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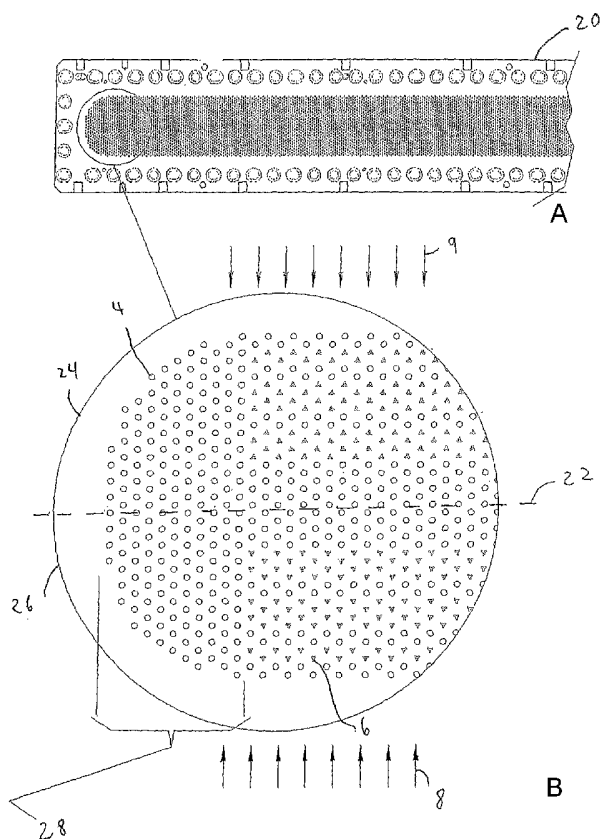
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(54) Title: FORMING SHAPED FIBER FABRICS



(57) Abstract: A fibrous product including a mixture of different shaped fibers is formed utilizing a spin pack assembly including a spinneret with at least two spinneret orifices having different cross-sections. In addition, the formation of the fibrous product is enhanced by controlling the pressure drop upstream from the spinneret orifices, which in turn facilitates effective control of fiber denier. A metering/distribution plate is preferably provided in the spin pack with channels having selected dimensions that control the pressure drop of molten polymer flowing through the spin pack. The metering/distribution plate can be retrofitted into existing systems and easily exchanged with other metering/distribution plates to enhance formation of the fibrous product with different fiber shapes.

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FORMING SHAPED FIBER FABRICS

CROSS-REFERENCE TO RELATED APPLICATION

5 This application claims priority from U.S. Provisional Patent Application Serial No. 60/588,328, entitled "Mixed Filament Spunbond" and filed July 16, 2004. The disclosure of the above-identified patent application is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

10 The present invention relates to equipment for forming fibrous fabrics comprising a mixture of shaped fibers.

BACKGROUND OF THE INVENTION

15 Commercial woven and nonwoven fabrics are typically comprised of synthetic polymers formed into fibers. These fabrics are typically produced with solid fibers that have a high inherent overall density, typically in the range of from about 0.9g/cm^3 to about 1.4g/cm^3 . The overall weight or basis weight of the fabric is often dictated by a desired
20 opacity and a set of mechanical properties of the fabric to promote an acceptable thickness, strength, and protection perception.

One reason for the increased usage of polyolefinic polymers, mainly polypropylene and polyethylene, is that their bulk density is significantly lower than polyester, polyamide and regenerated cellulose fiber. Polypropylene density is around
25 about 0.9g/cm^3 , while the regenerated cellulose and polyester density values can be higher than about 1.35g/cm^3 . The lower bulk density means that at equivalent basis weight and fiber diameter, more fibers are available to promote a thickness, strength and protection perception for the lower density polypropylene.

Another method of addressing consumer acceptance by increasing the opacity of a
30 fabric is by reducing the overall fiber diameter or denier. In fabrics, the spread of "microfiber" technology for improved softness and strength has become fashionable.

Other ways to improve opacity and strength while reducing basis weight and cost at the same time is desired.

SUMMARY OF THE INVENTION

5 In accordance with the present invention, a spinneret comprising at least two spinneret orifices having geometries distinct from each other is provided to form mixed filament fiber products. The different spinneret orifices can be provided at any selected ratio, and any types of cross-sectional fiber geometries can be formed (e.g., multi-lobal, mixed multi-lobal and round of various sizes).

10 In accordance with another embodiment of the present invention, a metering/distribution plate is provided for use in a spin pack assembly that comprises a spinneret including a first set of spinneret orifices and a second set of spinneret orifices, the spinneret orifices of the first set having geometries distinct from the spinneret orifices of the second set. The metering/distribution plate comprises a first set of passages
15 configured to deliver molten polymer flowing through the spin pack assembly to the first set of spinneret orifices, and a second set of passages configured to deliver molten polymer flowing through the spin pack assembly to the second set of spinneret orifices. The passages of the first set may have dimensions that differ from the dimensions of the passages of the second set, and the dimensions of the passages for each set are selected to
20 facilitate the formation of extruded fibers through the first and second sets of spinneret orifices having selected deniers. The metering/distribution plate decouples the pressure drop from the spinneret orifices to facilitate greater control in orifice geometry and fiber denier.

In still another embodiment of the present invention, a spin pack assembly
25 comprises a spinneret comprising a first set of spinneret orifices and a second set of spinneret orifices, the spinneret orifices of the first set having geometries distinct from the spinneret orifices of the second set. The spin pack assembly further comprises a metering/distribution plate configured to deliver molten polymer flowing through the spin pack assembly to the spinneret, the metering/distribution plate comprising a first set of
30 passages configured to deliver molten polymer flowing through the spin pack assembly to

the first set of spinneret orifices, and a second set of passages configured to deliver molten polymer flowing through the spin pack assembly to the second set of spinneret orifices. The spin pack is further configured to receive different metering/distribution plates, such that one metering/distribution plate can be exchanged for another depending upon a particular application.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of specific embodiments thereof, particularly when taken in conjunction with the accompanying drawings wherein like reference numerals in the various figures are utilized to designate like components.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a cross-sectional view of a round hollow fiber with a shaped hollow core.

Figure 2 illustrates a cross-sectional view of a round hollow fiber which has a round hollow core.

Figures 3A-3D illustrate cross-sectional views of several shaped fibers.

Figures 4A-4E illustrate cross-sectional views of several shaped hollow fibers.

Figure 5A depicts a bottom view in plan of a portion of a spinneret in accordance with an embodiment of the present invention, in which the quench air direction is shown with arrows and the spinneret includes trilobal and solid round spinneret orifices in a ratio of about 90:10 of trilobal to round.

Figures 5B and 5C depict the orifice configurations for forming solid round and trilobal fibers with the spinneret of Figure 5A.

Figure 5D depicts an enlarged view of a portion of the spinneret of Figure 5A.

Figure 6A depicts a bottom view in plan of a portion of a spinneret in accordance with another embodiment of the present invention, in which the quench air direction is shown with arrows and the spinneret includes trilobal and solid round spinneret orifices in a ratio of about 75:25 of trilobal to round.

Figure 6B depicts an enlarged view of a portion of the spinneret of Figure 6A.

Figure 7A depicts a bottom view in plan of a portion of a spinneret in accordance with another embodiment of the present invention, in which the quench air direction is shown with arrows and the spinneret includes trilobal and solid round spinneret orifices in a ratio of about 50:50 of trilobal to round.

5 Figure 7B depicts an enlarged view of a portion of the spinneret of Figure 7A.

Figure 8A depicts a bottom view in plan of a portion of a spinneret in accordance with a further embodiment of the present invention, in which the quench air direction is shown with arrows and the spinneret includes trilobal and hollow round spinneret orifices in a ratio of about 50:50 of trilobal to round.

10 Figures 8B and 8C depict the orifice configurations for forming hollow round and trilobal fibers with the spinneret of Figure 8A.

Figure 8D depicts an enlarged view of a portion of the spinneret of Figure 8A.

Figure 9A depicts a bottom view in plan of a portion of a spinneret in accordance with another embodiment of the present invention, in which the quench air direction is shown with arrows and the spinneret includes trilobal and solid round spinneret orifices in a ratio of about 75:25 of trilobal to round, with arrows showing a double sided quench and a reverse in trilobal spinneret orifice orientation occurring at opposite locations about a centerline of the spinneret.

Figure 9B depicts an enlarged view of a portion of the spinneret of Figure 9A.

20 Figure 10A depicts a top view in plan of a portion of a distribution metering plate that feeds each individual capillary orifice of a spinneret in accordance with the present invention.

Figure 10B depicts an enlarged view of a portion of the distribution metering plate of Figure 10A.

25 Figure 11 depicts an exploded view in elevation and partial section of a spin pack assembly in accordance with the present invention including two melt pumps for supplying and regulating molten polymer flow through the assembly.

Figure 12 depicts an exploded view in elevation and partial section of a spin pack assembly in accordance with the present invention including a single melt pump for supplying molten polymer to the assembly.

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Figure 13 depicts an exploded view in elevation and partial section of another spin pack assembly in accordance with the present invention including a single melt pump for supplying molten polymer to the assembly.

Figure 14A depicts a perspective view of a drilled metering plate for use with a spin pack assembly in accordance with the present invention.

Figure 14B depicts an enlarged view of a portion of the metering plate of Figure 14A.

Figure 15 depicts a schematic of an exemplary spunbond system incorporating a spin pack assembly in accordance with the present invention.

Figure 16 is a graph of the opacity measurement for different shaped fibers.

Figure 17 is a chart showing the MD-to-CD ratio of different shaped fibers.

Figure 18 is a graph of the CD tensile strength of different shaped fibers.

DETAILED DESCRIPTION OF THE INVENTION

All percentages, ratios and proportions used herein are by weight percent of the composition, unless otherwise specified. Examples in the present application are listed in parts of the total composition.

The specification contains a detailed description of (1) materials of the present invention, (2) configuration of the fibers, (3) distribution of fiber mixtures, (4) material properties of the fibers, (5) equipment and processes, and (6) articles.

(1) Materials

Thermoplastic polymeric and non-thermoplastic polymeric materials may be used in the present invention. 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 having 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.

The thermoplastic polymeric materials must be 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, 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 shaped fibers of the present invention may be comprised of a non-thermoplastic polymeric material. Examples of non-thermoplastic polymeric materials include, but are not limited to, viscose rayon, lyocell, cotton, wood pulp, regenerated cellulose, and mixtures thereof. The non-thermoplastic polymeric material may be produced via solution or solvent spinning. The regenerated cellulose is produced by extrusion through capillaries into an acid coagulation bath.

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, 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 be comprised of a single polymer, a blend of polymers, or be multicomponent fibers comprised of more than one polymer.

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.

Optionally, other ingredients may be incorporated into the spinnable composition.

5 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
10 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.

(2) Configuration

20 The fiber shapes 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
25 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 critical point along the outer surface of the fiber. A
30 critical 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 microvoids or internal fibrillation but are recognized as being substantially continuous. There are no critical 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). If described in three dimensional terms, the percent void volume of the fiber will be equivalent to the percent of hollow region.

The percent of hollow region must be controlled for the present invention. The percent hollow is preferably not below 2% or the benefit of the hollow region is not significant. However, the hollow region must not be greater 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 fiber "diameter" of the shaped fiber of the present invention is defined as the circumscribed diameter of 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 fiber will have a diameter of less than 200 micrometers. More preferably the fiber diameter will be from about 3 micrometers to about 100 micrometers and preferably from about 3 micrometer to about 50 micrometers. Fiber diameter is controlled by factors including, but not limited to, spinning speed, mass throughput, temperature, spinneret geometry, and blend composition. The term spundlaid diameter refers to fibers having a diameter greater than about 12.5 micrometers. This is determined from a denier of greater than about 1.0dpf. The basis for using denier in this invention is polypropylene. A 1.0 denier polypropylene fiber that is solid round with a density of about 0.900g/cm³ has a diameter of 12.55 micrometers. Spunlaid diameters are typically from about 12.5 to about 200 microns and preferably from about 12.5 to about 150 microns. 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.

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 diameter, adding the average diameters together, and dividing by the total number of fiber types (different shaped fibers). The average fiber denier is also calculated by measuring each fiber type's average denier, adding the average deniers together, and dividing by the total number of fiber types (different shaped fibers). A fiber is considered having a different diameter or denier 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.

The shaped fibers of the present invention will have a lower overall apparent bulk density. The apparent bulk density is less than the actual density of the same polymeric composition used for of a solid round fiber with the same circumscribed diameter. The

apparent bulk density will be from about 2% to about 50% and preferably from about 5% to about 35% less than the actual density. Apparent bulk density, as used herein, is defined as the density of a shaped fiber with a circular circumscribed diameter as if it were a solid round fiber. The apparent bulk density is less because the mass of the fiber is reduced while the circumscribed volume remains constant. The mass is proportional to the area. For example, the apparent bulk density of a tribal fiber is the circumscribed area of the shaped fiber. Therefore, the apparent bulk density is calculated by measuring the total solid area compared to the total circumscribed area. Similarly, the apparent bulk density of a hollow round fiber is measured by the total circumscribed area of the fiber minus the area of the hollow region. The apparent bulk density of the collection of shaped fibers in a layer can also be calculated.

Figure 1 illustrates a round hollow fiber. The shape of the hollow region of this fiber is not round. Figure 2 is used to illustrate a round hollow fiber. As shown, the center of the hollow region and the center of the hollow fiber are the same. Additionally, the shape or curvature of the perimeter of the hollow region and the hollow fiber are the same. Figures 3A-3D illustrate several different shapes of the fibers including various trilobal and multi-lobal shapes. Figures 4A-4E illustrate shaped hollow fibers.

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 critical point. Multi-lobal fibers in the present invention will generally have less than about 50 critical points, and most preferably less than about 20 critical 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.

The fibers of the present invention may be multicomponent fibers. Multicomponent fibers, commonly a bicomponent fiber, may be in a side-by-side, sheath-core, segmented pie, ribbon, or islands-in-the-sea configurations. Alternatively, the multicomponent fibers may be mixed homo or single component fibers. The sheath may
5 be non-continuous or continuous around the core. If present, a hollow region in the fiber may be singular in number or multiple. The hollow region may be produced by the spinneret design or possibly by dissolving out a water-soluble component, such as PVOH, EVOH and starch, for non-limiting examples.

10 (3) Distribution of Fiber Mixtures

The fiber shapes in the present invention are mixed together in a single layer to provide a synergistic effect versus the presence of substantially all round fibers alone or substantially all non-round fibers alone. "Substantially all" is defined as having less than about 5% of different shapes and is not intended to exclude layers wherein less than 5%
15 of the fibers are different due to not being able to completely control the process. The mixture of shaped fibers having cross-sectional shapes that are distinct from one another in a single layers is also more beneficial than a nonwoven with discrete layers of fibers having distinct cross-sectional shapes. For example, the fibrous fabric of the present invention may perform differently and be more desired than a nonwoven laminate where
20 one distinct layer has substantially all solid round fibers and another distinct layer has substantially all trilobal fibers. These benefits may be observed in opacity and/or mechanical properties. It is believed that the mixture of shaped fibers in a single layer may be beneficial because the different shapes may prevent roping or other non-uniformity issues during production.

25 Due to the need to control fabric opacity and mechanical properties, numerous combinations of fibers shapes mixed together are possible. In general, the fiber mixtures will comprise solid round and hollow round, solid round and multi-lobal, hollow round and multi-lobal, and solid round and hollow round and multi-lobal and combinations thereof.

In order to manifest the additional benefits of fiber mixtures, the minor component of the mixture must be present in sufficient amount to enable differentiation versus 100% isotropically shaped fibers. Therefore, the minor component is present in at least 5% by weight mass of the total fiber composition. Each of the two different shaped fibers can
5 comprise from about 5% by weight to about 95% by weight. The specific percent of each fiber desired depends upon the use of the nonwoven web and specific shape of the fiber.

(4) Material Properties

The fibrous fabrics of the present invention will have a basis weight and opacity
10 that can be measured. 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. The opacity of the fibrous fabric comprising at least one layer comprising a mixture of shaped fibers having cross-sectional shapes that are distinct from one another will be several percentage points of
15 opacity greater than the fibrous fabric containing substantially all round fibers with the same average fiber denier and basis weight and made of the same polymeric material. The opacity may be from about 2 to about 50 percentage points greater and commonly from about 4 to about 30 percentage points greater. Preferably, the opacity will be at least about 5% greater, more preferably 7% greater, and most preferably about 10% greater.

20 Figure 16 is a graph of the percent opacity versus basis weight for several different fiber shapes and mixtures of shaped fibers. As can be seen, a mixture of 75% trilobal fibers and 25% solid round fibers and a mixture of 50% trilobal fibers and 50% solid round fibers both have higher opacity measurements at equivalent basis weights than 100% hollow round fibers and 100% solid round fibers.

25 Basis weight is the mass per unit area of the substrate. Independent measurements of the mass and area of a specimen substrate are taken and calculation of the ratio of mass per unit area is made. Preferably, the basis weight of the layer comprising a mixture of shaped fibers having cross-sectional shapes that are distinct from one another will be from about 1 grams per square meter (gsm) to about 150 gsm depending upon the use of the
30 fibrous fabric. More preferable basis weights are from about 2 gsm to about 30 gsm and

from about 4 gsm to about 20 gsm. The basis weight of the total fibrous fabric (including the layer comprising a mixture of shaped fibers) is from about 4 gsm to about 500 gsm, preferably from about 4 gsm to about 250 gsm, and more preferably from about 5 gsm to about 100 gsm.

5 Additionally, the fibrous fabrics produced from the shaped fibers will also exhibit certain mechanical properties, particularly, strength, flexibility, elasticity, extensibility, softness, thickness, 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 that is related to both
10 flexibility and texture. Absorbency relates to the products' ability to take up fluids as well as the capacity to retain them. The fibrous fabrics of the present invention will also have desirable barrier properties.

Preferably, the fibrous fabric comprising at least one layer comprising a mixture of shaped fibers having cross-sectional shapes that are distinct from one another will have a
15 machine direction to cross-machine direction ratio (MD-to-CD ratio) lower than a fibrous fabric produced with substantially all trilobal cross-sectional fibers having the same polymeric material, equivalent fiber denier, and basis weight. Additionally, it is desired that the fibrous fabric of the present invention will also have a CD strength and/or total (MD+CD) strength that is greater than the fibrous fabric with substantially all trilobal
20 cross-sectional fibers. Having the MD-to-CD ratio lower than a substantially all trilobal layer can be desired as the CD strength of the trilobal layers is not as high as desired and the MD strength may be too high. It is desired to have a relatively high CD strength in a layer so that the basis weight does not need to be increased to achieve the relatively high CD strength. The relatively high CD strength is desired in some application for keeping
25 the tabs and/or fasteners attached in an absorbent article. If the MD strength is too high (or the basis weight must be increased to increase the CD strength creating a very high MD strength), issues in the converting process may occur. Therefore, to get the best performance, it is desired to control the MD-to-CD strength ratio and keep a high total strength. The MD and CD tensile strengths can be measured by ASTM D1682.

Figure 17 is a chart of the MD-to-CD ratio for several different fiber shapes and mixtures of shaped fibers. As can be seen, a mixture of 75% trilobal fibers and 25% solid round fibers and a mixture of 50% trilobal fibers and 50% solid round fibers both have a lower MD-to-CD ratio than 100% trilobal fibers. Figure 18 is a graph of CD tensile strength versus bonding temperature for several different fiber shapes and mixtures of shaped fibers. As can be seen, a mixture of 75% trilobal fibers and 25% solid round fibers and a mixture of 50% trilobal fibers and 50% solid round fibers both have a higher CD strength at all bonding temperatures than 100% trilobal fibers.

10 (5) Equipment and Processes

The fibrous fabric formed by the equipment of the present invention is a spunmelt nonwoven fibrous fabric. Spunmelt is defined to mean thermoplastic extrusion. Spunmelt includes spunlaid and meltblown processes. Spunmelt also includes spunbond fabrics.

The first step in producing a fiber is the heating of raw, extrudable polymer materials that are typically mixed together as they are melted and/or transported so as to form a homogeneous melt with proper selection of the composition. The melt is conveyed (e.g., via one or more extruders and/or melt pumps) through capillaries or channels to form fibers. The fibers are then attenuated and collected. The fibers are preferably substantially continuous (i.e., having a length to diameter ratio greater than about 2500:1), and will be referred to as spunlaid fibers. A collection of fibers is combined together using at least one of heat, pressure, chemical binder, mechanical entanglement, hydraulic entanglement, and combinations thereof resulting in the formation of a nonwoven fibrous fabric. The fibrous fabric may then be incorporated into an article.

Exemplary equipment that can be used to produce any of the shaped fibers and fibrous fabrics as described herein preferably includes the following main parts: (1) Extruders and/or melt pumps to melt, mix and meter the polymer component, (2) a spin pack system or assembly comprising a polymer melt distribution system and spinneret that delivers a polymer melt(s) to capillaries that have shaped orifices, (3) attenuation device driven by pneumatic air, positive pressure, direct force and/or vacuum by which air drag forces act on a polymer stream to attenuate the fiber diameter to smaller than the orifice

overall geometric shape, (4) fiber laydown region where fibers are collected underneath the attenuation device in a random orientation (defined by having machine direction and converse direction fiber orientation ratio less than 10), and (5) fiber bonding system that prevents long range collective fiber movement. Numerous companies manufacture fiber and fabric making technologies that can be used for the present invention, non-limiting examples include Hills Inc., Reifenhauser GmbH, Rieter Corporation, Neumag GmbH, Nordson Fiber Systems and others.

In particular, the equipment described herein is important for incorporating shaped fibers in fabrics for better opacity and mechanical properties, where shaped fibers are typically produced using a special spin pack system that shapes the polymer melt stream as it exits the spinneret.

In accordance with the invention, filaments of mixed shapes, such as round and trilobal, are formed with a spinneret that includes suitable mixtures of orifice geometries so as to form a blend of two or more types of fibers or filaments having different shapes or cross-sectional geometries at any selected ratios. While fibers having any suitable cross-sectional geometries can be formed, preferred blends of fibers are solid and/or hollow round fibers with multi-lobal fibers. Exemplary multi-lobal fibers that can be formed with the spinneret include, without limitation, trilobal, delta, cross shaped, and/or penta-lobal (e.g., shapes such as those described above and depicted in Figures 3A-3D). Trilobal is a preferred cross section because of the high surface area to weight ratio of the fiber, and the relative ease of manufacturing the spinneret orifice. The system can be configured to form mixed filaments that have the same polymer, the same polymer with different additives, two or more different polymers and/or multi-component fibers. If multi-component fibers are used, bi-components are the preferred type. However, other multi-component fiber types can also be formed including, without limitation, sheath/core, islands-in-the-sea, segmented pie, etc. The locations and orientations of the different shaped orifices along the spinneret can also enhance the formed product as described below.

Figures 5-9 depict exemplary embodiments of spinnerets in accordance with the invention that yield two types of filament shapes or geometries, namely trilobal and

round, in ratios from 90:10 to 50:50. However, it is noted that the invention is not limited to such range of ratios. In particular, spinneret configurations are possible that yield fabrics having different filaments ranging in ratios, for example, from 95:5 to 5:95 for two filament shapes (e.g., 80:20 of multi-lobal to round). In addition, spinnerets may also
5 include any suitable ratios of more than two different shapes of fibers. For example, a spinneret can be formed including suitable orifices that forms any selected ratio (such as a 25:40:35 ratio) of trilobal to solid round to hollow round filaments.

The spinneret holes or orifices are also preferably oriented for certain orifice geometries in a selected manner based upon the direction at which a quenching medium,
10 such as quench air, is directed to contact the fibers emerging from the spinneret. For example, when forming trilobal filaments from trilobal shaped spinneret orifices (e.g., such as fibers depicted in Figures 3A and 3D), optimum spinning conditions can be achieved when a single tip portion, leg or lobe (e.g., a lobe 1 as indicated in Figures 3A and 3D) of at least some of the trilobal fibers is aligned or oriented in a direction toward
15 or facing a source of quenching medium. Other multi-lobal fiber configurations can also be aligned in a similar manner as the arrangement of trilobal fibers described above to achieve enhanced spinning conditions. The spinneret orificies are therefore configured to achieve such an alignment for the multi-lobal fibers emerging from the spinneret. The orientation of the multi-lobal orifices on a spinneret in this manner is very important for
20 commercially producing fabrics as described herein, particularly when utilizing spinnerets having more than one multi-lobal orifice per 1cm^2 .

In the present invention, fiber mixtures are produced by distributing the various orifice geometries along the bottom or outlet surface of the spinneret to produce a relatively uniform fiber distribution of shapes on fiber laydown through their spatial
25 location across the spinneret face. The spinneret includes generally vertical channels or counterbores that extend from a top or inlet surface of the spinneret to spinneret orifices disposed at the bottom or outlet surface of the spinneret. Several examples of spinnerets are shown in Figures 5-9 with different spinneret orifice distributions. However, it is noted that any suitable spinneret orifice distribution can be configured for the spinneret in
30 accordance with the invention (i.e., the invention is in no way limited to these examples).

Referring to Figure 5A, a spinneret 2 is depicted including a distribution of orifices that yields a ratio of 90:10 of trilobal to solid round filaments. Figures 5B and 5C respectively depict round orifice 4 and trilobal orifice 6 geometries as can be seen along the bottom (i.e., outlet) surface of the spinneret. An enlarged view of a portion of spinneret 2 is depicted in Figure 5D, where it can be seen that the trilobal orifices 6 are all arranged along the outlet surface of the spinneret in the same or substantially similar alignment with each other. In particular, the trilobal orifices 6 are formed in the spinneret 2 such that a single lobe of each of the trilobal fibers emerging from the spinneret is aligned in a direction that generally faces a source of quench air. In other words, the trilobal fibers are formed such that a single lobe of each of these fibers is oriented in a direction that opposes a direction in which quench air (shown by arrows 8 in Figure 5A) is flowing from the quench source to contact the fibers.

This trilobal orientation allows the quench air to contact the majority of all the lobes of the trilobal fibers that are aligned with respect to the quench air, resulting in highly uniform quenching and physical properties for the fibers. This orientation also prevents the quench air from potentially rotating the trilobal fibers, which would have an adverse effect and cause turbulence and filament-to-filament collisions in the spinning process. As noted above, a spinneret including any number and types of multi-lobal orifices that produce multi-lobal fibers will benefit from a configuration similar to that depicted in Figures 5A-5D (as well as Figures 6-9 as described below), where the fibers are formed such that a lobe of at least some of the fibers emerging from the spinneret is aligned in a direction that faces the quench source and generally opposes the flow direction of a quench air used to quench the fibers.

Figures 6A - 6B and 7A - 7B depict a spinneret including solid round orifices 4 and trilobal orifices 6, where spinneret 10 of Figure 6A includes a 75:25 ratio of trilobal to round orifices and spinneret 12 of Figure 7A includes a 50:50 ratio of trilobal to round orifices. The trilobal orifices in each spinneret 10, 12 are aligned in a similar manner as the trilobal orifices for spinneret 2 described above and depicted in Figure 5A, such that a single lobe of each trilobal fiber 6 emerging from the spinneret is aligned in a direction

facing a quench air supply source and generally opposing the flow direction of quench air (shown by arrows 8) that is used to quench the fibers.

Figure 8A depicts a spinneret 14 that includes a 50:50 ratio of trilobal orifices 6 and hollow round orifices 7 (i.e., orifices that yield hollow round fibers). The trilobal orifices are arranged in spinneret 14 such that the trilobal fibers formed are aligned with respect to the quench air (shown by arrows 8) in the same manner as described above for the embodiments depicted in Figures 5-7.

Referring to Figure 9A, a spinneret 20 is depicted that includes a 75:25 ratio of trilobal orifices 6 to solid round orifices 4. However, in this embodiment, as can be seen from Figure 9B, fibers emerging from spinneret 20 are subjected to a two-sided quench, where two streams of quench air are directed in generally opposing directions with respect to each other toward the fibers and oriented at opposing sides of the spinneret (depicted as arrows 8 and 9 in Figure 9B). Two-sided quenching is often desired in spunbond processing to achieve rapid and effective cooling of the extruded fibers. To achieve a similar benefit as described above for the trilobal fibers being contacted with the quench air, the orientation or alignment of trilobal orifices 6 disposed along one section of spinneret 20 differs with respect to the orientation of trilobal orifices 6 disposed along at least one other section of the spinneret.

In particular, as can be seen in Figure 9B, spinneret 20 includes two halves that are separated along a centerline (indicated by dashed line 22 in Figure 9B) extending the length (i.e., between longitudinal ends) of the spinneret. The trilobal orifices 6 on a first half section 24 of the spinneret are aligned or oriented such that a single lobe of each of the trilobal fibers emerging from spinneret 20 is aligned in a direction that faces a quench supply providing the closest source of quench air (indicated by arrows 9) that quenches these fibers. The trilobal orifices 6 on a second half section 26 of the spinneret, as can be seen from the outlet surface of spinneret 20, have a reverse orientation (i.e., a 180° rotational orientation) in relation to the trilobal orifices 6 on the first half section 24, such that a lobe of each of the trilobal fibers emerging from spinneret 20 is aligned in a direction that faces a quench supply providing the closest source of quench air (indicated by arrows 8) that quenches these fibers.

Depending upon the directions of quenching medium flowing toward fibers emerging from the spinneret, spinnerets can be designed in accordance with the invention including the same type of multi-lobal orifices formed within the spinneret but with groups or sections of multi-lobal orifices being arranged along the spinneret in any number of different orientations with respect to multi-lobal orifices of other sections arranged along the spinneret, which facilitates the formation of multi-lobal fibers oriented in a similar manner as described above with respect to the varying directions of quenching medium flow aimed toward the fibers. For example, a spinneret can include two or more sections of the same multi-lobal orifices, where the multi-lobal orifices of one section are oriented on the outlet surface of the spinneret at any suitable angle of rotation (e.g., 45°, 90°, 135°, 180°, etc.) with respect to multi-lobal orifices of one or more other sections of the spinneret so as to facilitate alignment of a single lobe of at least some multi-lobal fibers of a section in a direction generally facing a closest source of quenching medium that is aimed toward this section of fibers.

Any suitable selection of grouping of orifices with different shapes or geometries can be provided on the spinneret to achieve a desired grouping of resultant mixed filaments or fibers that are extruded from the spinneret. While the embodiments described above and depicted in Figures 5-9 show orifices arranged in generally straight or linear rows and columns, the orientation of spinneret orifices is not limited to such arrangements. Any suitable alignment of spinneret orifices (e.g., selectively patterned or randomized) may be chosen to reduce turbulence and optimize fiber spinning and maximize quench rate. For example, in some applications it may be desirable to have random orientation to aid in the reduction of roping or other non-uniformity issues.

In another embodiment of the invention, the spinneret with mixed orifice geometries (e.g., any of the spinnerets described above and depicted in Figures 5-9) can be a full fabric width spinneret (i.e., a spinneret having a longitudinal dimension of at least about 500 millimeters).

In the spinneret embodiment of Figures 9A and 9B, the spinneret orifices are arranged such that substantially entirely round orifices are disposed at a selected distance from each of the lengthwise or longitudinal ends of spinneret 20 (as shown by

bracket 28 of Figure 9B). This selected distance from the longitudinal ends of the spinneret corresponds with the edge of the fiber product that is formed and which is typically trimmed or removed in some manner from the product. It is generally easier to yield good spinning and prevent or minimize filament breaks with round spinneret orifices, and round orifices are also less costly to manufacture than multi-lobal orifices. Thus, as can be seen in Figure 9B, substantially no trilobal orifices are provided within this selected outer area of the spinneret outlet surface (the area indicated by bracket 28).

Preferably, round orifices 4 are also disposed along all of the outer edges of the spinneret and also at or near the middle portion of the spinneret (as depicted in Figure 9B), since this is typically where turbulence in fiber flow is the greatest, and round fibers are less susceptible to twisting or breaking when exposed to turbulence in comparison to multi-lobal fibers. Thus, a spinneret configuration such as is depicted in Figures 9A and 9B provides enhanced fabric or other fiber product formation by minimizing twisting or breakage of fibers (particularly of the multi-lobal fibers) as well as enhancing the quenching of the formed fibers.

In addition to enhancing fiber product formation with mixed filament geometries by designing the spinneret in the manner described above, other components of the spin pack assembly can be designed to improve system performance and enhance the fiber product. A flexible spin pack system or assembly is provided in accordance with the invention, where the spin pack system is utilized in an economical and efficient manner to produce various types of mixed filaments. The spin pack system can include any suitable spinneret, such as the spinnerets described above. It is preferable that the flexible spin pack system, or at least portions of the system (e.g., metering/distribution plates) are configured to be retrofitted to existing spunlaid lines. The term "spunlaid" is used herein to describe a spinning system that includes the extruder, polymer metering system, spinpack, cooling section, fiber attenuation, fiber laydown and deposition onto a belt or drum and vacuum. The spunlaid system does not denote the type of fiber consolidation.

A spunbond line includes a spunlaid line and thermal point bonding. The equipment before the fiber consolidation is substantially similar or identical on a

spunbond line and a spunlaid line. An exemplary embodiment of a spunbond line is described below and depicted in Figure 15.

The flexible spin pack system of the present invention includes a metering/distribution system that effectively meters and distributes molten polymer to the various spinneret orifices. Preferably, the spin pack system utilizes one or more low cost metering/distribution plates. The metering/distribution plates can be of any suitable types, such as those described in U.S. Patent No. 5,162,074 ("the '074 patent"), which is incorporated herein by reference in its entirety, so as to deliver and meter the polymer in a homo or multipolymer system to each spinneret orifice. In particular, a metering/distribution plate includes horizontal passages (referred to as channels) and/or vertical flow passages (referred to as through-holes) that extend within the plate so as to facilitate metering and/or distribution of polymer flow through the plate and between a top or inlet surface of the plate and a bottom or outlet surface of the plate, which in turn facilitates the flow of polymer to the spinneret.

An exemplary embodiment of an etched metering/distribution plate 30 is depicted in Figures 10A and 10B. The plate includes a number of passages or channels etched within and extending generally horizontally along an upper or inlet surface of plate 30. Alternatively, it is noted that the channels may be formed via a suitable machining process. The generally horizontally-extending channels are formed having selected dimensions (e.g., lengths, widths and depths) that facilitate at least partial control of polymer flow through the metering/distribution plate to the spinneret. The generally horizontally-extending channels further extend to and are in fluid communication with vertical passages or through-holes that extend generally vertically within plate 30 to a bottom or outlet surface of the plate. The through-holes are aligned on the metering/distribution plate such that, when the plate is placed in the spin pack assembly over and in contact with the spinneret, the through-holes are in fluid communication with capillaries or counterbores of the spinneret that lead to the spinneret orifices.

Alternatively, it is noted that the vertical orientation of the etched or machined metering/distribution plate with respect to the spinneret can also be reversed, such that the top or inlet surface of the metering/distribution plate includes the through-holes and the

bottom or outlet surface of the plate includes the generally horizontal channels that are in communication with the counterbores of the spinneret.

The channel dimensions of each channel of the metering/distribution plate can remain generally constant or, alternatively, one or more channel dimensions can vary
5 along the length of the channel between the upstream channel end (i.e., the channel end that serves as the channel inlet that receives molten polymer from an upstream component of the spin pack assembly) and the downstream channel end (i.e., the channel end that is adjacent and communicates with the vertical through-hole of the plate).

In addition, the transverse cross-sectional geometries of each of the
10 metering/distribution plate channels can have any suitable shapes, with one or more channel walls being generally planar, curved (e.g., rounded, concave or convex) and/or pitched at any selected slopes between the upstream and downstream channel ends. In an exemplary embodiment, the etched (or machined) channels in the metering/distribution plate can include a transverse cross-sectional shape including a generally concave bottom
15 surface and generally flat or planar side wall surfaces. Other cross-sectional channel shapes can also be provided for the metering/distribution plate. In addition, the metering/distribution plate channels can be formed with a variety of different length to width and width to depth ratios, where the selection of specific dimensional ratios will depend upon a particular application. Exemplary channel width to channel depth ratios
20 for the metering/distribution plate channels are in the range of about 1.5:1 to about 15:1, but these ratios can also be larger or smaller depending upon a particular application.

The vertically extending through-holes of the metering/distribution plate can also have any suitable dimensions to facilitate a desired flow of polymer through the plate. However, it is noted that there is greater flexibility in selection of dimensions for the
25 etched (or machined) and generally horizontally extending channels of the metering/distribution plate, and polymer flow control through the plate can be controlled to a large degree by adjustment of these channel dimensions for a particular application. Thus, a suitable etching process provides an economical and effective metering/distribution plate that includes elaborate channels with varying dimensions.

The metering/distribution plate serves a distribution function by delivering molten polymer, via the various channels in the plate, to selected throughbores and orifices of the spinneret. The plate further serves a metering function in that each passage (e.g., etched or machined channel and/or through-hole) that corresponds with a respective spinneret orifice can be selectively dimensioned (e.g., by selecting etched or machined channel dimensions such as lengths, widths, depths, diameters, etc.) so as to control the pressure drop of the polymer flowing through the passage and thus the delivery of polymer at a desired flow rate to the respective spinneret orifice. This in turn facilitates the control of the formation of a fiber through the respective spinneret orifice at a selected denier and cross-sectional dimension (e.g., diameter). The term "denier," as used herein, refers to the linear mass density of a fiber and is defined as the mass in grams per 9,000 meters of the fiber.

As noted above, metering/distribution plates can be made by a low cost etching process, such as the process described in the '074 patent, to include horizontally aligned channels and vertically aligned through-holes that form the passages in the plates. Such channels and through-holes can also be formed in the plate by a machining process. Alternatively, the passages of the plates can be machined drilled and vertically aligned through-holes, with the drilled through-holes having suitable dimensions to control pressure drop in a similar manner as the horizontal channels of an etched or machined plate. The use of drilled metering plates is described in further detail below.

The use of a metering/distribution plate in a spin pack system in accordance with the present invention provides a number of advantages. In particular, the metering/distribution plate decouples the metering of molten polymer from the spinneret orifice geometry, which allows fibers to be produced from each spinning orifice at one or more desired deniers and also allows for optimization of the spinneret orifice geometry for various other functions, such as polymer shear rate, jet stretch (as described below), as well as final fiber cross section geometry (e.g., forming sharper or more well-defined multi-lobal fibers). One skilled in the art will recognize that the final geometry of an extruded fiber is determined, at least in part, by the design (e.g., geometry and dimensions) of the spinneret orifice. For example, if a sharp trilobal fiber is desired with

long, extended or skinny legs or lobes, the spinneret orifice will also require such a shape. However, such a shape may not be consistent with the metering requirements to produce the desired denier unless at least a portion of the metering can be controlled with a metering plate or some other suitable pressure control mechanism disposed upstream of the spinneret orifice.

Another advantage of the metering/distribution plate in accordance with the invention is that the plate can be changed (i.e., substituted with another plate) in the spin pack to facilitate a change of polymer flow to selected spinneret orifices. This results in a relatively easy and cost effective mechanism for changing the deniers of mixed fibers formed with different shapes in a single system without necessarily requiring a modification to the spinneret.

A still further advantage of the metering/distribution plate in accordance with the invention is that the plate provides for a low cost retrofit into existing and commercially plentiful machines, such as machines manufactured by Reifenhäuser GmbH (Germany) and described in U.S. Patent No. 5,814,349 ("the '349 Patent"), which is incorporated herein by reference in its entirety. The '349 patent describes a "closed" system, where quench air is used to both quench and draw the fibers. The metering/distribution plate of the invention is equally advantageous in "open" systems, where a separate source of compressed air is used to draw the fibers, such as the system described in U.S. Patent No. 6,183,684, which is incorporated herein in its entirety.

A change in metering of molten polymer to the spinneret orifices may be necessary based upon any number of desired changes in the physical dimensions or properties of the fibers formed and/or the process conditions during system operation. For example, any of the following changes in a system may require a change in metering of polymer flow through the spinneret orifices: a change in total polymer throughput (e.g., an increase in polymer throughput or mass flow rate may require a reduction in pressure drop to maintain desired fiber denier), a change in denier for one or more sets of fibers having different cross-sectional geometries, a change in temperature of polymer flowing through the spin pack assembly (which changes viscosity), and a change in the ratio of different shaped spinneret orifices (which results in a different number of formed fibers

having different cross-sectional geometries with respect to the total number of fibers formed from the spinneret) and/or arrangement or pattern of spinneret orifices disposed on the spinneret outlet surface (e.g., different arrangements of round orifices to multi-lobal orifices across the spinneret outlet surface).

5 In designing a spin pack assembly, one or more metering/distribution plates may be provided in the spin pack assembly. For example, a single metering/distribution plate may be provided. Alternatively, two more more metering/distribution plates can be provided in a vertically stacked alignment with each other within the spin pack assembly, where the flow passages of two adjacent plates are in fluid communication with each
10 other to facilitate the flow of molten polymer material between the two plates.

As noted above, the metering/distribution plate can be designed for a particular spin pack system and mixed filament spinneret so as to decouple the pressure drop from the shear rate and jet stretch, all of which are parameters that otherwise are typically addressed when selecting geometric designs for the spinneret orifices. In order to
15 maintain good fiber spinning for a particular application, it is necessary to control pressure drop, shear rate and jet stretch within predefined values. The pressure drop of polymer through a spinneret orifice will depend upon the orifice geometry. For example, in a round spinneret orifice, the pressure drop through the orifice can be calculated as follows (see, e.g., *Dynisco, "Extrusion Processors Handbook", 2nd Edition*):

20

$$P = \frac{2L T_w}{R} \quad (1)$$

where P = pressure drop (psi)

25 L = Length of capillary (inches)

Tw = Shear stress at wall (psi)

R = radius of capillary (inches)

The shear rate is defined as:

30

$$\gamma = \frac{3.3 Q}{R^3} \quad (2)$$

Where γ = shear rate (sec^{-1})

5 Q = flow rate (in^3/sec)

R = radius of capillary (inches)

The jet stretch is defined as the ratio of the maximum spinning velocity of the fibers to the velocity of the polymer at the exit of the spinneret hole.

10 Since at least two types of different shaped fibers are spun in mixed filament spinning, it is necessary to independently control the pressure drop, shear rate and jet stretch through each orifice type (i.e., different shape and/or diameter). By providing greater control in the pressure drop upstream from the spinneret orifice (e.g., via a suitable metering/distribution plate), more flexibility is provided in designing spinneret orifice
15 geometries that are desirable for a particular application. This is achieved in a number of different embodiments in accordance with the invention.

One embodiment employs a spin pack assembly and two metering pumps as depicted in Figure 11. In particular, a spin pack assembly 40 includes, in a vertically stacked alignment, a pack top 42, a filter support plate 44 disposed beneath the pack top, filters disposed within a cavity 43 formed between corresponding grooved portions of the
20 pack top and filter support plate to filter the polymer flowing through the assembly, a metering/distribution plate 46 disposed beneath the filter support plate and including suitable channels for directing polymer through plate 46 and to the spinneret, and a spinneret 48 disposed beneath plate 46 to receive metered polymer to the various orifices
25 of the spinneret.

The filter support plate 44 includes any suitable series of channels or cavities disposed at the bottom or outlet surface of the filter support plate to facilitate fluid communication between polymer flow passages of the filter support plate and the passages of the metering/distribution plate. For example, the outlet surface of the filter
30 support plate may include machined channels that correspond with the etched or

machined channels of the metering/distribution plate (or vertical through-holes of a drilled metering/distribution plate). Alternatively (or in addition to the channels) the outlet surface of the filter support may include one or more cavities to facilitate the formation of one or more melt pools of polymer material within the filter support plate that are to be directed to the metering/distribution plate. When providing cavities within the filter support plate to form melt pools, a valve plate is then provided between the filter support plate and the metering/distribution plate and includes flow passages extending through the valve plate that are in fluid communication with the melt pool(s) and the passages of the metering/distribution plate.

Depending upon a particular application, a series of metering/distribution plates could also be provided in the spin pack assembly of Figure 11 (as well as the spin pack assembly of Figure 12), where the metering/distribution plates are arranged in a vertically stacked alignment with respect to each other and include appropriately aligned passages (i.e., channels and/or through-holes) to facilitate fluid communication between two adjacent plates.

The spinneret includes orifices having different geometries, where the orifices can include any two or more cross-sectional geometries and at any selected ratio of geometries (e.g., spinneret 48 can be any of the types described above and depicted in Figures 5-9). A pump block 50, disposed above pack top 42, supports two metering pumps 52 and 54. The metering pumps deliver molten polymer through the pump block and to the spin pack assembly, where the molten polymer is then filtered and directed to the metering/distribution plate(s) for distribution and metering to the different shaped spinneret orifices.

It is noted that, in certain embodiments, the pack top is not needed and thus does not form part of the spin pack. Thus, the pack top in the assembly of Figure 11 (as well as the embodiments of Figures 12 and 13) can be removed such that the filter support plate lies directly below the pump block.

The flow channels through the various components of the two metering pump system of Figure 11 can be designed such that one pump feeds one type of spinneret orifice (e.g. multi-lobal) and the other pump feeds another type of spinneret orifice (e.g.,

round). In this two metering pump embodiment, the pump speeds can be selected to largely control metering of polymer material flowing through the metering/distribution plate and spinneret, such that the metering/distribution plate serves primarily to distribute the polymer to the different spinneret orifices. If more than two polymer components (or
5 two streams of the same polymer component including different additives) are desired to form the mixed filaments, each additional component would require an extra metering pump. The polymer temperatures fed to or from the two pumps may also be adjusted to assist in achieving desirable polymer conditions including, without limitation, enhanced cross sections, suitable shear rates, etc. The metering/distribution plate can also be used
10 to distribute polymer from the filtration areas to the two types of spinneret orifices. If the metering/distribution plate is manufactured by low cost techniques such as etching, two or more plates may be selectively exchanged within the spin pack assembly 40 to modify polymer flows to different spinneret orifices (resulting, e.g., in different fibers deniers) at a low cost and with relative ease.

15 In another embodiment depicted in Figure 12, a spin pack assembly 60 includes, in a vertically stacked alignment, a pack top 62, a filter support plate 66 disposed below the pack top, a filter formed between corresponding grooved portions of the pack top and filter support plate to filter the polymer flowing through the assembly, a metering/distribution plate 68 disposed below the filter support plate, and a spinneret 70
20 disposed below plate 68. The spinneret includes mixed orifice geometries and can be of any suitable type (such as the types described above and depicted in Figures 5-9). A pump block 72 is disposed above the pack top and supports a single metering pump 74 to deliver molten polymer to assembly 60. Fluid communication between the filter support plate and the metering/distribution plate can be provided in any suitable manner (e.g.,
25 similar to that described above for the embodiment of Figure 11).

During operation, polymer material is delivered by metering pump 74 into assembly 60, where the polymer material is filtered and then directed through the various passages of the metering/distribution plate. The metering/distribution plate 68 is designed in a suitable manner as described above to receive molten polymer from the filter support
30 plate 66, and to at least partially control the pressure drop of polymer flowing to each

spinneret orifice type. The control of the pressure drop through the metering/distribution plate facilitates effective control of the denier of each of the mixed filament fibers extruded from the spinneret.

A further embodiment is depicted in Figure 13 and includes a spin pack assembly 5 80 including, in a vertically stacked alignment, a pack top 82 that includes a filter 84 to filter molten polymer flowing through the assembly, a filter support plate 86 disposed below the pack top, and a spinneret 88 disposed below the filter support plate. As in the previous embodiment depicted in Figure 12, a single metering pump 92, which is supported by pump block 90 disposed above pack top 82, delivers molten polymer to 10 assembly 80. However, assembly 80 does not include a metering/distribution plate. Rather, a cavity 87 is formed within filter support plate 86 at a location where the filter support plate engages the spinneret. The cavity 87 facilitates the formation of a pressurized melt pool of molten polymer as polymer is delivered through the filter to counterbores in the spinneret that lead to the various spinneret orifices. Alternatively, it is 15 noted that the cavity in which the melt pool forms could be provided in the spinneret or both the filter support plate and the spinneret. In this embodiment, the vertically-extending capillaries or counterbores of the spinneret are designed with suitable dimensions (e.g., suitable length to diameter ratios) to facilitate the balance of pressure drops of polymer flow through the spinneret prior to emerging from the spinneret orifices 20 in a manner similar to that in which the metering/distribution plate is designed as in the previous embodiments described above and depicted in Figures 11 and 12.

The embodiment of Figure 13 is primarily suitable when the polymer pressure within the melt pool remains at a specific value. Thus, while it is possible to provide a spin pack assembly without the use of a metering/distribution plate to form the mixed 25 filament products as described herein (where the pressure drop, shear rate and jet stretch is controlled by designing suitable channels and orifices in the spinneret), the use of a metering/distribution plate to control pressure drop, which in turn enables control of the deniers of the mixed filament fibers, is applicable to a much wider range of applications and is thus preferable over spin pack assemblies that do not employ such 30 metering/distribution plates.

As noted above, etched (or machined) metering/distribution plates (such as the plate depicted in Figures 10A and 10B) are effective in at least partially controlling pressure drop to achieve the desired fiber size and denier of different shaped fibers. However, metering/distribution plates can also be manufactured utilizing a drilling process, where passages of varying cross-sectional dimensions are formed by drilling through the plate. In a drilled metering/distribution plate, there are no horizontally extending channels such as in the etched (or machined) plate. Rather, the passages of the drilled plate are generally vertical through-holes extending between the top or inlet surface of the plate and the bottom or outlet surface of the plate. A drilled metering plate typically requires a significant thickness to facilitate a sufficient hole length to achieve the desired control of pressure drop through the plate. In addition, different diameter holes can be used to control and adjust the flow rate through the drilled metering plate/spinneret combination to adjust the deniers of the two types of fibers being spun from the same melt pool.

An exemplary embodiment of a drilled metering/distribution plate 96 is depicted in Figures 14A and 14B. In this embodiment, plate 96 has a suitable thickness to facilitate the formation of through-holes of suitable lengths. The lengths and cross-sectional dimensions of the through-holes (e.g., the length to diameter ratios of the through-holes) can be selected in a similar manner as the channel dimensions in an etched (or machined) metering/distribution plate to facilitate control of pressure drop of polymer flow through the different shaped spinneret orifices, which in turn controls the deniers of different shaped fibers.

For example, through-holes can be drilled in the plate of varying diameters (such as through-holes 97 and 98 of plate 96 depicted in Figures 14A and 14B) to selectively adjust the flow rate through the drilled metering plate/spinneret combination, which in turn controls the deniers of the two types of filaments being spun from the same metering pump and/or melt pool. By using different metering plates, different denier ratios between the two types of spinneret orifices can be obtained without requiring a new spinneret.

However, it is noted that drilled metering/distribution plates are significantly more expensive to produce (e.g., as much as a tenfold or greater increase in cost) than etched

metering/distribution plates, due at least in part to the labor-intensive requirements of drilling thousands of holes per meter along the surface of the plate. In addition, since the drilled plate through-holes are vertically aligned, rather than having a horizontal channel component as in the etched plates, controlling pressure drop in different applications may require significant changes in the drilled plate thicknesses. Thus, certain drilled plates can be very thick (and heavy), depending upon certain applications that require certain through-hole dimensions. This renders the drilled plates less suitable for exchanging or retrofitting within existing spin pack assemblies. In contrast, etched metering/distribution plates with different channel dimensions can be easily changed in an existing spin pack assembly while maintaining generally the same thickness of the plate dimensions (since the horizontal etched channel component is changed). In addition, due to their economic design, etched channel plates can be disposable. Thus, the use of lower cost, etched metering/distribution plates is preferred in the various spin pack assembly embodiments of the invention.

The combination of one or more metering/distribution plates and spinnerets with selective orientations of orifice geometries in a spin pack system or assembly is highly effective in producing a homogenous mixture of shaped fibers in the nonwoven fabrics and other products described herein. As noted above, when utilizing a single spinneret with different shaped orifices, it is extremely important to be able to at least partially control the pressure drop upstream of the spinneret orifices to form fibers with mixed geometries. The mass flow rate through each spinneret orifice type will be different due to pressure drop differences as explained above. Further, at the same or similar mass flow rate in each spinneret orifice type, the spinning characteristics are different and do not lead to identical fiber diameter values. Therefore, the combination of the above-described features for the spinneret and spin pack assembly render enhanced control and production of fiber products including mixed filament geometries.

Spinning

The process of melt spinning is the most preferred embodiment for forming mixed filament products described herein. In melt spinning, there is no intentional mass loss in the

extrudate. Solution spinning may be used for producing fibers from cellulose, cellulosic derivatives, starch, and protein.

Spinning will typically occur at 100°C to about 350°C. The processing temperature is determined by the chemical nature, molecular weights and concentration of each component. Fiber spinning speeds of greater than 100 meters/minute are required. Preferably, the fiber spinning speed is from about 500 to about 14,000 meters/minute. The spinning may involve direct spinning, using techniques such as spunlaid or meltblown, as long as the fibers are mostly continuous in nature. Continuous fibers are hereby defined as having length to width ratio greater than about 2500:1.

The fibers and fabrics made in the present invention often contain a finish applied after formation to improve performance or tactile properties. These finishes typically are hydrophilic or hydrophobic in nature and are used to improve the performance of articles containing the finish. For example, Goulston Technologies' Lurol 9519 can be used with polypropylene and polyester to impart a semi-durable hydrophilic finish.

Figure 15 depicts a schematic of a typical spunbond line 100 utilizing a single polymer source. In this embodiment, any combination of the above described metering/distribution plates, melt pools and/or spinnerets may be employed (e.g., the types of systems described above and depicted in Figures 5-10, 12 and 13) in the spin pack assembly 118. Briefly, the spunbond system includes a hopper 110 into which pellets of polymer are placed. The polymer is fed from hopper 110 to a screw extruder 112, where the polymer is melted. The molten polymer flows through heated pipe 114 into metering pump 116 and spin pack assembly 118, including a spinneret 120 with orifices through which fibers 122 are extruded. The extruded fibers 122 are quenched with a quenching medium 124 (e.g., air), and are subsequently directed into a drawing unit 126 (e.g., aspirator). Upon exiting the drawing unit 126, the attenuated fibers 128 are laid down upon a continuous screen belt 130 supported and driven by rolls 132 and 134. The screen belt conveys the prebonded web of fibers from the lay down location to calendar rolls 144 and 146. The extruder and melt pumps are chosen based on the polymers desired.

While system 100 utilizes a single melt/metering pump, an alternative system can employ two or more metering pumps (e.g., for use with the spin pack assembly of Figure 11). In addition, system 100 may be used with a single polymer or a blend of polymers.

Equipment Examples

5 A spin pack assembly including an etched metering/distribution plate (MDP) and having a configuration similar to the assembly described above and depicted in Figure 12 was used in conducting each of the four examples described below, with results tabulated in Tables 1 and 2. The assembly included a mixed filament spinneret including 20,000 orifices of multi-lobal and solid round geometric configurations. In particular, the multi-
10 lobal fibers of Examples 1-3 are trilobal fibers (e.g., similar to the fiber depicted in Figure 3A), while the multi-lobal fibers of Example 4 are cross-shaped fibers having four lobes (e.g., similar to the fiber depicted in Figure 3B). A fiber spinning speed was set for each example at 4,000 meters per minute (MPM).

 In each example, a different MDP was utilized in the spin pack assembly, where the
15 horizontally etched MDP channel dimensions (length, width, depth) that lead to each of the multi-lobal and round spinneret orifices were modified. The MDP channels were designed to yield equal residence times for the polymer material flowing through the spinneret orifices. Table 1 tabulates the MDP channel and spinneret orifice dimensional information for forming the multi-lobal fibers of each example, as well as the calculated total pressure drop
20 (i.e., pressure drop through the MDP and the spinneret orifice), shear rate, jet stretch, denier per fiber (dpf) and fiber size for these fibers. Table 2 tabulates the same information for the round fibers that are formed in each example.

Table 1: Multi-lobal Fibers

	Example 1	Example 2	Example 3	Example 4
Spin Speed (MPM)	4000	4000	4000	4000
Polymer	PP	PP	PET	PP
Fiber Cross-section	Tri-lobal	Tri-lobal	Tri-lobal	Cross
# of Filaments	16000	16000	16000	16000
MDP channel dimensions (mm)	width: 0.7 depth: 0.381 length: 11.69	width: 0.7 depth: 0.381 length: 9	width: 0.7 depth: 0.381 length: 22.6	width: 0.7 depth: 0.381 length: 9.9
Spinneret Orifice dimensions (mm)	Leg L: 0.1705 Leg W: 0.127 Area: 0.082	Leg L: 0.1705 Leg W: 0.127 Area: 0.082	Leg L: 0.1705 Leg W: 0.127 Area: 0.082	Leg L: 0.18 Leg W: 0.125 Area: 0.099
Total Pressure Drop (psi)	750	750	750	750
Fiber Size (g/hole/min)	0.67	0.89	0.67	0.89
Denier (dpf)	1.5	2	1.5	2
Shear rate	5733	7644	3822	6125
Jet velocity (MPM)	10.4	13.9	6.95	8.63
Jet stretch	384	288	576	463

Table 2: Solid Round Fibers

	Example 1	Example 2	Example 3	Example 4
Spin Speed (MPM)	4000	4000	4000	4000
Polymer	PP	PP	PET	PP
# of Filaments	4000	4000	4000	4000
MDP channel dimensions (mm)	width: 0.7 depth: 0.381 length: 11.3	width: 0.7 depth: 0.381 length: 16.79	width: 0.7 depth: 0.381 length: 22.3	width: 0.7 depth: 0.381 length: 16.8
Spinneret Orifice dimensions (mm)	diameter: 0.35 length: 1.4	diameter: 0.35 length: 1.4	diameter: 0.35 length: 1.4	diameter: 0.35 length: 1.4
Total Pressure Drop (psi)	750	750	750	751
Fiber Size (g/hole/min)	0.67	0.44	0.67	0.44
Denier (dpf)	1.5	1	1.5	1
Shear rate	3381	2254	2254	2254
Jet velocity (MPM)	8.88	5.92	3.95	8.63
Jet stretch	450	675	1013	463

As can be seen from the tabulated information, the spin pack assembly of Examples 1-3 utilizes the same spinneret, which has a 75:25 ratio of trilobal to round fibers. The spinneret used for Example 4 is different from the previous examples in that the orifices are cross-shaped, with a 75:25 ratio of cross-shaped fibers to round fibers. In addition, a single molten polymer material, either polypropylene (PP) or polyethylene terephthalate (PET), is utilized to form both the round and multi-lobal fibers of each example. Example 1 serves as

a reference, while certain modifications are made to the equipment and/or polymer materials in each of Examples 2-4 for comparison purposes with Example 1.

In a comparison of Example 1 and Example 2, the channel dimensions of the MDP are modified in Example 2 for both the trilobal and round fibers so as to modify the dpf of the fibers. This demonstrates the ease with which fiber denier values can be modified by replacing one MDP with another MDP having different channel dimensions.

In comparing Example 1 with Example 3, the polymer material used to form the fibers is changed from polypropylene to polyethylene terephthalate. However, due to the change in MDP channel dimensions, the denier per fiber for each of the round and trilobal fibers is maintained at the same value. This example demonstrates that, when a change in polymer material and/or rheology occurs, the MDP channel dimensions can be selectively adjusted (e.g., by replacing one etched MDP with another etched MDP in the spin pack assembly) to maintain fiber deniers at desired values.

As noted above, the spinneret of the assembly is changed in Example 4, where the trilobal spinneret orifices are replaced with cross-shaped spinneret orifices. This example illustrates that the MDP channel dimensions can be easily changed (e.g., by switching plates) to effectively control pressure drop and fiber denier while allowing more flexibility in spinneret orifice designs and dimensions.

While a drilled MDP could also be utilized in each of these examples, it is preferable to utilize an etched MDP for all of the reasons noted above (e.g., costs, greater flexibility in channel dimensions for a spin pack assembly having specified dimensions, etc.).

(6) Articles

The spunmelt fibrous fabrics formed in accordance with the present invention are nonwoven webs. The fibrous fabric may comprise one or more layers. If the fibrous fabric contains more than one layer, the layers are typically consolidated by thermal point-bonding or other techniques to attain strength, integrity and certain aesthetic characteristics. A layer is part of (or all of) a fibrous fabric that is produced in a separate fiber lay down or forming step and will have the same fibers intimately mixed throughout

the layer. A laminate is defined as a two or more nonwoven layers contacting along at least a portion of their respective planar faces with or without interfacial mixing. A fibrous fabric may contain one or more laminates. In a spunlaid or meltblown process, the fibers are consolidated using industry standard spunbond type technologies. Typical bonding methods include, but are not limited to, calender (pressure and heat), thru-air heat, mechanical entanglement, hydraulic entanglement, needle punching, and chemical bonding and/or resin bonding. Thermally bondable fibers are required for the pressurized heat and thru-air heat bonding methods. Fibers may also be woven together to form yarns and other fiber products.

10 The mixture of shaped fibers of the present invention may also be bonded or combined with thermoplastic or non-thermoplastic nonwoven webs or with film webs to make various articles. The polymeric fibers, typically synthetic fibers, or non-thermoplastic polymeric fibers, often natural fibers, may be used in discrete layers. Suitable synthetic fibers include, without limitation, fibers made from polyolefins such as 15 polyethylene and polypropylene, polyesters such as polyethylene terephthalate (PET), polyethylene naphthalate (PEN), polytrimethylene terephthalate (PTT) and polybutylene terephthalate (PBT), polyactic acid, polyurethanes, polycarbonates, polyamides such as Nylon 6, Nylon 6,6 and Nylon 6,10, polyacrylates, and copolymers thereof as well as mixtures thereof. Natural fibers include lyocell and cellulosic fibers and derivatives 20 thereof. Suitable cellulosic fibers include those derived from any tree or vegetation, including hardwood fibers, softwood fibers, hemp, and cotton. Also included are fibers made from processed natural cellulosic resources such as rayon.

The single layer of shaped fibers of the present invention may be utilized by itself in an article, or the layer may be combined with other nonwoven layers or a film layer to 25 produce a laminate. Examples of suitable laminates include, but are not limited to spunbond-meltblown-spunbond laminates. Because of the higher opacity and control over the mechanical properties, a spunbond layer of shaped fibers may have a lower basis weight than a typical spunbond layer made of only solid round fibers, but still provide the same opacity and mechanical properties as the higher basis weight solid round fiber layer. 30 Alternatively, a shaped fiber layer may be utilized which enables the basis weight or

denier of the meltblown layer to be reduced or can eliminate the need for a meltblown layer. A spunbond layer of the shaped fibers of the present invention can also be used in a spunbond-nanofiber-spunbond laminate. The shaped fiber layer can be used as both spunbond layers or only as one spunbond layer. Each separate layer in a nonwoven is identified as a layer that is produced with a different composition of fibers. As described in the present invention, a single layer may have a combination of different fiber shapes, diameter, configuration, and compositions. The shaped fiber nonwoven layer may also be combined with a film web. These laminates are useful as backsheet and other barriers on disposable nonwoven articles.

10 The shaped fibers of the present invention may be used to make nonwovens, among other suitable articles. Nonwoven or fibrous fabric articles are defined as articles that contain greater than 15% of a plurality of fibers that are non-continuous or continuous and physically and/or chemically attached to one another. The nonwoven may be combined with additional nonwovens or films to produce a layered product used either by itself or as a component in a complex combination of other materials, such as a baby diaper or feminine care pad. Preferred articles are disposable, nonwoven articles. The resultant products may find use in filters for air, oil and water; vacuum cleaner filters; furnace filters; face masks; coffee filters, tea or coffee bags; thermal insulation materials and sound insulation materials; nonwovens for one-time use sanitary products such as
15 diapers, feminine pads, and incontinence articles; biodegradable textile fabrics for improved moisture absorption and softness of wear such as micro fiber or breathable fabrics; an electrostatically charged, structured web for collecting and removing dust; reinforcements and webs for hard grades of paper, such as wrapping paper, writing paper, newsprint, corrugated paper board, and webs for tissue grades of paper such as toilet
20 paper, paper towel, napkins and facial tissue; medical uses such as barrier products, surgical drapes, wound dressing, bandages, dermal patches and self-dissolving sutures; and dental uses such as dental floss and toothbrush bristles. The fibrous web may also include odor absorbents, termite repellants, insecticides, rodenticides, and the like, for specific uses. The resultant product absorbs water and oil and may find use in oil or water
25 spill clean-up, or controlled water retention and release for agricultural or horticultural
30

applications. The resultant fibers or fiber webs may also be incorporated into other materials such as saw dust, wood pulp, plastics, and concrete, to form composite materials, which can be used as building materials such as walls, support beams, pressed boards, dry walls and backings, and ceiling tiles; other medical uses such as casts, splints, and tongue depressors; and in fireplace logs for decorative and/or burning purpose. Preferred articles of the present invention include disposable nonwovens for hygiene applications, such as facial cloths or cleansing cloths, and medical applications. Hygiene applications include wipes, such as baby wipes or feminine wipes; diapers, particularly the top sheet, leg cuff, ear, side panel covering, back sheet or outer cover; and feminine pads or products, particularly the top sheet. Other preferred applications are wipes or cloths for hard surface cleansing. The wipes may be wet or dry.

Continuous Fiber Examples

The Examples below further illustrate the present invention. A polypropylene was purchased from ATOFINA as FINA 3860X. Two polypropylenes were purchased from Basell, Profax PH-835 and PDC-1274. A polyethylene was purchased from Dow Chemical as Aspun 6811A. Two polyester resins were purchased from Eastman Chemical Company as Eastman F61HC as a PET and Eastman 14285 as a coPET. The meltblown grade resin polypropylene was purchased from Exxon Chemical Company as Exxon 3456G.

The opacity measurements shown are made on an Opacimeter Model BNL-3 Serial Number 7628. Three measurements are made on one specimen with an average of three specimens for each material used.

Comparative Examples: 100% solid round, hollow round or trilobal

A polypropylene spunbond fabric is produced from Basell PH-835, except for examples C13-15 which are produced from FINA 3860X. C1-C7 and C13-C33 have a through-put per hole of 0.4ghm. C8-C12 have a through-put per hole of 0.65ghm. The shape of the fiber is indicated in the table as solid round (SR), hollow round (HR) and trilobal (TRI). All comparative examples are using 2016 hole spinneret. The fibers are attenuated to an

average fiber diameter or denier indicated in the table below. These fibers are thermally bonded together using heat and pressure. The following nonwoven fabrics are produced, basis weight determined, and the opacity and/or CD tensile strength of the nonwoven is measured on the samples.

5

Table 3: Comparative Opacity

No.	Shape	Basis Weight (gsm)	Fiber Diameter (μm)	Fiber Denier (dpf)	Opacity (%)
C1	SR	25	15.3	1.5	25.4
C2	SR	17	15.3	1.5	18.2
C3	SR	10	15.3	1.5	10.5
C4	SR	17	14	1.25	18.7
C5	SR	25	14	1.25	26.4
C6	SR	17	12.5	1.0	19.7
C7	SR	17	11.2	0.8	20.9
C8	SR	26	14	1.25	26.4
C9	SR	24	14	1.25	23.8
C10	SR	18	14	1.25	18.5
C11	SR	21	16	1.62	18.5
C12	SR	26	16	1.62	23.8
C13	SR	21	13	1.07	21.7
C14	SR	18	13	1.07	18.8
C15	SR	17	13	1.07	16.4
C16	HR	25	-	1.25	33.3
C17	HR	17	-	1.25	26.0
C18	HR	10	-	1.25	16.3
C19	TRI	25	-	1.25	41.8
C20	TRI	17	-	1.25	34.0
C21	TRI	10	-	1.25	21.6

Table 4: Comparative Mechanical Properties

No.	Shape	Basis Weight (gsm)	Fiber Denier (dpf)	Maximum CD Tensile Strength (g/in)
C22	SR	25	1.5	1370
C23	SR	25	1.25	1590
C24	SR	17	1.5	1170
C25	SR	17	1.25	1045
C26	SR	17	0.8	950
C27	SR	10	1.5	530
C28	HR	25	1.25	2040
C29	HR	17	1.25	1310
C30	HR	10	1.25	630
C31	TRI	25	1.25	810
C32	TRI	17	1.25	760
C33	TRI	10	1.25	470

5 **Examples:**

Example 5: Fibrous web containing mixture of hollow round, solid round and trilobal opacity and mechanical properties.

A polypropylene spunbond fabric is produced using solid round (SR), hollow round (HR) and trilobal fibers (TRI) made from Basell PH-835. A special spinneret is used that contains a mixture of fiber shapes and a metering plate to feed polymer to each orifice.
 10 The through-put per holes is 0.4ghm using 2016 hole spinneret. The fibers are attenuated to an average fiber diameter or denier indicated in the table. The fibers are thermally bonded together using heat and pressure. The following nonwoven fabrics are produced,

basis weight determined, and the opacity and/or CD tensile strength of the nonwoven is measured on the samples.

Table 5: Examples of shaped fiber web and opacity and mechanical properties

Basis Weight (gsm)	Fiber Ratio			Fiber Denier (dpf)			Opacity (%)	Maximum CD Strength (g/in)
	SR	H R	TRI	SR	HR	TRI		
25	80	10	10	1.25	1.25	1.25	28.6	1560
25	60	20	20	1.25	1.25	1.25	30.9	1520
25	40	30	30	1.25	1.25	1.25	33.1	1500
25	20	40	40	1.25	1.25	1.25	35.3	1460
25	10	45	45	1.25	1.25	1.25	36.4	1450
17	80	10	10	1.25	1.25	1.25	21.0	1040
17	60	20	20	1.25	1.25	1.25	23.2	1040
17	40	30	30	1.25	1.25	1.25	25.5	1040
17	20	40	40	1.25	1.25	1.25	27.7	1040
17	10	45	45	1.25	1.25	1.25	28.9	1040
10	80	10	10	1.25	1.25	1.25	11.0	510
10	60	20	20	1.25	1.25	1.25	13.0	520
10	40	30	30	1.25	1.25	1.25	15.0	530
10	20	40	40	1.25	1.25	1.25	17.0	540
10	10	45	45	1.25	1.25	1.25	18.0	545
25	90	0	10	1.25	-	1.25	27.9	1510
25	50	0	50	1.25	-	1.25	34.1	1200
25	10	0	90	1.25	-	1.25	40.3	900
17	90	0	10	1.25	-	1.25	32.5	790
17	50	0	50	1.25	-	1.25	26.4	900
17	10	0	90	1.25	-	1.25	20.2	1020

10	90	0	10	1.25	-	1.25	10.3	490
10	50	0	50	1.25	-	1.25	15.3	490
10	10	0	90	1.25	-	1.25	20.3	470
25	0	90	10	-	1.25	1.25	34.2	1920
25	0	50	50	-	1.25	1.25	37.6	1425
25	0	10	90	-	1.25	1.25	41.0	930
17	0	90	10	-	1.25	1.25	26.8	1255
17	0	50	50	-	1.25	1.25	30.0	1033
17	0	10	90	-	1.25	1.25	33.2	815
10	0	90	10	-	1.25	1.25	16.8	610
10	0	50	50	-	1.25	1.25	19.0	550
10	0	10	90	-	1.25	1.25	21.1	490
25	90	10	0	1.25	1.25	-	27.1	1630
25	50	50	0	1.25	1.25	-	29.9	1815
25	10	90	0	1.25	1.25	-	32.6	1995
17	90	10	0	1.25	1.25	-	19.4	1070
17	50	50	0	1.25	1.25	-	22.4	1180
17	10	90	0	1.25	1.25	-	25.3	1280
10	90	10	0	1.25	1.25	-	9.7	510
10	50	50	0	1.25	1.25	-	12.7	670
10	10	90	0	1.25	1.25	-	15.6	620

Example 6: Fibrous webs containing two polymers and two shapes

A spunbond machine is set-up to run polypropylene at 220°C or polyester at 290°C. A spinneret as shown in Figures 9A and 9B may be used to produce the fibers. A metering
5 system with two melt pumps may be used to control each polymer type and melt flow. Nonwovens can be produced at a range of mass flow ratios and deniers. Any combination of polymers and shapes may be used. For example, Basell PH-835 solid round fibers may be combined with Dow Aspun 6811A and/or Eastman F61HC trilobal fibers.

Alternatively, the Basell PH-835 could be used to make trilobal fibers and hollow round fibers made of ATOFINA 3860X.

Example 7: Fibrous webs containing two polymers and two shapes and a meltblown layer

5 The fibrous fabric of Example 6 is made and combined with a polypropylene meltblown layer made from Exxon 3546G. The average meltblown diameter is 3 microns at a through-put of 0.6 ghm. The two layers can be thermally bonded together or hydroentangled or combined with other bonding methods.

10 Example 8: Fibrous webs containing one polymer and two shapes

A fibrous web is produced with solid round meltblown diameter fibers supplied at 0.15 ghm and trilobal spunlaid diameter fiber supplied at 0.4 ghm. In another embodiment, a solid round spunlaid diameter fiber is also produced in the same layer to create a three-fiber layer.

15

Example 9: Fibrous web containing a mixture of multicomponent solid round and multicomponent trilobal fibers

A spunbond nonwoven is produced containing a 50/50 weight percent mixture of multicomponent solid round and multicomponent trilobal fibers. The multicomponent
20 solid round fibers are sheath and core with a 50/50 weight percent ratio of ATOFINA 3860X as the sheath material and Basell Profax PH-835 as the core. The solid round fibers are attenuated to a range of diameters down to 1.0 dpf, depending on the mass throughput per capillary. The trilobal fibers are composed of a 20/80 weight percent ratio of ATOFINA as the trilobal tip material and Basell Profax PH-835 as the core. The
25 trilobal fibers are attenuated to a range of diameters down to 1.0 dpf, depending on the mass throughput per capillary. These fibers are then consolidated together using conventional bonding methods, most commonly thermal point bonding, but hydroentangling can also be used. Basis weight down to 5 gsm can be produced. If desired, a polypropylene meltblown layer can be produced using Exxon 3546G. The
30 average meltblown diameter is 3 microns at a through-put of 0.6 ghm. The meltblown

layer is then combined with the spunlaid layer either by direct collection or brought in from a second source. Other alternate layers can be added. The fibers are thermally bonded together using heat and pressure. This nonwoven has high opacity characteristics with improved strength due to the presence of the lower molecular weight ATOFINA 3860X outer component of the multicomponent fibers. The component ratio of individual fibers can be changed to further adjust the strength and the ratio of shaped fibers can be changed to alter the opacity and strength, as needed for a desired application.

Example 10: Fibrous web containing a mixture of multicomponent solid round and multicomponent trilobal fibers plus mixed meltblown diameter

A spunbond nonwoven is produced containing a 45/45/10 weight percent mixture of multicomponent solid round, multicomponent trilobal fibers, and meltblown diameter fibers. The multicomponent solid round fibers are sheath and core with a 50/50 weight percent ratio of ATOFINA 3860X as the sheath material and Basell Profax PH-835 as the core. The solid round fibers are attenuated to a range of diameters down to 1.0 dpf, depending on the mass throughput per capillary. The trilobal fibers are composed of a 20/80 weight percent ratio of ATOFINA as the trilobal tip material and Basell Profax PH-835 as the core. The trilobal fibers are attenuated to a range of diameters down to 1.0 dpf, depending on the mass throughput per capillary. The solid round and trilobal spunbond orifice are supplied a polymer at 0.4 ghm, while the meltblown diameter orifices are supplied polymer at 0.15 ghm. All of these fibers are extruded from an etched metering plate and spinneret. The meltblown diameter fibers have an average diameter of 6 microns. These fibers are then consolidated together using conventional bonding methods. This nonwoven also has high opacity characteristics with improved strength due to the presence of the lower molecular weight ATOFINA 3860X outer component of the multicomponent fibers. The component ratio in individual fibers can be changed to further adjust the strength and the ratio of shaped fibers can be changed to alter the opacity and strength, as needed for a desired application.

Example 11: Fibrous web containing a mixture of multicomponent solid round, monocomponent trilobal fibers, and meltblown diameter fibers.

A spunbond nonwoven is produced containing a 20/70/10 weight percent mixture of multicomponent solid round, monocomponent trilobal fibers and meltblown diameter
5 fibers. The multicomponent solid round fibers are a 75/25 weight percent ratio of Eastman F61HC polyester as the core material and Eastman 14285 as the sheath material. The multicomponent round fibers are attenuated to a range of diameters down to 1.0 dpf, depending on the mass throughput per capillary. The monocomponent trilobal fibers are composed of Eastman F61HC. The polyester meltblown fibers are produced using an
10 Eastman F33HC. The monocomponent trilobal fibers are attenuated to a range of sizes down to 1.0 dpf, depending on the mass throughput per capillary. The average meltblown diameter is 3 microns at a through-put of 0.6 ghm. This construction is used to produce a high strength and loft polyester spunbond. The component ratio in individual fibers and between fiber types can be changed to further alter the opacity and strength, as needed for
15 a desired application.

Example 12: Fibrous web containing a mixture of multicomponent solid round and monocomponent trilobal fibers.

A spunbond nonwoven is produced containing a 20/70/10 weight percent mixture
20 of multicomponent solid round, monocomponent trilobal fibers and meltblown diameter fibers from the same spinneret. Alternatively, a spunbond nonwoven can be produced containing a 30/70 weight percent mixture of multicomponent solid round and monocomponent trilobal fibers. The multicomponent solid round fibers are a 75/25 weight percent ratio of Eastman F61HC polyester as the core material and Eastman 14285
25 as the sheath material. The multicomponent round fibers are attenuated to a range of diameters down to 1.0 dpf, depending on the mass throughput per capillary. The monocomponent trilobal fibers are composed of Eastman F61HC. If present, the polyester meltblown fibers are produced using an Eastman F33HC. The monocomponent trilobal fibers are attenuated to a range of sizes down to 1.0 dpf, depending on the mass
30 throughput per capillary. The average meltblown diameter is 6 microns at a through-put of

0.15 ghm. The nonwoven web with shaped fibers may be combined with a meltblown layer. Other alternate layers can be added.

Many examples have been shown and given here to demonstrate the various equipment embodiments, methods of forming mixed fiber products having different geometries and the breadth of fibers that can be produced to illustrate the invention. Although not limited by the data presented in this invention, further variations are known.

The disclosures of all patents, patent applications (and any patents which issue thereon, as well as any corresponding published foreign patent applications), and publications mentioned throughout this description are hereby incorporated by reference herein. It is expressly not admitted, however, that any of the documents incorporated by reference herein teach or disclose the present invention.

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 intended to cover in the appended claims all such changes and modifications that are within the scope of the invention.

WHAT IS CLAIMED:

1. A spinneret comprising at least two spinneret orifices having geometries different from each other.
2. The spinneret of claim 1, wherein at least one spinneret orifice has a geometry that is configured to form a hollow fiber.
3. The spinneret of claim 1, wherein the geometries of the spinneret orifices include round and multi-lobal.
4. The spinneret of claim 3, wherein the geometries of the spinneret orifices include trilobal.
5. The spinneret of claim 3, wherein at least some of the round spinneret orifices are located closer to peripheral portions of the spinneret in relation to all multi-lobal spinneret orifices.
6. The spinneret of claim 3, wherein only round spinneret orifices are located within a selected section disposed at each longitudinal end portion of the spinneret.
7. The spinneret of claim 3, wherein only round spinneret orifices are located within a central portion of the spinneret.
8. The spinneret of claim 1, wherein at least one group of the multi-lobal spinneret orifices are formed along an outlet surface the spinneret such that a lobe of a multi-lobal fiber extruded from each multi-lobal spinneret orifice of the at least one group is aligned to face in a direction of a quench medium source that directs a quench medium toward fibers extruded from the spinneret.

9. The spinneret of claim 1, wherein the spinneret includes a first group of multi-lobal spinneret orifices and a second group of multi-lobal spinneret orifices that have the same geometric shape as the first group of multi-lobal spinneret orifices, the multi-lobal orifices of the first group being aligned along an outlet surface of the spinneret
5 at a selected angle of rotation with respect to the multi-lobal spinneret orifices of the second group.

10. The spinneret of claim 9, wherein the multi-lobal spinneret orifices of the first group are aligned at a 180° rotation with respect to the multi-lobal spinneret orifices of the second group.

10

11. The spinneret of claim 1, wherein at least 50% of the spinneret orifices have a multi-lobal geometry.

12. The spinneret of claim 1, wherein at least 75% of the spinneret orifices
15 have a multi-lobal geometry.

13. The spinneret of claim 1, wherein at least 80% of the spinneret orifices have a multi-lobal geometry.

14. A metering/distribution plate for use in a spin pack assembly that
20 comprises a spinneret including a first set of spinneret orifices and a second set of spinneret orifices, the spinneret orifices of the first set having geometries that are different from geometries of the spinneret orifices of the second set, the metering/distribution plate comprising:

a first set of passages configured to deliver molten polymer flowing through the
25 spin pack assembly to the first set of spinneret orifices; and

a second set of passages configured to deliver molten polymer flowing through the spin pack assembly to the second set of spinneret orifices;

wherein the passages for each set are selected to facilitate the formation of extruded fibers through the first and second sets of spinneret orifices having selected deniers.

5 15. The metering/distribution plate of claim 14, wherein the passages of the plate are vertical through-holes that have been drilled in the plate.

 16. The metering/distribution plate of claim 14, wherein the passages of the plate include horizontally formed channels disposed along a first surface of the plate and
10 vertical through-holes in fluid communication with the channels and extending to a second surface of the plate.

 17. The metering/distribution plate of claim 16, wherein the channels have a channel width to a channel depth ratio of about 1.5:1 to about 15:1.

15 18. A spin pack assembly comprising:
 a spinneret comprising a first set of spinneret orifices and a second set of spinneret orifices, the spinneret orifices of the first set having geometries different from geometries of the spinneret orifices of the second set; and
 a metering/distribution plate configured to deliver molten polymer flowing
20 through the spin pack assembly to the spinneret, the metering/distribution plate comprising a a first set of passages configured to deliver molten polymer flowing through the spin pack assembly to the first set of spinneret orifices, and a second set of passages configured to deliver molten polymer flowing through the spin pack assembly to the second set of spinneret orifices, wherein the passages for each set are selected to facilitate
25 the formation of extruded fibers through the first and second sets of spinneret orifices having selected deniers.

 19. The spin pack assembly of claim 18, wherein the geometries of the spinneret orifices include round and multi-lobal.

20. The spin pack assembly of claim 18, wherein the spin pack assembly is configured to receive different metering/distribution plates including different sets of passages having different passage dimensions.

21. A method of forming a mixed filament product including polymer fibers
5 with different cross-sectional geometries, the method comprising:

providing a spin pack assembly including a spinneret with a first set of spinneret orifices and a second set of spinneret orifices, the spinneret orifices of the first set having geometries that are different from geometries of the spinneret orifices of the second set.

22. The method of claim 21, wherein the geometries of the spinneret orifices
10 include round and multi-lobal.

23. The method of claim 22, wherein at least one group of the multi-lobal spinneret orifices are formed in the spinneret such that a lobe of a multi-lobal fiber extruded from each multi-lobal spinneret orifice of the at least one group is aligned to face in a direction of a quench medium source that directs a quench medium toward fibers
15 extruded from the spinneret.

24. The method of claim 21, further comprising:
providing a metering/distribution plate for the spin pack assembly, the metering/distribution plate being configured to deliver molten polymer flowing through the spin pack assembly to the spinneret and including a first set of passages configured to
20 deliver molten polymer flowing through the spin pack assembly to the first set of spinneret orifices, and a second set of passages configured to deliver molten polymer flowing through the spin pack assembly to the second set of spinneret orifices.

25. The method of claim 24, further comprising:

providing the passages of the first set of the metering/distribution plate with selected dimensions to control the deniers of fibers extruded from the first set of spinneret orifices; and

providing the passages of the second set of the metering/distribution plate with selected dimensions to control the deniers of fibers extruded from the second set of spinneret orifices.

26. The method of claim 24, further comprising:

modifying at least one operating parameter selected from: polymer throughput through the spin pack assembly, fiber cross-sectional geometry of fibers formed from the spinneret, the arrangement of spinneret orifices along the spinneret, a temperature of polymer material flowing through the spin pack assembly, denier of fibers formed from at least one of the first and second sets of spinneret orifices, the number of spinneret orifices in at least one of the first and second sets of spinneret orifices, and polymer material of fibers extruded from the spinneret; and

replacing the metering/distribution plate in the spin pack assembly with a different metering/distribution plate including selected passage dimensions to facilitate selective control of the deniers of fibers extruded from the spinneret after the modification of the at least one operating parameter.

27. The method of claim 21, wherein fibers formed from the spinneret include at least one of: fibers having different cross-sectional geometries but with the same one or more polymer components, and fibers having different cross-sectional geometries and different polymer components.

28. The method of claim 21, wherein at least some of the fibers formed from the spinneret include multi-polymer components.

29. A spunlaid system comprising:
a spin pack assembly comprising:

a spinneret comprising a first set of spinneret orifices and a second set of spinneret orifices, the spinneret orifices of the first set having geometries different from geometries of the spinneret orifices of the second set; and

5 a metering/distribution plate configured to deliver molten polymer flowing through the spin pack assembly to the spinneret, the metering/distribution plate comprising a first set of passages configured to deliver molten polymer flowing through the spin pack assembly to the first set of spinneret orifices, and a second set of passages configured to deliver molten polymer flowing through the spin pack assembly to the second set of spinneret orifices, wherein the channels for each set are selected to facilitate
10 the formation of extruded fibers through the first and second sets of spinneret orifices having selected deniers; and

a quench source aligned and configured to direct at least one source of quench medium toward fibers extruded from the spinneret.

30. The system of claim 29, wherein at least one group of the multi-lobal
15 spinneret orifices are formed along an outlet surface the spinneret such that a lobe of a multi-lobal fiber extruded from each multi-lobal spinneret orifice of the at least one group is aligned to face in a direction of a quench medium source that directs a quench medium toward fibers extruded from the spinneret.

20 31. The system of claim 29, further comprising:
a plurality of metering pumps to independently meter molten polymer material to the spin pack assembly.

32. The system of claim 31, wherein a first metering pump meters a molten
25 polymer material to the first set of passages of the metering/distribution plate, and a second metering pump meters molten polymer material to the second set of passages of the metering/distribution plate.

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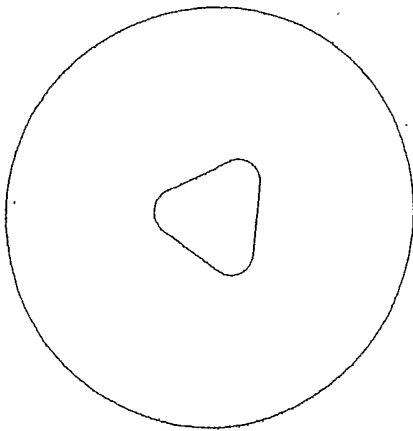


Fig. 1

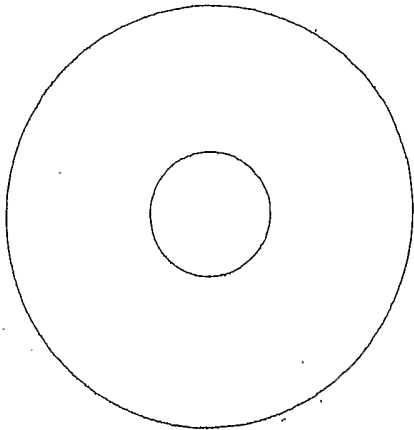


Fig. 2

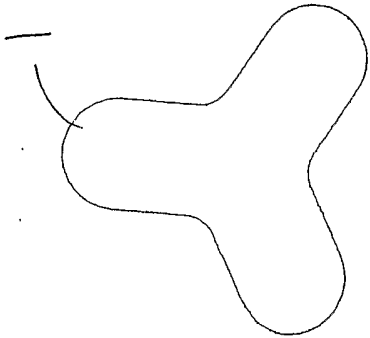


Fig. 3A

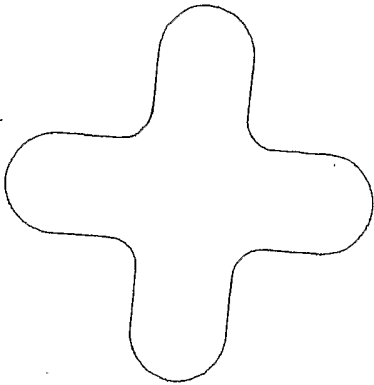


Fig. 3B

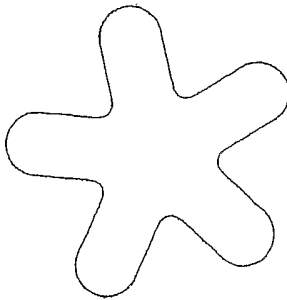


Fig. 3C

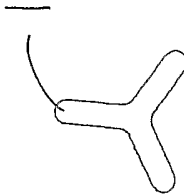


Fig. 3D

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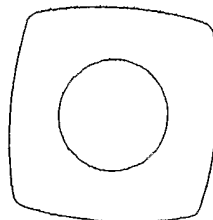


Fig. 4A

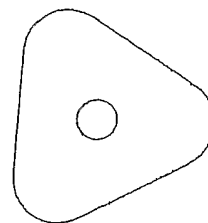


Fig. 4B

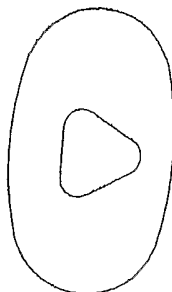


Fig. 4C

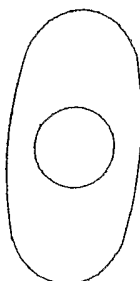


Fig. 4D

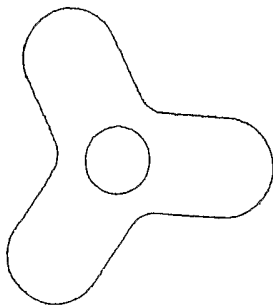
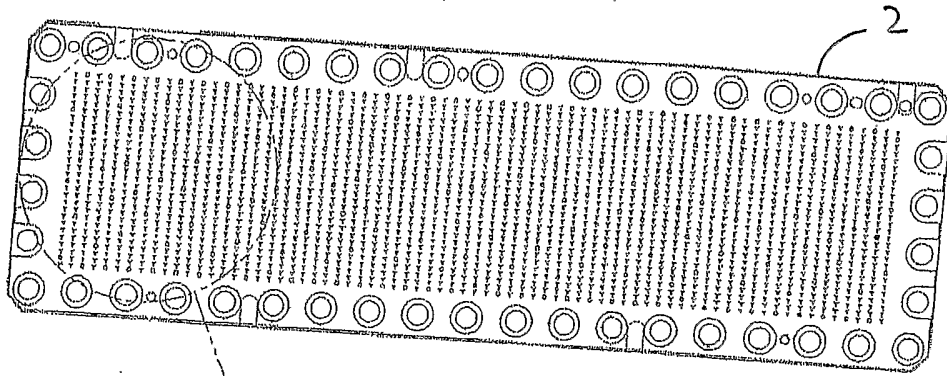


Fig. 4E

Figure 5A



||| 8

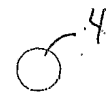


Figure 5B



Figure 5C

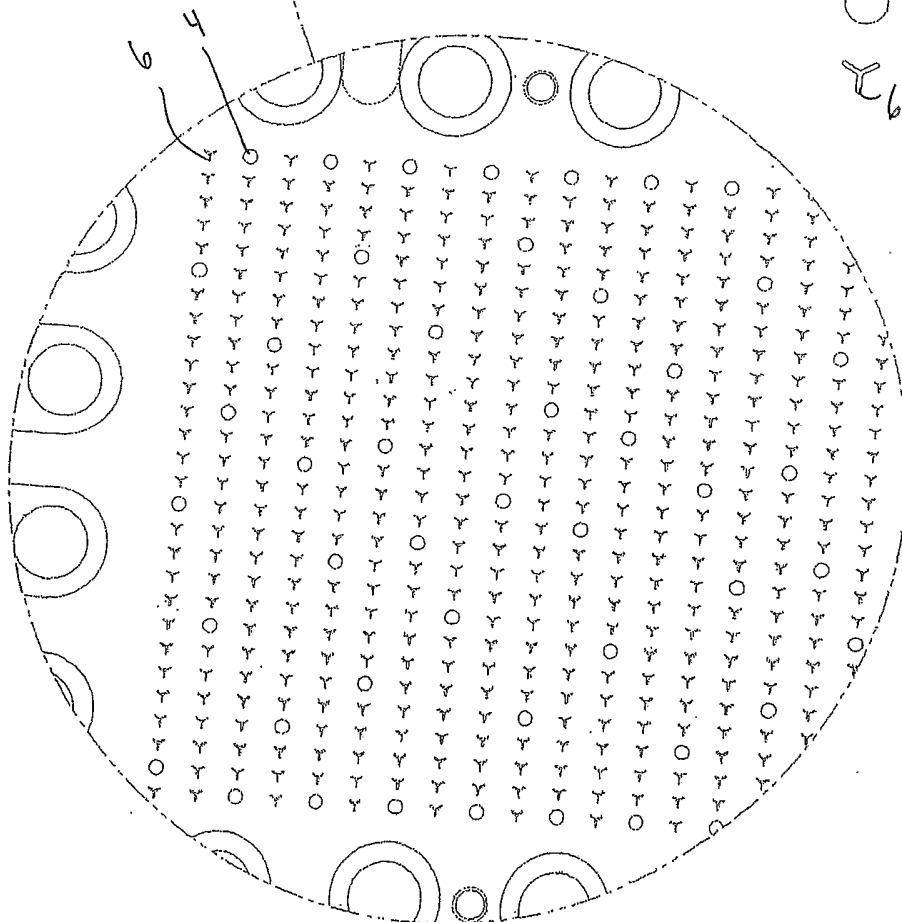
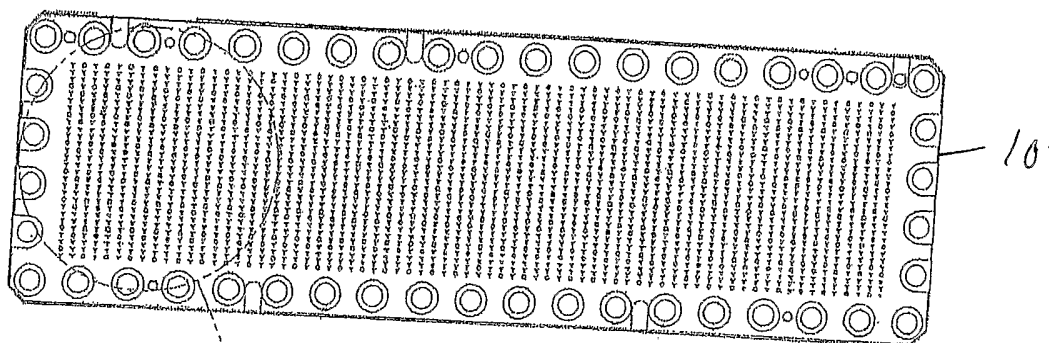


Figure 5D

Figure 6A



8-8

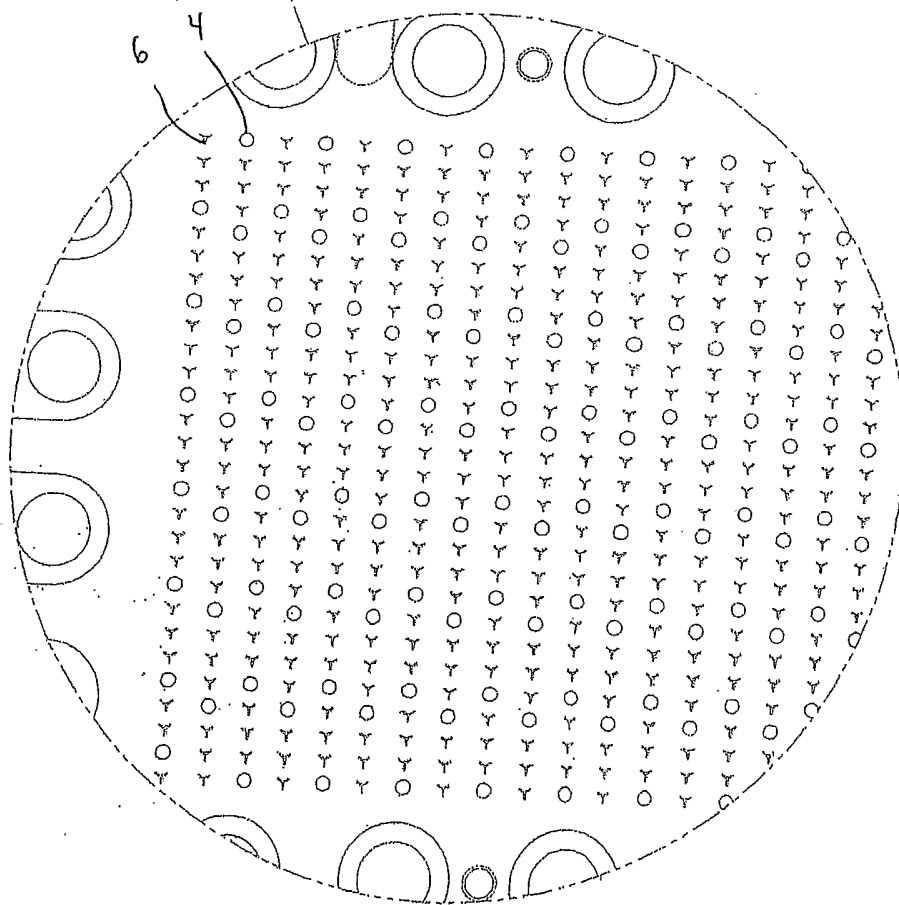


Figure 6B

Figure 7A

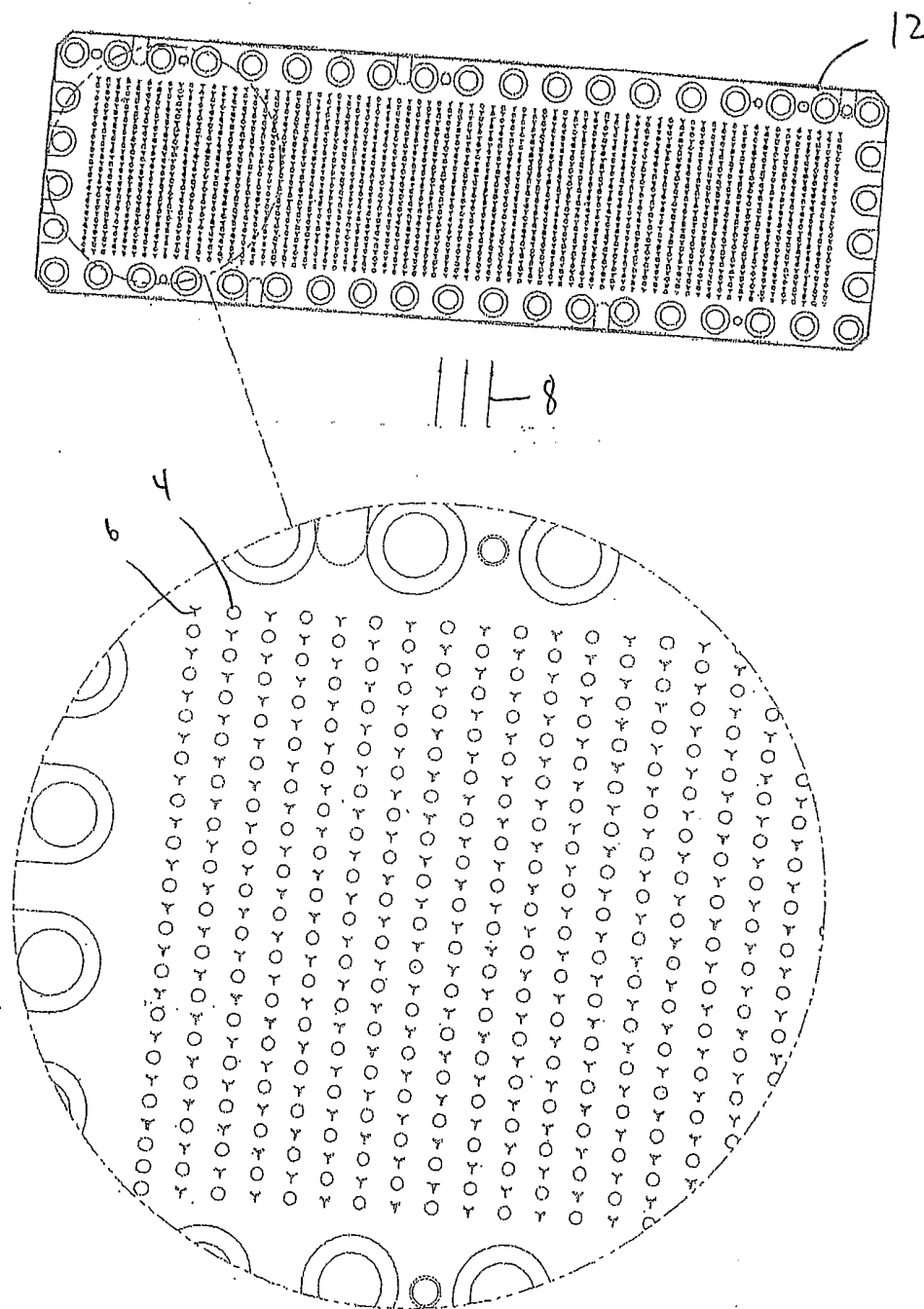
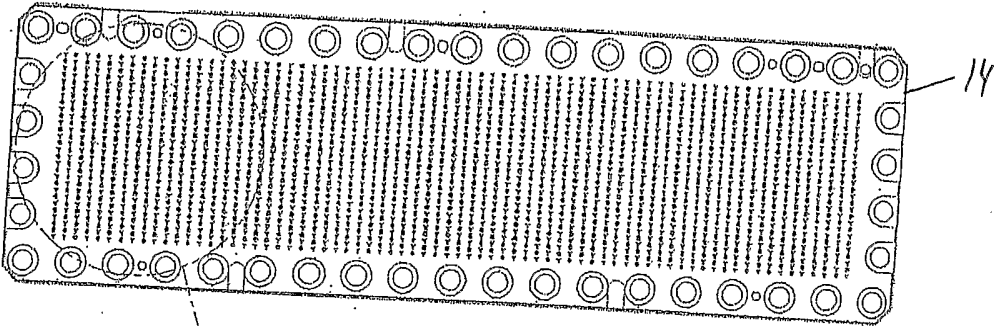


Figure 8A



8



Figure 8B



Figure 8C

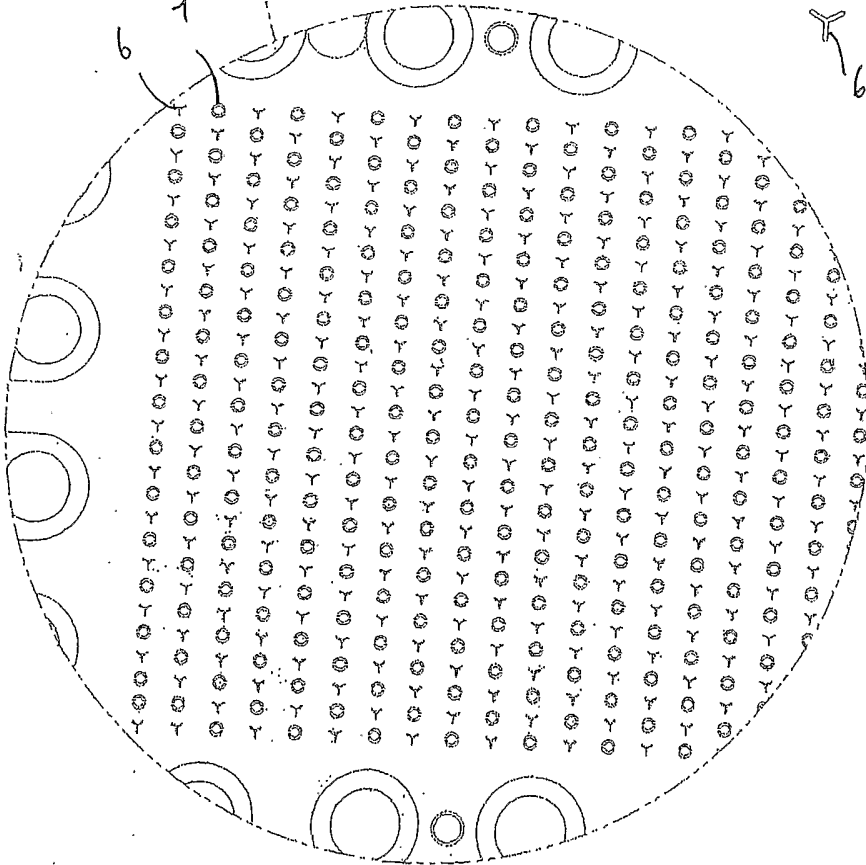


Figure 8D

Figure 9A

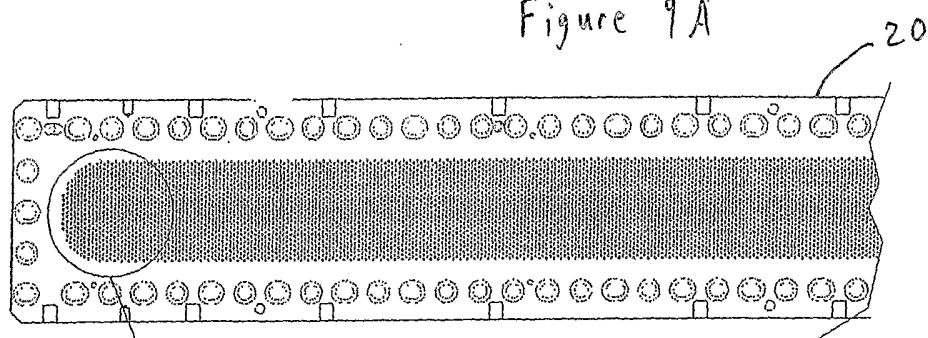
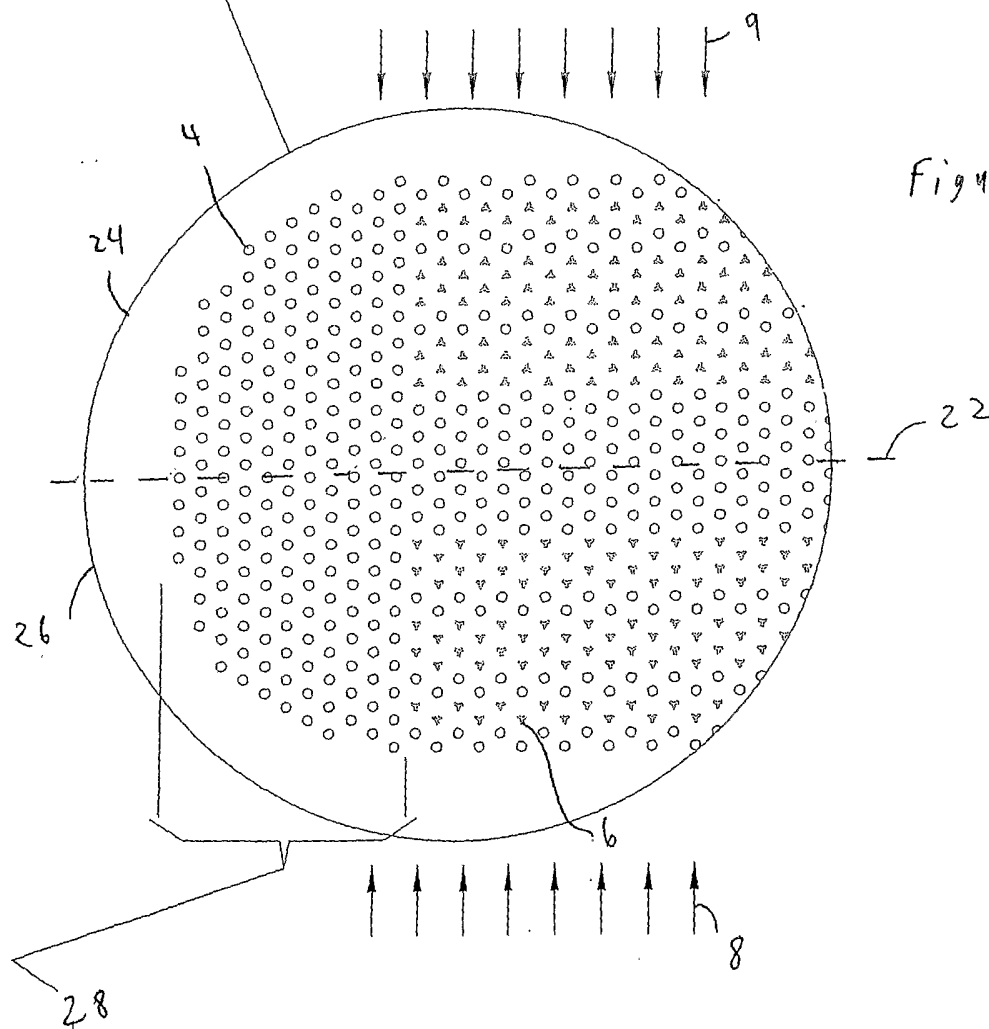


Figure 9B



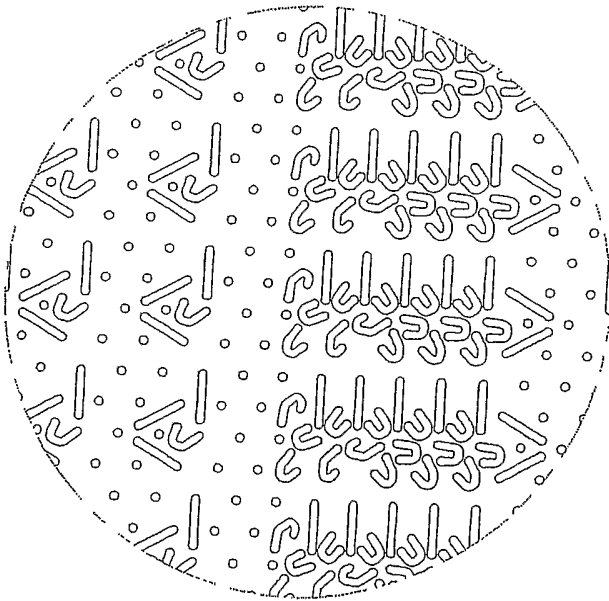


Figure 10B

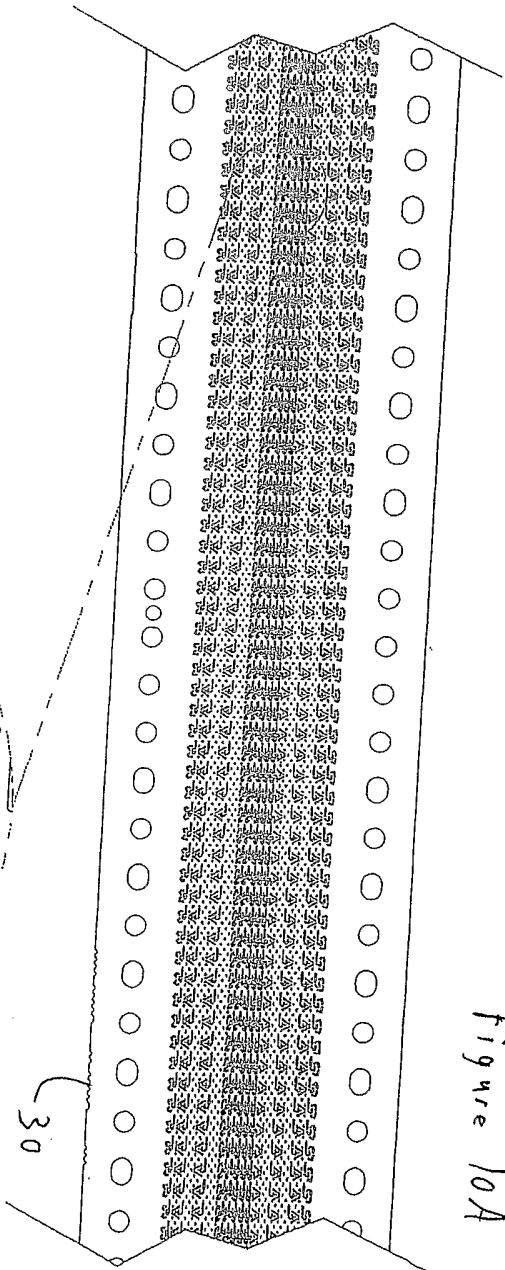


Figure 10A

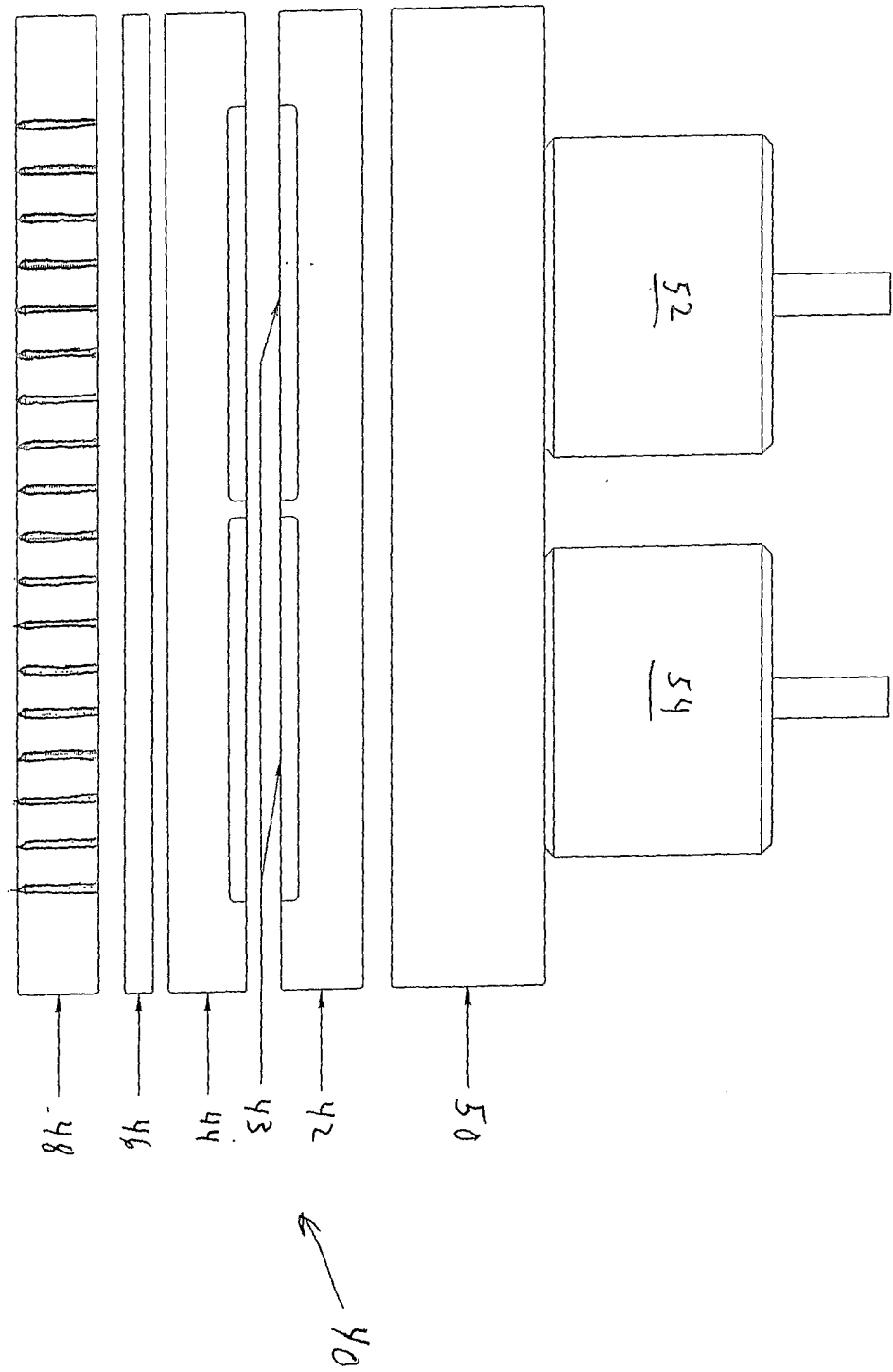
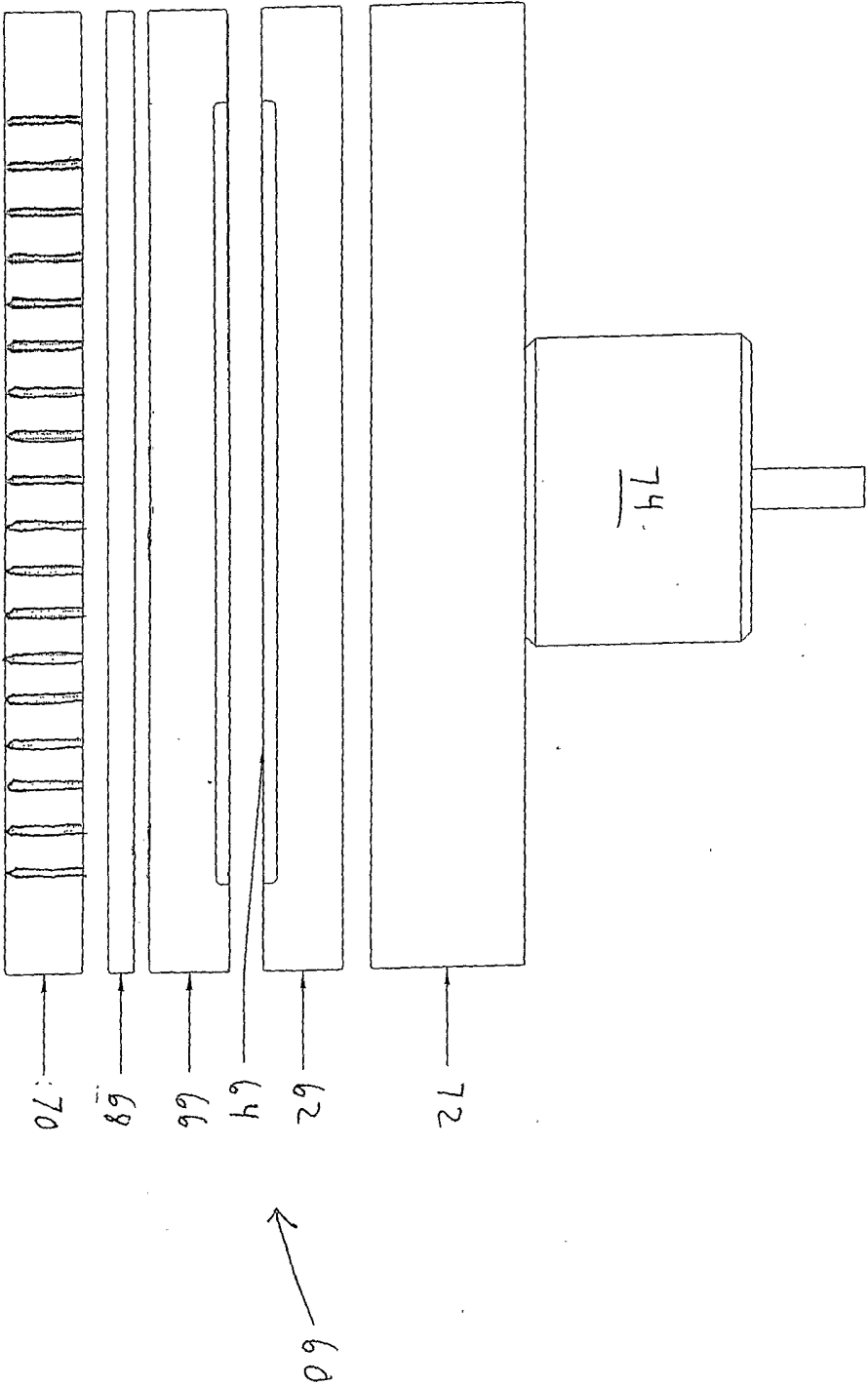


Figure 11

Figure 12



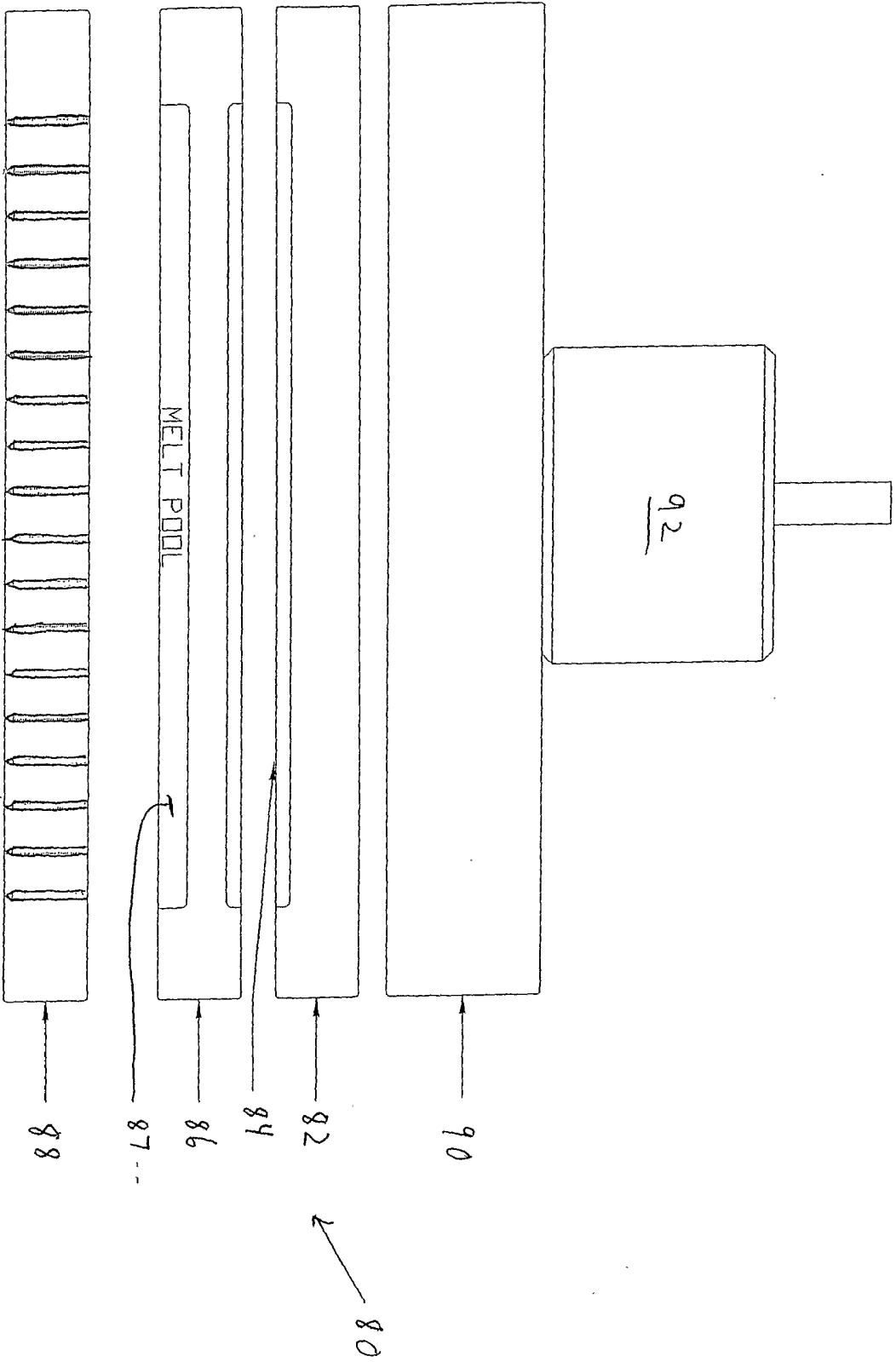


Figure 13

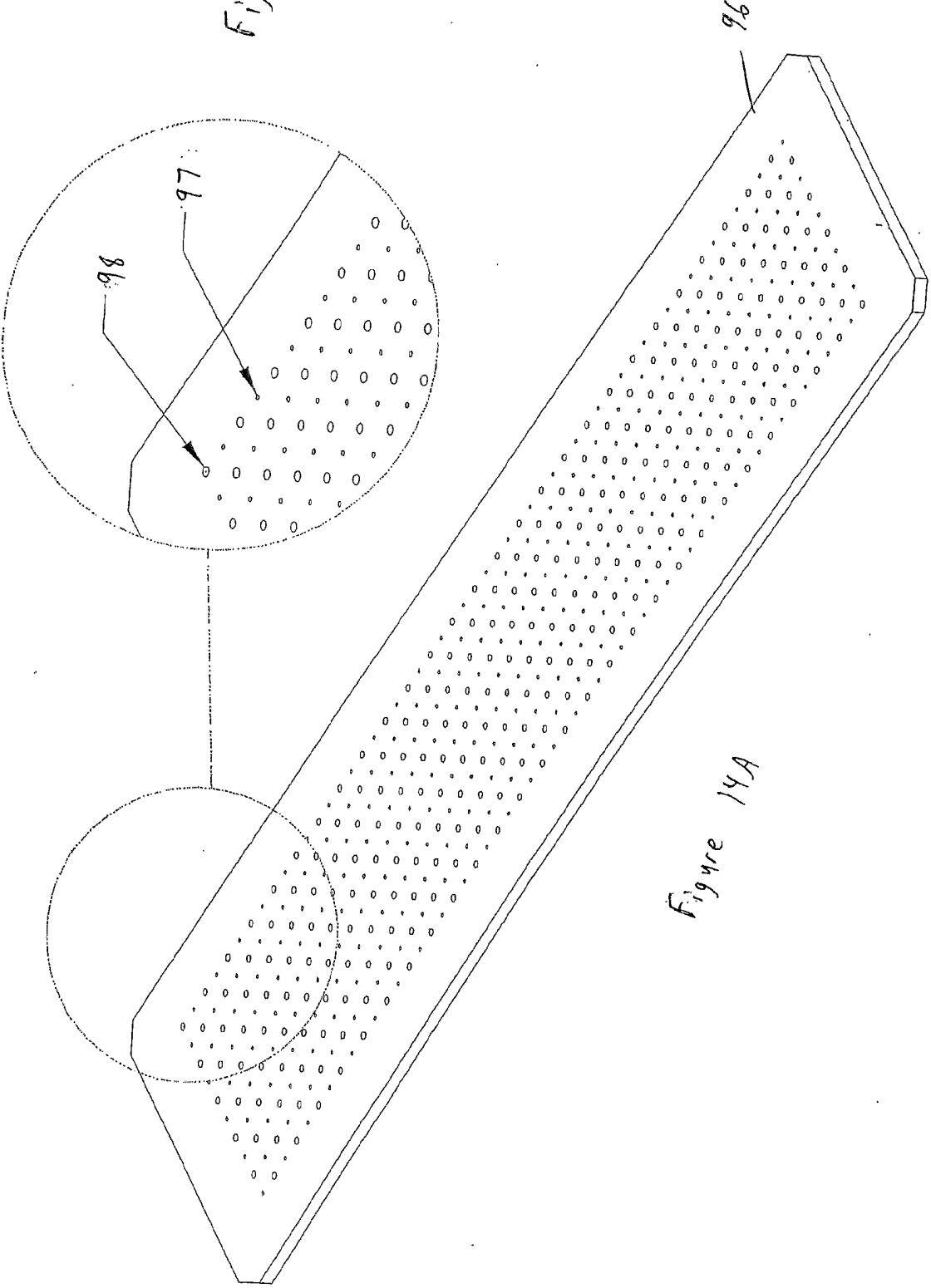


Figure 14B

Figure 14A

Figure 15

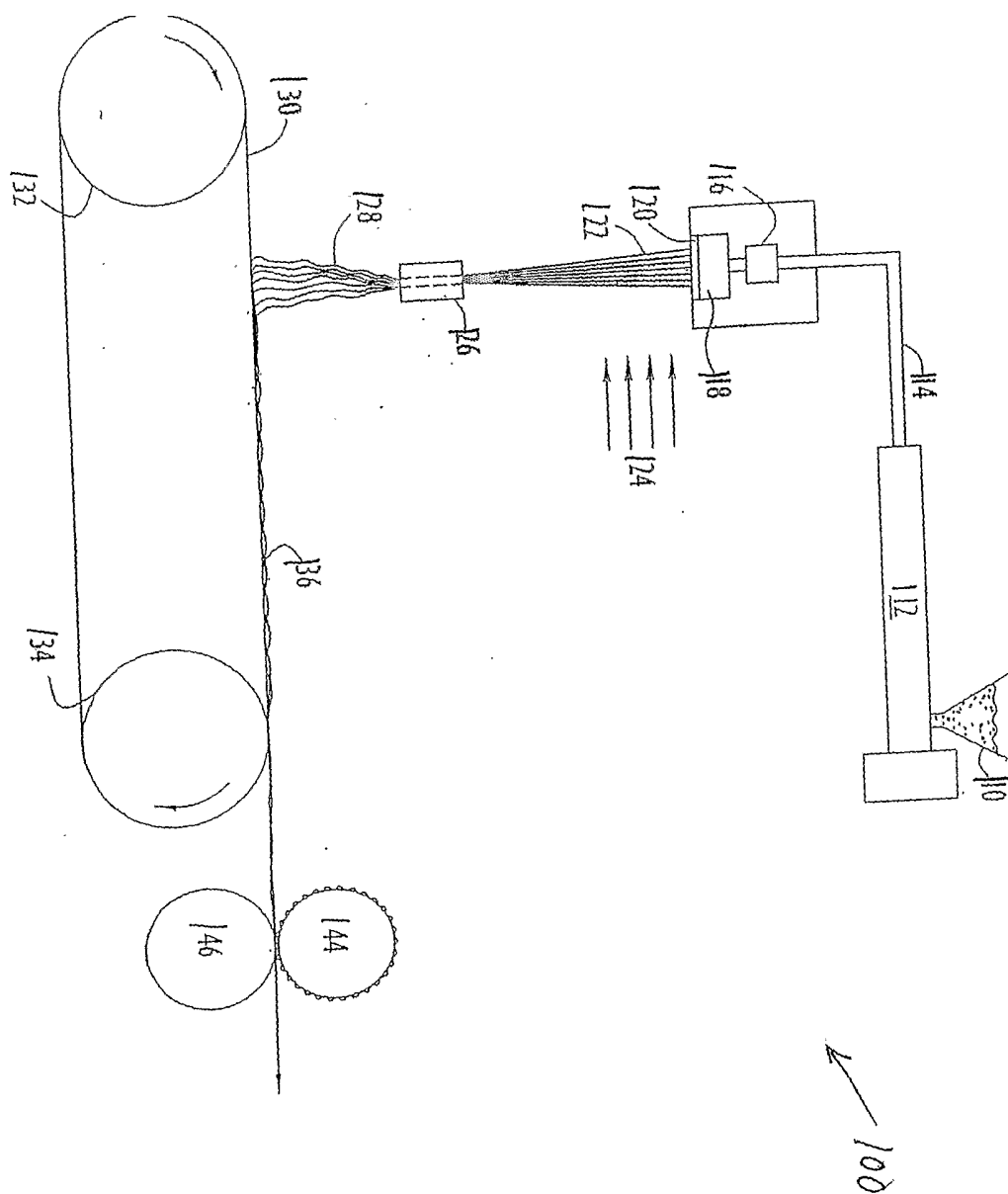


Figure 1b

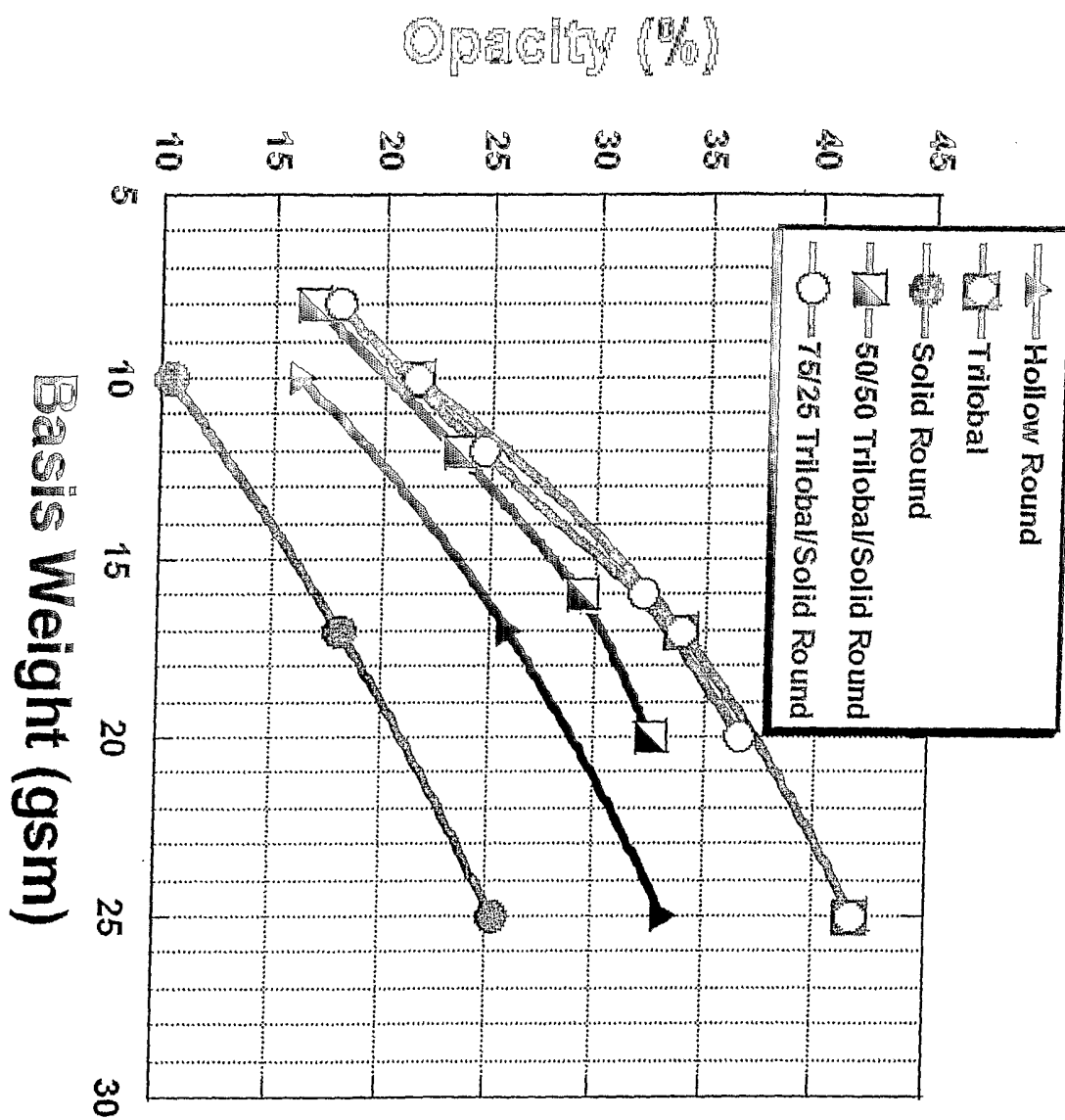
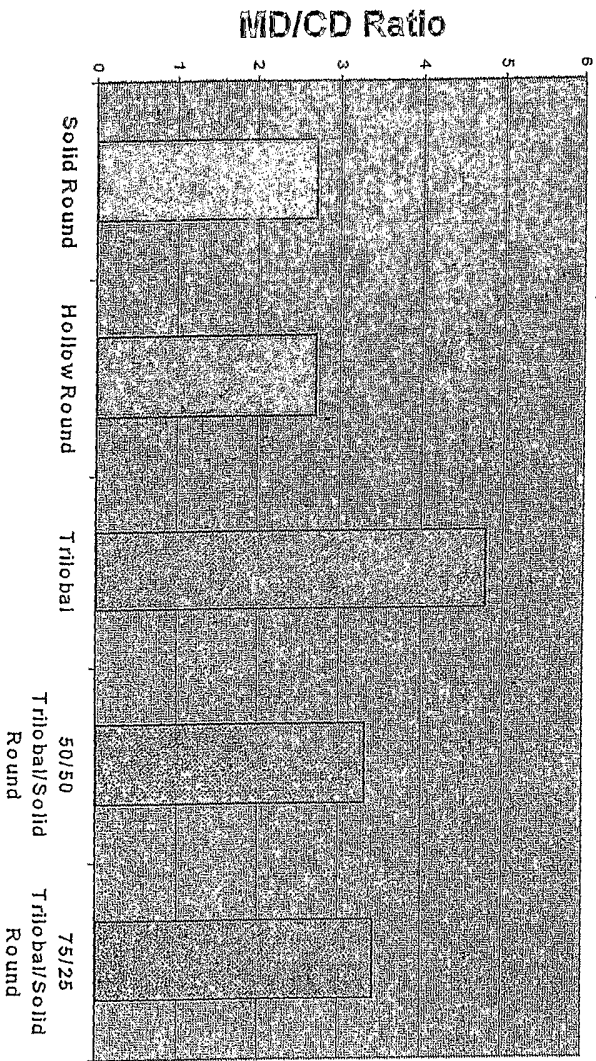


Figure 17



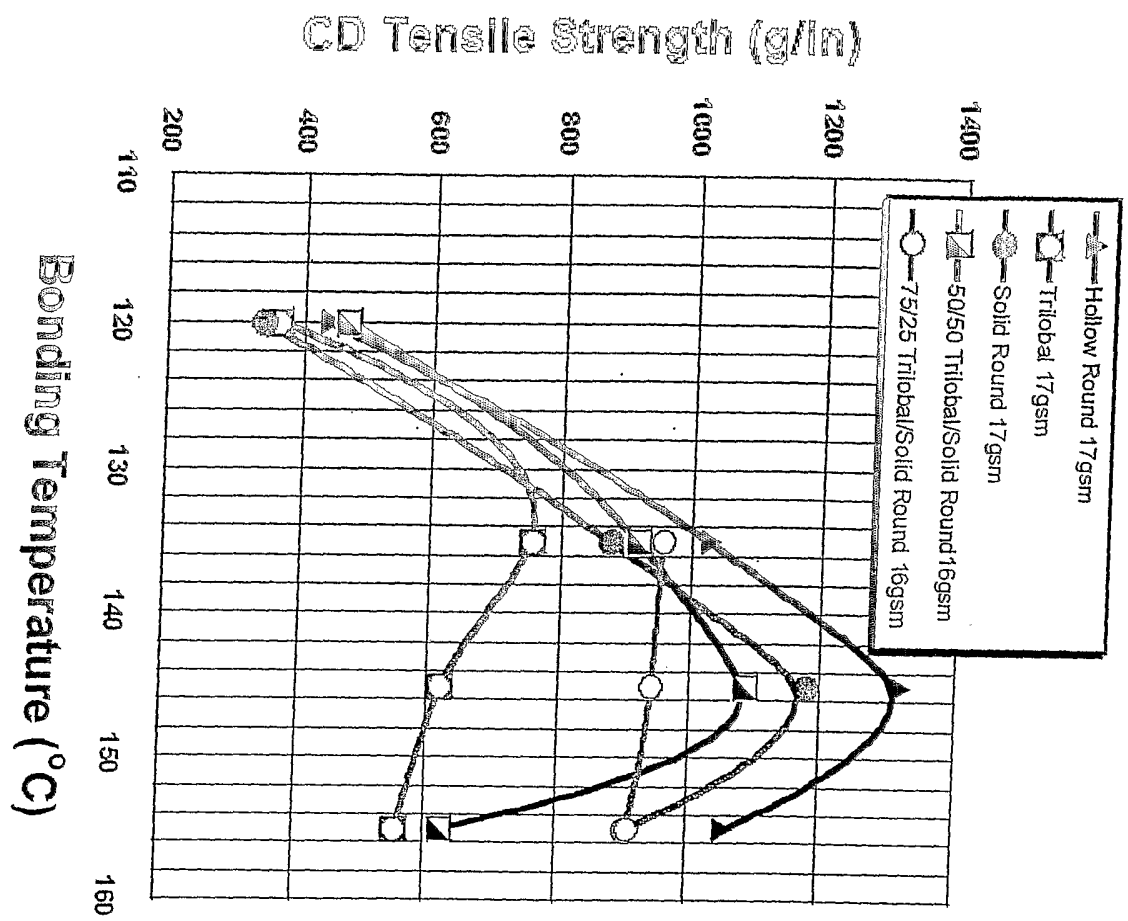


Figure 18