transverse axis **T** generally orthogonal to longitudinal axis **L** in the **MD**-**CD** plane. In the embodiment shown in FIGS. 2-6, longitudinal axis **L** is parallel to the **MD**. In one embodiment, all the spaced apart second regions **4** have generally parallel longitudinal axes **L**. In preferred embodiments second regions **4** will have a longitudinal orientation, i.e. second regions will have an elongate shape and will not be circular. As shown in FIG. 4, and more clearly in FIGS. 5 and 6, when elongated teeth **110** are utilized on roll **104**, one characteristic of the broken fibers **8** of displaced fibers **6** in one embodiment of structured substrate **21** is the predominant directional alignment of the broken fibers **8**. As shown in FIGS. 5 and 6, many of broken fibers **8** can have a substantially uniform alignment with respect to transverse axis **T** when viewed in plan view, such as in FIG. 6. By "broken" fibers **8** is meant that displaced fibers **6** begin on the first side **11** of second regions **4** and are separated along a second side **13** of second regions **4** opposite the first side **11** in structured substrate **21**.

As can be understood with respect to apparatus **150**, therefore, displaced fibers **6** of structured substrate **21** are made by mechanically deforming base substrate **20** that can be described as generally planar and two dimensional. By "planar" and "two dimensional" is meant simply that the web is flat relative to the finished structured substrate **1** that has distinct, out-of-plane, Z-direction three-dimensionality imparted due to the formation of second regions **4**. "Planar" and "two-dimensional" are not meant to imply any particular flatness, smoothness or dimensionality. As base substrate **20** goes through the nip **116** the teeth **110** of roll **104** enter grooves **108** of roll **102A** and simultaneously urge fibers out of the plane of base substrate **20** to form second regions **4**, including displaced fibers **6** and discontinuities **16**. In effect, teeth **110** "push" or "punch" through base substrate **20**. As the tip of teeth **110** push through base substrate **20** the portions of fibers that are oriented predominantly in the **CD** and across teeth **110** are urged by the teeth **110** out of the plane of base substrate **20** and are stretched, pulled, and/or plastically deformed in the Z-direction, resulting in formation of second region **4**, including the broken fibers **8** of displaced fibers **6**. Fibers that are predominantly oriented generally parallel to the longitudinal axis **L**, i.e., in the machine direction of base substrate **20**, can be simply spread apart by teeth **110** and remain substantially in the first region **2** of base substrate **20**.

In FIG. 2, the apparatus **100** is shown in one configuration having one patterned roll, e.g., roll **104**, and one non-patterned grooved roll **102**. However, in certain embodiments it may be preferable to form nip **116** by use of two patterned rolls having either the same or differing patterns, in the same or different corresponding regions of the respective rolls. Such an apparatus can produce webs with displaced fibers **6** protruding from both sides of the structured web **21**, as well as macro-patterns embossed into the web **21**.

The number, spacing, and size of displaced fibers **6** can be varied by changing the number, spacing, and size of teeth **110** and making corresponding dimensional changes as necessary to roll **104** and/or roll **102**. This variation, together with the variation possible in base substrate **20** and the variation in processing, such as line speeds, permits many varied structured webs **21** to be made for many purposes.

From the description of structured web **21**, it can be seen that the broken fibers **8** of displaced fibers **6** can originate and extend from either the first surface **12** or the second surface **14** of structured substrate **21**. Of course the broken fibers **8** of displaced fibers **6** can also extend from the interior **19** of structured substrate **21**. As shown in FIG. 5, the broken fibers **8** of displaced fibers **6** extend due to having been urged out of the generally two-dimensional plane of base substrate **20** (i.e., urged in the "Z -direction" as shown in FIG. 3). In general, the broken fibers **8** or loose ends **18** of the second regions **4** comprise fibers that are integral with and extend from the fibers of the fibrous web first regions **2**.

The extension of broken fibers **8** can be accompanied by a general reduction in fiber cross sectional dimension (e.g., diameter for round fibers) due to plastic deformation of the fibers and the effects of Poisson's ratio. Therefore, portions of the broken fibers **8** of displaced fibers **6** can have an average fiber diameter less than the average fiber diameter of the fibers of base substrate **20** as well as the fibers of first regions **2**. It has been found that the reduction in fiber cross-sectional dimension is greatest intermediate the base **5** and the loose ends **3** of displaced fibers **6**. This is believed to be due to portions of fibers at the base **5** and distal portion **3** of displaced fibers **6** are adjacent the tip of teeth **110** of roll **104**, described more fully below, such that they are frictionally locked and immobile during processing. In the present invention the fiber cross section reduction is minimal due to the high fiber strength and low fiber elongation.

FIG. 7 shows in cross section a portion of the intermeshing rolls **102** (and **102A** and **102B**, discussed below) and **104** including ridges **106** and teeth **110**. As shown teeth **110** have a tooth height **TH** (note that **TH** can also be applied to ridge **106** height; in a preferred embodiment tooth height and ridge height are equal), and a tooth-to-tooth spacing (or ridge-to-ridge spacing) referred to as the pitch **P**. As shown, depth of engagement, (DOE) **E** is a measure of the level of intermeshing of rolls **102** and **104** and is measured from tip of ridge **106** to tip of tooth **110**. The depth of engagement **E**, tooth height **TH**, and pitch **P** can be varied as desired depending on the properties of base substrate **20** and the desired characteristics of structured substrate **1** of the present invention. For example, in general, to obtain broken fibers **8** in displaced fibers **6** requires a level of engagement **E** sufficient to elongate and plastically deform the displaced fibers to a point where the fibers break. Also, the greater the density of second regions **4** desired (second regions **4** per unit area of structured substrate **1**), the smaller the pitch should be, and the smaller the tooth length **TL** and tooth distance **TD** should be, as described below.

FIG. 8 shows a portion of one embodiment of a roll **104** having a plurality of teeth **110** useful for making a structured substrate **21** or structured substrate **1** of spunbond nonwoven material from a spunbond nonwoven base substrate **20**. An enlarged view of teeth **110** shown in FIG. 8 is shown in FIG. 9. In this view of roll **104**, teeth **110** have a uniform circumferential length dimension **TL** of about 1.25 mm measured generally from the leading edge **LE** to the trailing edge **TE** at the tooth tip **111**, and are uniformly spaced from one another circumferentially by a distance **TD** of about 1.5 mm. For making a fibrous structured substrate 1 from a base substrate 20, teeth **110** of roll **104** can have a length **TL** ranging from about 0.5 mm to about 3 mm and a spacing **TD** from about 0.5 mm to about 3 mm, a tooth height **TH** ranging from about 0.5 mm to about 10 mm, and a pitch **P** between about 1 mm (0.040 inches) and 2.54 mm (0.100 inches). Depth of engagement **E** can be from about 0.5 mm to about 5 mm (up to a maximum approaching the tooth height **TH**). Of course, **E**, **P**, **TH**, **TD** and

TL can each be varied independently of each other to achieve a desired size, spacing, and area density of displaced fibers **6** (number of displaced fibers **6** per unit area of structured substrate 1).

As shown in FIG. 9, each tooth **110** has a tip **111**, a leading edge **LE** and a trailing edge **TE**. The tooth tip **111** can be rounded to minimize fiber breakage and is preferably elongated and has a generally longitudinal orientation, corresponding to the longitudinal axes **L** of second regions **4**. It is believed that to get the displaced fibers **6** of the structured substrate 1, the **LE** and **TE** should be very nearly orthogonal to the local peripheral surface **120** of roll **104**. As well, the transition from the tip **111** and the **LE** or **TE** should be a relatively sharp angle, such as a right angle, having a sufficiently small radius of curvature such that, in use the teeth **110** push through base substrate **20** at the **LE** and **TE**. An alternative tooth tip **111** can be a flat surface to optimize bonding.

Referring back to FIG. 1, after displaced fibers **6** are formed, structured substrate 21 may travel on rotating roll **104** to nip **117** between roll **104** and a first bonding roll **156**. Bonding roll **156** can facilitate a number of bonding techniques. For example, bonding roll **156** can be a heated steel roller for imparting thermal energy in nip **117**, thereby melt-bonding adjacent fibers of structured web **21** at the distal ends (tips) of displaced fibers **6**.

In a preferred embodiment, as discussed in the context of a preferred structured substrate below, bonding roll **156** is a heated roll designed to impart sufficient thermal energy to structured web **21** so as to thermally bond adjacent fibers of the distal ends of displaced fibers **6**. Thermal bonding can be by melt-bonding adjacent fibers directly, or by melting an intermediate thermoplastic agent, such as polyethylene powder, which in turn, adheres adjacent fibers. Polyethylene powder can be added to base substrate **20** for such purposes.

First bonding roll **156** can be heated sufficiently to melt or partially melt fibers at the distal ends **3** of displaced fibers **6**. The amount of heat or heat capacity necessary in first bonding roll **156** depends on the melt properties of the fibers of displaced fibers **6** and the speed of rotation of roll **104**. The amount of heat necessary in first bonding roll **156** also depends on the pressure induced between first bonding roll **156** and tips of teeth **110** on roll **104**, as well as the degree of melting desired at distal ends **3** of displaced fibers **6**.

In one embodiment, first bonding roll **156** is a heated steel cylindrical roll, heated to have a surface temperature sufficient to melt-bond adjacent fibers of displaced fibers **6**. First bonding roll

156 can be heated by internal electrical resistance heaters, by hot oil, or by any other means known in the art for making heated rolls. First bonding roll **156** can be driven by suitable motors and linkages as known in the art. Likewise, first bonding roll can be mounted on an adjustable support such that nip **117** can be accurately adjusted and set.

FIG. 10 shows a portion of structured substrate **21** after being processed through nip **117** to be structured substrate **22**, which, without further processing can be a structured substrate **21** of the present invention. Structured substrate **22** is similar to structured substrate **21** as described earlier, except that the distal ends **3** of displaced fibers **6** are bonded, and are preferably thermally melt-bonded such that adjacent fibers are at least partially bonded to form distally-disposed melt-bonded portions **9**. After forming displaced fibers **6** by the process described above, the distal portions **3** of displaced fibers **6** can be heated to thermally join portions of fibers such that adjacent fiber portions are joined to one another to form displaced fibers **6** having melt-bonded portions **9**, also referred to as “tip bonding”.

The distally-disposed melt-bonded portions **9** can be made by application of thermal energy and pressure to the distal portions of displaced fibers **6**. The size and mass of the distally-disposed melt-bonded portions **9** can be modified by modifying the amount of heat energy imparted to the distal portions of displaced fibers **6**, the line speed of apparatus **150**, and the method of heat application.

In another embodiment, distally-disposed melt-bonded portions **9** can be made by application of radiant heat. That is, in one embodiment bonding roll **156** can be replaced or supplemented by a radiant heat source, such that radiant heat can be directed toward structured substrate **21** at a sufficient distance and corresponding sufficient time to cause fiber portions in the distally-disposed portions of displaced fibers **6** to soften or melt. Radiant heat can be applied by any of known radiant heaters. In one embodiment, radiant heat can be provided by a resistance-heated wire disposed in relation to structured substrate **21** such that it is extended in the CD direction at a sufficiently-close, uniformly-spaced distance that as the web is moved in relation to the wire, radiant heat energy at least partially melts the distally-disposed portions of displaced fibers **6**. In another embodiment, a heated flat iron, such as a hand-held iron for ironing clothes, can be held adjacent the distal ends **3** of displaced fibers **6**, such that melting is effected by the iron.

The benefit of processing the structured substrate **22** as described above is that the distal ends **3** of displaced fibers **6** can be melted under a certain amount of pressure in nip **117** without compressing or flattening displaced fibers **6**. As such, a three-dimensional web can be produced and set, or "locked in" to shape, so to speak by providing for thermal bonding after forming. Moreover, the distally-disposed bonded or melt-bonded portions **9** can aid in maintaining the lofty structure of displaced fibers **6** and aged caliper of the structured substrate when structured substrate **22** is subjected to compression or shearing forces. For example, a structured substrate **22** processed as disclosed above to have displaced fibers **6** comprising fibers integral with but extending from first region **2** and having distally-disposed melt-bonded portions **9** can have improved shape retention after compression due to winding onto a supply roll and subsequently unwinding. It is believed that by bonding together adjacent fibers at distal portions of displaced fibers **6**, the fibers experience less random collapse upon compression; that is, the entire structure of displaced fibers **6** tends to move together, thereby permitting better shape retention upon a disordering event such as compression and/or shear forces associated with rubbing the surface of the web. When used in a wiping or rubbing application, the bonded distal ends of displaced fibers **6** can also reduce fuzzing or pilling of structured substrate 1.

In an alternate embodiment described in reference to FIG. 1, substrate **20** is moved in the machine direction over roller **154** and to the nip **116** of the first set of counter-rotating intermeshing rolls **102A** and **104** where the depth of engagement is between 0.01 inch and 0.15 inch such that partial fiber displacement occurs but there is little, if any, fiber breakage. The web then proceeds to nip **117** formed between roll **104** and bonding roll **156** where tips of the partial displaced fibers are bonded. After passing through nip **117,** the structured substrate **22** proceeds to nip **118** formed between roll **104** and **102B** where the depth of engagement is greater than the depth of engagement at nip **116** such that the displaced fibers are further displaced forming broken fibers. This process can result in a larger number of the displaced fibers **6** being joined by the melt-bonded portions **9**.

Over bonding

Over bonding refers to melt bonding performed on a substrate that has been previously undergone fiber displacement. Over bonding is an optional process step. The over bonding can be done in-line, or can alternatively, be done on a separate converting process.

The over bonding relies upon heat and pressure to fuse the filaments together in a coherent pattern. A coherent pattern is defined as a pattern that is reproducible along the length of the structured substrate so that a repeat pattern can be observed. The over bonding is done through a pressurized roller nip in which at least one of the rolls is heated, preferably both rolls are heated. If the over bonding is done when the base substrate is already heated, then the pressurized roller nip would not need to be heated. Examples of patterns of over bond regions **11** are shown in FIG.s 12A through 12F; however, other over bond patterns are possible. FIG. 12F shows over bond regions **11** forming a continuous pattern in the machine direction. FIG. 12B shows continuous over bond regions **11** in both the machine and cross-directions so that a continuous network of over bonds **11** is formed. This type of system can be produced with a single-step over bonding roll or multiple roll bonding systems. FIG. 12C shows over bond regions **11** that are discontinuous in the machine direction. The MD over bond pattern shown in FIG. 12C could also include over bond regions **11** in the CD connecting the MD over bond lines in a continuous or non-continuous design. FIG. 12D shows over bond regions **11** forming a wave pattern in the MD. FIG. 12E shows over bond regions **11** forming a herringbone pattern while FIG. 12F shows a wavy herringbone pattern.

The over bond patterns do not need to be evenly distributed and can be contoured to suit a specific application. The total area affected by over bonding is less than 75% of the total area of the fibrous web, preferably less than 50%, more preferably less than 30% and most preferably less than 25%, but should be at least 3%.

FIG. 13 illustrates the characteristics of over bonding. The over bonded region **11** has a thickness property relative to the first region thickness **32** of the base substrate **20** measured in-between the over bonded regions. The over bonded region **11** has a compressed thickness **42**. The over bonded region has a characteristic width **44** on the structured substrate **21** and a spacing **46** between over bond regions.

The first region thickness **32** is preferably between 0.1 mm and 1.5 mm, more preferably between 0.15 mm and 1.3 mm, more preferably between 0.2 mm and 1.0 mm and most preferably between 0.25 mm and 0.7 mm. Over bonded region thickness **42** is preferably between 0.01 mm and 0.5 mm, more preferably between 0.02 mm and 0.25 mm, still more preferably between 0.03 mm and 0.1 mm and most preferably between 0.05 mm and 0.08 mm. The width **44** of the overbonded region **11** is between 0.05 mm and 15 mm, more preferably between 0.075 mm and 10 mm, still more preferably between 0.1 mm and 7.5 mm and most preferably between 0.2 mm and 5 mm. The spacing **46** between overbonded regions **11** is not required to be uniform in the structured substrate **21**, but the extremes will fall within the range of 0.2 mm and 16 mm, preferably between 0.4 mm and 10 mm, more preferably between 0.8 mm and 7 mm and most preferably between 1 mm and 5.2 mm. Spacing **46**, width **44** and thickness **42** of the over bonded regions **11** is based on the properties desired for the structured substrate **21** such as tensile strength and fluid handling properties.

FIG. 13 shows that the over bonds **11** having over bond thickness **42** can be created on one side of the structured substrate **21**. FIG. 14 shows that the over bonds **11** can be on either side of the structured substrate **21** depending on the method used to make the structured substrate **21**. Over bonds **11** on both sides **12, 14** of the structured substrate **21** may be desired to create tunnels when the structured substrate is combined with other nonwovens to further aid in the management of fluids. For instance, a double sided structured substrate may be used in a multi-layered high volume fluid acquisition system.

Over Bonding process

Referring to the apparatus in FIG. 1, structured substrate **23** can have bonded portions that are not, or not only, at distally-disposed portions of displaced fibers **6**. For example, by using a mating ridged roller instead of a flat, cylindrical roll for bonding roll **156** other portions of the structured substrate **23** such as at locations on the first surface **12** in the first regions **2** between the second regions **4** can be bonded. For instance, continuous lines of melt-bonded material could be made on first surface **12** between rows of displaced fibers **6**. The continuous lines of melt-bonded material form over bonded regions **11** as previously described.

In general, while one first bonding roll **156** is illustrated, there may be more than one bonding roll at this stage of the process, such that bonding takes place in a series of nips **117** and/or involving different types of bonding rolls **156**. Further, rather than being only a bonding roll, similar rolls can be provided to transfer various substances to base substrate **20** or structured web **21**, such as various surface treatments to impart functional benefits. Any processes known in the art for such application of treatments can be utilized.

After passing through nip **117,** structured substrate **22** proceeds to nip **118** formed between roll **104** and **102B**, with roll **102B** preferably being identical to roll **102A**. The purpose of going around roll **102B** is to remove structured substrate **22** from roll **104** without disturbing the displaced fibers **6** formed thereon. Because roll **102B** intermeshes with roll **104** just as roll **102A** did, displaced fibers **6** can fit into the grooves **108** of roll **102B** as structured substrate **22** is wrapped around roll **102B**. After passing through nip **118**, structured substrate **22** can be taken up on a supply roll for further processing as structured substrate **23** of the present invention. However, in the embodiment shown in FIG. 1, structured substrate **22** is processed through nip **119** between roll **102B** and second bonding roll **158**. Second bonding roll **158** can be identical in design to first bonding roll **156**. Second bonding roll **158** can provide sufficient heat to at least partially melt a portion of the second surface **14** of structured substrate **22** to form a plurality of non-intersecting, substantially continuous over bond regions **11** corresponding to the nip pressures between the tips of ridges **106** of roll **102B** and the generally flat, smooth surface of roll **158**.

Second bonding roll **158** can be used as the only bonding step in the process (i.e., without first having structured substrate **22** formed by bonding the distal ends of displaced fibers **6**). In such a case structured web **22** would be a structured web **23** with bonded portions on the second side **14** thereof. However, in general, structured web **23** is preferably a double over bonded structured web **22** having bonded distal ends of displaced fibers **6** (tip bonding) and a plurality of non-intersecting, substantially continuous melt-bonded regions on first side **12** or second side **14** thereon.

Finally, after structured substrate **23** is formed, it can be taken up on a supply roll **160** for storage and further processing as a component in other products.

In an alternate embodiment a second substrate **21A** can be added to the structured substrate **21** using the process shown in FIG. 1A. The second substrate **21A** can be a film, a nonwoven or a second base substrate as previously described. For this embodiment, base substrate **20** is moved in the machine direction over roller **154** and to the nip **116** of the first set of counter-rotating intermeshing rolls **102A** and **104** where the fibers are fully displaced forming broken fibers. The web then proceeds to nip **117** formed between roll **104** and bonding roll **156** where second substrate **21A** is introduced and bonded to the distal portions **3** of the displaced fibers **6**. After passing through nip **117,** the structured substrate **22** proceeds to nip **118** formed between rolls **104** and **102B** where the depth of engagement is zero such that rolls **104** and **102B** are not engaged, or the depth of engagement is less than the depth of engagement formed at nip **116** between rolls **102A** and **104** such that the no additional fiber displacement occurs in the structured substrate. Alternatively, for this embodiment, the depth of engagement at nip **118** can be set such that deformation occurs in the second substrate **21A** but no additional fiber displacement occurs in the structured substrate **22**. In other words, the depth of engagement at nip **118** is still less than the depth of engagement at nip **116.**

Materials

The composition used to form fibers for the base substrate of the present invention can include thermoplastic polymeric and non-thermoplastic polymeric materials. The thermoplastic polymeric material must have rheological characteristics suitable for melt spinning. The molecular weight of the polymer must be sufficient to enable entanglement between polymer molecules and yet low enough to be melt spinnable. For melt spinning, thermoplastic polymers have molecular weights below about 1,000,000 g/mol, preferably from about 5,000 g/mol to about 750,000 g/mol, more preferably from about 10,000 g/mol to about 500,000 g/mol and even more preferably from about 50,000 g/mol to about 400,000 g/mol. Unless specified elsewhere, the molecular weight indicated is the number average molecular weight.

The thermoplastic polymeric materials are able to solidify relatively rapidly, preferably under extensional flow, and form a thermally stable fiber structure, as typically encountered in known processes such as a spin draw process for staple fibers or a spunbond continuous fiber process. Preferred polymeric materials include, but are not limited to, polypropylene and polypropylene copolymers, polyethylene and polyethylene copolymers, polyester and polyester copolymers, polyamide, polyimide, polylactic acid, polyhydroxyalkanoate, polyvinyl alcohol, ethylene vinyl alcohol, polyacrylates, and copolymers thereof and mixtures thereof. Other suitable polymeric materials include thermoplastic starch compositions as described in detail in U.S. publications 2003/0109605A1 and 2003/0091803. Other suitable polymeric materials include ethylene acrylic acid, polyolefin carboxylic acid copolymers, and combinations thereof. The polymers described in US publications 6746766, US 6818295, US 6946506 and US application 03/0092343. Common thermoplastic polymer fiber grade materials are preferred, most notably polyester based resins, polypropylene based resins, polylactic acid based resin, polyhydroxyalkonoate based resin, and polyethylene based resin and combination thereof. Most preferred are polyester and polypropylene based resins.

Nonlimiting examples of thermoplastic polymers suitable for use in the present invention include aliphatic polyesteramides; aliphatic polyesters; aromatic polyesters including polyethylene terephthalates (PET) and copolymer (coPET), polybutylene terephthalates and copolymers; polytrimethylene terephthalates and copolymers; polypropylene terephthalates and copolymers; polypropylene and propylene copolymers; polyethylene and polyethylene copolymers; aliphatic/aromatic copolyesters; polycaprolactones; poly(hydroxyalkanoates) including poly(hydroxybutyrate-co-hydroxyvalerate), poly(hydroxybutyrate-co-hexanoate), or other higher poly(hydroxybutyrate-co-alkanoates) as referenced in U.S. patent 5,498,692 to Noda, herein incorporated by reference; polyesters and polyurethanes derived from aliphatic polyols (i.e., dialkanoyl polymers); polyamides; polyethylene/vinyl alcohol copolymers; lactic acid polymers including lactic acid homopolymers and lactic acid copolymers; lactide polymers including lactide homopolymers and lactide copolymers; glycolide polymers including glycolide homopolymers and glycolide copolymers; and mixtures thereof. Preferred are aliphatic polyesteramides, aliphatic polyesters, aliphatic/aromatic copolyesters, lactic acid polymers, and lactide polymers.

Suitable lactic acid and lactide polymers include those homopolymers and copolymers of lactic acid and/or lactide which have a weight average molecular weight generally ranging from about 10,000 g/mol to about 600,000 g/mol, preferably from about 30,000 g/mol to about 400,000 g/mol, more preferably from about 50,000 g/mol to about 200,000 g/mol. An example of commercially available polylactic acid polymers includes a variety of polylactic acids that are available from the Chronopol Incorporation located in Golden, Colorado, and the polylactides sold under the tradename EcoPLA®. Examples of suitable commercially available polylactic acid are NATUREWORKS from Cargill Dow and LACEA from Mitsui Chemical. Preferred is a homopolymer or copolymer of poly lactic acid having a melting temperature from about 160° to about 175°C. Modified poly lactic acid and different stereo configurations may also be used, such as poly L-lactic acid and poly D,L-lactic acid with D-isomer levels up to 75%. Optional racemic combinations of D and L isomers to produce high melting temperature PLA polymers are also preferred. These high melting temperature PL polymers are special PLA copolymers (with the understanding that the D-isomer and L-isomer are treated as different stereo monomers) with melting temperatures above 180°C. These high melting temperatures are achieved by special control of the crystallite dimensions to increase the average melting temperature.

Depending upon the specific polymer used, the process, and the final use of the fiber, more than one polymer may be desired. The polymers of the present invention are present in an amount to improve the mechanical properties of the fiber, the opacity of the fiber, optimize the fluid interaction with the fiber, improve the processability of the melt, and improve attenuation of the fiber. The selection and amount of the polymer will also determine if the fiber is thermally bondable and affect the softness and texture of the final product. The fibers of the present invention may comprise a single polymer, a blend of polymers, or be multicomponent fibers comprising more than one polymer. The fibers in the present invention are thermally bondable.

Multiconstituent blends may be desired. For example, blends of polyethylene and polypropylene (referred to hereafter as polymer alloys) can be mixed and spun using this technique. Another example would be blends of polyesters with different viscosities or monomer content. Multicomponent fibers can also be produced that contain differentiable chemical species in each component. Non-limiting examples would include a mixture of 25 melt flow rate (MFR) polypropylene with 50MFR polypropylene and 25MFR homopolymer polypropylene with 25MFR copolymer of polypropylene with ethylene as a comonomer.

The more preferred polymeric materials have melting temperatures above 110°C, more preferably above 130°C, even more preferably above 145°C, still more preferably above 160°C and most preferably above 200°C. A still further preference for the present invention is polymers with high glass transition temperatures. Glass transition temperatures above -10°C in the end-use fiber form are preferred, more preferably above 0°C, still more preferably above 20°C and most preferably above 50°C. This combination of properties produces fibers that are stable at elevated temperatures. Exemplary examples of materials of this type are polypropylene, polylactic acid based polymers, and polyester terephthalate (PET) based polymer systems.

Optional Materials

Optionally, other ingredients may be incorporated into the spinnable composition used to form fibers for the base substrate. The optional materials may be used to modify the processability and/or to modify physical properties such as opacity, elasticity, tensile strength, wet strength, and modulus of the final product. Other benefits include, but are not limited to, stability, including oxidative stability, brightness, color, flexibility, resiliency, workability, processing aids, viscosity modifiers, and odor control. Examples of optional materials include, but are not limited to, titanium dioxide, calcium carbonate, colored pigments, and combinations thereof. Further additives including, but not limited to, inorganic fillers such as the oxides of magnesium, aluminum, silicon, and titanium may be added as inexpensive fillers or processing aides. Other suitable inorganic materials include, but are not limited to, hydrous magnesium silicate, titanium dioxide, calcium carbonate, clay, chalk, boron nitride, limestone, diatomaceous earth, mica glass quartz, and ceramics. Additionally, inorganic salts, including, but not limited to, alkali metal salts, alkaline earth metal salts and phosphate salts may be used.

Optionally, other ingredients may be incorporated into the composition. These optional ingredients may be present in quantities of less than about 50%, preferably from about 0.1% to about 20%, and more preferably from about 0.1% to about 12% by weight of the composition. The optional materials may be used to modify the processability and/or to modify physical properties such as elasticity, tensile strength and modulus of the final product. Other benefits include, but are not limited to, stability including oxidative stability, brightness, flexibility, color, resiliency, workability, processing aids, viscosity modifiers, biodegradability, and odor control. Nonlimiting examples include salts, slip agents, crystallization accelerators or retarders, odor masking agents, cross-linking agents, emulsifiers, surfactants, cyclodextrins, lubricants, other processing aids, optical brighteners, antioxidants, flame retardants, dyes, pigments, fillers, proteins and their alkali salts, waxes, tackifying resins, extenders, and mixtures thereof. Slip agents may be used to help reduce the tackiness or coefficient of friction in the fiber. Also, slip agents may be used to improve fiber stability, particularly in high humidity or temperatures. A suitable slip agent is polyethylene. Thermoplastic starch (TPS) may also be added to the polymeric composition. Especially important are polymer additives used to reduce static electricity build-up in the production and use of polyester thermoplastic materials, particularly PET. Such preferred materials are acetaldehyde acid scavengers, ethoxylated sorbitol esters, glycerol esters, alkyl sulphonate, combinations and mixtures thereof and derivative compounded.

Further additives including inorganic fillers such as the oxides of magnesium, aluminum, silicon, and titanium may be added as inexpensive fillers or processing aides. Other inorganic materials include hydrous magnesium silicate, titanium dioxide, calcium carbonate, clay, chalk, boron nitride, limestone, diatomaceous earth, mica glass quartz, and ceramics. Additionally, inorganic salts, including alkali metal salts, alkaline earth metal salts, phosphate salts, may be used as processing aides. Other optional materials that modify the water responsiveness of the thermoplastic starch blend fiber are stearate based salts, such as sodium, magnesium, calcium, and other stearates, as well as rosin component, such as gum rosin.

Hydrophilic agents can be added to the polymeric composition. The hydrophilic agents can be added in standard methods known to those skilled in the art. The hydrophilic agents can be low molecular weight polymeric materials or compounds. The hydrophilic agent can also be a polymeric material with higher molecular weight. The hydrophilic agent can be present in an amount from 0.01 wt% to 90 wt%, with preferred range of 0.1 wt% to 50 wt% and a still more preferred range of 0.5 wt% to 10 wt%. The hydrophilic agent can be added when the initial resin is produced at the resin manufacturer, or added as masterbatch in the extruder when the fibers are made. Preferred agents are polyester polyether, polyester polyether copolymers and nonionic polyester compounds for polyester bases polymers. Ethoxylated low and high molecular weight polyolefinic compounds can also be added. Compatibilizing agents can be added to these materials to aid in better processing for these materials, and to make for a more uniform and homogenous polymeric compound. One skilled in the art would understand that using compatibilizing agents can be added in a compounding step to produce polymer alloys with melt additives not inherently effective with the base polymer. For example, a base polypropylene resin can be combined with a hydrophilic polyester polyether copolymer through the use of maleated polypropylene as a compatibilizer agent.

Fibers

The fibers forming the base substrate in the present invention may be monocomponent or multicomponent. The term “fiber” is defined as a solidified polymer shape with a length to thickness ratio of greater than 1,000. The monocomponent fibers of the present invention may also be multiconstituent. Constituent, as used herein, is defined as meaning the chemical species of matter or the material. Multiconstituent fiber, as used herein, is defined to mean a fiber containing more than one chemical species or material. Multiconstituent and alloyed polymers have the same meaning in the present invention and can be used interchangeably. Generally, fibers may be of monocomponent or multicomponent types. Component, as used herein, is defined as a separate part of the fiber that has a spatial relationship to another part of the fiber. The term multicomponent, as used herein, is defined as a fiber having more than one separate part in spatial relationship to one another. The term multicomponent includes bicomponent, which is defined as a fiber having two separate parts in a spatial relationship to one another. The different components of multicomponent fibers are arranged in substantially distinct regions across the cross-section of the fiber and extend continuously along the length of the fiber. Methods for making multicomponent fibers are well known in the art. Multicomponent fiber extrusion was well known in the 1960's. DuPont was a lead technology developer of multicomponent capability, with US 3,244,785 and US 3,704,971 providing a technology description of the technology used to make these fibers. "Bicomponent Fibers" by R. Jeffries from Merrow Publishing in 1971 laid a solid groundwork for bicomponent technology. More recent publications include "Taylor-Made Polypropylene and Bicomponent Fibers for the Nonwoven Industry," Tappi Journal December 1991 (p103) and "Advanced Fiber Spinning Technology" edited by Nakajima from Woodhead Publishing.

The nonwoven fabric formed in the present invention may contain multiple types of monocomponent fibers that are delivered from different extrusion systems through the same spinneret. The extrusion system, in this example, is a multicomponent extrusion system that delivers different polymers to separate capillaries. For instance, one extrusion system would deliver polyester terephthalate and the other a polyester terephthalate copolymer such that the copolymer composition melts at a different temperatures. In a second example, one extrusion system might deliver a polyester terephthalate resin and the other polypropylene. In a third example, one extrusion system might deliver a polyester terephthalate resin and the other an additional polyester terephthalate resin that has a molecular weight different from the first polyester terephthalate resin. The polymer ratios in this system can range from 95:5 to 5:95, preferably from 90:10 to 10:90 and 80:20 to 20:80.

Bicomponent and multicomponent fibers may be in a side-by-side, sheath-core, segmented pie, ribbon, islands-in-the-sea configuration, or any combination thereof. The sheath may be continuous or non-continuous around the core. Non-inclusive examples of exemplarily multicomponent fibers are disclosed in US Patent 6,746,766. The ratio of the weight of the sheath to the core is from about 5:95 to about 95:5. The fibers of the present invention may have different geometries that include, but are not limited to; round, elliptical, star shaped, trilobal, multilobal with 3-8lobes, rectangular, H-shaped, C-shaped, I-shape, U-shaped and other various eccentricities. Hollow fibers can also be used. Preferred shapes are round, trilobal and H-shaped. The round and trilobal fiber shapes can also be hollow.

A "highly attenuated fiber" is defined as a fiber having a high draw down ratio. The total fiber draw down ratio is defined as the ratio of the fiber at its maximum diameter (which is typically results immediately after exiting the capillary) to the final fiber diameter in its end use. The total fiber draw down ratio will be greater than 1.5, preferable greater than 5, more preferably greater than 10, and most preferably greater than 12. This is necessary to achieve the tactile properties and useful mechanical properties.

The fiber "diameter" of the shaped fiber of the present invention is defined as the diameter of a circle which circumscribes the outer perimeter of the fiber. For a hollow fiber, the diameter is not of the hollow region but of the outer edge of the solid region. For a non-round fiber, fibers diameters are measured using a circle circumscribed around the outermost points of the lobes or edges of the non-round fiber. This circumscribed circle diameter may be referred to as that fiber's effective diameter. Preferably, the highly attenuated multicomponent fiber will have an effective fiber diameter of less than 500 micrometers. More preferably the effective fiber diameter will be 250 micrometer or less, even more preferably 100 micrometers or less, and most preferably less than 50 micrometers. Fibers commonly used to make nonwovens will have an effective fiber diameter of from about 5 micrometers to about 30 micrometers. Fibers in the present invention tend to be larger than those found in typical spunbond nonwovens. As such fibers with effective diameters less than 10 micrometers are not of use. Fibers useful in the present invention have an effective diameter greater than about 10 microns, more preferably greater than 15 micrometers, and most preferably greater than 20 micrometers. Fiber diameter is controlled by spinning speed, mass through-put, and blend composition. When the fibers in the present invention are made into a discrete layer, that layer can be combined with additional layers that may contain small fibers, even nano-dimension fibers.

The term spunlaid diameter refers to fibers having an effective diameter greater than about 12.5 micrometers up to 50 micrometers. This diameter range is produced by most standard spunlaid equipment. Micrometers and micron (μm) mean the same thing and can be used interchangeably. Meltblown diameters are smaller than spunlaid diameters. Typically, meltblown diameters are from about 0.5 to about 12.5 micrometers. Preferable meltblown diameters range from about 1 to about 10 micrometers.

Because the diameter of shaped fibers can be hard to determine, the denier of the fiber is often referenced. Denier is defined as the mass of a fiber in grams at 9000 linear meters of length, expressed as dpf (denier per filament). Thus, the inherent density of the fiber is also factored in when converting from diameter to denier and visa versa. For the present invention, the preferred denier range is greater than 1 dpf and less than 100 dpf. A more preferred denier range is 1.5 dpf to 50 dpf and a still more preferred range from 2.0 dpf to 20 dpf, and a most preferred range of 4 dpf to 10 dpf. An example of the denier to diameter relationship for polypropylene is a 1 dpf fiber of polypropylene that is solid round with a density of about 0.900 g/cm^3 has a diameter of about 12.55 micrometers.

For the present invention, it is desirable for the fibers to have limited extensibility and exhibit a stiffness to withstand compressive forces. The fibers of the present invention will have individual fiber breaking loads of greater than 5 grams per filament. Tensile properties of fibers are measured following a procedure generally described by ASTM standard D 3822-91 or an equivalent test, but the actual test that was used is fully described below. The tensile modulus (initial modulus as specified in ASTM standard D 3822-91 unless otherwise specified) should be greater than 0.5 GPa (giga pascals), more preferably greater than 1.5 GPa, still more preferably more than 2.0 GPa and most preferably greater than 3.0 GPa. The higher tensile modulus will produce stiffer fibers that provide a sustainable specific volume. Examples will be provided below.

The hydrophilicity and hydrophobicity of the fibers can be adjusted in the present invention. The base resin properties can have hydrophilic properties via copolymerization (such as the case for certain polyesters (EASTONE from Eastman Chemical, the sulfopolyester family of polymers in general) or polyolefins such as polypropylene or polyethylene) or have materials added to the base resin to render it hydrophilic. Exemplarily examples of additives include CIBA Irgasurf® family of additives. The fibers in the present invention can also be treated or coated after they are made to render them hydrophilic. In the present invention, durable hydrophilicity is preferred. Durable hydrophilicity is defined as maintaining hydrophilic characteristics after more than one fluid interaction. For example, if the sample being evaluated is tested for durable hydrophilicity, water can be poured on the sample and wetting observed. If the sample wets out it is initially hydrophilic. The sample is then completely rinsed with water and dried. The rinsing is best done by putting the sample in a large container and agitating for ten seconds and then drying. The sample after drying should also wet out when contacted again with water.

The fibers of the present invention are thermally stable. Fiber thermal stability is defined as having less than 30% shrinkage in boiling water, more preferably less than 20% shrinkage and most preferably less than 10% shrinkage. Some fibers in the present invention will have shrinkage less than 5%. The shrinkage is determined by measuring the fiber length before and after being placed in boiling water for one minute. Highly attenuated fibers would enable production of thermally stable fibers.

The fiber shapes used in the base substrate in the present invention may consist of solid round, hollow round and various multi-lobal shaped fibers, among other shapes. A mixture of shaped fibers having cross-sectional shapes that are distinct from one another is defined to be at least two fibers having cross-sectional shapes that are different enough to be distinguished when examining a cross-sectional view with a scanning electron microscope. For example, two fibers could be trilobal shape but one trilobal having long legs and the other trilobal having short legs. Although not preferred, the shaped fibers could be distinct if one fiber is hollow and another solid even if the overall cross-sectional shape is the same.

The multi-lobal shaped fibers may be solid or hollow. The multi-lobal fibers are defined as having more than one inflection point along the outer surface of the fiber. An inflection point is defined as being a change in the absolute value of the slope of a line drawn perpendicular to the surface of fiber when the fiber is cut perpendicular to the fiber axis. Shaped fibers also include crescent shaped, oval shaped, square shaped, diamond shaped, or other suitable shapes.

Solid round fibers have been known to the synthetic fiber industry for many years. These fibers have a substantially optically continuous distribution of matter across the width of the fiber cross section. These fibers may contain micro voids or internal fibrillation but are recognized as being substantially continuous. There are no inflection points for the exterior surface of solid round fibers.

The hollow fibers of the present invention, either round or multi-lobal shaped, will have a hollow region. A solid region of the hollow fiber surrounds the hollow region. The perimeter of the hollow region is also the inside perimeter of the solid region. The hollow region may be the same shape as the hollow fiber or the shape of the hollow region can be non-circular or non-concentric. There may be more than one hollow region in a fiber.

The hollow region is defined as the part of the fiber that does not contain any material. It may also be described as the void area or empty space. The hollow region will comprise from about 2% to about 60% of the fiber. Preferably, the hollow region will comprise from about 5% to about 40% of the fiber. More preferably, the hollow region comprises from about 5% to about 30% of the fiber and most preferably from about 10% to about 30% of the fiber. The percentages are given for a cross sectional region of the hollow fiber (i.e. two dimensional).

The percent of hollow region must be controlled for the present invention. The percent hollow region is preferably greater than 2% or the benefit of the hollow region is not significant. However, the hollow region is preferably less than 60% or the fiber may collapse. The desired percent hollow depends upon the materials used, the end use of the fiber, and other fiber characteristics and uses.

The average fiber diameter of two or more shaped fibers having cross-sectional shapes that are distinct from on another is calculated by measuring each fiber type's average denier, converting the denier of each shaped fiber into the equivalent solid round fiber diameter, adding the average diameters together of each shaped fiber weighted by their percent total fiber content, and dividing by the total number of fiber types (different shaped fibers). The average fiber denier is also calculated by converting the average fiber diameter (or equivalent solid round fiber diameter) through the relationship of the fiber density. A fiber is considered having a different diameter if the average diameter is at least about 10% higher or lower. The two or more shaped fibers having cross-sectional shapes that are distinct from one another may have the same diameter or different diameters. Additionally, the shaped fibers may have the same denier or different denier. In some embodiments, the shaped fibers will have different diameters and the same denier.

Multi-lobal fibers include, but are not limited to, the most commonly encountered versions such as trilobal and delta shaped. Other suitable shapes of multi-lobal fibers include triangular, square, star, or elliptical. These fibers are most accurately described as having at least one slope inflection point. A slope inflection point is defined as the point along the perimeter of the surface of a fiber where the slope of the fiber changes. For example, a delta shaped trilobal fiber would have three slope inflection points and a pronounced trilobal fiber would have six slope inflection points. Multilobal fibers in the present invention will generally have less than about 50 slope inflection points, and most preferably less than about 20 slope inflection points. The multi-lobal fibers can generally be described as non-circular, and may be either solid or hollow.

The mono and multiconstituent fibers of the present invention may be in many different configurations. Constituent, as used herein, is defined as meaning the chemical species of matter or the material. Fibers may be of monocomponent in configuration. Component, as used herein, is defined as a separate part of the fiber that has a spatial relationship to another part of the fiber.

After the fiber is formed, the fiber may further be treated or the bonded fabric can be treated. A hydrophilic or hydrophobic finish can be added to adjust the surface energy and chemical nature of the fabric. For example, fibers that are hydrophobic may be treated with wetting agents to facilitate absorption of aqueous liquids. A bonded fabric can also be treated with a topical solution containing surfactants, pigments, slip agents, salt, or other materials to further adjust the surface properties of the fiber.

The fibers in the present invention can be crimped, although it is preferred that they are not crimped. Crimped fibers are generally produced in two methods. The first method is mechanical deformation of the fiber after it is already spun. Fibers are melt spun, drawn down to the final filament diameter and mechanically treated, generally through gears or a stuffer box that imparts either a two dimensional or three dimensional crimp. This method is used in producing most carded staple fibers; however, carded staple fiber fabrics are not preferred because the fibers are not continuous and the fabrics produced from crimped fibers are generally very lofty before the fiber deformation technology is used. The second method for crimping fibers is to extrude multicomponent fibers that are capable of crimping in a spunlaid process. One of ordinary skill in the art would recognize that a number of methods of making bicomponent crimped spunbond fibers exists; however, for the present invention, three main techniques are considered for making crimped spunlaid nonwovens. The first is crimping that occurs in the spinline due to differential polymer crystallization in the spinline, a result of differences in polymer type, polymer molecular weight characteristics (e.g. molecular weight distribution) or additives content. A second method is differential shrinkage of the fibers after they have been spun into a spunlaid substrate. For instance, heating the spunlaid web can cause fibers to shrink due to differences in crystallinity in the as-spun fibers, for example during the thermal bonding process. A third method of causing crimping is to mechanically stretch the fibers or spunlaid web (generally for mechanical stretching the web has been bonded together). The mechanical stretching can expose differences in the stress-strain curve between the two polymer components, which can cause crimping.

The last two methods are commonly called latent crimping processes because they have to be activated after the fibers are spun. In the present invention, there is an order of preference for use of crimped fibers. Carded staple fiber fabrics can be used, so long as they have a base substrate thickness of less than 1.3mm. Spunlaid or spunbond fabrics are preferred because they contain continuous filaments, which can be crimped, as long as the base substrate thickness or caliper is less than 1.3mm. For the present invention, the base substrate contains less than 100wt% crimped fibers, preferably less than 50wt% crimped fibers, more preferably less than 20wt% crimped fibers, more preferably less than 10wt% and most preferably 0wt% crimped fibers. Uncrimped fibers are preferred because the crimping process can reduce the amount of fluids transferred on the surface of the fibers and also the crimping can reduce the inherent capillarity of the base substrate by decreasing the specific density of the base substrate.

Short length fibers are defined as fibers having a length of less than 50mm. In the present invention, continuous fibers are preferred over short cut fibers as they provide two additional benefits. The first benefit is that fluids can be transferred greater distances without fiber ends, thus providing enhanced capillarity. The second benefit is that continuous fibers produce base substrates with higher tensile strengths and stiffness, because the bonded network has continuous matrix of fibers that collectively are more inter-connected than one composed of short length fibers. It is preferred that the base substrate of the present invention contain very few short length fibers, preferably less than 50wt% short length fibers, more preferably less than 20wt% short length fibers, more preferably less than 10wt% and most preferably 0wt% short length fibers.

The fibers produced for the base substrate in the present invention are preferably thermally bondable. Thermally bondable in the present invention is defined as fibers that soften when they are raised near or above their peak melting temperature and that stick or fuse together under the influence of at least low applied pressures. For thermal bonding, the total fiber thermoplastic content should be more than 30 wt%, preferably more than 50 wt%, still more preferably more than 70 wt% and most preferably more than 90 wt%.

Spunlaid Process

The fibers forming the base substrate in the present invention are preferably continuous filaments forming spunlaid fabrics. Spunlaid fabrics are defined as unbonded fabrics having basically no cohesive tensile properties formed from essentially continuous filaments. Continuous filaments are defined as fibers with high length to diameter ratios, with a ratio of more than 10,000:1. Continuous filaments in the present invention that compose the spunlaid fabric are not staple fibers, short cut fibers or other intentionally made short length fibers. The continuous filaments in the present invention are on average, more than 100 mm long, preferably more than 200 mm long. The continuous filaments in the present invention are also not crimped, intentionally or unintentionally.

The spunlaid processes in the present invention are made using a high speed spinning process as disclosed in US Patents Nos 3,802,817; 5,545,371; 6,548,431 and 5,885,909. In these melt spinning processes, extruders supply molten polymer to melt pumps, which deliver specific volumes of molten polymer that transfer through a spinpack, composed of a multiplicity of capillaries formed into fibers, where the fibers are cooled through an air quenching zone and are pneumatically drawn down to reduce their size into highly attenuated fibers to increase fiber strength through molecular level fiber orientation. The drawn fibers are then deposited onto a porous belt, often referred to as a forming belt or forming table.

The spunlaid process in the present invention used to make the continuous filaments will contain 100 to 10,000 capillaries per meter, preferably 200 to 7,000 capillaries per meter, more preferably 500 to 5,000 capillaries per meter, and still more preferably 1,000 to 3,000 capillaries per meter. The polymer mass flow rate per capillary in the present invention will be greater than 0.3GHM (grams per hole per minute). The preferred range is from 0.4GHM to 15GHM, preferably between 0.6GHM and 10GHM, still more preferred between 0.8GHM and 5GHM and the most preferred range from 1GHM to 4GHM.

The spunlaid process in the present invention contains a single process step for making the highly attenuated, uncrimped continuous filaments. Extruded filaments are drawn through a zone of quench air where they are cooled and solidified as they are attenuated. Such spunlaid processes are disclosed in US 3338992, US 3802817, US 4233014 US 5688468, US 6548431B1, US 6908292B2 and US Application 2007/0057414A1. The technology described in EP 1340843B1 and EP 1323852B1 can also be used to produce the spunlaid nonwovens. The highly attenuated continuous filaments are directly drawn down from the exit of the polymer from the spinneret to the attenuation device, wherein the continuous filament diameter or denier does not change substantially as the spunlaid fabric is formed on the forming table. A preferred spunlaid process in the current invention includes a drawing device that pneumatically draws the fibers between the spinneret exits to the pneumatic drawing device enabling fibers to lay down onto the forming belt. The process differs from other spunlaid processes that mechanically draw the fibers from the spinneret.

The spunlaid process for the present invention produces, in a single step; thermally stable, continuous, uncrimped fibers that have a defined inherent tensile strength, fiber diameter or denier as disclosed earlier. Preferred polymeric materials include, but are not limited to, polypropylene and polypropylene copolymers, polyethylene and polyethylene copolymers, polyester and polyester copolymers, polyamide, polyimide, polylactic acid, polyhydroxyalkanoate, polyvinyl alcohol, ethylene vinyl alcohol, polyacrylates, and copolymers thereof and mixtures thereof. Other suitable polymeric materials include thermoplastic starch compositions as described in detail in U.S. publications 2003/0109605A1 and 2003/0091803. Still other suitable polymeric materials include ethylene acrylic acid, polyolefin carboxylic acid copolymers, and combinations thereof. The polymers described in US Patents 6746766, US 6818295, US 6946506 and US Published Application 03/0092343. Common thermoplastic polymer fiber grade materials are preferred, most notably polyester based resins, polypropylene based resins, polylactic acid based resin, polyhydroxyalkonoate based resin, and polyethylene based resin and combination thereof. Most preferred are polyester and polypropylene based resins. Exemplary polyester terephthalate (here after referred to as polyester unless stated otherwise) resins are Eastman F61HC (IV=0.61dl/g), Eastman 9663 (IV=0.80dl/g), DuPont Crystar 4415 (IV=0.61gl/g). A suitable copolyester is Eastman 9921 (IV-0.81). The polyester intrinsic viscosity (IV) range suitable for the present invention ranges from 0.3 dl/g to 0.9 dl/g, preferably from 0.45 dl/g to 0.85 dl/g and more preferably from 0.55 dl/g to 0.82 dl/g. Intrinsic viscosity is a measure of polymer molecular weight and is well known to those skilled in polymer art. Polyester fibers in the present invention may be alloys, monocomponent and shaped. A preferred embodiment is polyester fibers that are multilobal, preferably trilobal, that are produced from a 0.61 dl/g resin with a denier between 3 dpf and 8 dpf. Although PET is most commonly referenced in this invention, other polyester terephthalate polymers can be used, such as PBT, PTT, PCT.

It has been unexpectedly discovered that a specific combination of resin properties can be used in a spunbond process to produce a thermally bonded PET nonwoven at high denier. Eastman F61HC PET polymer and Eastman 9921 coPET have been found to provide an ideal combination for producing thermally bondable, yet thermally stable fibers. The unexpected discovery is that F61HC and 9921 can be extruded through separate capillaries in a ratio ranging from 70:30 to 90:10 (F61HC:9921 ratio) and the resultant web can be thermally bonded together to produce a nonwoven that is thermally stable. Thermally stable in this example is defined as having less than 10% shrinkage in the MD in boiling water after 5 minutes. The thermal stability is achieved through a spinning speed greater than 4000 meter/minute and producing filament deniers ranging from 1dpf to 10 dpf in both round and shaped fibers. Basis weights ranging from 5 g/m^2 to 100 g/m^2 have been produced. These fabrics have been produced with thermal point bonding. These types of fabrics can be used in a wide range of applications, such as disposable absorbent articles, dryer sheets, and roof felting. If desired, a multibeam system can be used alone or can have a fine fiber diameter layer placed in between two spunlaid layers and then bonded together.

An additional preferred embodiment is the use of polypropylene fibers and spunlaid nonwovens. The preferred resin properties for polypropylene are melt flow rates between 5 MFR (melt flow rate in grams per 10 minutes) and 400 MFR, with a preferred range between 10 MFR and 100 MFR and a still more preferred range between 15 MFR and 65 MFR with the most preferred range between 23 MFR and 40 MFR. The method used to measure MFR is outlined in ASTM D1238 measured at 230°C with a mass of 2.16 kg.

The nonwoven products produced from the monocomponent and multicomponent fibers will also exhibit certain properties, particularly, strength, flexibility, softness, and absorbency. Measures of strength include dry and/or wet tensile strength. Flexibility is related to stiffness and can attribute to softness. Softness is generally described as a physiologically perceived attribute which is related to both flexibility and texture. Absorbency relates to the products' ability to take up fluids as well as the capacity to retain them. Absorbency in the present invention does not involve the internal regions of the fiber itself up taking water, such as is found with pulp fibers, regenerated cellulose fibers (e.g. rayon). Because some thermoplastic polymers inherently take-up small amount of water (e.g. polyamides), the water uptake is limited to less than 10 wt%, preferably less than 5 wt% and most preferably less than 1 wt%. The absorbency in the present invention arises from the hydrophilicity of the fibers and nonwoven structure and depends primarily on the fiber surface area, pore size, and bonding intersections. Capillarity is the general phenomenon used to describe the fluid interaction with the fibrous substrate. The nature of capillarity is well understood to those skilled in the art and is presented in detail in “Nonwovens: Theory, Process, Performance and Testing” by Albin Turbak, Chapter 4.

The spunlaid web forming the base substrate in the present invention will have an absorbency uptake or holding capacity ($C_{holding}$) between 1g/g (gram per gram) to 10g/g, more preferably between 2g/g and 8g/g and most preferably between 3g/g and 7g/g. This uptake measurement is done by weighing a dry sample (in grams) that is 15 cm long in MD and 5cm wide in CD, dry weight is m_{dry} then submerging the sample in distilled water for 30 seconds and then removing the sample from water, suspending it vertically (in MD) for 10 seconds and then weighing the sample again, wet weight is m_{wet}. The final wet sample weight (m_{wet}) minus the dry sample weight (m_{dry}) divided by the dry samples weight (m_{dry}) gives the absorbency or holding capacity for the sample ($C_{holding}$). i.e.:

$$C_{holding} := \frac{m_{wet} - m_{dry}}{m_{dry}}$$

The structured substrates have similar holding capacity.

The spunlaid process in the current invention will produce a spunlaid nonwoven with a desired basis weight. Basis weight is defined as a fiber/nonwoven mass per unit area. For the present invention, the basis weight of the base substrate is between 10 g/m^2 and 200 g/m^2, with a preferred range between 15 g/m^2 and 100 g/m^2, with a more preferred range between 18 g/m^2 and 80 g/m^2 and even a more preferred range between 25 g/m^2 and 72 g/m^2. The most preferred range is between 30 g/m^2 and 62 g/m^2.

The first step in producing a multiconstituent fiber is the compounding or mixing step. In the compounding step, the raw materials are heated, typically under shear. The shearing in the presence of heat will result in a homogeneous melt with proper selection of the composition. The melt is then placed in an extruder where fibers are formed. A collection of fibers is combined together using heat, pressure, chemical binder, mechanical entanglement, and combinations thereof resulting in the formation of a nonwoven web. The nonwoven is then modified and assembled into a base substrate.

The objective of the compounding step is to produce a homogeneous melt composition. For multiconstituent blends, the purpose of this step is to melt blend the thermoplastic polymers materials together where the mixing temperature is above the highest melting temperature thermoplastic component. The optional ingredients can also be added and mixed together. Preferably, the melt composition is homogeneous, meaning that a uniform distribution is found over a large scale and that no distinct regions are observed. Compatibilizing agents can be added to combine materials with poor miscibility, such as when polylactic acid is added to polypropylene or thermoplastic starch is added to polypropylene.

Twin-screw compounding is well known in the art and is used to prepare polymer alloys or to properly mix together polymers with optional materials. Twin-screw extruders are generally a stand alone process used between the polymer manufacture and the fiber spinning step. In order to reduce cost, the fiber extrusion can begin with twin-screw extruder such that the compounding is directly coupled with fiber making. In certain types of single screw extruders, good mixing and compatibilization can occur in-line.

The most preferred mixing device is a multiple mixing zone twin screw extruder with multiple injection points. A twin screw batch mixer or a single screw extrusion system can also be used. As long as sufficient mixing and heating occurs, the particular equipment used is not critical.

The present invention utilizes the process of melt spinning. In melt spinning, there is no mass loss in the extrudate. Melt spinning is differentiated from other spinning, such as wet or dry spinning from solution, where a solvent is being eliminated by volatilizing or diffusing out of the extrudate resulting in a mass loss.

Spinning will occur at 120°C to about 350°C, preferably 160° to about 320°, most preferably from 190°C to about 300°. Fiber spinning speeds of greater than 100 meters/minute are required. Preferably, the fiber spinning speed is from about 1,000 to about 10,000 meters/minute, more preferably from about 2,000 to about 7,000, and most preferably from about 2,500 to about 5,000 meters/minute. The polymer composition must be spun fast to make strong and thermally stable fibers, as determined by single fiber testing and thermal stability of the base substrate or structured substrate.

The homogeneous melt composition can be melt spun into monocomponent or multicomponent fibers on commercially available melt spinning equipment. The equipment will be chosen based on the desired configuration of the multicomponent fiber. Commercially available melt spinning equipment is available from Hills, Inc. located in Melbourne, Florida. An outstanding resource for fiber spinning (monocomponent and multicomponent) is "Advanced Fiber Spinning Technology" by

Nakajima from Woodhead Publishing. The temperature for spinning range from about 120° C to about 350° C. The processing temperature is determined by the chemical nature, molecular weights and concentration of each component. Examples of air attenuation technology are sold commercially by Hill's Inc, Neumag and REICOFIL. An example of technology suitable for the present invention is the Reifenhäuser REICOFIL 4 spunlaid process. These technologies are well known in the nonwoven industry.

Fluid Handling

The structured substrate of the present invention can be used to manage fluids. Fluid management is defined as the intentional movement of fluid through control of the structured substrate properties. In the present invention, fluid management is achieved through two steps. The first step is engineering the base substrate properties through fiber shape, fiber denier, basis weight, bonding method, and surface energy. The second step involves engineering the void volume generated through fiber displacement.

The following base substrates were produced at Hills Inc on a 0.5 m wide spunbond line. The specifics are mentioned in each example. Measured properties of the materials produced in Examples 1, 2, 4, and 7 are produced in the tables provided below.

Example 1: Spunbond fabrics were produced composed of 90 wt% Eastman F61HC PET resin and 10wt% Eastman 9921 coPET. The spunbond fabrics were produced using a pronounced trilobal spinneret that had 1.125 mm length and 0.15 mm width with a round end point. The hydraulic length-to-diameter ratio was 2.2:1. The spinpack had 250 capillaries of which 25 extruded the coPET resin and 225 extruded the PET resin. The beam temperature used was 285°C. The spinning distance was 33 inches and the forming distance was 34 inches. Different distances could be used in this and subsequent examples, but distance indicated provided the best results. The remainder of the relevant process data is included in Table 1-3.

Comparative Example 1: Spunbond fabrics were produced composed of 90 wt% Eastman F61HC PET resin and 10 wt% Eastman 20110. The spunbond fabrics were produced using a pronounced trilobal spinneret that had 1.125 mm length and 0.15 mm width with a round end point. The hydraulic length-to-diameter ratio was 2.2:1. The spinpack had 250 capillaries of which 25 extruded the coPET resin and 225 extruded the PET resin. The beam temperature used was 285°C. The spinning distance was 33 inches and the forming distance was 34 inches. It was difficult to produce thermally stable spunbond nonwovens with this polymer combination. The coPET fibers were not thermally stable and caused the entire fiber structure to shrink when heated above 100°C. The MD fabric shrinkage was 20%.

Example 2: Spunbond fabrics were produced composed of 100 wt% Eastman F61HC PET. The spunbond fabrics were produced using a pronounced trilobal spinneret that had 1.125 mm length and 0.15 mm width with a round end point. The hydraulic length-to-diameter ratio was 2.2:1. The spinpack had 250 capillaries. The beam temperature used was 285°C. The spinning distance was 33 inches and the forming distance was 34 inches. The remainder of the relevant process data is included in Table 1-3.

Example 3: Spunbond fabrics were produced composed of 90 wt% Eastman F61HC PET resin and 10 wt% Eastman 9921 coPET. The spunbond fabrics were produced using a standard trilobal spinneret that had 0.55 mm length and 0.127 mm width with a round end point with radius 0.18 mm. The hydraulic length-to-diameter ratio was 2.2:1. The spinpack had 250 capillaries of which 25 extruded the coPET resin and 225 extruded the PET resin. The beam temperature used was 285°C. The spinning distance was 33 inches and the forming distance was 34 inches. The remainder of the relevant process data is included in Table 4-6.

Comparative Example 2: Spunbond fabrics were produced composed of 90 wt% Eastman F61HC PET resin and 10 wt% Eastman 20110. The spunbond fabrics were produced using a standard trilobal spinneret that had 0.55 mm length and 0.127 mm width with a round end point with radius 0.18 mm. The hydraulic length-to-diameter ratio 2.2:1. The spinpack had 250 capillaries of which 25 extruded the coPET resin and 225 extruded the PET resin. The beam temperature used was 285°C. The spinning distance was 33 inches and the forming distance was 34 inches. It was difficult to produce thermally stable spunbond nonwovens with this polymer combination. The coPET fibers were not thermally stable and caused the entire fiber structure to shrink when heated above 100°C. The MD fabric shrinkage was 20%.

Example 4: Spunbond fabrics were produced composed of 90 wt% Eastman F61HC PET resin and 10 wt% Eastman 9921 coPET. The spunbond fabrics were produced using a solid round spinneret with capillary exit diameter of 0.35 mm and length-to-diameter ratio 4:1. The spinpack had 250 capillaries of which 25 extruded the coPET resin and 225 extruded the PET resin. The beam temperature used was 285°C. The spinning distance was 33 inches and the forming distance was 34 inches. The remainder of the relevant process data is included in Table 7-9.

Comparative Example 3: Spunbond fabrics were produced composed of 90 wt% Eastman F61HC PET resin and 10 wt% Eastman 20110. The spunbond fabrics were produced using a solid round spinneret with capillary exit diameter of 0.35 mm and length-to-diameter ratio 4:1. The spinpack had 250 capillaries of which 25 extruded the coPET resin and 225 extruded the PET resin. The beam temperature used was 285°C. The spinning distance was 33 inches and the forming distance was 34 inches. It was difficult to produce thermally stable spunbond nonwovens with this polymer combination. The coPET fibers were not thermally stable and caused the entire fiber structure to shrink when heated above 100°C. The MD fabric shrinkage was 20%.

Sample Description: The following information provides sample description nomenclature used to identify the examples in the tables of data provided below.

- The first number references the example number in which it was produced.
- The letter following the number is to designate a sample produced under a different condition in the example description, which is described broadly. This letter and number combination specifies production of a base substrate.
- A number following the letter designates production of a structured substrate, which is described in the patent. Different numbers indicate different conditions used to produce the structured substrate.

There are two reference samples included in the present invention to compare the base substrate and structured substrate samples vs carded resin bonded samples.

- 43 g/m^2- Consisting of 30% styrene butadiene latex binder and 70% of a fiber mix. The fiber mix contains a 40:60 mixture of 6den solid round PET fibers and 9den solid round PET fibers respectively.

- 60 g/m^2- Consisting of 30% (carboxylated) styrene butadiene latex binder and 70% of a fiber mix. The fiber mix contains a 50:50 mixture of 6den solid round PET fibers and 9 den hollow spiral PET fibers (25-40% hollow) respectively.

If samples in any of the methods being disclosed have been previously aged or has been removed from a product, they should be stored at 23 ± 2°C and at 50 ± 2% relative humidity for 24 hours with no compression, prior to any of the testing protocols. The samples after this aging would be referred to as “as-produced”.

Definitions and Test Method for Properties in Invention: The test methods for properties in the property tables are listed below. Unless specified otherwise, all tests are carried out at about 23 ± 2°C and at 50 ± 2% relative humidity. Unless specified explicitly, the specific synthetic urine used is made with 0.9% (by weight) saline (NaCL) solution made with deinonized water.

- **Mass Throughput**: Measures the polymer flow rate per capillary, measured in grams per hole per minute (GHM) and is calculated based on polymer melt density, polymer melt pump displacement per revolution and number of capillaries fed by the melt pump.

- **Shape**: Designates the fiber shape based on the capillary geometry listed in the Example Designation.

- **Actual Basis Weight**: The preferred basis weight is measured by cutting out at least ten 7500 mm^2 (50 mm wide by 150 mm long sample size) sample areas at random from the sample and weighing them to within ± 1 mg, then averaging the mass by the total number of samples weighed. Basis Weight units are in grams per square meter (g/m^2). If 7500mm^2 square area cannot be used for basis weight measurement, then the sample size can be reduced down to 2000mm^2, (for example 100mm by 20mm sample size or 50mm by 40mm sample size), but the number of samples should be increased to at least 20 measurements.

The actual basis weight is determined by dividing the average mass by the sample area and making sure the units are in grams per square meter.

- **Fabric Thickness**: Thickness is also referred to as caliper and the two words are used interchangeably. Fabric thickness and fresh caliper refer to the caliper without any aging conditions. The test conditions for as-produced caliper are measured at 0.5 kPa and at least five measurements are averaged. A typical testing device is a Thwing Albert ProGage system. The diameter of the foot is between 50 mm to 60 mm. The dwell time is 2 seconds for each measurement. The sample must be stored at 23 ± 2°C and at 50 ± 2% relative humidity for 24 hours with no compression, then subjected to the fabric thickness measurement. The preference is to make measurements on the base substrate before modification, however, if this material is not available an alternative method can be used. For a structured substrate, the thickness of the first regions in between the second regions (displaced fiber regions) can be determined by using a electronic thickness gauge (for instance available from McMaster-Carr catalog as Mitutoyo No 547-500). These electronic thickness gauges can have the tips changed to measure very small areas. These devises have a preloaded spring for making the measurement and vary by brand. For example, a blade shaped tip can be used that is 6.6mm long and 1mm wide. Flat round tips can also be inserted that measure area down below 1.5mm in diameter. For measuring on the structured substrate, these tips need to be inserted between the structured regions to measure the as-produced fabric thickness. The pressure used in the measurement technique cannot be carefully controlled using this technique, with the applied pressure being generally higher than 0.5kPa.

- **Aged Caliper**: This refers to the sample caliper after it has been aged at 40°C under 35 kPa pressure for 15 hours and then relaxed at 23 ± 2°C and at 50 ± 2% relative humidity for 24 hours with no compression. This can also be called the caliper recovery. The aged caliper is measured under a pressure of 2.1 kPA. A typical testing device is a Thwing Albert ProGage system. The diameter of the foot is between 50 mm to 60 mm. The dwell time is 2 seconds for each measurement. All samples are stored at 23 ± 2°C and at 50 ± 2% relative humidity for 24 hours with no compression, and then subjected to the aged caliper test.

- **Mod Ratio**: The "Mod Ratio" or modification ratio is used to compensate for additional surface area geometry of non-round fibers. The modification ratio is determined by measuring the longest continuous straight line distance in the cross section of the fiber perpendicular to its longest axis, and dividing by the width of the fiber at 50% of that distance. For some complex fiber shapes, it may be difficult to easily determine the modification ratio. FIG 19A-19C provide examples of shaped fiber configurations. The "A" designation is the long axis dimension and the "B" designation is the width dimension. The ratio is determined by dividing the short dimension into the long dimension. These units are measured directly via microscopy.

- **Actual Denier:** Actual denier is the measured denier of the fiber for a given example. Denier is defined as the mass of a fiber in grams at 9000 linear meters of length. Thus the inherent density of the fiber is also factored in for the calculation of denier when comparing fibers from different polymers, expressed as dpf (denier per filament), so a 2dpf PP fiber and a 2dpf PET fiber will have different fiber diameters. An example of the denier to diameter relationship for polypropylene is a 1dpf fiber of polypropylene that is solid round with a density of about 0.900g/cm^3 has a diameter of about 12.55 micrometers. The density of PET fibers in the present invention are taken to be 1.4g/cm^3 (grams per cubic centimeter) for denier calculations. For those skilled in the art, converting from solid round fiber diameter to denier for PP and PET fibers is routine.

- **Equivalent Solid Round Fiber Diameter**: The equivalent solid round fiber diameter is used for calculating the modulus of fibers for fiber property measurements for non-round or hollow shaped fibers. The equivalent solid round fiber diameter is determined from the actual denier of the fiber. The actual denier of the non-round fiber is converted into an equivalent solid round fiber diameter by taking the actual fiber denier and calculating the diameter of the filament with the assumption it was solid round. This conversion is important for determining the modulus of a single fiber for a non-round fiber cross-section.

- **Tensile Properties of the Nonwoven Fabrics:** The tensile properties of base substrates and structured substrates were all measured the same way. The gauge width is 50 mm, gauge length is 100 mm and the extension rate is 100 mm/min. The values reported are for strength and elongation at peak, unless stated otherwise. Separate measurements are made for the MD and CD properties. The typical units are Newton (N) per centimeter (N/cm). The values presented are the average of at least five measurements. The perforce load is 0.2 N. The samples should be stored at 23 ± 2°C and at 50 ± 2% relative humidity for 24 hours with no compression, then tested at 23 ± 2°C and at 50 ± 2%. The tensile strength as reported here is the peak tensile strength in the stress-strain curve. The elongation at tensile peak is the percent elongation at which the tensile peak is recorded.

- **MD/CD Ratio:** Is defined as the MD tensile strength divided by the CD tensile strength. The MD/CD ratio is a method used for comparing the relative fiber orientation in a nonwoven fibrous substrate.

- **Fiber Perimeter**: Was directly measured via microscopy and is the perimeter of a typical fiber in the nonwoven, expressed in micrometers. The values presented are the average of at least five measurements.

- **Opacity**: Opacity is a measurement of the relative amount of light that passes through the base substrate. The characteristic opacity depends, amongst others, on the number, size, type and shape of fibers present in a given location that is measured. For the present invention, the base substrate opacity is preferably greater than 5%, more preferably greater than 10%, more preferably greater than 20%, still more preferably greater than 30% and most preferably greater than 40%. Opacity is measured using TAPPI Test Method T 425 om-01 "Opacity of Paper (15/d geometry, Illuminant A/2 degrees, 89% Reflectance Backing and Paper Backing)". The opacity is measured as a percentage.

- **Base Substrate Density**: The base substrate density is determined by dividing the actual basis weight of the sample by the aged caliper of the sample, converting into the same units and reporting as grams per cubic meter.

- **Base Substrate Specific Volume**: The base substrate specific volume is the inverse of base substrate density in units of cubic centimeters per gram.

- **Line Speed**: The line speed is the linear machine direction speed at which the sample was produced.

- **Bonding Temperature**: The bonding temperature is the temperature at which the spunbond sample was bonded together. Bonding temperature includes two temperatures. The first temperature is the temperature of the engraved or patterned roll and the second is the temperature of the smooth roll. Unless specified otherwise, the bonding area was 18% and the calender linear pressure was 400 pounds per linear inch.

- **Surfactant Addition to Invention Samples**: Refers to the material used for treating the base substrate and structured substrates to render them hydrophilic. In the present invention the same surfactant was used for all samples. The surfactant was a Procter & Gamble development grade material with code DP-988A. The material is a polyester polyether copolymer. Commercial grade soil release polymers (SRPs) from Clariant (TexCare SRN-240 and TexCare SRN-170) was also used and found to work well. The basic procedure was as follows:

    - 200 mL of surfactant is mixed with 15 L of tap water at 80°C in a five gallon bucket.

    - The samples to be coated are placed into the diluted surfactant bucket for five minutes. Each sample is nominally 100mm wide and 300mm long. Up to nine samples are placed in the bucket at one time, with the samples being agitated for the first ten seconds. The same bucket can be used for up to 50 samples.

    - Each sample is then removed, held vertically over the bucket at one corner and residual water drained into the bucket for five to ten seconds.

    - The samples are rinsed and soaked in a clean bucket of tap water for at least two minutes. Up to nine samples are placed in the bucket at one time, with the samples being agitated for the first ten seconds. The rinse bucket is changed after one set of nine samples.

    - The sample is dried at 80°C in a forced air oven until dry. A typical time is two to three minutes.

- **Holding Capacity**: The holding capacity measurement takes the surfactant coated sample and measures fluid uptake of the material. The 200 mm X 100 mm sample is submerged in tap water at 20°C for one minute and then removed. The sample is held by one corner upon removal for 10 seconds and then weighed. The final weight is divided by the initial weight to calculate the holding capacity. Holding capacity is measured on as-produced fabric samples that correspond to conditions measured in the as-produced fabric thickness test, unless specified otherwise. These samples are not compression aged before testing. Different samples sizes can be used in this test. Alternative samples sizes that can be used are 100 mm x 50 mm or 150 mm x 75 mm. The calculation method is the same regardless of the sample size selected.

- **Wicking Spread Area**: The wicking spread is broken down into a MD and CD spread. A surfactant treated sample is cut that is at least 30 cm long and 20 cm wide. Non-treated samples do not wick any fluid. The sample is set on top of a series of petri dishes (10 cm diameter and 1 cm deep) with one centered in the middle of the sample and two on either side. 20 mL of distilled water is then pored onto the sample at a rate of 5 mL per second. The engraved roll side of the nonwoven is up, facing the fluid pouring direction. The distance the fluid is wicked is measured in the MD and CD after one minute. The distilled water can be colored if needed (Merck Indigocarmin c.i. 73015). The pigment should not alter the surface tension of the distilled water. At least three measurements should be made per material. Wicking spread is measured on as-produced fabric samples that correspond to conditions measured in the as-produced fabric thickness test, unless specified otherwise. These samples are not compression aged before testing. If samples size smaller than 30 cm long and 20 cm wide is used, the sample must first be tested to determine if the wicking spreads to the edges of the material before one minute. If the wicking spread in the MD or CD is greater than the sample width before one minute, the MD horizontal wicking test height method should be used. The petri dishes are emptied and cleaned for every measurement.

- **MD Horizontal Transport**:

Apparatus

- Pipette or Burette: being able to discharge 5.0ml
- Tray: size: width: 22cm ±1cm, length: 30cm±5cm, height: 6cm ±1cm
- Funnel: 250ml glass funnel attached with valve, orifice diameter: 7mm
- Metal clamps: width of clamps: 5cm
- Scissors: Suitable for cutting samples for desired dimension
- Balance: having an accuracy of 0.01g

Reagent

- **Simulated urine:** Prepare a 0.9% saline solution (9.0g/l of analytical grade sodium chloride in deionized water, with a surface tension of 70±2mN/m at 23±2°C colored with blue pigment (e.g. Merck Indigocarmin c.i. 73015)

Facilities

Conditioned Room ....Temperature ....23° Celsius (± 2°C)
Relative Humidity ..50% (± 2%)

Procedure

1.) Cut a sample (70 ±1) mm wide * (300±1) mm long in machine direction
2.) Measure and report the weight (w1) of the sample to the nearest 0.01g
3.) Clamp the sample with the baby side upwards (textured side if measuring the structured substrate or engraved roll side if measuring the base substrate) over the width on the upper edges of the tray. Material is now hanging freely above the bottom of the tray.
4.) Adjust the outlet of a 250ml glass funnel attached with a valve 25.4±3mm above the sample centered in machine and cross direction over the sample
5.) Prepare the simulated urine
6.) Dispense with the pipette or burette 5.0ml of simulated urine (4.) into the funnel, while keeping the valve of the funnel closed
7.) Open the valve of the funnel to discharge the 5.0ml of simulated urine
8.) Wait for a time period of 30 seconds (use stopwatch)
9.) Measure the max MD distribution. Report to the nearest centimeter.

- **Vertical Wicking Height**: The vertical wicking test is conducted by placing a preferred samples size of at least 20 cm long and 5 cm wide sample, held vertically above a large volume of distilled water. The lower end of the sample is submerged in the water to at least one cm under the fluid surface. The highest point the fluid raises to in five minutes is recorded. Vertical wicking is measured on as-produced fabric samples that correspond to conditions measured in the as-produced fabric thickness test, unless specified otherwise. Other sample sizes can be used, however, the sample width can effect the measurement when performed on a structured substrate. The smallest samples width should be 2cm wide, with a minimum length of 10cm.

- **Thermal Stability**: Thermal stability of the base substrate or structured substrate nonwoven is assessed based on how much a 10cm in MD x at least 2cm in CD sample shrinks in boiling water after five minutes. The base substrate should shrink less than 10%, or have a final dimension in the MD of more than 9 cm to be considered thermally stable. If the sample shrinks more than 10% it is not thermally stable. The measurement was made by cutting out the 10cm by 2cm sample size, measuring the exact length in the MD and placing the sample in boiling water for five minutes. The sample is removed and the sample length measured again the MD. For all samples tested in the present invention, even ones with high shrinkage in the comparative examples, the sample remained flat after the time in the boiling water. Without being bound by theory, the nonwoven thermal stability depends on the thermal stability of constituent fibers. If the fibers comprising the nonwoven shrink, the nonwoven will shrink. Therefore, the thermal stability measurement here also captures the thermal stability of the fibers. The thermal stability of the nonwoven is important for the present invention. For samples that show significant shrinkage, well beyond the 10% preferred in the present invention, they can bundle or curl up in boiling water. For these samples, a 20 gram weight can be attached at the bottom of the sample and the length measured vertically. The 20 gram weight can be metal binder clips or any other suitable weight that can attached at the bottom and still enable the length to be measured.

- **FDT**: FDT stands for Fiber Displacement Technology and refers to mechanical treatment of the base substrate to form a structured substrate having displaced fibers. If the base substrate is modified by any type of fiber deformation or relocation, it has undergone FDT. Simple handling of a nonwoven across flat rollers or bending is not FDT. FDT implies deliberate movement of fibers through focused mechanical or hydrodynamic forces for the intentional movement of fibers in the z-directional plane.

- **Strain Depth**: The mechanical straining distance used in the FDT process.

- **Over Thermal Bond**: Designates whether or not the sample has been overbonded with a second discrete bonding step, using heat and/or pressure.

- **FS-Tip**: Designates whether the tip or top of the displaced fibers have been bonded.

- **Structured Substrate Density**: The structured substrate density is determined by dividing the actual basis weight by the structured substrate aged caliper, converting into the same units and reporting as grams per cubic centimeter.

- **Structured Substrate Specific Volume**: The structured substrate volume is the inverse of structured substrate density in units of cubic centimeters per gram.

- **Void Volume Creation**: Void volume creation refers the void volume created during the fiber displacement step. Void volume creation is the difference between the structured substrate specific volume and the base substrate specific volume.

Aged Strike Through and Rewet Test: For the Strike Through test Edana method 150.3-96 has been used with the following modifications:

B. Testing Conditions

- Conditioning of samples and measurement is carried out at 23°C±2°C and 50%±5% humidity

E: Equipment

- As reference absorbing pad 10 layers of Ahlström Grade 989 or equivalent (av. Strike Through time: 1.7s±0.3s, dimensions: 10 x 10 cm)

F: Procedure

2. Reference absorbent pad as described in E
3. Test piece is cut into rectangle of 70 x 125 mm
4. Conditioning as described in B
5. The test piece is placed on set of 10 plies of filter paper. For structured substrates the structured side is facing upward.

10. The procedure is repeated 60s after absorption of the 1st gush and the 2nd gush respectively to record the time of the 2nd and 3rd Strike Through.
11. A minimum of 3 tests on test pieces from each specimen is recommended.

For the measurement of the rewet the Edana method 151.1-96 has been used with the following modifications:

B. Testing Conditions

- Conditioning of samples and measurement is carried out at 23°C±2°C and 50%±5% humidity

D. Principle

- The set of filter papers with the test piece on top from the Strike Through measurement is used to measure the rewet.

E. Equipment

- Pick-up paper: Ahlström Grade 632 or equivalent, cut into dimensions of 62mm x 125mm, centered on top of the test piece so that it is not in contact with the reference absorbent pad.
- Simulated Baby Weight: Total weight 3629g±20g

F. Procedure

12. Start procedure as of step 12 directly after completion of the 3rd gush of the Strike Through method. The additional quantity (L) is determined by subtracting the 15ml of the 3

gushes of the Strike Through test from the total quantity of liquid (Q) required for the wetback test.

21. The wetback value equals the rewet in the present invention.

- **Fiber Properties**: Fiber properties in the present invention were measured using an MTS Synergie 400 series testing system. Single fibers were mounted on template paper that has been precut to produce holes that are exactly 25 mm length and 1cm wide. The fibers were mounted such that they are length wise straight across the hole in the paper with no slack. The average fiber diameter for solid round or equivalent solid round fiber diameter for non-round is determined by making at least ten measurements. The average of these ten measurements is used as the fiber diameter in determining the fiber modulus through the software input. The fibers were mounted into the MTS system and the sides of the template paper were cut before testing. The fiber sample is strained at 50 mm/min speed with the strength profile initiated with a load force above 0.1g of force. The peak fiber load and strain at break are measured with the MTS software. The fiber modulus is also measured by the MTS at 1% strain. The fiber modulus as presented in Table 10 was reported in this manner. The elongation at fiber break and peak fiber load are also reported in Table 10. The results are an average of ten measurements. In calculating the modulus of the fibers, the fiber diameter is used for solid round fibers or the equivalent solid round fiber diameter is used for non-round or hollow fibers.

- **Percentage of Broken Filaments**: The percentage of broken filaments at a fiber displacement location can be measured. The method for determining the number of broken filaments is by counting. Samples produced having displaced fibers can be with or without tip bonding. Precision tweezers and scissors are needed for making actual fiber count measurements. The brand Tweezerman makes such tools for these measurements, such as Tweezers with item code 1240T and scissors with item code 3042-R can be used. Medical Supplier Expert item code MDS0859411 can also be used for scissors. Other suppliers also make tooling that can be used.

- For samples without tip bonding: Generally, one side of the displaced fiber location will have more broken filaments as shown in FIG. 16. The structured fibrous web should be cut on the first surface at the side of the displaced fibers in the second region with fewer broken filaments. As shown in FIG. 16, this would be the left side identified as the 1st cut **82**. This should be cut along the first surface at the base of the displaced fibers. The cutting is shown in FIG.s 17A and 17B. The side view shown in FIG. 17B is oriented in the MD as shown. Once this cut is made, any loose fibers should be shaken free or brushed off until no more fibers fall out. The fibers should be collected and counted. Then the other side of the second region should be cut (identified as the 2nd cut **84** in FIG. 16) and the number of fibers counted. The first cut details the number of broken fibers. The number of fibers counted in the first cut and second cut combined equals the total number of fibers. The number of fibers in the first cut divided by the total number of fibers times 100 gives the percentage of broken fibers. In most cases, a visual inspection can show whether or not the majority of the fibers are broken. When a quantitative number is needed, the procedure above should be used. The procedure should be done on at least ten samples and the total averaged together. If the sample has been compressed for some time, it may need to be lightly brushed before cutting to reveal the dislocation area for this test. If the percentages are close and a statically significant samples size has not been generated, the number of samples should be increased by increments of ten to render sufficient statistical certainty within a 95% confidence interval.

- For samples with tip bonding: Generally, one side of the displaced fiber location will have more broken filaments as shown in FIG. 18. The side with fewer broken filaments should be cut first. As shown in FIG. 18, this would be the left side upper region labeled as the 1st cut, which is at the top of the where the tip bond is located, but does not include any of the tip bonded material (i.e. it should be cut on the side of the tip bond towards the side of the broken fibers). This cut should be made and loose fibers shaken free, counted and designated as fiber count 1. The second cut should be at the base of the displaced fibers, labeled as the second cut FIG. 18. The fibers should be shaken loose and counted, with this count designated as fiber count 2. A third cut is made on the other side of the tip bonded region, shaken, counted and designated as fiber count 3. A fourth cut is made at the base of the displaced fibers, shaken loose and counted and designated as fiber count 4. The cutting is shown in FIG. 17A and 17B. The number of fibers counted in the fiber count 1 and fiber count 2 equals the total number of fibers on that side 1-2. The number of fibers counted in the fiber count 3 and fiber count 4 equals the total number of fibers on that side 3-4. The difference between fiber count 1 and fiber count 2 is determined and then divided by the sum of fiber count 1 and fiber count 2 then multiplied by 100 and is called broken filament percentage 1-2. The difference between fiber count 3 and fiber count 4 is determined and then divided by the sum of fiber count 3 and fiber count 4 then multiplied by 100 and is called broken filament percentage 3-4. For the present invention broken filament percentage 1-2 or broken filament percentage 3-4 should be greater than 50%. In most cases, a visual inspection can show whether or not the majority of the fibers are broken. When a quantitative number is needed, the procedure above should be used. The procedure should be done on at least ten samples and the total averaged together. If the sample has been compressed for some time, it may need to be lightly brushed before cutting to reveal the dislocation area for this test. If the percentages are close and a statically significant samples size has not been generated, the number of samples should be increased by increments of ten to render sufficient statistical certainty within a 95% confidence interval.

- **In Plane Radial Permeability (IPRP)**: In plane radial permeability or IPRP or shortened to permeability in the present invention is a measure of the permeability of the nonwoven fabric and relates to the pressure required to transport liquids through the material. The following test is suitable for measurement of the In-Plane Radial Permeability (IPRP) of a porous material. The quantity of a saline solution (0.9% NaCl) flowing radially through an annular sample of the material under constant pressure is measured as a function of time. (Reference: J.D. Lindsay, "The anisotropic Permeability of Paper" TAPPI Journal, (May 1990, pp223) Darcy's law and steady-state flow methods are used for determining in-plane saline flow conductivity).

The IPRP sample holder **400** is shown in FIG. 20 and comprises a cylindrical bottom plate **405**, top plate **420**, and cylindrical stainless steel weight **415** shown in detail in FIGs. 21A-C.

Top plate **420** is 10 mm thick with an outer diameter of 70.0 mm and connected to a tube **425** of 190 mm length fixed at the center thereof. The tube **425** has in outer diameter of 15.8 mm and an inner diameter of 12.0 mm. The tube is adhesively fixed into a circular 12 mm hole in the center of the top plate **420** such that the lower edge of the tube is flush with the lower surface of the top plate, as depicted in FIG. 21A. The bottom plate **405** and top plate **420** are fabricated from Lexan® or equivalent. The stainless steel weight **415** has an outer diameter of 70 mm and an inner diameter of 15.9 mm so that the weight is a close sliding fit on tube **425**. The thickness of the stainless steel weight **415** is approximately 25 mm and is adjusted so that the total weight of the top plate **420**, the tube **425** and the stainless steel weight **415** is 788 g to provide 2.1 kPa of confining pressure during the measurement.

As shown in FIG. 21C, bottom plate **405** is approximately 50 mm thick and has two registration grooves **430** cut into the lower surface of the plate such that each groove spans the diameter of the bottom plate and the grooves are perpendicular to each other. Each groove is 1.5 mm wide and 2 mm deep. Bottom plate **405** has a horizontal hole **435** which spans the diameter of the plate. The horizontal hole **435** has a diameter of 11 mm and its central axis is 12 mm below the upper surface of bottom plate **405**. Bottom plate **405** also has a central vertical hole **440** which has a diameter of 10 mm and is 8 mm deep. The central hole **440** connects to the horizontal hole **435** to form a T-shaped cavity in the bottom plate **405**. As shown in FIG 21B, the outer portions of the horizontal hole **435** are threaded to accommodate pipe elbows **445** which are attached to the bottom plate **405** in a watertight fashion. One elbow is connected to a vertical transparent tube **460** with a height of 190 mm and an internal diameter of 10 mm. The tube **460** is scribed with a suitable mark **470** at a height of 50 mm above the upper surface of the bottom plate **420**. This is the reference for the fluid level to be maintained during the measurement. The other elbow **445** is connected to the fluid delivery reservoir **700** (described below) via a flexible tube.

A suitable fluid delivery reservoir **700** is shown in FIG. 22. Reservoir **700** is situated on a suitable laboratory jack **705** and has an air-tight stoppered opening **710** to facilitate filling of the reservoir with fluid. An open-ended glass tube **715** having an inner diameter of 10 mm extends through a port **720** in the top of the reservoir such that there is an airtight seal between the outside of the tube and the reservoir. Reservoir **700** is provided with an L-shaped delivery tube **725** having an inlet **730** that is below the surface of the fluid in the reservoir, a stopcock **735**, and an outlet **740**. The outlet **740** is connected to elbow **445** via flexible plastic tubing **450** (e.g. Tygon®). The internal diameter of the delivery tube **725**, stopcock **735**, and flexible plastic tubing **450** enable fluid delivery to the IPRP sample holder **400** at a high enough flow rate to maintain the level of fluid in tube **460** at the scribed mark **470** at all times during the measurement. The reservoir **700** has a capacity of approximately 6 litres, although larger reservoirs may be required depending on the sample thickness and permeability. Other fluid delivery systems may be employed provided that they are able to deliver the fluid to the sample holder **400** and maintain the level of fluid in tube **460** at the scribed mark **470** for the duration of the measurement.

The IPRP catchment funnel **500** is shown in FIG. 20 and comprises an outer housing **505** with an internal diameter at the upper edge of the funnel of approximately 125 mm. Funnel **500** is constructed such that liquid falling into the funnel drains rapidly and freely from spout **515**. A horizontal flange **520** around the funnel **500** facilitates mounting the funnel in a horizontal position. Two integral vertical internal ribs **510** span the internal diameter of the funnel and are perpendicular to each other. Each rib **510** s 1.5 mm wide and the top surfaces of the ribs lie in a horizontal plane. The funnel housing **500** and ribs **510** are fabricated from a suitably rigid material such as Lexan® or equivalent in order to support sample holder **400**. To facilitate loading of the sample it is advantageous for the height of the ribs to be sufficient to allow the upper surface of the bottom plate **405** to lie above the funnel flange **520** when the bottom plate **405** is located on ribs **510**. A bridge **530** is attached to flange **520** in order to mount a dial gauge **535** to measure the relative height of the stainless steel weight **415**. The dial gauge **535** has a resolution of ± 0.01 mm over a range of 25 mm. A suitable digital dial gauge is a Mitutoyo model 575-123 (available from McMaster Carr Co., catalog no. 19975-A73), or equivalent. Bridge **530** has two circular holes 17 mm in diameter to accommodate tubes **425** and **460** without the tubes touching the bridge.

Funnel **500** is mounted over an electronic balance **600**, as shown in Fig. 20. The balance has a resolution of ± 0.01 g and a capacity of at least 2000g. The balance **600** is also interfaced with a computer to allow the balance reading to be recorded periodically and stored electronically on the computer. A suitable balance is Mettler-Toledo model PG5002-S or equivalent. A collection container **610** is situated on the balance pan so that liquid draining from the funnel spout **515** falls directly into the container **610**.

The funnel **500** is mounted so that the upper surfaces of ribs **510** lie in a horizontal plane. Balance **600** and container **610** are positioned under the funnel **500** so that liquid draining from the funnel spout **515** falls directly into the container **610**. The IPRP sample holder **400** is situated centrally in the funnel **700** with the ribs **510** located in grooves **430**. The upper surface of the bottom plate **405** must be perfectly flat and level. The top plate **420** is aligned with and rests on the bottom plate **405**. The stainless steel weight **415** surrounds the tube **425** and rests on the top plate **420**. Tube **425** extends vertically through the central hole in the bridge **530**. The dial gauge **535** is mounted firmly to the bridge **530** with the probe resting on a point on the upper surface of the stainless steel weight **415**. The dial gauge is set to zero in this state. The reservoir **700** is filled with 0.9% saline solution and re-sealed. The outlet **740** is connected to elbow **445** via flexible plastic tubing **450.**

A an annular sample **475** of the material to be tested is cut by suitable means. The sample has an outer diameter of 70 mm and an inner hole diameter of 12 mm. One suitable means of cutting the sample is to use a die cutter with sharp concentric blades.

The top plate **420** is lifted enough to insert the sample **475** between the top plate and the bottom plate **405** with the sample centered on the bottom plate and the plates aligned. The stopcock **735** is opened and the level of fluid in tube **460** is set to the scribed mark **470** by adjusting the height of the reservoir **700** using the jack **705** and by adjusting the position of the tube **715** in the reservoir. When the fluid level in the tube **460** is stable at the scribed mark **470** and the reading on the dial gauge **535** is constant, the reading on the dial gauge is noted (initial sample thickness) and the recording of data from the balance by the computer is initiated. Balance readings and time elapsed are recorded every 10 seconds for five minutes. After three minutes the reading on the dial gauge is noted (final sample thickness) and the stopcock is closed. The average sample thickness L_p is the average of the initial sample thickness and the final sample thickness expressed in cm.

The flow rate in grams per second is calculated by a linear least squares regression fit to the data between 30 seconds and 300 seconds. The permeability of the material is calculated using the following equation:

$$k = \frac{(Q/\rho)\,\mu\,\ln(R_o/R_i)}{2\pi\, L_p\, \Delta P}$$

where:

- k is the permeability of the material (cm^2)
- Q is the flow rate (g/s)
- ρ is the density of the liquid at 22°C (g/cm^3)
- μ is the viscosity of the liquid at 22°C (Pa·s)
- R_o is the sample outer radius (mm)
- R_i is the sample inner radius (mm)
- L_p is average sample thickness (cm)
- ΔP is the hydrostatic pressure (Pa)

$$\Delta P = \left(\Delta h - \frac{L_p}{2}\right) G\,\rho\,10$$

where:

- Δh is the height of the liquid in tube **460** above the upper surface of the bottom plate (cm), and
- G is the gravitational acceleration constant (m/s^2)

$$K_r = \frac{k}{\mu}$$

where:

- K_r is the IPRP value expressed in units of $cm^2/(Pa \cdot s)$

Discussion of Data in Tables: The information below will provide a basis for including the information found in the tables in the invention.

- Table 1 and Table 2: Base substrate material properties for pronounced trilobal shaped fibers, solid round and standard trilobal base substrate as-produced properties. Table 1 describes the base substrate as-produced properties. The table lists the specifics for each example. The important properties to point out in Table 1 are the modification ratio for the pronounced trilobal filaments and the relatively low MD elongation for these point bonded PET substrates.

- Table 3: The fluid handling properties of the base substrate are shown. The Holding Capacity of these base substrates indicated that they are not absorbent materials, with gram per gram holding capacities below 10.

- Table 4: Lists the process settings and property changes of structured substrates versus the base substrate properties. The examples for the 1D collection of samples highlight a primary purpose in the present invention. 1D is the base substrate (60 g/m^2 6.9dpf PET) while 1D1 through 1D6 show the changes in caliper with increasing fiber displacement, as indicated by the strain depth. Increasing strain increases caliper. The over bonding is indicated by the over thermal bonding. Tip bonding is indicated by FS-Tip and as shown, can also affect the aged caliper and the amount of void volume created. The purpose of the present invention is to create void volume for liquid acquisition. The over thermal bonding also can be used to increase mechanical properties, as illustrated in the MD tensile strength increase vs. the base substrate. The Example 1N data set compare the base substrate with 1N1 through 1N9, which have undergone different strain depth processes. This data set shows that there is an optimization in caliper generation that is determined by any over thermal bonding, FS-tip and overall strain. The data shows that too much strain can produce samples with worse aged caliper. In one execution of the present invention, this would correspond to completely broken filament in the activated region, while the region with the highest void volume creation has the preferred broken filament range. The results also show that similar structured substrate volumes can be created for the present invention as typical resin bonded structures, while also having fluid transport properties.

- Table 5: The data and example show that the caliper increase and void volume creation in the present invention can be used for fiber shapes standard trilobal and solid round. The benefit of the present invention is not restricted to pronounced trilobal fibers.

- Table 6 lists fluid handling properties of structured substrates vs. base substrate properties. The examples in Table 6 are the same as Table 4. The data in Table 6 show that the use of FDT does increase the MD Horizontal Transport properties of the structured substrate vs. the base substrate. The over bonding has been found to increase fluid transport in the MD. The Vertical wicking height component shows similar properties of the structured substrate vs. the base substrate at moderate FDT strains, but at higher strains the Vertical wicking height component does decrease slightly. Relative to the carded resin bonded nonwovens; the vertical transport component is still very good. The aged strike through data shows a dramatic improvement of fluid acquisition rates of the structured substrate vs the base substrate. The strike through times decreases dramatically with FDT vs the base substrate. The rewet properties generally decrease with FDT vs the base substrate. The data in Table 6 demonstrates the structured substrate's ability to provide fluid transport along with the ability to control the fluid acquisition rates. The table also includes the fluid permeability of a material via IPRP on the samples, which shows the dramatic improvement after FDT, and also how the structured substrates have higher permeability at calipers similar to the carded resin bonded structures.

- Table 7 lists some additional fluid handling properties of some pronounced fiber shaped structured substrates vs base substrates. The activation conditions used in the sample description are listed in Table 5. Table 5 shows that changes in FDT can improve fluid acquisition rates.

- Table 8 shows additional structured substrate vs base substrate samples with improved fluid acquisition rates for solid round (SR) and standard trilobal fibers (TRI). The activation conditions used for the structured substrate samples are provided in Table 9.

- Table 9 lists the process conditions for the samples made in Table 8.

- Table 10 lists the single fiber property values for substrates used in the present invention. Because the present invention uses high speed fiber spinning to produce thermal stable PET, the modulus values are very high for fibers having strength >10g per filament.

Table 1: Base Substrate example material properties.

Example Designation	Resin Type	Mass Throughput	Shape	Actual Basis Weight (g/m^2)	Aged Caliper	Mod Ratio	Actual Denier	MD Tensile Strength	MD Elongation at Peak	CD Tensile Strength	CD Elongation at Peak	MD/CD Ratio
				(g/m^2)	(mm)		(dpf)	(N/5cm)	(%)	(N/5cm)	(%)	
1D	F61HC/9921	3GHM	p-TRI	60.6	0.36	1.72	6.9	96.9	4	60.3	33	1.61
1F	F61HC/9921	4GHM	p-TRI	41.1	0.35	2.09	8.6	80.6	26	39.5	35	2.04
1N	F61HC/9921	4GHM	p-TRI	44.1	0.39	1.72	6.9	61.7	5	36.2	36	1.7
1O	F61HC/9921	4GHM	p-TRI	67.0	0.43	1.72	6.9	120.0	6	67.2	33	1.8
2K	F61HC	4GHM	p-TRI	40.6	0.32	1.98	9.2	82.5	28	38.2	32	2.16
3E	F61HC/9921	4.0	std-TRI	41.7	0.29	1.18	10.5	74.3	29	42.5	41	1.75
4B	F61HC/9921	3GHM	SR	42.7	0.36	N/A	4.9	58.0	24.0	50.2	39.0	1.2

Table 2: Base Substrate material properties.

Example Designation	Fiber Perimeter (µm)	Equivalent SR Fiber Diameter (µm)	Actual Basis Weight (g/m^2)	Aged Caliper	Opacity	Base Substrate Specific Density	Base Substrate Specific Volume
			(g/m^2)	(mm)	(%)	(g/m3)	(cm3/g)
1D	99.7	26.8	60.6	0.36	40	168333	5.94
1F	135.5	30.0	41.1	0.35	25	117429	8.52
1N	135.5	30.0	44.1	0.39		113077	8.84
1O	135.5	30.0	67.0	0.43		155814	6.42
2K	138.0	31.0	40.6	0.32		126875	7.88
3E	33.2	118	41.7	0.29	26	143793	6.95
4B	71.0	22.6	42.7	0.36	16	118611	8.43

Table 3: Base Substrate fluid handling properties.

Example Designation	Line Speed	Bonding Temperature, Engraved/Smooth	Surfactant	Holding Capacity w/SRP	Wicking Spread		Vertical Wicking Height	FDT	Thermally Stable?	%Shrinkage
	(m/min)	(°C)		(g/g)	MD (cm)	CD (cm)	(mm)			
1D	23	200/190	DP988A	4.33	26.0	16.0	108	NO	YES	2
1F	43	200/190	DP988A	5.20	18.0	16.0	27	NO	YES	5
1N	44	210/200	DP988A		19	17	51	NO	YES	2
1O	30	210/200	DP988A		30	21	80	NO	YES	0
2K	43	200/190	DP988A	5.30	13.0	11.0		NO	YES	3
3E	43	200/190	DP988A	4.8	2.5	2.5	22	NO	YES	2
4B	31	200/190	DP988A	4.00	11.9	9.0	29	NO	YES	4

Table 4: Mechanical Property changes of Base Substrate vs Structured substrate.

Example Designation	Basis Weight (g/m^2)	FDT	Strain Depth (inches)	Line Speed (MPM)	Over Thermal Bond (inches)	FS-Tip	Fresh Caliper (mm)	Aged Caliper (mm)	Base Substrate Specific Volume (cm3/g)	Structured Substrate Specific Volume (cm3/g)	Void Volume Creation (cm3/g)	MD Tensile Strength (N/5cm)	MD Elongation at Peak (%)
1D	60.1	NO	NO	NO	NO	NO	0.36	0.35	5.82			96.3	4
1D1	60.1	YES	0.01	17	YES	NO	No Data	No Data				90.5	5
1D2	60.1	YES	0.01	17	YES	NO	0.42	0.38		6.32	0.50	154.1	26
1D3	60.1	YES	0.07	17	YES	NO	0.53	0.48		7.99	2.16	147.7	23
1D4	60.1	YES	0.07	17	YES	YES	No Data	No Data				152.1	26
1D5	60.1	YES	0.13	17	YES	YES	0.90	0.74		12.31	6.49	127.6	37
1D6	60.1	YES	0.13	17	YES	NO	0.84	0.58		9.65	3.83	109.8	41
Resin Bond 43 g/m^2	43	NO	NO	NO	NO	NO	0.80	0.63	14.65				
Resin Bond 60 g/m^2	60	NO	NO	NO	NO	NO	1.14	0.91	15.17				
1N	44.1	NO	NO	NO	NO	NO	0.4	0.4	9.07		0.00		
1N1	44.1	YES	0.1	17	YES	NO	0.84	0.72		16.33	7.26		
1N2	44.1	YES	0.1	17	YES	YES	0.76	0.7		15.87	6.80		
1N3	44.1	YES	0.1	17	NO	NO	0.91	0.79		17.91	8.84		
1N4	44.1	YES	0.1	17	NO	YES	0.75	0.65		14.74	5.67		
1N5	44.1	YES	0.13	17	YES	YES	1.2	0.83		18.82	9.75		
1N6	44.1	YES	0.13	17	YES	NO	1.31	0.69		15.65	6.58		
1N9	44.1	YES	0.16	17	YES	YES	1.17	0.65		14.74	5.67		

Table 5: Mechanical Property changes of Base Substrate vs Structured Substrate.

Example Designation	Basis Weight (g/m^2)	FDT	Strain Depth (inches)	Line Speed (MPM)	Over Thermal Bond (inches)	FS-Tip	Fresh Caliper (mm)	Aged Caliper (mm)	Base Substrate Specific Volume (cm3/g)	Structured Substrate Specific Volume (cm3/g)	Void Volume Creation (cm3/g)
1O	67.0	NO	NO	NO	NO	NO	0.43	0.43	6.42		0.00
1O1	67.0	YES	0.1	17	YES	NO	0.89	0.80		11.94	5.52
1O2	67.0	YES	0.1	17	YES	YES	0.81	0.75		11.19	4.78
1O3	67.0	YES	0.1	17	NO	NO	0.99	0.86		12.84	6.42
1O4	67.0	YES	0.13	17	YES	NO	1.45	1.00		14.93	8.51
1O5	67.0	YES	0.13	17	YES	YES	1.31	1.11		16.57	10.15
1O6	67.0	YES	0.13	17	NO	NO	1.34	0.90		13.43	7.01
1K	40.6	NO	NO	NO	NO	NO	0.32	0.32	7.88		0.00
1K1	40.6	YES	0.13	17	YES	YES	0.94	0.48		11.82	3.94
1F	41.1	NO	NO	NO	NO	NO	0.35	0.35	8.52		0.00
1F1	41.1	YES	0.13	17	YES	YES	0.92	0.52		12.65	4.14
4B	42.7	NO	NO	NO	NO	NO	0.36	0.36	8.43		0.00
4B1	42.7	YES	0.07	17	YES	YES	0.56	0.49		11.48	3.04
4B2	42.7	YES	0.13	17	YES	YES	1.07	0.50		11.71	3.28
3E	41.7	NO	NO	NO	NO	NO	0.31	0.31	7.43		0.00
3E1	41.7	YES	0.07	17	YES	YES	0.42	0.33		7.91	0.48
3E2	41.7	YES	0.13	17	YES	YES	0.62	0.38		9.11	1.68

Table 6: Fluid Management Properties of Base Substrate and Structured Substrates.

Example Designation	Fresh Caliper	Aged Caliper	FDT	IPRP	MD Horizontal Transport	Vertical Wicking Height	Aged Strike Through 1	Aged Strike Through 2	Aged Strike Through 3	Rewet
	(mm)	(mm)		$cm^2/(Pa \cdot s)$	(cm)	(cm)	(s)	(s)	(s)	(g)
1D	0.36	0.35	NO	5,060	19.5	10.8	1.2	1.8	1.7	1.5
1D1	No Data	No Data	YES		20.0	10.7				
1D2	0.42	0.38	YES	11,200	23.0	10.8	0.5	1.2	1.4	0.8
1D3	0.53	0.48	YES	13,400	25.0	11.0	0.6	1.3	1.3	2.0
1D4	No Data	No Data	YES		25.0	9.0				
1D5	0.90	0.74	YES	24,500	27.0	8.0	0.4	0.7	0.7	0.2
1D6	0.84	0.58	YES	17,300	23.0	8.0	0.6	0.7	0.5	0.1
Resin Bond 43 g/m^2	0.80	0.63	NO	11,900	2	0	0.7	1.2	1.1	0.0
Resin Bond 60 g/m^2	1.14	0.91	NO	13,200	2	0	0.5	1.0	0.9	0.1
1N	0.4	0.4	NO	7,900	19.0	8.1	1.2	1.4	1.6	1.3
1N1	0.84	0.72	YES	29,439	20.0	8.2	0.3	0.7	0.6	0.9
1N2	0.76	0.7	YES	30,320	21.0	8.4	0.4	0.9	0.9	1.2
1N3	0.91	0.79	YES	22,934	21.0	8.3	0.2	0.8	0.8	0.9
1N4	0.75	0.65	YES	19,132	22.0	7.8	0.4	1.0	0.6	1.5
1N5	1.2	0.83	YES	24,634	22.0	7.7	0.0	0.7	0.6	0.2
1N6	1.31	0.69	YES	17,455	21.0	7.7	0.4	0.7	0.4	0.5
1N9	1.17	0.65	YES	10,795	22.5	6.8	0.0	0.6	0.6	0.2

Table 7: Fluid Management Properties of Base Substrate and Structured substrates.

Example Designation	Fresh Caliper (mm)	Aged Caliper (mm)	FDT	IPRP $cm^2/(Pa \cdot s)$	MD Horizontal Transport (cm)	Vertical Wicking Height (cm)	Aged Strike Through 1 (s)	Aged Strike Through 2 (s)	Aged Strike Through 3 (s)	Rewet (g)
1O	0.43	0.43	NO	5,060	30.0	13.5	1.2	1.8	1.7	1.5
1O1	0.89	0.80	YES	31,192	32.0	13.7	0.0	0.1	0.5	1.8
1O2	0.81	0.75	YES	32,134	33.0	14.1	0.6	0.5	0.8	1.9
1O3	0.99	0.86	YES	29,158	33.0	12.6	0.1	0.5	0.2	1.8
1O4	1.45	1.00	YES	32,288	32.5	12.3	0.2	0.3	0.4	0.5
1O5	1.31	1.11	YES	39,360	33.0	12.4	0.4	0.1	0.3	0.5
1O6	1.34	0.90	YES	26,298	32.0	12.5	0.0	0.1	0.5	0.7

Table 8: Fluid Management Properties of Different Shaped Fibers.

Example Designation	Fiber Shape	Fresh Caliper (mm)	Aged Caliper (mm)	FDT	MD Horizontal Transport (cm)	Vertical Wicking Height (cm)	Aged Strike Through 1 (s)	Aged Strike Through 2 (s)	Aged Strike Through 3 (s)	Rewet (g)
3E	TRI	0.29	0.29	NO	2.5	2.2	1.1	1.3	1.6	1.2
3E1	TRI	0.48	0.42	YES	4.0	2.9	0.49	1.01	1.03	0.29
3E2	TRI	0.66	0.48	YES	3.0	2.7	0.53	0.73	0.70	0.33
4B	SR	0.36	0.36	NO	11.9	2.9	1.3	1.5	1.7	1.3
4B1	SR	0.43	0.41	YES	14.1	4.8	0.79	1.10	1.13	0.71
4B2	SR	0.56	0.52	YES	13.2	4.6	0.60	0.94	0.93	0.07
Resin Bond 43 g/m^2		0.80	0.63		2	0	0.68	1.19	1.10	0.04
Resin Bond 60 g/m^2		1.14	0.91		2	0	0.49	1.04	0.85	0.06

Table 9: Process settings for samples in Table 8.

Example Designation	FDT	Strain Depth (inches)	Line Speed (MPM)	Over Thermal Bond (inches)	FS-Tip	Fresh Caliper (mm)	Aged Caliper (mm)
4B1	YES	0.07	17	YES	YES	0.48	0.42
4B2	YES	0.13	17	YES	YES	0.66	0.48
3E1	YES	0.07	17	YES	YES	0.43	0.41
3E2	YES	0.13	17	YES	YES	0.56	0.52

Table 10: Single fiber property data for sample used in present invention.

Fiber Shape	Polymer Type	Fiber Denier	Peak Fiber Load	Strain at Break	Modulus
		(dpf)	(g)	(%)	(GPa)
Pronounced Trilobal	PET	6.9	15.1	94	4.3
Pronounced Trilobal	PET	8.6	15.6	126	3.5
Pronounced Trilobal	PET	10.7	15.3	170	3.2
Pronounced Trilobal	PET	13.0	15.5	186	3.4
Standard Trilobal	PET	6.5	15.3	165	3.8
Standard Trilobal	PET	9.6	15.9	194	2.7
Standard Trilobal	PET	10.5	16.0	247	2.4
Standard Trilobal	PET	14.5	17.5	296	2.6
Solid Round	PET	2.9	10.0	167	3.0
Solid Round	PET	4.9	15.6	268	2.8
Solid Round	PET	8.9	15.9	246	3.3

Articles

The base substrate and the structured substrate of the present invention may be used for a wide variety of applications, including various filter sheets such as air filter, bag filter, liquid filter, vacuum filter, water drain filter, and bacterial shielding filter; sheets for various electric appliances such as capacitor separator paper, and floppy disk packaging material; various industrial sheets such as tacky adhesive tape base cloth, and oil absorbing material; various dry or premoistened wipes such as hard surface cleaning, floor care, and other home care uses, various wiper sheets such as wipers for homes, services and medical treatment, printing roll wiper, wiper for cleaning copying machine, baby wipers, and wiper for optical systems; various medicinal and sanitary sheets, such as surgical gown, medical gowns, wound care, covering cloth, cap, mask, sheet, towel, gauze, base cloth for cataplasm. Other applications include disposable absorbent articles as a means for managing fluids. Disposable absorbent article applications include tampon liners and diaper acquisition layers.

The dimensions and values disclosed herein are not to be understood as being strictly limited to the exact numerical values recited. Instead, unless otherwise specified, each such dimension is intended to mean both the recited value and a functionally equivalent range surrounding that value. For example, a dimension disclosed as “40 mm” is intended to mean “about 40 mm”.

Every document cited herein, including any cross referenced or related patent or application, is hereby incorporated herein by reference in its entirety unless expressly excluded or otherwise limited. The citation of any document is not an admission that it is prior art with respect to any invention disclosed or claimed herein or that it alone, or in any combination with any other reference or references, teaches, suggests or discloses any such invention. Further, to the extent that any meaning or definition of a term in this document conflicts with any meaning or definition of the same term in a document incorporated by reference, the meaning or definition assigned to that term in this document shall govern.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention.

CLAIMS

What is claimed is:

1. A fluid permeable structured fibrous web comprising thermoplastic fibers wherein the fibrous web has an aged caliper of less than 1.5 mm, vertical wicking height of at least 5 mm, a permeability of at least 10,000 $cm^2/(Pa \cdot s)$, and a structured substrate specific volume of at least 5 cm^3/g.

2. The fibrous web of Claim 1 wherein the fibers are thermally stable.

3. The fibrous web of Claim 1 wherein the fibers are continuous, uncrimped spunbond fibers.

4. The fibrous web of Claim 1 wherein the fibers are thermally point bonded.

5. The fibrous web of Claim 4 wherein the fibrous web is fully bonded.

6. The fibrous web of Claim 1 wherein the vertical wicking height is at least 20 mm.

7. The fibrous web of Claim 1 wherein the structured substrate specific volume is at least 10 cm^3/g.

8. The fibrous web of Claim 1 wherein the fibrous web has a permeability of at least 20,000 $cm^2/(Pa \cdot s)$.

9. The fibrous web of Claim 1 wherein the fibers comprise PET.

10. The fibrous web of claim 1 wherein the fibers comprise shaped fibers.

11. The fibrous web of claim 1 wherein the fibrous web has an aged second strike through of less than 2 seconds.

12. The fibrous web of claim 1 wherein the fibrous web has a rewet of less than 3.0 g.

13. The fibrous web of claim 1 wherein the fibrous web has a basis weight of between 30 and 80 g/m^2.

14. The fibrous web of claim 1 wherein the aged caliper is greater than 0.5 mm.

15. The fibrous web of claim 1 wherein the fibrous web has fiber content comprising at least 50% thermoplastic fibers.

11349Q

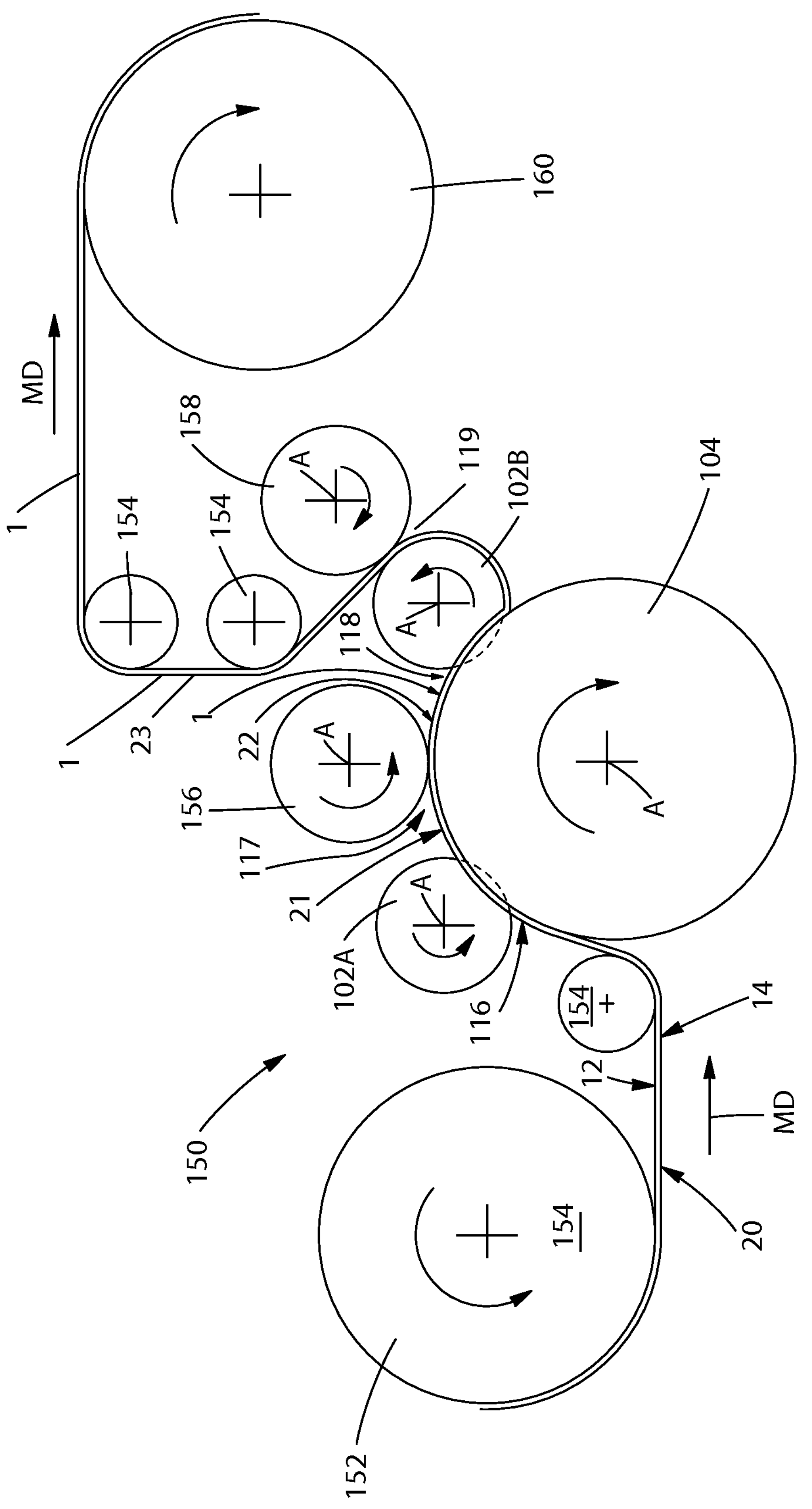
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Fig. 1

11349Q

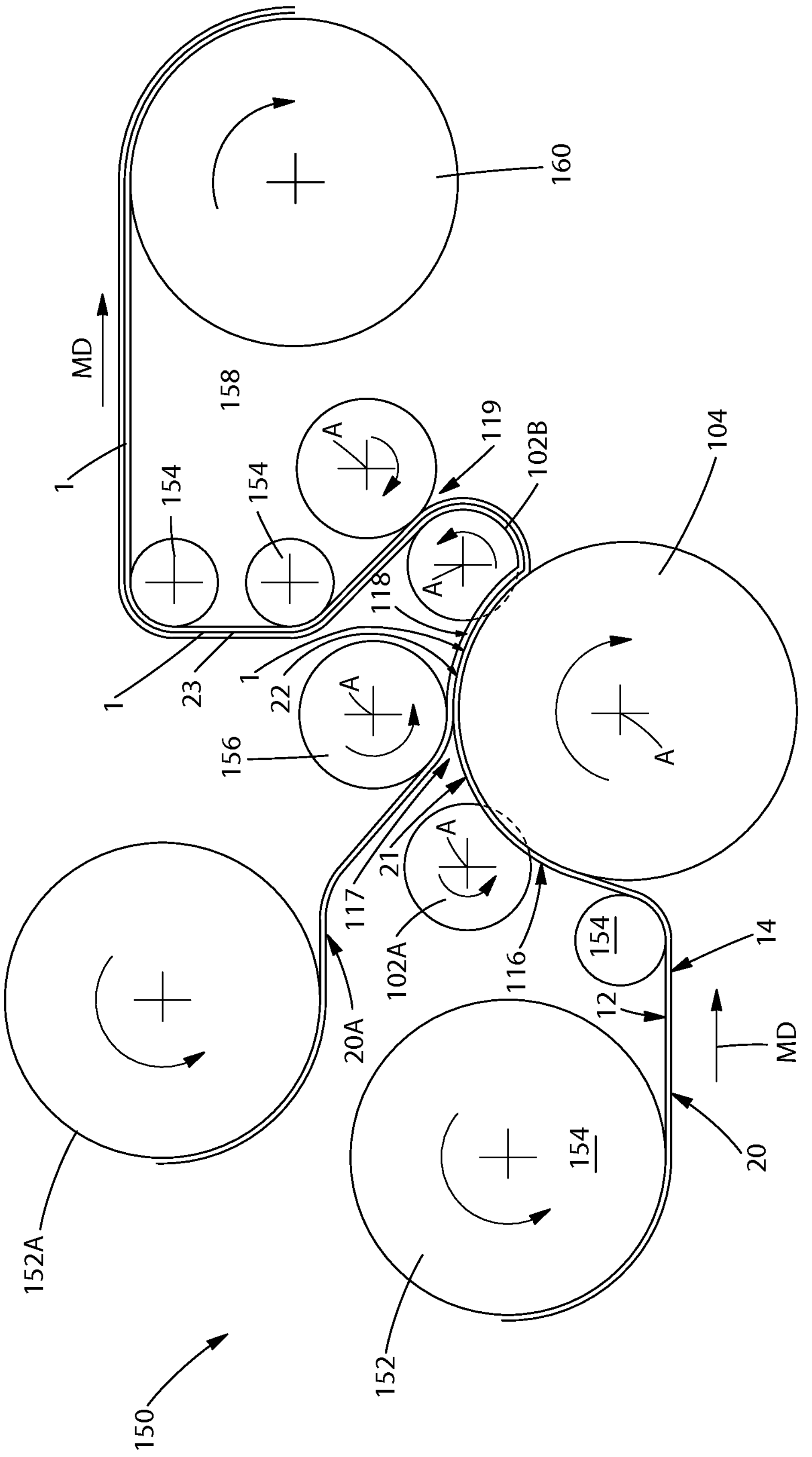

Fig. 1A

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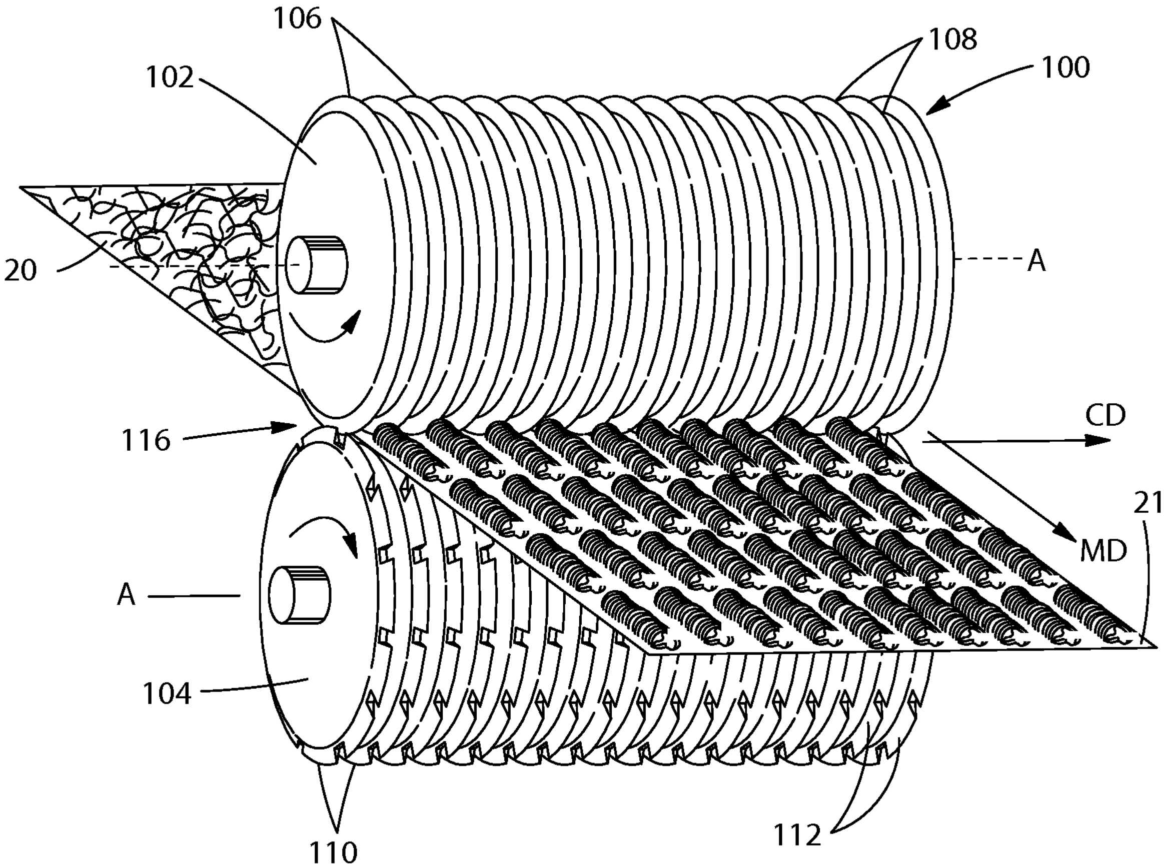

Fig. 2

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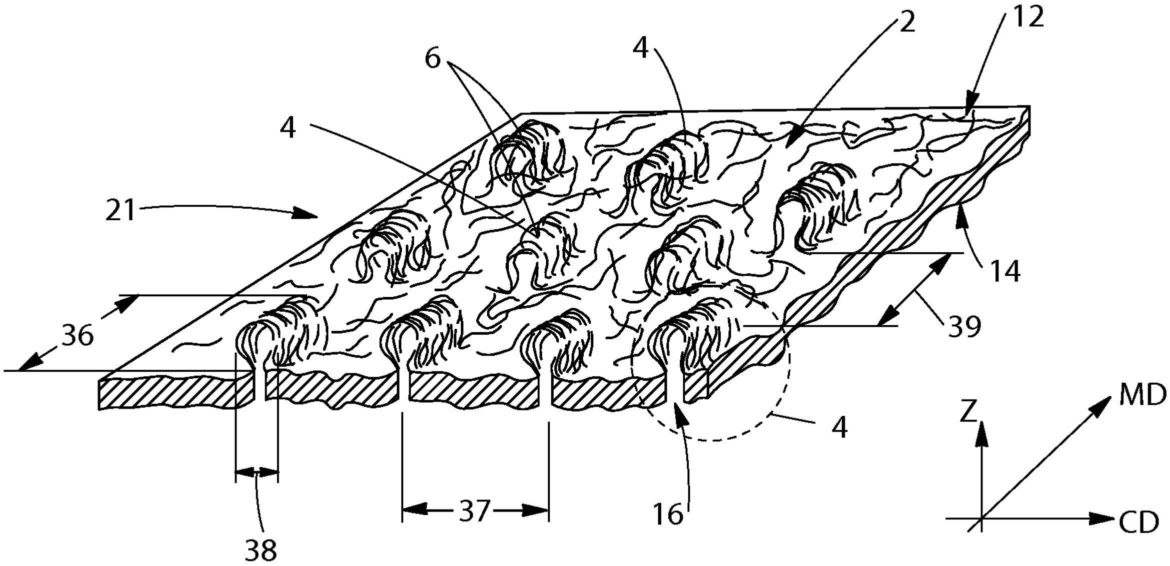

Fig. 3

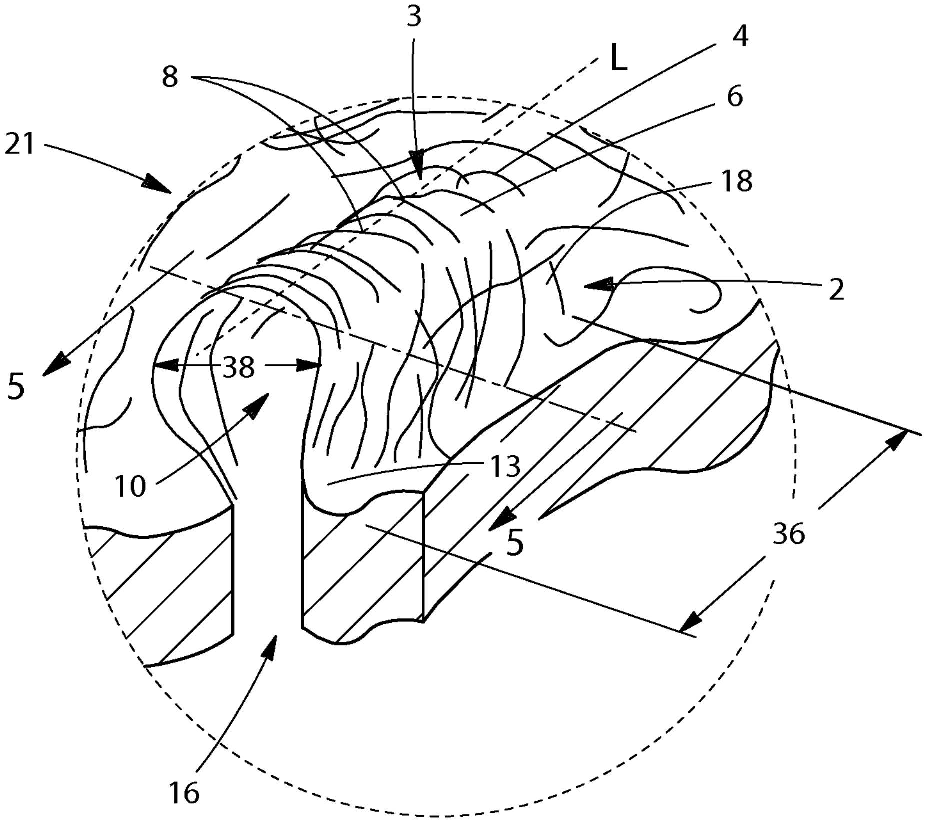

Fig. 4

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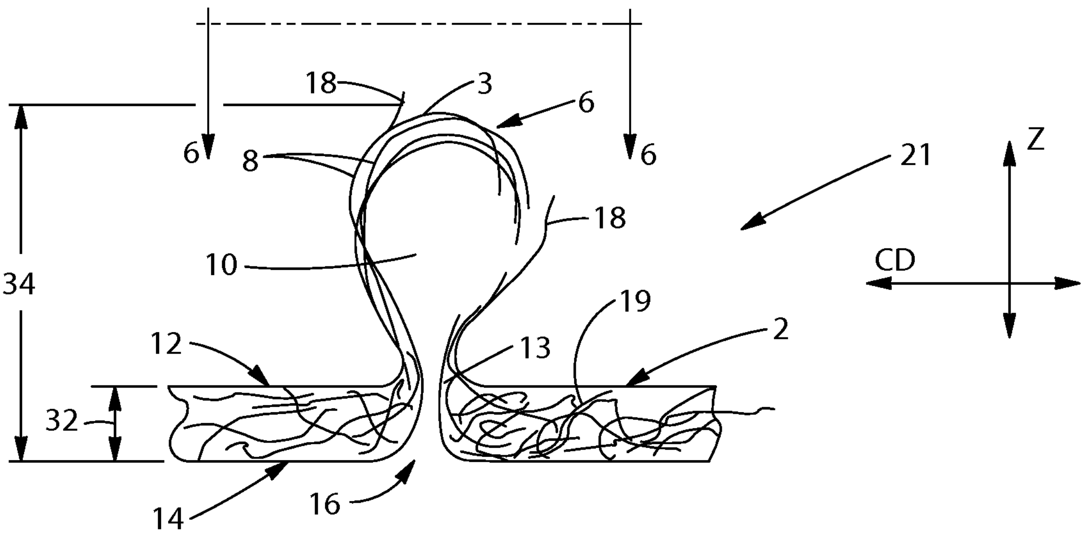

Fig. 5

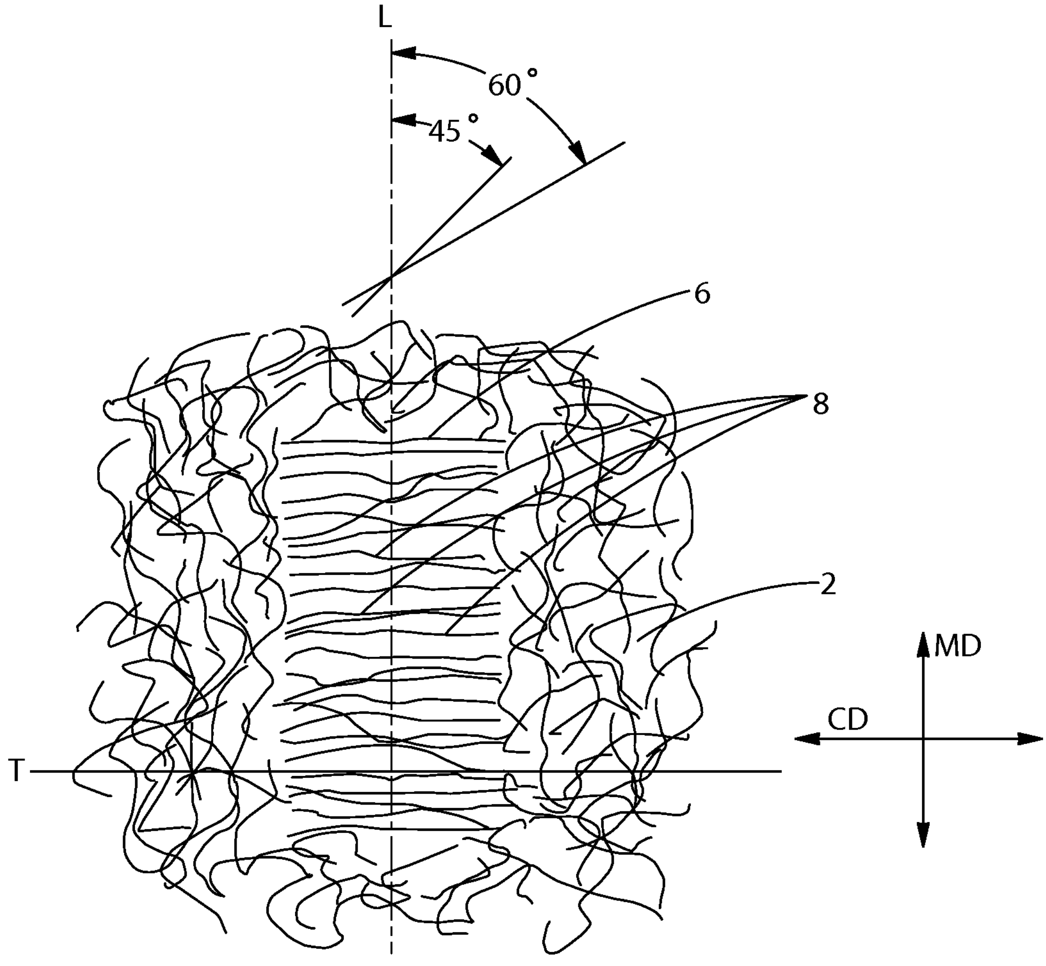

Fig. 6

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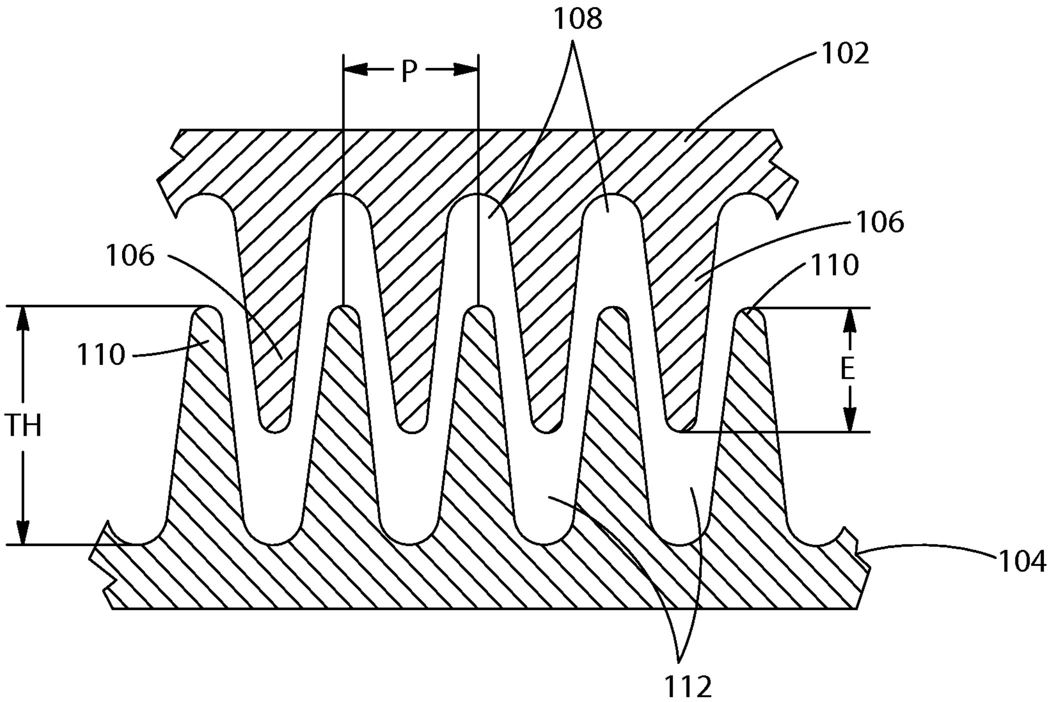

Fig. 7

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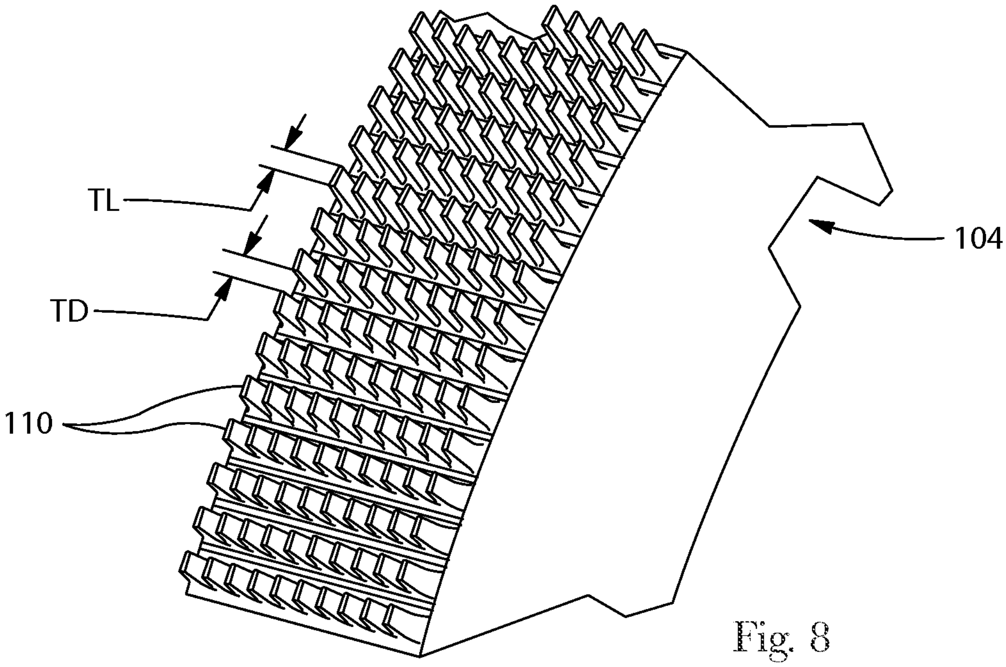

Fig. 8

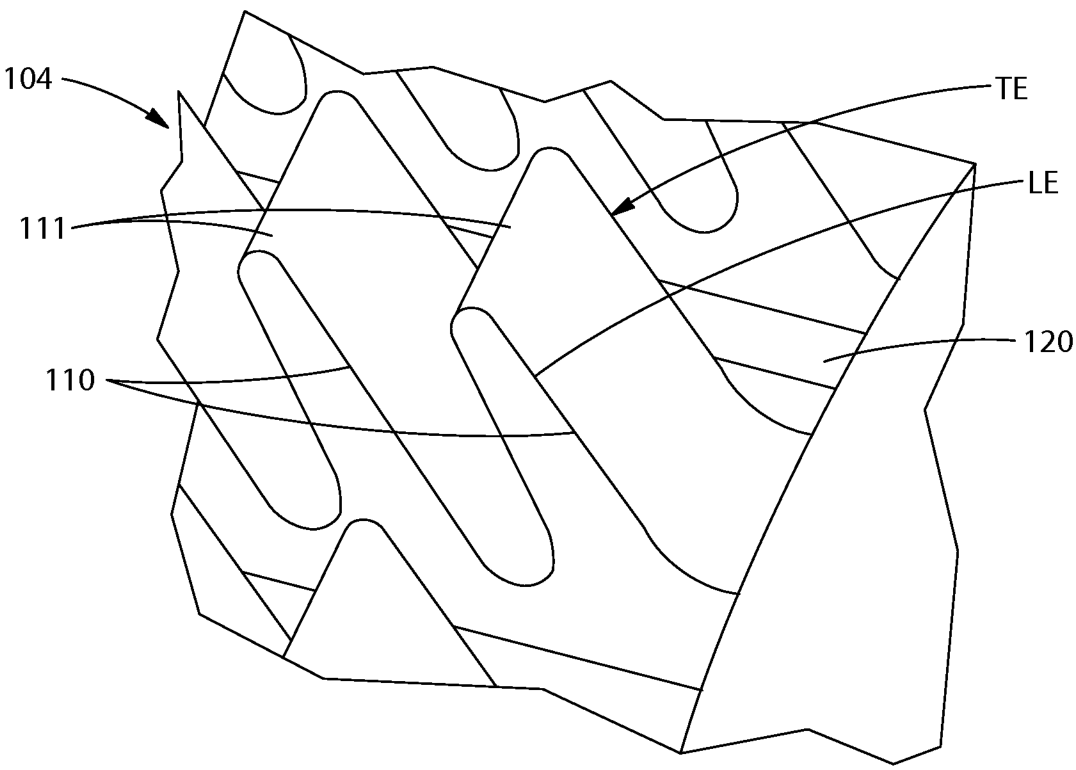

Fig. 9

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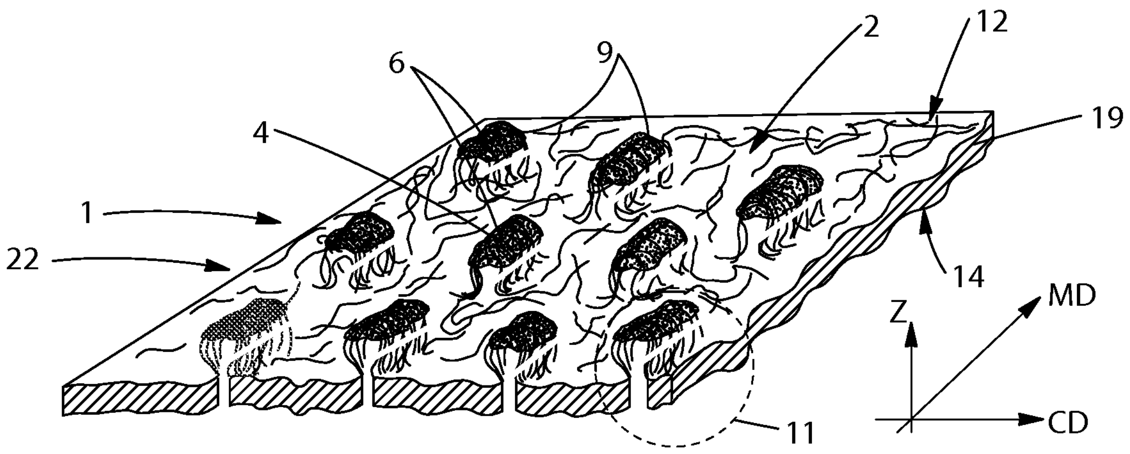

Fig. 10

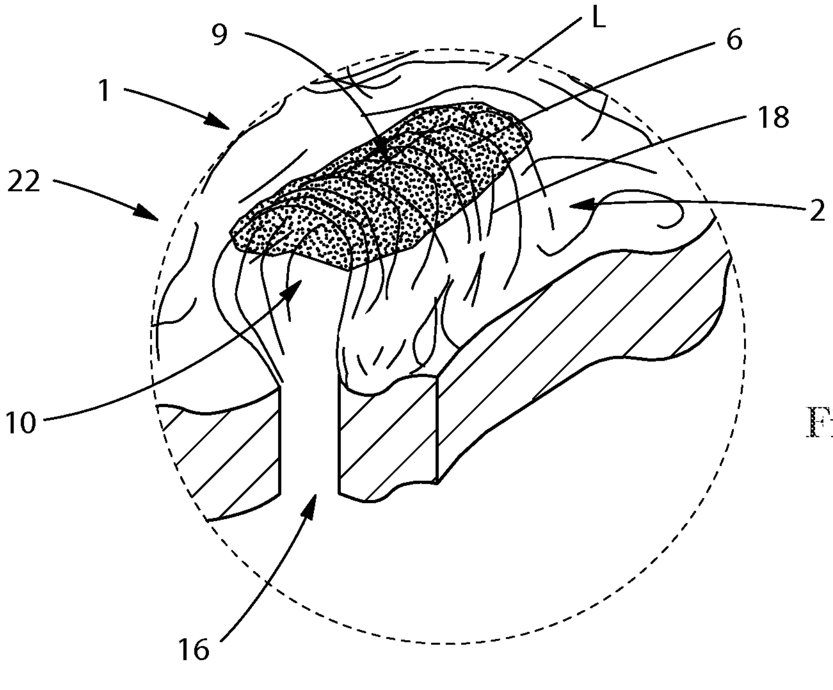

Fig. 11

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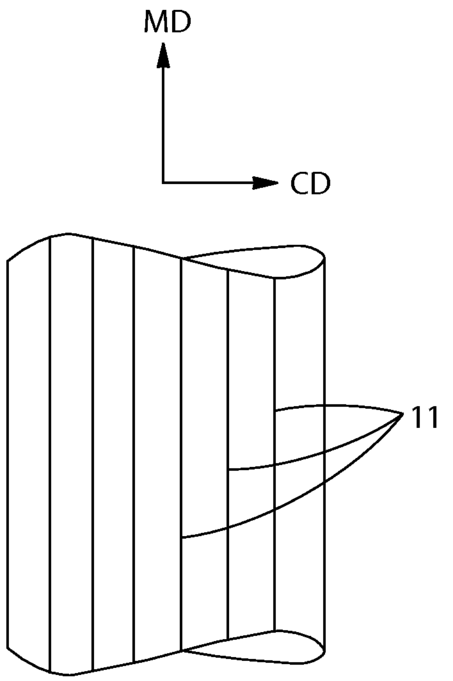

Fig. 12A

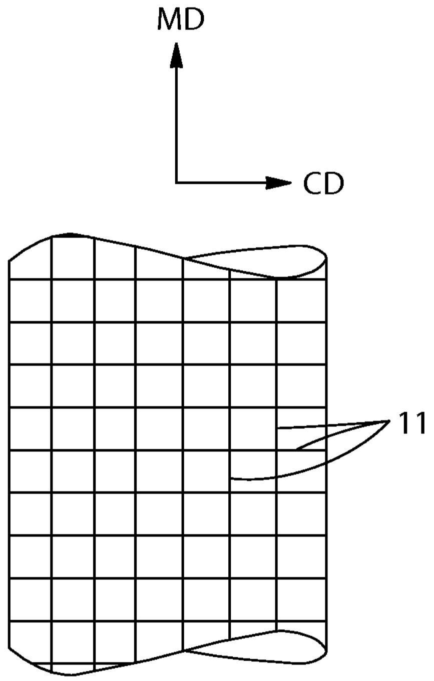

Fig. 12B

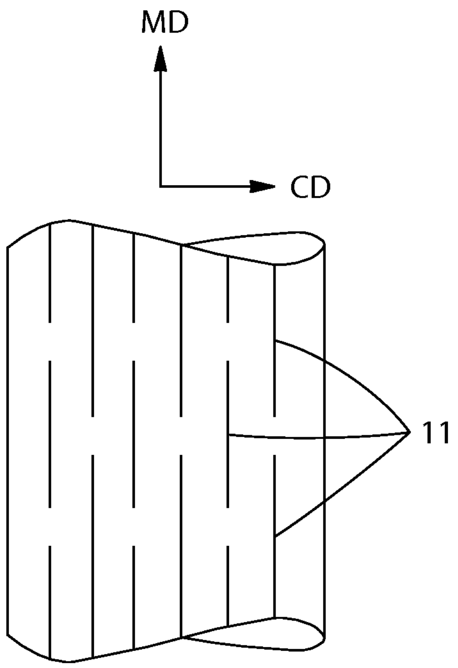

Fig. 12C

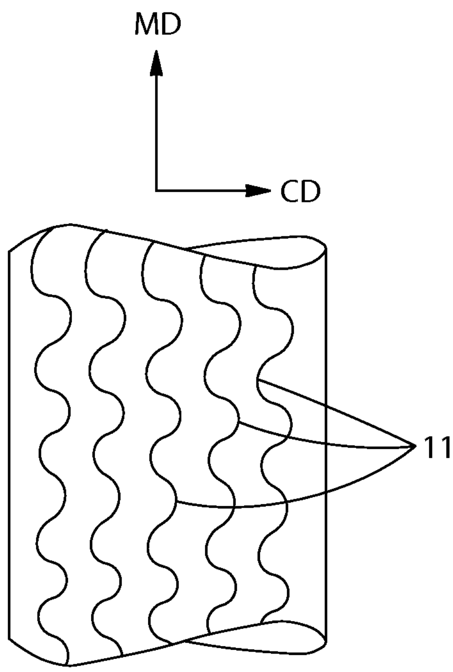

Fig. 12D

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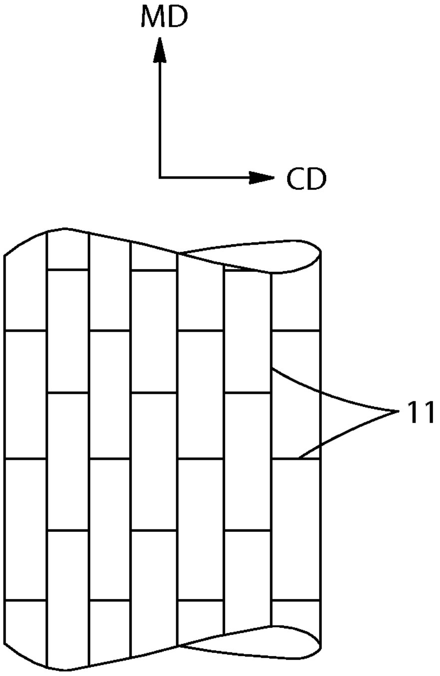

Fig. 12E

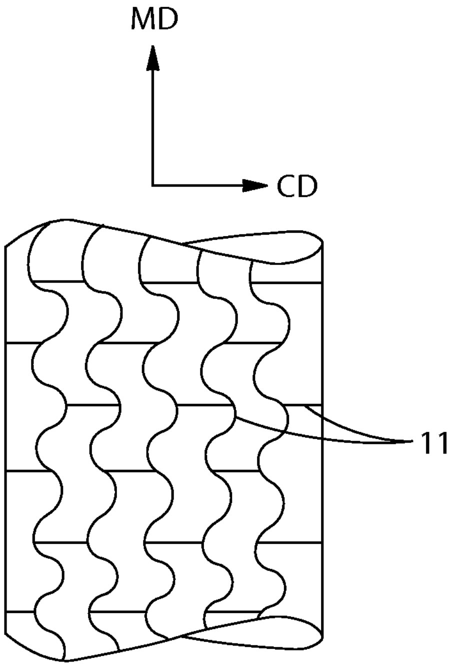

Fig. 12F

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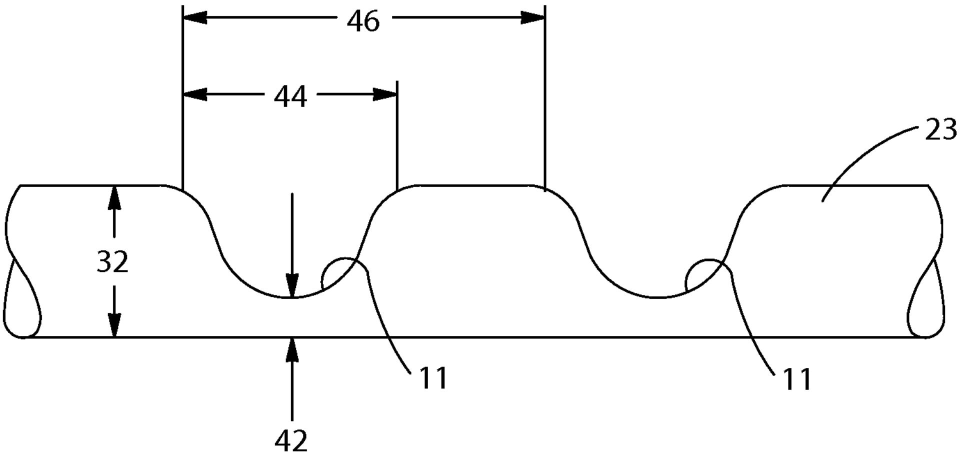

Fig. 13

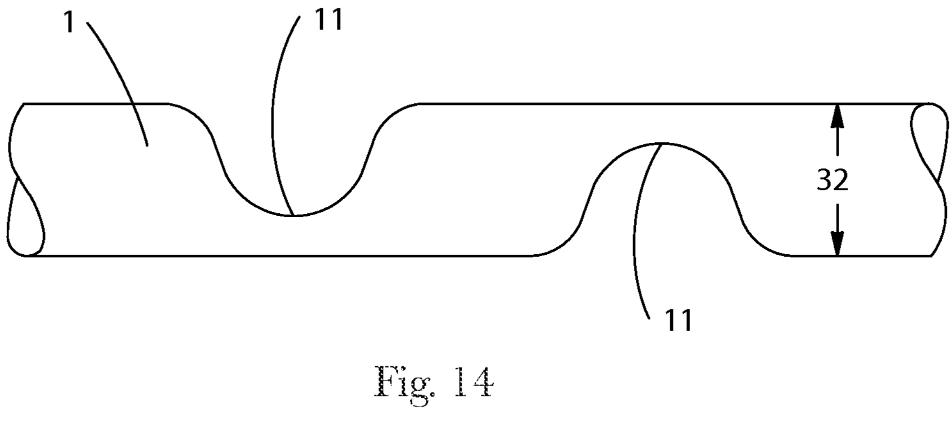

Fig. 14

Fig. 15

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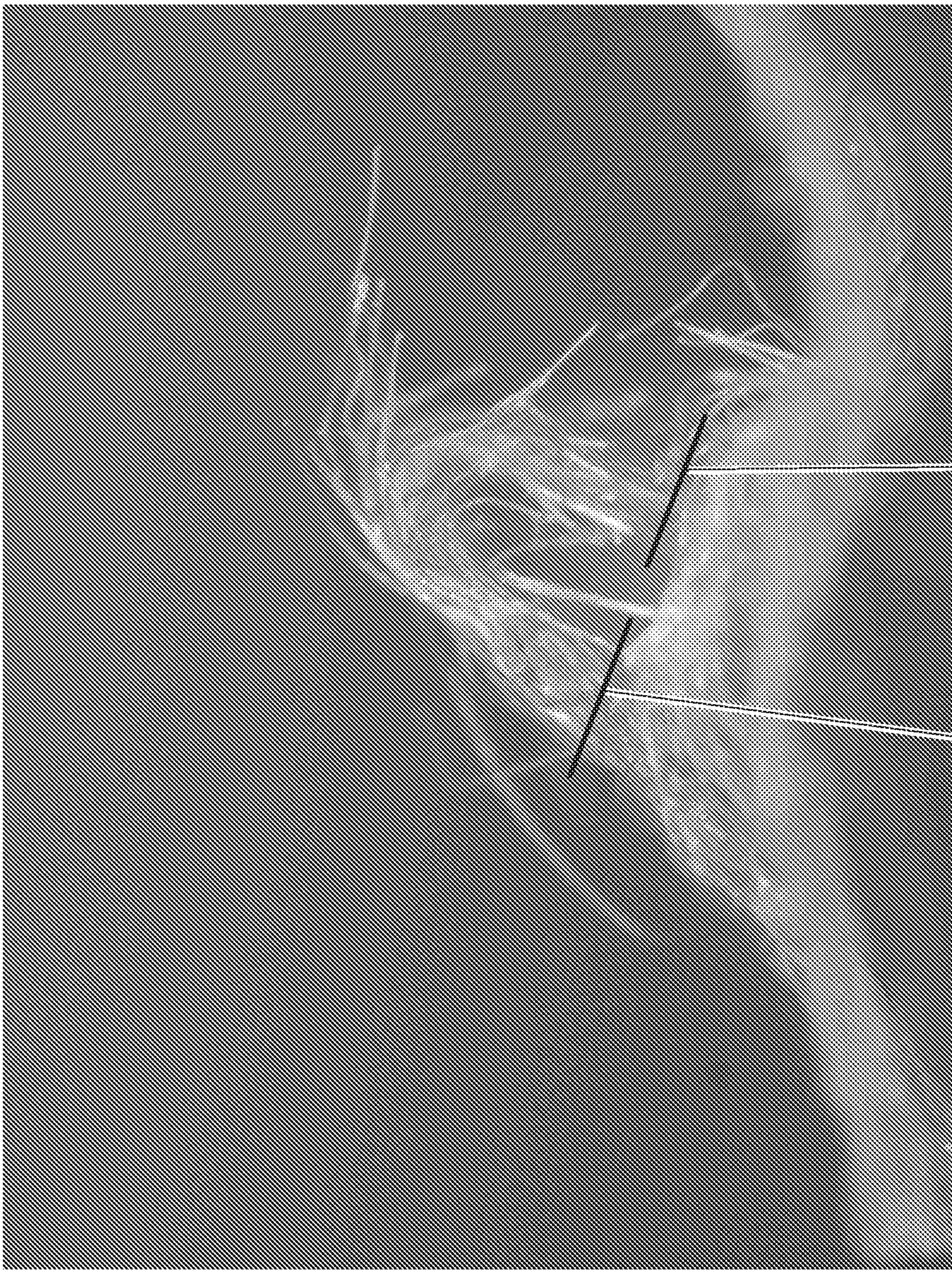

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Fig. 16

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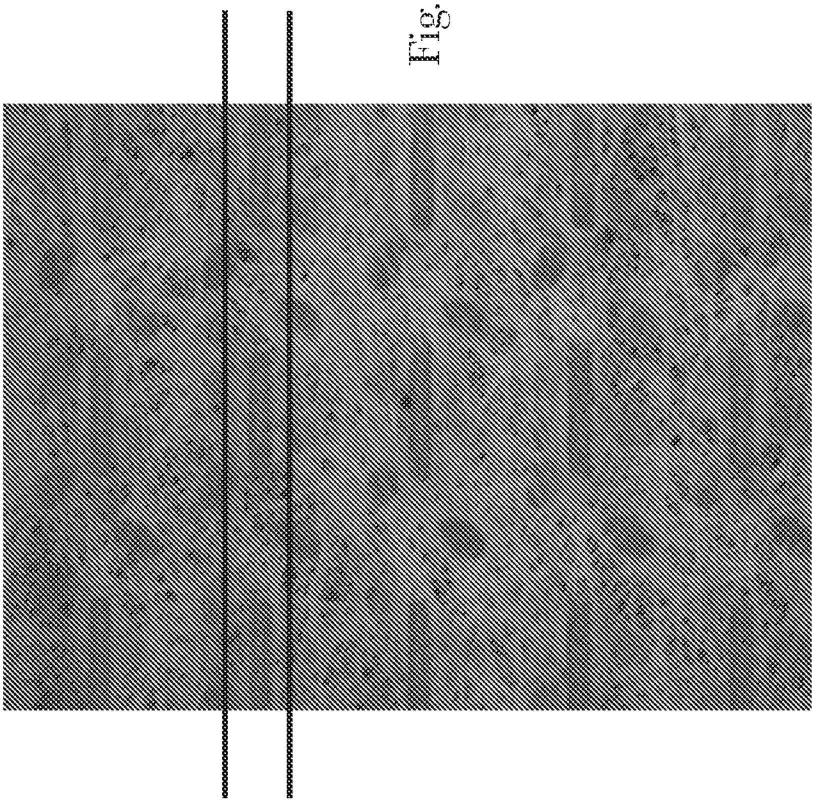

Fig. 17A

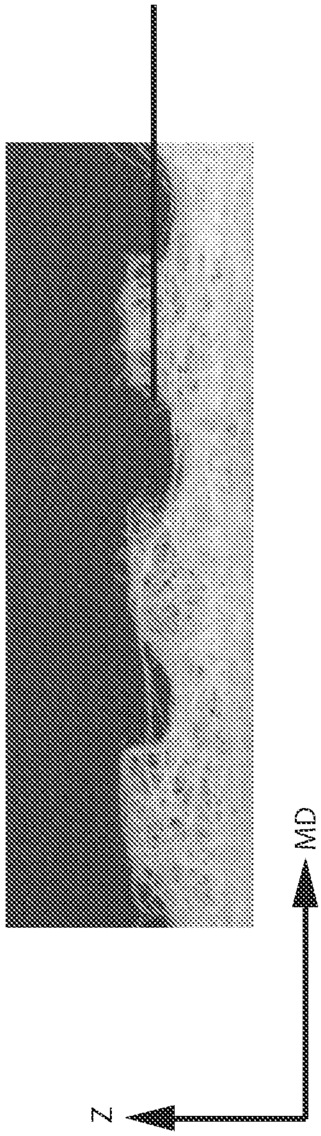

Fig. 17B

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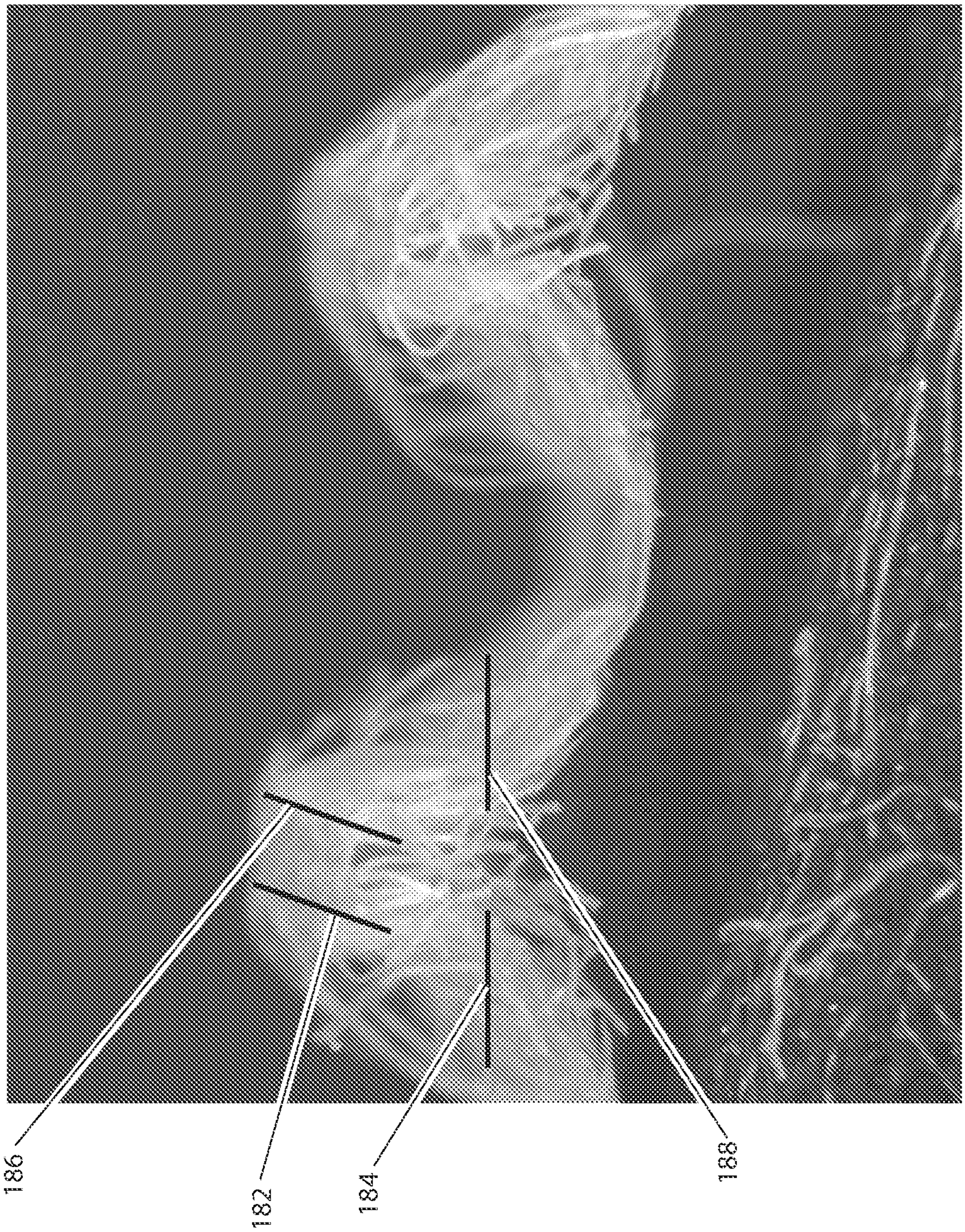

Fig. 18

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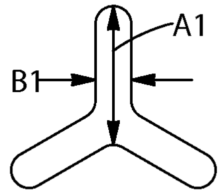

Fig. 19A

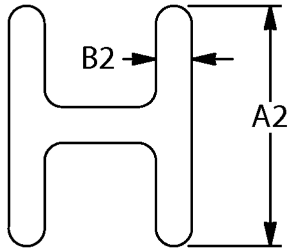

Fig. 19B

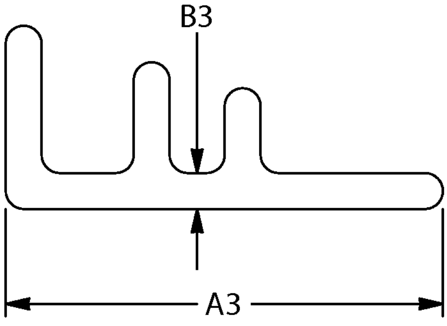

Fig. 19C

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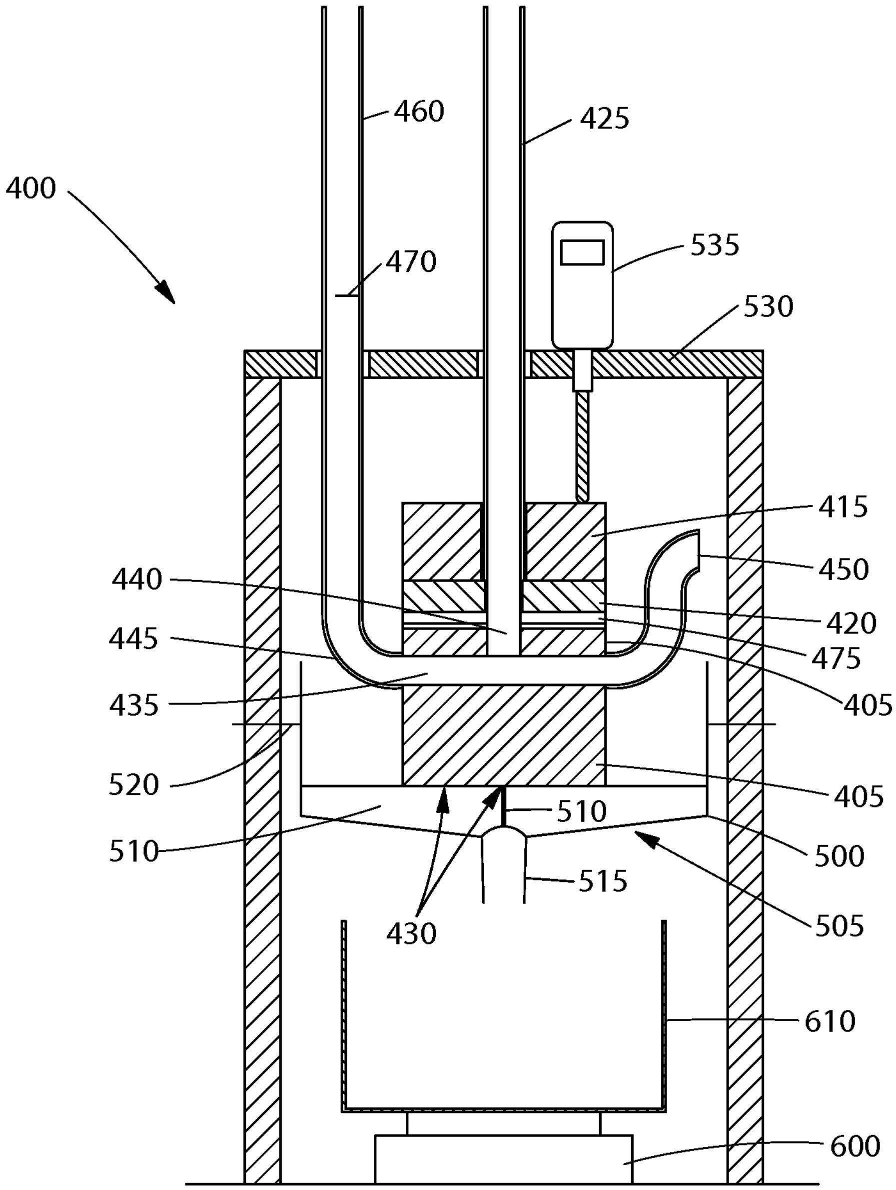

Fig. 20

11349Q

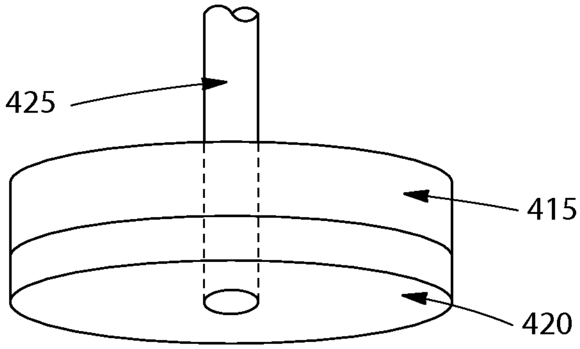

Fig. 21A

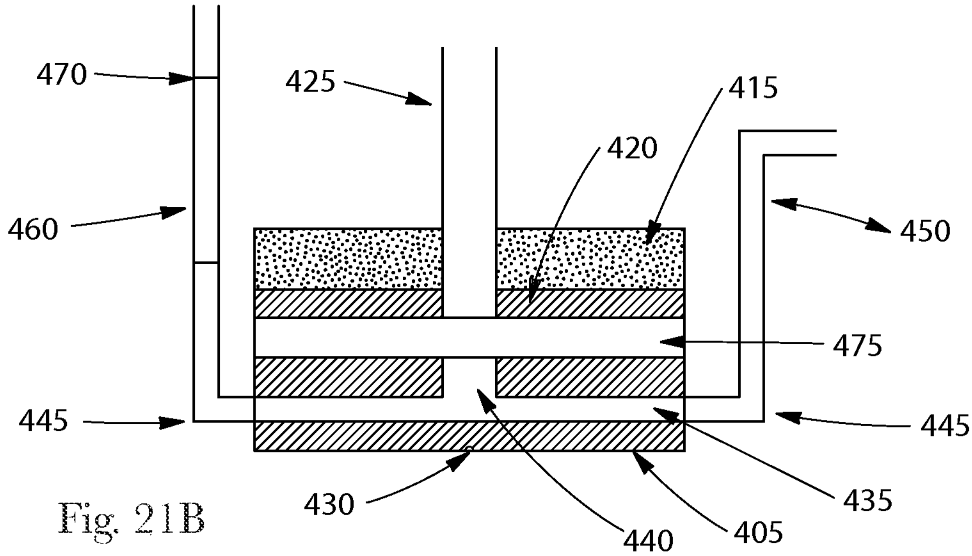

Fig. 21B

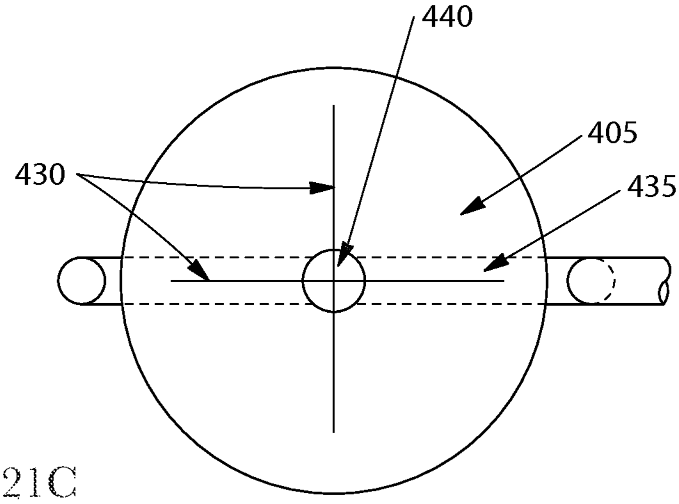

Fig. 21C

11349Q

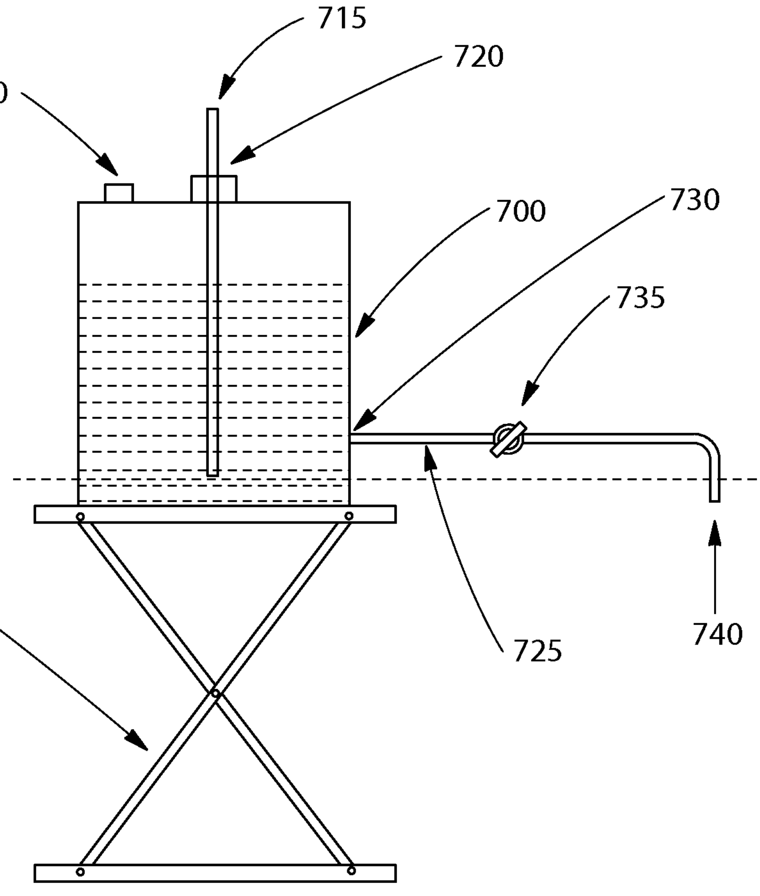

Fig. 22

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2010/037145

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61F13/15 D04H11/08
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61F D04H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/265534 A1 (CURRO JOHN JOSEPH [US] ET AL) 30 December 2004 (2004-12-30) paragraphs [0030], [0101]; figures 1-15; table 1	1-15
X	WO 2008/005500 A2 (PROCTER & GAMBLE [US]; HUPP MATTHEW TODD [US]; REDD CHARLES ALLEN [US]) 10 January 2008 (2008-01-10) page 5, line 5 - page 5, line 8; figures 1,2	1-15
X	WO 2004/058117 A1 (PROCTER & GAMBLE [US]) 15 July 2004 (2004-07-15) page 6, paragraph 3; figures 1-24	1-15
X	WO 2004/058214 A1 (PROCTER & GAMBLE [US]) 15 July 2004 (2004-07-15) page 8, last paragraph - page 10, line first; figures 1,2	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 October 2010	28/10/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Gennari, Silvia

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2010/037145

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