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(54) Title: METHOD OF FORMING A WEB FROM FIBROUS MATERAILS

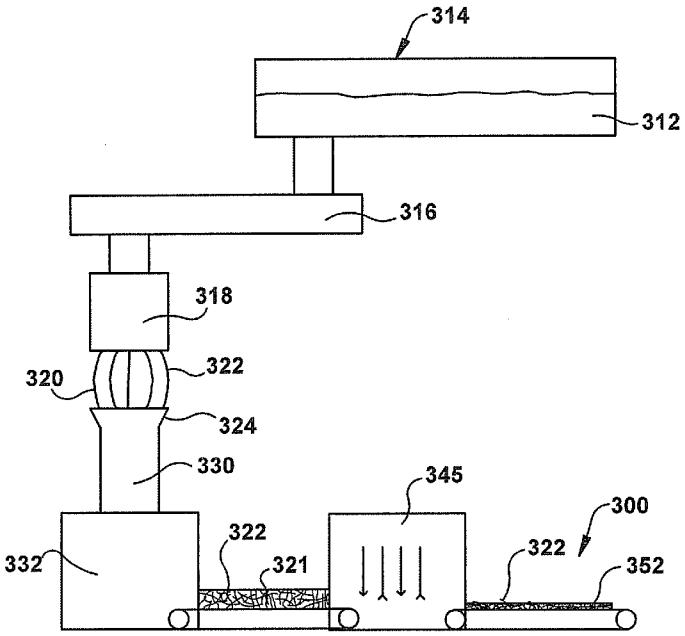


FIG. 3B

(57) Abstract: Fibrous material webs and methods of making the fibrous material webs. Binderless webs can be formed in a continuous process where fiber material, such as glass is melted and formed into fibers. The fibers are formed into a web of binderless glass fibers or a web with a dry binder. The binderless web or the web with dry binder can be layered and/or the fibers that make up the web can be mechanically entangled, for example, by needling.

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METHOD OF FORMING A WEB FROM FIBROUS MATERIALS

RELATED APPLICATIONS

[0001] This application claims priority from provisional application number 61/541,162 filed on September 30, 2011, titled "Method of Forming a Pack from Fibrous Materials." Provisional application number 61/541,162 is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Fibrous material can be formed into various products including webs, packs, batts and blankets. Packs of fibrous material can be used in many applications, including the non-limiting examples of insulation and sound-proofing for buildings and building components, appliances and aircraft. Packs of fibrous material are typically formed by processes that include fiberizers, forming hoods, ovens, trimming and packaging machines. Typical processes also include the use of wet binders, binder reclaim water and washwater systems.

SUMMARY

[0003] The present application discloses multiple exemplary embodiments of fibrous material webs and methods of making the fibrous material webs. Binderless webs or webs with dry binder can be formed in a continuous process where fiber material, such as glass is melted and formed into fibers. The fibers are formed into a web of binderless glass fibers or a web with a dry binder. The binderless web or the web with dry binder can be layered and/or the fibers that make up the web can be mechanically entangled, for example, by needling.

[0004] Other advantages of the webs, batts, and methods of producing the webs and batts will become apparent to those skilled in the art from the following detailed description, when read in view of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Figure 1A is a flowchart of an exemplary embodiment of method for forming a binderless layered web or pack of glass fibers;

[0006] Figure 1B is a flowchart of an exemplary embodiment of a method for forming a binderless entangled web of glass fibers;

[0007] Figure 1C is a flowchart of an exemplary embodiment of a method for forming a binderless layered and entangled web or pack of glass fibers;

[0008] Figure 2A is a flowchart of an exemplary embodiment of method for forming a layered web or pack of glass fibers with dry binder;

[0009] Figure 2B is a flowchart of an exemplary embodiment of a method for forming a binderless entangled web of glass fibers with dry binder;

[0010] Figure 2C is a flowchart of an exemplary embodiment of a method for forming a binderless layered and entangled web or pack of glass fibers with dry binder;

[0011] Figure 2D is a flowchart of an exemplary embodiment of a method for forming a binderless layered and entangled web or pack of glass fibers with dry binder;

[0012] Figure 3A is a schematic illustration of an exemplary apparatus for forming a binderless layered web or pack of glass fibers;

[0013] Figure 3B is a schematic illustration of an exemplary apparatus for forming a binderless entangled web of glass fibers;

[0014] Figure 3C is a schematic illustration of an exemplary apparatus for forming a binderless layered and entangled web or pack of glass fibers;

[0015] Figure 4 is a schematic illustration of a forming apparatus for forming a web of glass fibers;

[0016] Figure 5 is a schematic illustration of an exemplary apparatus for forming a web or pack of glass fibers with a dry binder;

[0017] Figure 6 is a schematic representation, in elevation of a process for forming a pack of fibrous materials; and

[0018] Figure 7 is a schematic representation, in plan view, of a process for forming a pack from fibrous materials.

DETAILED DESCRIPTION OF THE INVENTION

[0019] The present invention will now be described with occasional reference to the specific exemplary embodiments of the invention. This invention may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

[0020] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. The terminology used in the description of the invention herein is for describing particular embodiments only and is not intended to be limiting of the invention. As used in the description of the invention and the appended claims, the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise.

[0021] Unless otherwise indicated, all numbers expressing quantities of dimensions such as length, width, height, and so forth as used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless otherwise indicated, the numerical properties set forth in the specification and claims are approximations that may vary depending on the desired properties sought to be obtained in embodiments of the present invention. Notwithstanding that the numerical ranges and parameters setting forth the broad scope of the invention are approximations, the numerical values set forth in the specific examples are reported as precisely as possible. Any numerical values, however, inherently contain certain errors necessarily resulting from error found in their respective measurements.

[0022] The description and figures disclose an improved method of forming a pack from fibrous materials. Generally, the improved continuous methods replace the traditional

methods of applying a wet binder to fiberized materials with new methods of making a batt or pack of fibers without any binder (i.e. material that binds fibers together) and/or new methods of making a batt or pack of fibers with dry binders.

[0023] The term "fibrous materials", as used herein, is defined to mean any material formed from drawing or attenuating molten materials. The term "pack", as used herein, is defined to mean any product formed by fibrous materials that are joined together by an adhesive and/or by mechanical entanglement.

[0024] Figures 1A and 3A illustrate a first exemplary embodiment of a continuous process or method 100 of forming a pack 300 (see Figure 3A) from fibrous materials. The dashed line 101 around the steps of the method 100 indicates that the method is a continuous method, as will be described in more detail below. The methods and packs will be described in terms of glass fibers, but the methods and packs are applicable as well to the manufacture of fibrous products formed from other mineral materials, such as the non-limiting examples of rock, slag and basalt.

[0025] Referring to Figure 1A, glass is melted 102. For example, Figure 3A schematically illustrates a melter 314. The melter 314 may supply molten glass 312 to a forehearth 316. Melters and forehearths are known in the art and will not be described herein. The molten glass 312 can be formed from various raw materials combined in such proportions as to give the desired chemical composition.

[0026] Referring back to Figure 1A, the molten glass 312 is processed to form 104 glass fibers 322. The molten glass 312 can be processed in a variety of different ways to form the fibers 322. For example, in the example illustrated by Figure 3A, the molten glass 312 flows from the forehearth 316 to one or more rotary fiberizers 318. The rotary fiberizers 18 receive the molten glass 312 and subsequently form veils 320 of glass fibers 322. As will be discussed in more detail below, the glass fibers 322 formed by the rotary fiberizers 318 are long and thin. Accordingly, any desired fiberizer, rotary or otherwise, sufficient to form long and thin glass fibers 322 can be used. While the embodiment illustrated in Figure 3A shows one rotary fiberizer 318, it should be appreciated that any desired number of rotary fiberizers 318 can be used.

[0027] The long and thin fibers may take a wide variety of different forms. In an exemplary embodiment, the long and thin fibers have a length in a range of from about 0.25 inches to about 10.0 inches and a diameter dimension in a range of from about 9 HT to about 35 HT. HT stands for hundred thousandths of an inch. In an exemplary embodiment, the fibers 322 have a length in a range of from about 1.0 inch to about 5.0 inches and a diameter dimension in a range of from about 14 HT to about 25 HT. In an exemplary embodiment, the fibers 322 have a length of about 3 inches and an average diameter of about 16-17 HT. While not being bound by the theory, it is believed the use of the relatively long and thin fibers advantageously provides a pack having better thermal and acoustic insulative performance, as well as better strength properties, such as higher tensile strength and/or higher bond strength, than a similar sized pack having shorter and thicker fibers.

[0028] In the exemplary embodiments described herein, the glass fibers 322 can optionally be coated or partially coated with a lubricant after the glass fibers are formed. For example, the glass fibers 322 can be coated with any lubricating material that does not bind the glass fibers together. In an exemplary embodiment, the lubricant can be a silicone compound, such as siloxane, dimethyl siloxane and/or silane. The lubricant can also be other materials or combinations of materials, such as, oil or an oil emulsion. The oil or oil emulsion may be a mineral oil or mineral oil emulsion and/or a vegetable oil or vegetable oil emulsion.

[0029] The glass fibers can be coated or partially coated with a lubricant in a wide variety of different ways. For example, the lubricant can be sprayed onto the glass fibers 322. In an exemplary embodiment, the lubricant is configured to prevent damage to the glass fibers 322 as the glass fibers 322 move through the manufacturing process and come into contact with various apparatus as well as other glass fibers. The lubricant can also be useful to reduce dust in the manufacturing process. The application of the optional lubricant can be precisely controlled by any desired structure, mechanism or device.

[0030] Referring to Figure 1A, a web 321 of fibers without a binder or other material that binds the fibers together is formed 106. The web 321 can be formed in a wide variety of different ways. In the example illustrated by Figure 3A, the glass fibers 322 are gathered by an optional gathering member 324. The gathering member 324 is shaped and sized to receive the glass fibers 322. The gathering member 324 is configured to divert the glass fibers 322 to a duct 330 for transfer to downstream processing stations, such as for example forming

apparatus 332, which forms the web 321. In other embodiments, the glass fibers 322 can be gathered on a conveying mechanism (not shown) to form the web.

[0031] The forming apparatus 332 can be configured to form a continuous dry web 321 of fibrous material having a desired thickness. In one exemplary embodiment, the dry webs 321 disclosed in this application can have a thickness in the range of about 0.25 inches to about 4 inches thick and a density in the range of about 0.2 lb/ft^3 to about 0.6 lb/ft^3. In one exemplary embodiment, the dry webs 321 disclosed in this application can have a thickness in the range of about 1 inch to about 3 inches thick and a density in the range of about 0.3 lb/ft^3 to about 0.5 lb/ft^3. In one exemplary embodiment, the dry webs 321 disclosed in this application can have a thickness of about 1.5 inches and a density of about 0.4 lb/ft^3. The forming apparatus 332 can take a wide variety of different forms. Any arrangement for forming a dry web 321 of glass fibers can be used.

[0032] In one exemplary embodiment, the forming apparatus 332 includes a rotating drum with forming surfaces and areas of higher or lower pressure. Referring to Figure 4, the pressure P1 on a side 460 of the forming surface 462 where the fibers 322 are collected is higher than the pressure P2 on the opposite side 464. This pressure drop ΔP causes the fibers 322 to collect on the forming surface 462 to form the dry web 321. In one exemplary embodiment, the pressure drop ΔP across the forming surface 462 is controlled to be a low pressure and produce a low area weight web. For example, the pressure drop ΔP can be from about 0.5 inches of water and 30 inches of water. A velocity V of the air traveling through the web being formed that results in this low pressure drop ΔP may be up to 1,000 feet per minute.

[0033] A low area weight web 321 having an area weight of about 5 to about 50 grams per square foot. The low area weight web may have the density and thickness ranges mentioned above. The low area weight web may have a thickness in the range of about 0.25 inches to about 4 inches thick, about 1 inch to about 3 inches thick, or about 1.5 inches. The low area weight web may have a density in the range of about 0.2 lb/ft^3 to about 0.6 lb/ft^3, about 0.3 lb/ft^3 to about 0.5 lb/ft^3 or about 0.4 lb/ft^3. Referring to Figure 3A, the dry web 321 leaves the forming apparatus 332. In one exemplary embodiment, the low area weight web 321 has a measured area weight distribution Coefficient of Variation = Sigma (One Standard Deviation)/Mean (Average) x 100% = of between 0 and 40%. In exemplary embodiments,

the weight distribution Coefficient of Variation is less than 30%. Less than 20% or less than 10%. In one exemplary embodiment, the weight distribution Coefficient of Variation is between 25% and 30%, such as about 28%.. In one exemplary embodiment, the weight distribution Coefficient of Variation is about 28%. The weight distribution Coefficient of Variation by measuring multiple small sample area sizes, for example, 2" x 2", of a large sample, for example a 6ft by 10 ft sample with a light table.

[0034] In the example illustrated by Figure 1A, the web 321 or multiple webs are layered 108. For example, a single web 321 may be lapped in the machine direction or cross-lapped at ninety degrees to the machine direction to form a layered web 350. In another embodiment, the web may be cut into portions and the portions are stacked on top of one another to form the layered web. In yet another exemplary embodiment, one or more duplicate fiberizers 318 and forming apparatus 332 can be implemented such that two or more webs are continuously produced in parallel. The parallel webs are then stacked on top of each other to form the layered web.

[0035] In one exemplary embodiment, the layering mechanism 332 is a lapping mechanism or a cross-lapping mechanism that functions in association with a conveyor 336. The conveyor 336 is configured to move in a machine direction as indicated by the arrow Dl. The lapping or cross-lapping mechanism is configured to receive the continuous web 321 and deposit alternating layers of the continuous web on the first conveyer 336 as the first conveyor moves in machine direction Dl. In the deposition process, a lapping mechanism 334 would form the alternating layers in a machine direction as indicated by the arrows D1 or the cross-lapping mechanism 334 would form the alternating layers in a cross-machine direction. Additional webs 321 may be formed and lapped or cross-lapped by additional lapping or cross-lapping mechanisms to increase the number of layers and throughput capacity.

[0036] In one exemplary embodiment, a cross-lapping mechanism is configured to precisely control the movement of the continuous web 321 and deposit the continuous web on the conveyor 336 such that the continuous web is not damaged. The cross-lapping mechanism can include any desired structure and can be configured to operate in any desired manner. In one exemplary embodiment, the cross-lapping mechanism includes a head (not shown) configured to move back and forth at 90 degrees to the machine direction D1. In this

embodiment, the speed of the moving head is coordinated such that the movement of the head in both cross-machine directions is substantially the same, thereby providing uniformity of the resulting layers of the fibrous body. In an exemplary embodiment, the cross-lapping mechanism comprises vertical conveyors (not shown) configured to be centered with a centerline of the conveyor 336. The vertical conveyors are further configured to swing from a pivot mechanism above the conveyor 336 such as to deposit the continuous web on the conveyor 336. While multiple examples of cross lapping mechanisms have been described above, it should be appreciated that the cross-lapping mechanism can be other structures, mechanisms or devices or combinations thereof.

[0037] The layered web 350 can have any desired thickness. The thickness of the layered web is a function of several variables. First, the thickness of the layered web 350 is a function of the thickness of the continuous web 321 formed by the forming apparatus 332. Second, the thickness of the layered web 350 is a function of the speed at which the layering mechanism 334 deposits layers of the continuous web 321 on the conveyer 336. Third, the thickness of the layered web 334 is a function of the speed of the conveyor 336. In the illustrated embodiment, the layered web 350 has a thickness in a range of from about 0.1 inches to about 20.0 inches. In an exemplary embodiment, a cross lapping mechanism 334 may form a layered web 350 having from 1 layer to 60 layers. Optionally, a cross-lapping mechanisms can be adjustable, thereby allowing the cross-lapping mechanisms 334 and 334 to form a pack having any desired width. In certain embodiments, the pack can have a general width in a range of from about 98.0 inches to about 236.0 inches.

[0038] In one exemplary embodiment, the layered web 350 is produced in a continuous process indicated by dashed box 101 in Figure 1A. The fibers produced by the fiberizer 318 are sent directly to the forming apparatus 332 (i.e. the fibers are not collected and packed and then unpacked for use at a remote forming apparatus). The web 321 is provided directly to the layering device 352 (i.e. the web is not formed and rolled up and then unrolled for use at a remote layering device 352). In an exemplary embodiment of the continuous process, each of the processes (forming and layering in Figure 1A) are connected to the fiberizing process, such that fibers from the fiberizer are used by the other processes without being stored for later use.

[0039] In one exemplary embodiment, the web 321 is relatively thick and has a low area weight, yet the continuous process has a high throughput. For example, a single layer of the web 321 may have an area weight of about 5 to about 50 grams per square foot. The low area weight web may have the density and thickness ranges mentioned above. The high output continuous process may produce between about 750 lbs/hr and 1500 lbs/hr, such as at least 900 lbs/hr or at least 1250 lbs/hr. The layered web 350 can be used in a wide variety of different applications.

[0040] Figures 1B and 3B illustrate a second exemplary embodiment of a method 150 of forming a pack 300 (see Figure 3B) from fibrous materials without the use of a binder. The dashed line 151 around the steps of the method 150 indicates that the method is a continuous method .Referring to Figure 1B, glass is melted 102. The glass may be melted as described above with respect to Figure 3A. The molten glass 312 is processed to form 104 glass fibers 322. The molten glass 312 can be processed as described above with respect to Figure 3A to form the fibers 322. A web 321 of fibers without a binder or other material that binds the fibers together is formed 106. The web 321 can be formed as described above with respect to Figure 3A.

[0041] Referring to Figure 1B, the fibers 322 of the web 321 are mechanically entangled 202 to form an entangled web 352 (see Figure 3B). Referring to Figure 3B, the fibers of the web 321 can be mechanically entangled by an entangling mechanism 345, such as a needling device. The entanglement mechanism 345 is configured to entangle the individual fibers 322 of the web 321. Entangling the glass fibers 322 ties the fibers of the web together. The entanglement causes mechanical properties of the web, such as for example, tensile strength and shear strength, to be improved. In the illustrated embodiment, the entanglement mechanism 345 is a needling mechanism. In other embodiments, the entanglement mechanism 345 can include other structures, mechanisms or devices or combinations thereof, including the non-limiting example of stitching mechanisms.

[0042] The entangled web 352 can have any desired thickness. The thickness of the entangled web is a function of the thickness of the continuous web 321 formed by the forming apparatus 332 and the amount of compression of the continuous web 321 by the entanglement mechanism 345. In an exemplary embodiment, the entangled web 352 has a thickness in a range of from about 0.1 inches to about 2.0 inches. In an exemplary

embodiment, the entangled web 352 has a thickness in a range of from about 0.5 inches to about 1.75 inches. For example, in one exemplary embodiment, the thickness of the entangled web is about ½".

[0043] In one exemplary embodiment, the entangled web 352 is produced in a continuous process 151. The fibers produced by the fiberizer 318 are sent directly to the forming apparatus 332 (i.e. the fibers are not collected and packed and then unpacked for use at a remote forming apparatus). The web 321 is provided directly to the entangling device 345 (i.e. the web is not formed and rolled up and then unrolled for use at a remote entangling device 345). The entangled web 352 can be used in a wide variety of different applications. In an exemplary embodiment of the continuous process, each of the processes (forming and entangling in Figure 1B) are connected to the fiberizing process, such that fibers from the fiberizer are used by the other processes without being stored for later use.

[0044] Figures 1C and 3C illustrate a third exemplary embodiment of a method 170 of forming a pack 370 (see Figure 3C) from fibrous materials without the use of a binder. Referring to Figure 1C, glass is melted 102. The dashed line 171 around the steps of the method 170 indicates that the method is a continuous method The glass may be melted as described above with respect to Figure 3A. Referring back to Figure 1C, the molten glass 312 is processed to form 104 glass fibers 322. The molten glass 312 can be processed as described above with respect to Figure 3A to form the fibers 322. Referring to Figure 1C, a web 321 of fibers without a binder or other material that binds the fibers together is formed 106. The web 321 can be formed as described above with respect to Figure 3A. Referring to Figure 1C, the web 321 or multiple webs are layered 108. The web 321 or multiple webs can be layered as described above with respect to Figure 3A. Referring to Figure 1C, the fibers 322 of the layered webs 350 are mechanically entangled 302 to form an entangled pack 370 of layered webs.

[0045] Referring to Figure 3C, the fibers of the layered webs 350 can be mechanically entangled by an entangling mechanism 345, such as a needling device. The entanglement mechanism 345 is configured to entangle the individual fibers 322 forming the layers of the layered web. Entangling the glass fibers 322 ties the fibers of the layered webs 350 together to form the pack. The mechanical entanglement causes mechanical properties, such as for example, tensile strength and shear strength, to be improved. In the illustrated embodiment,

the entanglement mechanism 345 is a needling mechanism. In other embodiments, the entanglement mechanism 345 can include other structures, mechanisms or devices or combinations thereof, including the non-limiting example of stitching mechanisms.

[0046] The entangled pack 370 of layered webs 350 can have any desired thickness. The thickness of the entangled pack is a function of several variables. First, the thickness of the entangled pack is a function of the thickness of the continuous web 321 formed by the forming apparatus 332. Second, the thickness of the entangled pack 370 is a function of the speed at which the lapping or cross-lapping mechanism 334 deposits layers of the continuous web 321 on the conveyer 336. Third, the thickness of the entangled pack 370 is a function of the speed of the conveyor 336. Fourth, the thickness of the entangled pack 370 is a function of the amount of compression of the layered webs 350 by the entanglement mechanism 345. The entangled pack 370 can have a thickness in a range of from about 0.1 inches to about 20.0 inches. In an exemplary embodiment, the entangled pack 370 may having from 1 layer to 60 layers. Each entangled web layer 352 may be from 0.1 to 2 inches thick. For example, each entangled web layer may be about 0.5 inches thick.

[0047] In one exemplary embodiment, the entangled pack 370 is produced in a continuous process. The fibers produced by the fiberizer 318 are sent directly to the forming apparatus 332 (i.e. the fibers are not collected and packed and then unpacked for use at a remote forming apparatus). The web 321 is provided directly to the layering device 352 (i.e. the web is not formed and rolled up and then unrolled for use at a remote layering device 352). The layered web 350 is provided directly to the entangling device 345 (i.e. the layered web is not formed and rolled up and then unrolled for use at a remote entangling device 345). In an exemplary embodiment of the continuous process, each of the processes (forming, layering, and entangling in Figure 1C) are connected to the fiberizing process, such that fibers from the fiberizer are used by the other processes without being stored for later use.

[0048] In one exemplary embodiment, the entangled pack 370 of layered webs is made from a web 321 or webs that is relatively thick and has a low area weight, yet the continuous process has a high throughput. For example, a single layer of the web 321 may have the area weights, thicknesses, and densities mentioned above. The high output continuous process may produce between about 750 lbs/hr and 1500 lbs/hr, such as at least 900 lbs/hr or at least 1250 lbs/hr. In an exemplary embodiment, the combination of high web throughput and

mechanical entanglement, such as needling, of a continuous process is facilitated by layering of the web 321, such as lapping or cross-lapping of the web. By layering the web 321, the linear speed of the material moving through the layering device is slower than the speed at which the web is formed. For example, in a continuous process, a two layer web will travel through the entangling apparatus 345 at ½ the speed at which the web is formed (3 layers -1/3 the speed, etc.). This reduction in speed allows for a continuous process where a high throughput, low area weight web 321 is formed and converted into a multiple layer, mechanically entangled pack 370. The entangled pack 370 of layered webs can be used in a wide variety of different applications.

[0049] In an exemplary embodiment, the layering and entangling of the long, thin fibers results in a strong web 370. For example, the entanglement of the long, thin glass fibers described in this application results in a layered, entangled web with a high tensile strength and a high bond strength. Tensile strength is the strength of the web 370 when the web is pulled in the direction of the length or width of the web. Bond strength is the strength of the web when the web 370 is pulled apart in the direction of the thickness of the web.

[0050] Tensile strength and bond strength may be tested in a wide variety of different ways. In one exemplary embodiment, a machine, such as an Instron machine, pulls the web 370 apart at a fixed speed (12 inches per second in the examples described below) and measures the amount of force required to pull the web apart. Forces required to pull the web apart, including the peak force applied to the web before the web rips or fails, are recorded.

[0051] In one method of testing tensile strength, the tensile strength in the length direction is measured by clamping the ends of the web along the width of the web, pulling the web 370 along the length of the web with the machine at the fixed speed (12 inches per second in the examples provided below), and recording the peak force applied in the direction of the length of the web. The tensile strength in the width direction is measured by clamping the sides of the web along the width of the web, pulling the web 370 along the width of the web at the fixed speed (12 inches per second in the examples provided below), and recording the peak force applied. The tensile strength in the length direction and the tensile strength in the width direction are averaged to determine the tensile strength of the sample.

[0052] In one method of testing bond strength, a sample of a predetermined size (6" by 6" in the examples described below) is provided. Each side of the sample is bonded to a substrate, for example by gluing. The substrates on the opposite side of the sample are pulled apart with the machine at the fixed speed (12 inches per second in the examples provided below), and recording the peak force applied. The peak force applied is divided by the area of the sample (6" by 6" in the examples described below) to provide the bond strength in terms of force over area.

[0053] The following examples are provided to illustrate the increased strength of the layered, entangled web 370. In these examples, no binder is included. That is, no aqueous or dry binder is included. These examples do not limit the scope of the present invention, unless expressly recited in the claims. Examples of layered, entangled webs having 4, 6, and 8 layers are provided. However, the layered entangled web 370 may be provided with any number of layers. The layered, entangled web 370 sample length, width, thickness, number of laps, and weight may vary depending on the application for the web 370.

[0054] In one exemplary embodiment, a web 370 sample that is 6 inches by 12 inches, has multiple layers, such as two laps (i.e. four layers), is between 0.5 inches thick and 2.0 inches thick, has a weight per square foot between 0.1 and 0.3 lbs/sq ft, has a tensile strength that is greater than 3 lbf, and has a tensile strength to weight ratio that is greater than 40 lbf/lbm, such as from about 40 to about 120 lbf/lbm. In an exemplary embodiment, a bond strength of this sample is greater than 0.1 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 5 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 7.5 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 10 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 12.5 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 13.75 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is between 3 and 15 lbf. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 2 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 5 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 10 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater

than 15 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 20 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 5 lbf and the bond strength is greater than 2 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 7.5 lbf and the bond strength is greater than 7.5 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 10 lbf and the bond strength is greater than 10 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 12.5 lbf and the bond strength is greater than 15 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 13.75 lbf and the bond strength is greater than 20 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is between 3 and 15 lbf and the bond strength is between 0.3 and 30 lbs/ sq ft.

[0055] In one exemplary embodiment, a web 370 sample that is 6 inches by 12 inches, has multiple layers, such as two laps (i.e. four layers), is between 0.5 inches thick and 1.75 inches thick, has a weight per square foot between 0.12 and 0.27 lbs/sq ft, has a tensile strength that is greater than 3 lbf, and has a tensile strength to weight ratio that is greater than 40 lbf/lbm, such as from about 40 to about 120 lbf/lbm, and a bond strength that is greater than 1 lb/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 5 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 7.5 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 10 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 12.5 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 13.75 lbf. In one exemplary embodiment, the tensile strength of the sample described in this paragraph is between 3 and 15 lbf. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 2 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 5 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 10 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 15 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 20 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is

greater than 5 lbf and the bond strength is greater than 2 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 7.5 lbf and the bond strength is greater than 7.5 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 10 lbf and the bond strength is greater than 10 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 12.5 lbf and the bond strength is greater than 15 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 13.75 lbf and the bond strength is greater than 20 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is between 3 and 15 lbf and the bond strength is between 0.3 and 30 lbs/ sq ft.

[0056] In one exemplary embodiment, a web 370 sample that is 6 inches by 12 inches, has multiple layers, such as two laps (i.e. four layers), is between 0.5 inches thick and 1.25 inches thick, has a weight per square foot between 0.2 and 0.3 lbs/sq ft, has a tensile strength that is greater than 10 lbf, and has a tensile strength to weight ratio that is greater than 75 lbf/lbm, such as from about 75 about 120 lbf/lbm. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 12.5 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 13.75 lbf. In one exemplary embodiment, the tensile strength of the sample described in this paragraph is between 3 and 15 lbf. In one exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 3 lb/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 10 lb/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 15 lb/sq ft. In one exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 10 lbf and the bond strength is greater than 3 lb/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 12.5 lbf and the bond strength is greater than 10 lb/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 13.75 lbf and the bond strength is greater than 15 lb/sq ft.

[0057] In one exemplary embodiment, a web 370 sample that is 6 inches by 12 inches, has multiple layers, such as three laps (i.e. six layers), is between 1.0 inches thick and 2.25 inches thick, has a weight per square foot between 0.15 and 0.4 lbs/sq ft, has a tensile strength that is greater than 5 lbf, and has a tensile strength to weight ratio that is greater than 40 lbf/lbm,

such as from about 40 to about 140 lbf/lbm. In an exemplary embodiment, the bond strength of this sample is greater than 0.1 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 7.5 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 10 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 12.5 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 13.75 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is between 5 and 20 lbf. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 0.5 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 1.0 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 1.5 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 2.0 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 2.5 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 3.0 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 7.5 lbf and the bond strength is greater than 0.40 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 10 lbf and the bond strength is greater than 0.6 lbs/ sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 12.5 lbf and the bond strength is greater than 0.9 lbs/ sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is between 5 and 20 lbf and the bond strength is between 0.1 and 4 lbs/sq ft.

[0058] In one exemplary embodiment, a web 370 sample that is 6 inches by 12 inches, has multiple layers, such as three laps (i.e. six layers), is between 1.0 inches thick and 1.50 inches thick, and has a weight per square foot between 0.25 and 0.4 lbs/sq ft, has a tensile strength that is greater than 9 lbf, and has a tensile strength to weight ratio that is greater than 50 lbf/lbm, such as from about 50 to about 140 lbf/lbm. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 12.5lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 13.75 lbf. In one exemplary embodiment, the tensile strength of the sample described in this paragraph is between 9 and 15 lbf. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 0.5 lbs/sq ft. In an

exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 1.0 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 1.5 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 2.0 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 2.5 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 3.0 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 9 lbf and a bond strength that is greater than 0.5 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 12.5lbf and a bond strength that is greater than 1.0 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 13.75 lbf and a bond strength that is greater than 2 lbs/sq ft.

[0059] In one exemplary embodiment, a web 370 sample that is 6 inches by 12 inches, has multiple layers, such as four laps (i.e. eight layers), is between 0.875 inches thick and 2.0 inches thick, and has a weight per square foot between 0.15 and 0.4 lbs/sq ft, has a tensile strength that is greater than 3 lbf, and has a tensile strength to weight ratio that is greater than 40 lbf/lbm, such as from about 40 to about 130 lbf/lbm. In one exemplary embodiment, the web has a bond strength that is greater than 0.3 lbs/sq ft. In an exemplary embodiment, the bond strength of this sample is greater than 0.1 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 7.5 lbf. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 10 lbf. In one exemplary embodiment, the tensile strength of the sample described in this paragraph is between 3 and 15 lbf. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 0.5 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 1.0 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 2 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 3 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 4 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 5 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 10 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 7.5 lbf and the

bond strength is greater than .5 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 10 lbf and the bond strength is greater than 1.0 lbs/sq ft. In one exemplary embodiment, the tensile strength of the sample described in this paragraph is between 3 and 15 lbf and the bond strength is between 0.3 and 15 lbs/sq ft.

[0060] In one exemplary embodiment, a web 370 sample that is 6 inches by 12 inches, has multiple layers, such as four laps (i.e. eight layers), is between 1.0 inches thick and 2.0 inches thick, and has a weight per square foot between 0.1 and 0.3 lbs/sq ft, has a tensile strength that is greater than 9 lbf, and has a tensile strength to weight ratio that is greater than 70 lbf/lbm. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 10 lbf. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 0.5 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 1.0 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 2 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 3 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 4 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 5 lbs/sq ft. In an exemplary embodiment, the bond strength of the sample described in this paragraph is greater than 10 lbs/sq ft. In an exemplary embodiment, the tensile strength of the sample described in this paragraph is greater than 10 lbf and the bond strength is greater than 5 lbs/sq ft.

[0061] Figures 2A-2C illustrate exemplary embodiments of methods that are similar to the embodiments of Figures 1A-1C, except the web 521 (see Figure 5) is formed 260 with a dry or non-aqueous binder. The method 200 of Figure 2A generally corresponds to the method 100 of Figure 1A. The method 250 of Figure 2B generally corresponds to the method 150 of Figure 1B. The method 270 of Figure 2C generally corresponds to the method 170 of Figure 1C.

[0062] Figure 2D illustrates a method 290 that is similar to the method 270 of Figure 2C. In Figure 2D, the steps in boxes with dashed lines are optional. In the exemplary embodiment illustrated by Figure 2D, the dry binder can optionally be added to the web step 292 and/or

the layered web at step 294, instead of (or in addition to) before the web is formed. For example, if step 292 is included, the web may be formed without a dry binder, and then the dry binder is added to the web before layering and/or during layering. If step 294 is included, the web may be formed and layered without a dry binder, and then the dry binder is added to the layered web.

[0063] Referring to Figure 5, the dry binder (indicated by the large arrows) can be added to the fibers 322 and/or the web 521 at a variety of different points in the process. Arrow 525 indicates that the dry binder can be added to the fibers 322 at or above the collecting member. Arrow 527 indicates that the dry binder can be added to the fibers 322 in the duct 330. Arrow 529 indicates that the dry binder can be added to the fibers 322 in the forming apparatus 332. Arrow 531 indicates that the dry binder can be added to the web 321 after the web leaves the forming apparatus 332. Arrow 533 indicates that the dry binder can be added to the web 321 as the web is layered by the layering apparatus 334. Arrow 535 indicates that the dry binder can be added to the web 321 after the web is layered. Arrow 537 indicates that the dry binder can be added to the web 321 or layered web in the oven 550. The dry binder can be added to the fibers 322 or the web 321 to form a web 521 with dry binder in any manner.

[0064] In one exemplary embodiment, the dry binder is applied to the fibers 322 at a location that is significant distance downstream from the fiberizer 318. For example, the dry binder may be applied to the fibers at a location where the temperature of the fibers and/or a temperature of the air surrounding the fibers is significantly lower than the temperature of the fibers and the surrounding air at the fiberizer. In one exemplary embodiment, the dry binder is applied at a location where a temperature of the fibers and/or a temperature of air that surrounds the fibers is below a temperature at which the dry binder melts or a temperature at which the dry binder fully cures or reacts. For example, a thermoplastic binder may be applied at a point in the production line where a temperature of the fibers 322 and/or a temperature of air that surrounds the fibers are below the melting point of the of the thermoplastic binder. A thermoset binder may be applied at a point in the production line where a temperature of the fibers 322 and/or a temperature of air that surrounds the fibers are below a curing temperature of the thermoset binder. That is, the thermoset binder may be applied at a point where a temperature of the fibers 322 and/or a temperature of air that surrounds the fibers is below a point where the thermoset binder fully reacts or full cross-linking of the thermoset binder occurs. In one exemplary embodiment, the dry binder is

applied at a location in the production line where the temperature of the fibers 322 and/or a temperature of air that surrounds the fibers are below 250 degrees F. In one exemplary embodiment, the temperature of the fibers and/or a temperature of air that surrounds the fibers at the locations indicated by arrows 527, 529, 531, 533, and 535 in Figure 5 is below a temperature at which the dry binder melts or fully cures.

[0065] In one exemplary embodiment, the binder applicator is a sprayer configured for dry powders. The sprayer may be configured such that the force of the spray is adjustable, thereby allowing more or less penetration of the dry powder into the continuous web of fibrous material. Alternatively, the binder applicator can be other structures, mechanisms or devices or combinations thereof, such as for example a vacuum device, sufficient to draw the dry binder into the continuous web 321 of glass fibers.

[0066] The optional dry binder can take a wide variety of different forms. Any non-aqueous medium that holds the fibers 322 together to form a web 521 can be used. In one exemplary embodiment, the dry binder, while being initially applied to the fibers, is comprised of substantially 100% solids. The term "substantially 100% solids", as used herein, means any binder material having diluents, such as water, in an amount less than or equal to approximately two percent, and preferably less than or equal to approximately one percent by weight of the binder (while the binder is being applied, rather than after the binder has dried or cured). However, it should be appreciated that certain embodiments, the binder can include diluents, such as water, in any amount as desired depending on the specific application and design requirements. In one exemplary embodiment, the dry binder is a thermoplastic resin-based material that is not applied in liquid form and further is not water based. In other embodiments, the dry binder can be other materials or other combinations of materials, including the non-limiting example of polymeric thermoset resins. The dry binder can have any form or combinations of forms including the non-limiting examples of powders, particles, fibers and/or hot melt. Examples of hot melt polymers include, but are not limited to, ethylene-vinyl acetate copolymer, ethylene-acrylate copolymer, low density polyethylene, high density polyethylene, atactic polypropylene, polybutene-1, styrene block copolymer, polyamide, thermoplastic polyurethane, styrene block copolymer, polyester and the like. In one exemplary embodiment, sufficient dry binder is applied such that a cured fibrous pack can be compressed for packaging, storage and shipping, yet regains its thickness - a process known as "loft recovery" - when installed.

[0067] In the examples illustrated by Figures 2A-2D and 5, the glass fibers 322 can optionally be coated or partially coated with a lubricant before or after the dry binder is applied to the glass fibers. In an exemplary embodiment, the lubricant is applied after the dry binder to enhance the adhesion of the dry binder to the glass fibers 322. The lubricant can be any of the lubricants described above.

[0068] Referring to Figure 5, the continuous web with unreacted dry binder 521 is transferred from the forming apparatus 332 to the optional layering mechanism 334. The layering mechanism may take a wide variety of different forms. For example, the layering mechanism may be a lapping mechanism that layers the web 321 in the machine direction D1 or a cross-lapping mechanism that laps the web in a direction that is substantially orthogonal to the machine direction. The cross-lapping device described above for layering the binderless web 321 can be used to layer the web 521 with unreacted dry binder.

[0069] In an exemplary embodiment, the dry binder of the continuous web 521 is configured to be configured to be thermally set in a curing oven 550. In an exemplary embodiment, the curing oven 550 replaces the entanglement mechanism 345, since the dry binder holds the fibers 322 together. In another exemplary embodiment, both a curing oven 550 and an entanglement mechanism 345 are included.

[0070] Figures 6 and 7 schematically illustrate another exemplary embodiment of a method for forming a pack from fibrous materials is illustrated generally at 610. Referring to Figure 6, molten glass 612 is supplied from a melter 614 to a forehearth 616. The molten glass 612 can be formed from various raw materials combined in such proportions as to give the desired chemical composition. The molten glass 612 flows from the forehearth 616 to a plurality of rotary fiberizers 618.

[0071] Referring to Figure 6, the rotary fiberizers 618 receive the molten glass 612 and subsequently form veils 620 of glass fibers 622 entrained in a flow of hot gases. As will be discussed in more detail below, the glass fibers 622 formed by the rotary fiberizers 618 are long and thin. Accordingly, any desired fiberizer, rotary or otherwise, sufficient to form long and thin glass fibers 22 can be used. While the embodiment illustrated in Figures 6 and 7 show a quantity of two rotary fiberizers 618, it should be appreciated that any desired number of rotary fiberizers 18 can be used.

[0072] The flow of hot gases can be created by optional blowing mechanisms, such as the non-limiting examples of annular blowers (not shown) or annular burners (not shown). Generally, the blowing mechanisms are configured to direct the veil 620 of glass fibers 622 in a given direction, usually in a downward manner. It should be understood that the flow of hot gasses can be created by any desired structure, mechanism or device or any combination thereof.

[0073] As shown in Figure 6, optional spraying mechanisms 626 can be positioned beneath the rotary fiberizers 618 and configured to spray fine droplets of water or other fluid onto the hot gases in the veils 620 to help cool the flow of hot gases, protect the fibers 622 from contact damage and/or enhance the bonding capability of the fibers 622. The spraying mechanisms 626 can be any desired structure, mechanism or device sufficient to spray fine droplets of water onto the hot gases in the veils 620 to help cool the flow of hot gases, protect the fibers 622 from contact damage and/or enhance the bonding capability of the fibers 22. While the embodiment shown in Figure 6 illustrates the use of the spraying mechanisms 626, it should be appreciated that the use of the spraying mechanisms 626 is optional and the method of forming the pack from fibrous materials 610 can be practiced without the use of the spraying mechanisms 626.

[0074] Optionally, the glass fibers 622 can be coated with a lubricant after the glass fibers are formed. In the illustrated embodiment, a plurality of nozzles 628 can be positioned around the veils 620 at a position beneath the rotary fiberizers 618. The nozzles 628 can be configured to supply a lubricant (not shown) to the glass fibers 622 from a source of lubricant (not shown).

[0075] The application of the lubricant can be precisely controlled by any desired structure, mechanism or device, such as the non-limiting example of a valve (not shown). In certain embodiments, the lubricant can be a silicone compound, such as siloxane, dimethyl siloxane, and/or silane. The lubricant can also be other materials or combinations of materials, such as for example an oil or an oil emulsion. The oil or oil emulsion may be a mineral oil or mineral oil emulsion and/or a vegetable oil or vegetable oil emulsion. In an exemplary embodiment, the lubricant is applied in an amount of about 1.0 percent oil and/or silicone compound by weight of the resulting pack of fibrous materials. However, in other embodiments, the amount of the lubricant can be more or less than about 1.0 percent oil and/or silicone compound by weight.

[0076] While the embodiment shown in Figure 6 illustrates the use of nozzles 628 to supply a lubricant (not shown) to the glass fibers 622, it should be appreciated that the use of nozzles 628 is optional and the method of forming the pack from fibrous materials 610 can be practiced without the use of the nozzles 628.

[0077] In the illustrated embodiment, the glass fibers 622, entrained within the flow of hot gases, can be gathered by an optional gathering member 624. The gathering member 624 is shaped and sized to easily receive the glass fibers 622 and the flow of hot gases. The gathering member 624 is configured to divert the glass fibers 622 and the flow of hot gases to a duct 630 for transfer to downstream processing stations, such as for example forming apparatus 632a and 632b. In other embodiments, the glass fibers 622 can be gathered on a conveying mechanism (not shown) such as to form a blanket or batt (not shown). The batt can be transported by the conveying mechanism to further processing stations (not shown). The gathering member 624 and the duct 630 can be any structure having a generally hollow configuration that is suitable for receiving and conveying the glass fibers 622 and the flow of hot gases. While the embodiment shown in Figure 6 illustrates the use of the gathering member 624, it should be appreciated that the use of gathering member 624 to divert the glass fibers 622 and the flow of hot gases to the duct 630 is optional and the method of forming the pack from fibrous materials 610 can be practiced without the use of the gathering member 624.

[0078] In the embodiment shown in Figures 6 and 7, a single fiberizer 618 is associated with an individual duct 630, such that the glass fibers 622 and the flow of hot gases from the single fiberizer 618 are the only source of the glass fibers 622 and the flow of hot gasses entering the duct 630. Alternatively, an individual duct 630 can be adapted to receive the glass fibers 622 and the flow of hot gases from multiple fiberizers 618 (not shown).

[0079] Referring again to Figure 6, optionally, a header system (not shown) can be positioned between the forming apparatus 632a and 632b and the fiberizers 618. The header system can be configured as a chamber in which glass fibers 622 and gases flowing from the plurality of fiberizers 618 can be combined while controlling the characteristics of the resulting combined flow. In certain embodiments, the header system can include a control system (not shown) configured to combine the flows of the glass fibers 622 and gases from the fiberizers 618 and further configured to direct the resulting combined flows to the

forming apparatus 632a and 632b. Such a header system can allow for maintenance and cleaning of certain fiberizers 618 without the necessity of shutting down the remaining fiberizers 618. Optionally, the header system can incorporate any desired means for controlling and directing the glass fibers 22 and flows of gases.

[0080] Referring now to Fig. 7, the momentum of the flow of the gases, having the entrained glass fibers 622, will cause the glass fibers 622 to continue to flow through the duct 630 to the forming apparatus 632a and 632b. The forming apparatus 632a and 632b can be configured for several functions. First, the forming apparatus 632a and 632b can be configured to separate the entrained glass fibers 622 from the flow of the gases. Second, the forming apparatus 632a and 632b can be configured to form a continuous thin and dry web of fibrous material having a desired thickness. Third, the forming apparatus 632a and 632b can be configured to allow the glass fibers 622 to be separated from the flow of gasses in a manner that allows the fibers to be oriented within the web with any desired degree of "randomness". The term "randomness", as used herein, is defined to mean that the fibers 622, or portions of the fibers 622, can be nonpreferentially oriented in any of the X, Y or Z dimensions. In certain instances, it may be desired to have a high degree of randomness. In other instances, it may be desired to control the randomness of the fibers 622 such that the fibers 622 are non-randomly oriented, in other words, the fibers are substantially coplanar or substantially parallel to each other. Fourth, the forming apparatus 632a and 632b can be configured to transfer the continuous web of fibrous material to other downstream operations.

[0081] In the embodiment illustrated in Figure 7, each of the forming apparatus 632a and 632b include a drum (not shown) configured for rotation. The drum can include any desired quantity of foraminous surfaces and areas of higher or lower pressure. Alternatively, each of the forming apparatus 332a and 332b can be formed from other structures, mechanisms and devices, sufficient to separate the entrained glass fibers 622 from the flow of the gases, form a continuous web of fibrous material having a desired thickness and transfer the continuous web of fibrous material to other downstream operations. In the illustrated embodiment shown in Figure 7, each of the forming apparatus 632a and 632b are the same. However, in other embodiments, each of the forming apparatus 632a and 632b can be different from each other.

[0082] Referring again to Figure 7, the continuous web of fibrous material is transferred from the forming apparatus 632a and 632b to an optional binder applicator 646. The binder

applicator 646 is configured to apply a "dry binder" to the continuous web of fibrous material. The term "dry binder", as used herein, is defined to mean that the binder is comprised of substantially 100% solids while the binder is being applied. The term "substantially 100% solids", as used herein, is defined to mean any binder material having diluents, such as water, in an amount less than or equal to approximately two percent, and preferably less than or equal to approximately one percent by weight of the binder (while the binder is being applied, rather than after the binder has dried and/or cured). However, it should be appreciated that certain embodiments, the binder can include diluents, such as water, in any amount as desired depending on the specific application and design requirements. The binder may be configured to thermally set in a curing oven 650. In this application, the terms “cure” and “thermally set” refer to a chemical reaction and/or one or more phase changes that cause the dry binder to bind the fibers of the web together. For example, a thermoset dry binder (or thermoset component of the dry binder) cures or thermally sets as a result of a chemical reaction that occurs as a result of an application of heat. A thermoplastic dry binder (or thermoplastic component of the dry binder) cures or thermally sets as a result of being heated to a softened or melted phase and then cooled to a solid phase.

[0083] In an exemplary embodiment, the dry binder is a thermoplastic resin-based material that is not applied in liquid form and further is not water based. In other embodiments, the dry binder can be other materials or other combinations of materials, including the non-limiting example of polymeric thermoset resins. The dry binder can have any form or combinations of forms including the non-limiting examples of powders, particles, fibers and/or hot melt. Examples of hot melt polymers include, but are not limited to, ethylene-vinyl acetate copolymer, ethylene-acrylate copolymer, low density polyethylene, high density polyethylene, atactic polypropylene, polybutene-1, styrene block copolymer, polyamide, thermoplastic polyurethane, styrene block copolymer, polyester and the like. Sufficient dry binder is applied such that a cured fibrous pack can be compressed for packaging, storage and shipping, yet regains its thickness - a process known as "loft recovery" - when installed. Applying the dry binder to the continuous web of fibrous material forms a continuous web, optionally with unreacted binder.

[0084] In the embodiment illustrated by Figures 6 and 7, the binder applicator 646 is a sprayer configured for dry powders. The sprayer is configured such that the force of the spray

is adjustable, thereby allowing more or less penetration of the dry powder into the continuous web of fibrous material. Alternatively, the binder applicator 646 can be other structures, mechanisms or devices or combinations thereof, such as for example a vacuum device, sufficient to draw a "dry binder" into the continuous web of fibrous material.

[0085] While the embodiment illustrated in Figure 7 shows a binder applicator 646 configured to apply a dry binder to the continuous web of fibrous material, it is within the contemplation of this invention that in certain embodiments no binder will be applied to the continuous web of fibrous material.

[0086] Referring again to Figure 7, the continuous web, optionally with unreacted binder is transferred from the binder applicators 646 to the corresponding cross-lapping mechanism 634a and 634b. As shown in Figure 7, forming apparatus 632a is associated with cross-lapping mechanism 634a and forming apparatus 632b is associated with cross-lapping mechanism 634b. The cross-lapping mechanisms 634a and 634b function in association with a first conveyor 636. The first conveyor 636 is configured to move in a machine direction as indicated by the arrow Dl. The cross-lapping mechanism 634a is configured to receive the continuous web, optionally with unreacted binder, from the optional binder applicators 646 and is further configured to deposit alternating layers of the continuous web, optionally with unreacted binder, on the first conveyer 636 as the first conveyor 636 moves in machine direction Dl, thereby forming the initial layers of a fibrous body. In the deposition process, the cross-lapping mechanism 634a forms the alternating layers in a cross-machine direction as indicated by the arrows D2. Accordingly, as the deposited continuous web, optionally with unreacted binder, from crosslapping mechanism 634a travels in machine direction Dl, additional layers are deposited on the fibrous body by the downstream cross-lapping mechanism 634b. The resulting layers of the fibrous body deposited by cross-lapping mechanisms 634a and 634b form a pack.

[0087] In the illustrated embodiment, the cross-lapping mechanisms 634a and 634b are devices configured to precisely control the movement of the continuous web with unreacted binder and deposit the continuous web with unreacted binder on the first conveyor 636 such that the continuous web, optionally with unreacted binder, is not damaged. The cross-lapping mechanisms 634a and 634b can include any desired structure and can be configured to operate in any desired manner. In one example, the cross-lapping mechanisms 634a and 634b

can include a head (not shown) configured to move back and forth in the cross-machine direction D2. In this embodiment, the speed of the moving head is coordinated such that the movement of the head in both cross-machine directions is substantially the same, thereby providing uniformity of the resulting layers of the fibrous body. In another example, vertical conveyors (not shown) configured to be centered with a centerline of the first conveyor 636 can be utilized. The vertical conveyors are further configured to swing from a pivot mechanism above the first conveyor 636 such as to deposit the continuous web, optionally with unreacted binder, on the first conveyor 36. While several examples of cross lapping mechanisms have been described above, it should be appreciated that the cross-lapping mechanisms 634a and 634b can be other structures, mechanisms or devices or combinations thereof.

[0088] Referring again to Figure 7, optionally the positioning of the continuous web, optionally with unreacted binder, on the first conveyor 636 can be accomplished by a controller (not shown), such as to provide improved uniformity of the pack. The controller can be any desired structure, mechanism or device or combinations thereof.

[0089] The layered web or pack can have any desired thickness. The thickness of the pack is a function of several variables. First, the thickness of the pack is a function of the thickness of the continuous web, optionally with unreacted binder, formed by each of the forming apparatus 632a and 632b. Second, the thickness of the pack is a function of the speed at which the cross-lapping mechanisms 634a and 634b alternately deposit layers of the continuous web, optionally with unreacted binder, on the first conveyer 636. Third, the thickness of the pack is a function of the speed of the first conveyor 636. In the illustrated embodiment, the pack has a thickness in a range of from about 0.1 inches to about 20.0 inches. In other embodiments, the pack can have a thickness less than about 0.1 inches or more than about 20.0 inches.

[0090] As discussed above, the cross lapping mechanisms 634a and 634b are configured to deposit alternating layers of the continuous web, optionally with unreacted binder, on the first conveyer 636 as the first conveyor 636 moves in machine direction Dl, thereby forming layers of a fibrous body. In the illustrated embodiment, the cross lapping mechanism 634a and 634b and the first conveyor 636 are coordinated such as to form a fibrous body having a quantity of layers in a range of from about 1 layer to about 60 layers. In other embodiments,

the cross lapping mechanism 634a and 634b and the first conveyor 636 can be coordinated such as to form a fibrous body having any desired quantity of layers, including a fibrous body having in excess of 60 layers.

[0091] Optionally, the cross-lapping mechanisms 634a and 634b can be adjustable, thereby allowing the cross-lapping mechanisms 634a and 634b to form a pack having any desired width. In certain embodiments, the pack can have a general width in a range of from about 98.0 inches to about 236.0 inches. Alternatively, the pack can have a general width less than about 98.0 inches or more than about 236.0 inches.

[0092] While the cross-lapping mechanisms 634a and 634b have been described above as being jointly involved in the formation of a fibrous body, it should be appreciated that in other embodiments, the cross-lapping mechanisms 634a and 634b can operate independently of each other such as to form discrete lanes of fibrous bodies.

[0093] Referring to Figures 6 and 7, the pack, having the layers formed by the cross-lapping mechanisms 634a and 634b, is carried by the first conveyor 636 to an optional trim mechanism 640. The optional trim mechanism 640 is configured to trim the edges of the pack, such as to form a desired width of the pack. In an exemplary embodiment, the pack can have an after-trimmed width in a range of from about 98.0 inches to about 236.0 inches. Alternatively, the pack can have an after trimmed width less than about 98.0 inches or more than about 236.0 inches.

[0094] In the illustrated embodiment, the optional trim mechanism 640 includes a saw system having a plurality of rotating saws (not shown) positioned on either side of the pack. Alternatively, the trim mechanism 640 can be other structures, mechanisms or devices or combinations thereof including the non-limiting examples of water jets, compression knives.

[0095] In the illustrated embodiment, the trim mechanism 640 is advantageously positioned upstream from the curing oven 650. Positioning the trim mechanism 640 upstream from the curing oven 650 allows the pack to be trimmed before the pack is thermally set in the curing oven 650. Optionally, materials that are trimmed from the pack by the trim mechanism 640 can be returned to the flow of gasses and glass fibers in the ducts 630 and recycled in the forming apparatus 632a and 632b. Recycling of the trim materials advantageously prevents potential environmental issues connected with the disposal of the trim materials. As shown in

Figure 6, ductwork 642 connects the trim mechanism 640 with the ducts 630 and is configured to facilitate the return of trim materials to the forming apparatus 632a and 632b. While the embodiment shown in Figures 6 and 7 illustrate the recycling of the trimmed materials, it should be appreciated that the recycling of the trimmed materials is optional and the method of forming the pack from fibrous materials 610 can be practiced without recycling of the trimmed materials. In another exemplary embodiment, the trim mechanism 640 is positioned downstream from the curing oven 650. This positioning is particularly useful if the trimmed materials are not recycled. Trimming the pack forms a trimmed pack.

[0096] The trimmed pack is conveyed by the first conveyor 636 to a second conveyor 644. As shown in Figure 6, the second conveyor 644 may be positioned to be "stepped down" from the first conveyor 636. The term "stepped down", as used herein, is defined to mean the upper surface of the second conveyor 644 is positioned to be vertically below the upper surface of the first conveyor 636. The stepping down of the conveyors will be discussed in more detail below.

[0097] Referring again to Figures 1 and 2, the trimmed pack is carried by the second conveyor 644 to an optional entanglement mechanism 645. The entanglement mechanism 645 is configured to entangle the individual fibers 622 forming the layers of the trimmed pack. Entangling the glass fibers 622 within the pack ties the pack together. In the embodiments where dry binder is included, entangling the glass fibers 622 advantageously allows mechanical properties, such as for example, tensile strength and shear strength, to be improved. In the illustrated embodiment, the entanglement mechanism 645 is a needling mechanism. In other embodiments, the entanglement mechanism 645 can include other structures, mechanisms or devices or combinations thereof, including the non-limiting example of stitching mechanisms. While the embodiment shown in Figs. 6 and 7 illustrate the use of the entanglement mechanism 645, it should be appreciated that the use of the entanglement mechanism 645 is optional and the method of forming the pack from fibrous materials 610 can be practiced without the use of the entanglement mechanism 645. Entangling the fibers within the pack forms an entangled pack.

[0098] The second conveyor 644 conveys the pack with optional dry binder, that is optionally trimmed, and/or optionally entangled (hereafter both the trimmed pack and the entangled pack are simply referred to as the "pack") to a third conveyor 648. When the pack includes a

dry binder, the third conveyor 648 is configured to carry the pack to an optional curing oven 650. The curing oven 650 is configured to blow a fluid, such as for example, heated air through the pack such as to cure the dry binder and rigidly bond the glass fibers 622 together in a generally random, three-dimensional structure. Curing the pack in the curing oven 650 forms a cured pack.

[0099] As discussed above, the pack optionally includes a dry binder. The use of the dry binder, rather than a traditional wet binder, advantageously allows the curing oven 650 to use less energy to cure the dry binder within the pack. In the illustrated embodiment, the use of the dry binder in the curing oven 650 results in an energy savings in a range of from about 30.0% to about 80.0% compared to the energy used by conventional curing ovens to cure wet or aqueous binder. In still other embodiments, the energy savings can be in excess of 80.0%. The curing oven 650 can be any desired curing structure, mechanism or device or combinations thereof.

[00100] The third conveyor 648 conveys the cured pack to a fourth conveyor 652. The fourth conveyor 652 is configured to carry the cured pack to a cutting mechanism 654. Optionally, the cutting mechanism 654 can be configured for several cutting modes. In a first optional cutting mode, the cutting mechanism is configured to cut the cured pack in vertical directions along the machine direction Dl such as to form lanes. The formed lanes can have any desired widths. In a second optional cutting mode, the cutting mechanism is configured to bisect the cured pack in a horizontal direction such as to form continuous packs having thicknesses. The resulting bisected packs can have any desired thicknesses. Cutting the cured pack forms cut pack.

[00101] In the illustrated embodiment, the cutting mechanism 654 includes a system of saws and knives. Alternatively, the cutting mechanism 654 can be other structures, mechanisms or devices or combinations thereof. Referring again to Figures 6 and 7, the cutting mechanism 654 is advantageously positioned such as to allow the capture of dust and other waste materials formed during the cutting operation. Optionally, dust and other waste materials stemming from the cutting mechanism can be returned to the flow of gasses and glass fibers in the ducts 630 and recycled in the forming apparatus 632a and 632b. Recycling of the dust and waste materials advantageously prevents potential environmental issues connected with the disposal of the dust and waste materials. As shown in Figures 6 and 7, ductwork 655

connects the cutting mechanism 654 with the ducts 630 and is configured to facilitate the return of dust and waste materials to the forming apparatus 632a and 632b. While the embodiment shown in Figures 6 and 7 illustrate the recycling of the dust and waste materials, it should be appreciated that the recycling of the dust and waste materials is optional and the method of forming the pack from fibrous materials 10 can be practiced without recycling of the dust and waste materials.

[00102] Optionally, prior to the conveyance of the cured pack to the cutting mechanism 654, the major surfaces of the cured pack can be faced with facing material or materials by facing mechanisms 662a, 662b as shown in Figure 6. In the illustrated embodiment, the upper major surface of the cured pack is faced with facing material 663a provided by facing mechanism 662a and the lower major surface of the cured pack is faced with facing material 663b provided by facing mechanism 662b. The facing materials can be any desired materials including paper, polymeric materials or non-woven webs. The facing mechanisms 662a and 662b can be any desired structures, mechanisms or devices or combinations thereof. In the illustrated embodiment, the facing materials 663a and 663b are applied to the cured pack (if the pack includes a binder) by adhesives. In other embodiments, the facing materials 663a and 663b can be applied to the cured pack by other methods, including the non-limiting example of sonic welding. While the embodiment shown in Figure 6 illustrates the application of the facing materials 663a and 663b to the major surfaces of the cured pack, it should be appreciated that the application of the facing materials 663a and 663b to the major surfaces of the cured pack is optional and the method of forming the pack from fibrous materials 610 can be practiced without the application of the facing materials 663a and 663b to the major surfaces of the cured pack.

[00103] Referring to Figures 6 and 7, the fourth conveyor 652 conveys the cut pack to an optional chopping mechanism 656. The chopping mechanism 656 is configured to section the cut pack into desired lengths across the machine direction Dl. In the illustrated embodiment, the chopping mechanism 656 is configured to section the cut pack as the cut pack continuously moves in the machine direction Dl. Alternatively, the chopping mechanism 656 can be configured for batch chopping operation. Sectioning the cut pack into lengths forms a dimensioned pack. The lengths of the chopped pack can have any desired dimension.

[00104] Chopping mechanisms are known in the art and will not be described herein. The chopping mechanism 656 can be any desired structure, mechanism or device or combinations thereof.

[00105] Optionally, prior to the conveyance of the cut pack to the chopping mechanism 656, the minor surfaces of the cut pack can be faced with edging material or materials by edging mechanisms 666a, 666b as shown in Figure 7. The edging materials can be any desired materials including paper, polymeric materials or nonwoven webs. The edging mechanisms 666a and 666b can be any desired structures, mechanisms or devices or combinations thereof. In the illustrated embodiment, the edging materials 667a and 667b are applied to the cut pack by adhesives. In other embodiments, the edging materials 667a and 667b can be applied to the cut pack by other methods, including the non-limiting example of sonic welding. While the embodiment shown in Figure 7 illustrate the application of the edging materials 667a and 667b to the minor surfaces of the cut pack, it should be appreciated that the application of the edging materials 667a and 667b to the minor surfaces of the cut pack is optional and the method of forming the pack from fibrous materials 610 can be practiced without the application of the edging materials 667a and 667b to the minor surfaces of the cut pack.

[00106] Referring again to Figure 6, the fourth conveyor 652 conveys the dimensioned pack to a fifth conveyor 658. The fifth conveyor 658 is configured to convey the dimensioned pack to a packaging mechanism 660. The packaging mechanism 660 is configured to package the dimensioned pack for future operations. The term "future operations," as used herein, is defined to include any activity following the forming of the dimensioned pack, including the non-limiting examples of storage, shipping, sales and installation.

[00107] In the illustrated embodiment, the packaging mechanism 660 is configured to form the dimensioned pack into a package in the form of a roll. In other embodiments, the packaging mechanism 660 can form packages having other desired shapes, such as the non-limiting examples of slabs, batts and irregularly shaped or die cut pieces. The packaging mechanism 660 can be any desired structure, mechanism or device or combinations thereof.

[00108] Referring again to Fig. 6, the conveyors 636, 644, 648, 652 and 658 are in a "stepped down" relationship in the machine direction Dl. The "stepped down" relationship means that the upper surface of the successive conveyor is positioned to be vertically below the upper

surface of the preceding conveyor. The "stepped down" relationship of the conveyors advantageously provides a self-threading feature to the conveyance of the pack. In the illustrated embodiment, the vertical offset between adjacent conveyors is in a range of from about 3.0 inches to about 10.0 inches. In other embodiments, the vertical offset between adjacent conveyors can be less than about 3.0 inches or more than about 10.0 inches.

[00109] As illustrated in Figures 6 and 7, the method for forming a pack from fibrous materials 610 eliminates the use of a wet binder, thereby eliminating the traditional needs for washwater and washwater related structures, such as forming hoods, return pumps and piping. The elimination of the use of water, with the exception of cooling water, and the application of lubricant, color and other optional chemicals, advantageously allows the overall size of the manufacturing line (or "footprint") to be significantly reduced as well as reducing the costs of implementation, operating costs and maintenance and repair costs.

[00110] As further illustrated in Figures 6 and 7, the method for forming a pack from fibrous materials 610 advantageously allows the uniform and consistent deposition of long and thin fibers on the forming apparatus 632a and 632b. In the illustrated embodiment, the fibers 622 have a length in a range of from about 0.25 inches to about 10.0 inches and a diameter dimension in a range of from about 9 HT to about 35 HT. In other embodiments, the fibers 22 have a length in a range of from about 1.0 inch to about 5.0 inches and a diameter dimension in a range of from about 14 HT to about 25 HT. In still other embodiments, the fibers 22 can have a length less than about 0.25 inches or more than about 10.0 inches and a diameter dimension less than about 9 HT or more than about 35 HT. While not being bound by the theory, it is believed the use of the relatively long and thin fibers advantageously provides a pack having better thermal and acoustic insulative performance than a similar sized pack having shorter and thicker fibers.

[00111] While the embodiment illustrated in Figures 6 and 7 have been generally described above to form packs of fibrous materials, it should be understood that the same apparatus can be configured to form "unbonded loosefill insulation". The term "unbonded loosefill insulation", as used herein, is defined to mean any conditioned insulation material configured for application in an airstream.

[00112] While exemplary embodiments of packs and methods for forming a pack from fibrous materials 610 have been described generally above, it should be appreciated that other embodiments and variations of the method 610 are available and will be generally described below.

[00113] Referring to Figure 7 in another embodiment of the method 610, the cross lapping mechanisms 634a and 634b are configured to provide precise deposition of alternating layers of the continuous web on the first conveyer 36, thereby allowing elimination of downstream trim mechanism 40.

[00114] Referring again to Figure 7 in another embodiment of the method 610, the various layers of the pack can be "stratified". The term "stratified", as used herein, is defined to mean that each of the layers can be configured with different characteristics, including the non-limiting examples of fiber diameter, fiber length, fiber orientation, density, thickness and glass composition. It is contemplated that the associated mechanisms forming a layer, that is, the associated fiberizer, forming apparatus and cross lapping mechanism can be configured to provide a layer having specific and desired characteristics. Accordingly, a pack can be formed from layers having different characteristics.

[00115] In another embodiment, the dry binder can include or be coated with additives to impart desired characteristics to the pack. One non-limiting example of an additive is a fire retardant material, such as for example baking soda. Another non-limiting example of an additive is a material that inhibits the transmission of ultraviolet light through the pack. Still another non-limiting example of an additive is a material that inhibits the transmission of infrared light through the pack.

[00116] Referring to Fig. 6 in another embodiment of the method 610 and as discussed above, a flow of hot gases can be created by optional blowing mechanisms, such as the non-limiting examples of annular blowers (not shown) or annular burners (not shown). It is known in the art to refer to the heat created by the annular blowers and the annular burners as the "heat of fiberization". It is contemplated in this embodiment, that the heat of fiberization is captured and

recycled for use in other mechanisms or devices. The heat of fiberization can be captured at several locations in the method 610. As shown in Figures 6 and 7, duct work 670 is configured to capture the heat emanating from the fiberizers 618 and convey the heat for use in other mechanisms, such as for example the optional curing oven 650. Similarly, duct work 672 is configured to capture the heat emanating from the flow of hot gases within the duct 30 and duct work 674 is configured to capture the heat emanating from the forming apparatus 632a and 632b. The recycled heat can also be used for purposes other than the forming of fibrous packs, such as for example heating an office

[00117] In certain embodiments, the duct 630 can include heat capturing devices, such as for example, heat extraction fixtures configured to capture the heat without significantly interfering with the momentum of the flow of the hot gasses and entrained glass fibers 622. In other embodiments, any desired structure, device or mechanism sufficient to capture the heat of fiberization can be used.

[00118] Referring to Fig. 6 in another embodiment of the method 610, fibers or other materials having other desired characteristics can be mixed with glass fibers 622 entrained in the flow of gasses. In this embodiment, a source 676 of other materials, such as for example, synthetic or ceramic fibers, coloring agents and/or particles can be provided to allow such materials to be introduced into a duct 678.

[00119] The duct 678 can be connected to the duct 630 such as to allow mixing with the glass fibers 622 entrained in the flow of gasses. In this manner, the characteristics of the resulting pack can be engineered or tailored for desired properties, such as the nonlimiting examples acoustic, thermal enhancing or UV inhibiting characteristics.

[00120] In still other embodiments, it is contemplated that other materials can be positioned between the layers deposited by the cross-lapping mechanisms 634a and 634b on the first conveyor 636. The other materials can include sheet materials, such as for example, facings, vapor barriers or netting, or other non-sheet materials including the non-limiting examples of powders, particles or adhesives. The other materials can be positioned between the layers in any desired manner. In this manner, the characteristics of the resulting pack can be further engineered or tailored as desired.

[00121] While the embodiments shown in Figure 6 illustrates the application of a dry binder by the binder applicator 646, it should be appreciated that in other embodiments, the dry binder can be applied to the glass fibers 622 entrained in the flow of gasses. In this embodiment, a source 680 of dry binder can be introduced into a duct 682. The duct 682 can be connected to the duct 630 such as to allow mixing of the dry binder with the glass fibers 622 entrained in the flow of gasses. The dry binder can be configured to attach to the glass fibers in any desired manner, including by electrostatic processes.

[00122] While the embodiment illustrated in Figure 6 illustrates use of the continuous web by the cross-lapping mechanisms 634a and 634b, it should be appreciated that in other embodiments, the web can be removed from the forming apparatus 632a and 632b and stored for later use.

[00123] As discussed above, optionally the trimmed materials can be can be returned to the flow of gasses and glass fibers in the ducts 630 and recycled in the forming apparatus 632a and 632b. In an exemplary embodiment, when an optional binder is included in the pack, the operating temperature of the forming apparatus 332a and 332b is kept below the softening temperature of the dry binder, thereby preventing the dry binder from curing prior to the downstream operation of the curing oven 550. In this embodiment, the maximum operating temperature of the curing oven 650 is in a range of from about 165°F to about 180°F. In other embodiments, the maximum operating temperature of the curing oven 650 can be less than about 165°F or more than about 180°F.

[00124] Several exemplary embodiments of mineral fiber webs and packs and methods of producing mineral fiber webs and packs are disclosed by this application. Mineral fiber webs and packs and methods of producing mineral fiber webs and packs in accordance with the present invention may include any combination or subcombination of the features disclosed by the present application.

[00125] In accordance with the provisions of the patent statutes, the principles and modes of the improved methods of forming a pack from fibrous materials have been explained and illustrated in its preferred embodiment. However, it must be understood that the improved method of forming a pack from fibrous materials may be practiced otherwise than as specifically explained and illustrated without departing from its spirit or scope.

Claims

1. A continuous method for forming a pack of glass fibers comprising:

melting glass;

processing the molten glass to form glass fibers;

forming a binderless web of the glass fibers;

mechanically entangling the fibers of the web to form the pack of glass fibers.

2. The continuous method of claim 1 wherein the fibers are entangled by needling.

3. The continuous method of claim 1 wherein the binderless web of glass fibers has an area weight of about 5 to about 50 grams per square foot and a thickness of about 0.25 inches to about 4 inches.

4. The continuous method of claim 1 wherein the continuous method produces between about 750 lbs/hr and 1500 lbs/hr of the pack of glass fibers.

5. The continuous method of claim 1 wherein the glass fibers have a diameter range of in a range of from about 9 HT to about 35 HT.

6. The continuous method of claim 5 wherein the glass fibers have a length range from about 0.25 inches to about 10.0 inches.

7. A binderless web of glass fibers comprising:

glass fibers that are mechanically entangled to form the web;

wherein the web has an area weight of about 5 to about 50 grams per square foot;

wherein the glass fibers have a diameter range of in a range of from about 9 HT to about 35 HT;

wherein the glass fibers have a length range from about 0.25 inches to about 10.0 inches.

8. The binderless web of glass fibers of claim 7 wherein the glass fibers used to form the have never been compressed for packaging or shipping.

9. The binderless web of glass fibers of claim 1 wherein the glass fibers are mechanically entangled by needling.

10. A continuous method for forming a pack of glass fibers comprising:

melting glass;

processing the molten glass to form glass fibers;

forming a binderless web of the glass fibers;

layering the binderless web of glass fibers to form the pack.

11. The continuous method of claim 10 further comprising mechanically entangling the fibers of the layered webs to form the pack.

12. The continuous method of claim 10 wherein the fibers are entangled by needling.

13. The continuous method of claim 10 wherein a single layer of the binderless web of glass fibers has an area weight of about 5 to about 50 grams per square foot and a thickness of about 0.25 inches to about 4 inches.

14. The continuous method of claim 10 wherein the continuous method produces between about 750 lbs/hr and 1500 lbs/hr of the pack of glass fibers.

15. The continuous method of claim 10 wherein the glass fibers have a diameter range of in a range of from about 9 HT to about 35 HT.

16. The continuous method of claim 15 wherein the glass fibers have a length range from about 0.25 inches to about 10.0 inches.

17. A layered binderless web of glass fibers comprising:

a first web of glass fibers;

at least one additional web of glass fibers disposed on the first web of glass fibers;

wherein the first web has an area weight of about 5 to about 50 grams per square foot;

wherein the glass fibers have a diameter range of in a range of from about 9 HT to about 35 HT;

wherein the glass fibers have a length range from about 0.25 inches to about 10.0 inches.

18. The layered binderless web of glass fibers of claim 17 wherein the glass fibers of the first web are mechanically entangled with the glass fibers of the at least one additional web.

19. The binderless web of glass fibers of claim 17 wherein the glass fibers used to form the have never been compressed for packaging or shipping.

20. The binderless web of glass fibers of claim 18 wherein the glass fibers are mechanically entangled by needling.

21. A continuous method for forming a web of glass fibers comprising:

melting glass;

processing the molten glass to form glass fibers;

forming a web of the glass fibers;

wherein a dry binder is blended with the glass fibers while a temperature of the glass fibers and a temperature of air surrounding the glass fibers is below a temperature required to thermally set the dry binder.

22. The continuous method of claim 21 wherein the dry binder is mixed with the glass fibers as the web of glass fibers is formed.

23. The continuous method of claim 21 further comprising layering the web of glass fibers to form a layered pack.

24. The continuous method of claim 21 wherein the dry binder is mixed with the glass fibers after the web of glass fibers is formed.

25. The continuous method of claim 23 wherein the dry binder is mixed with the glass fibers as the web of glass fibers is layered to form the layered pack.

26. The continuous method of claim 21 further comprising mechanically entangling the fibers of the layered webs.

27. A layered web of glass fibers comprising:

a first web of glass fibers;

at least one additional web of glass fibers disposed on the first web of glass fibers;

wherein a dry binder is blended with the glass fibers to hold said first layer and said at least one additional layers together to form the pack.

28. The layered web of glass fibers of claim 27 wherein the first web has an area weight of about 5 to about 50 grams per square foot.

29. The layered web of glass fibers of claim 28 wherein the glass fibers have a diameter range of in a range of from about 9 HT to about 35 HT;

30. The layered web of glass fibers of claim 29 wherein the glass fibers have a length range from about 0.25 inches to about 10.0 inches.

31. The layered web of glass fibers of claim 27 wherein the glass fibers of the first web are mechanically entangled with the glass fibers of the at least one additional web.

32. The layered web of glass fibers of claim 27 wherein the glass fibers used to form the webs have never been compressed for packaging or shipping.

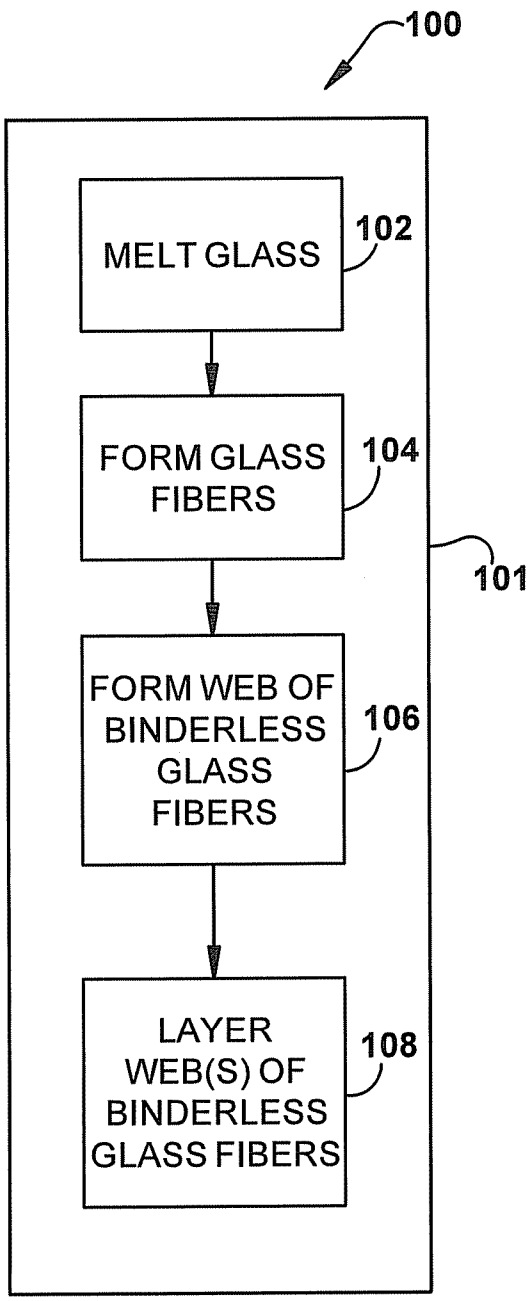

100
MELT GLASS
102
FORM GLASS FIBERS
104
101
FORM WEB OF BINDERLESS GLASS FIBERS
106
LAYER WEB(S) OF BINDERLESS GLASS FIBERS
108

FIG. 1A

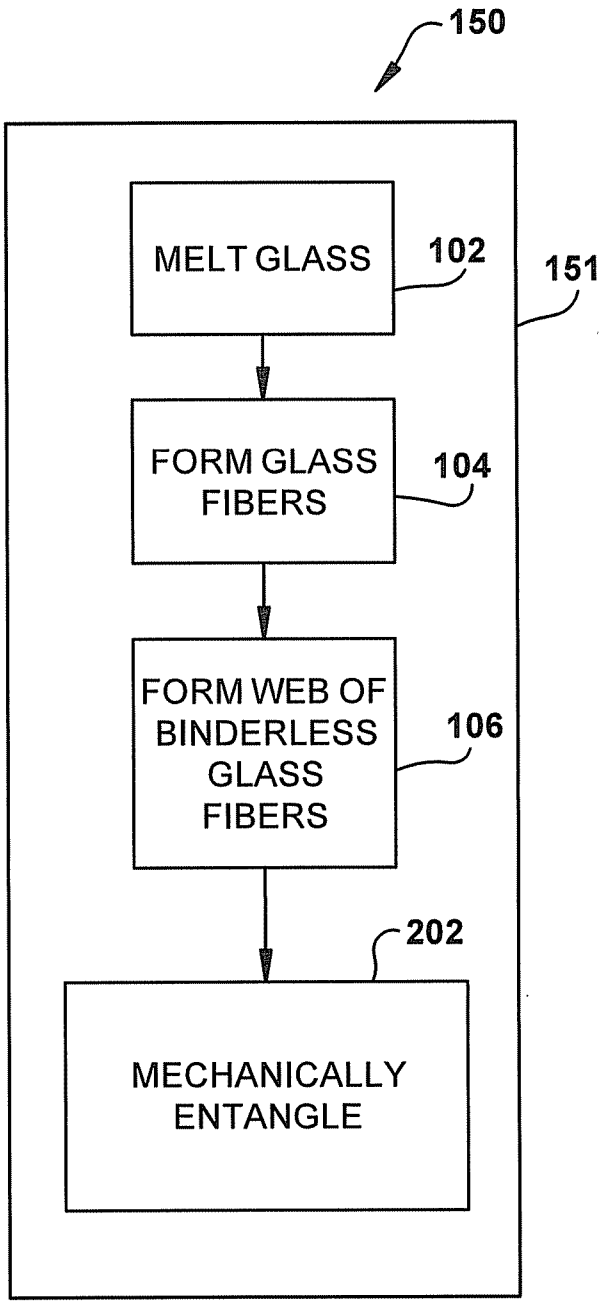

150
MELT GLASS
102
151
FORM GLASS FIBERS
104
FORM WEB OF BINDERLESS GLASS FIBERS
106
202
MECHANICALLY ENTANGLE

FIG. 1B

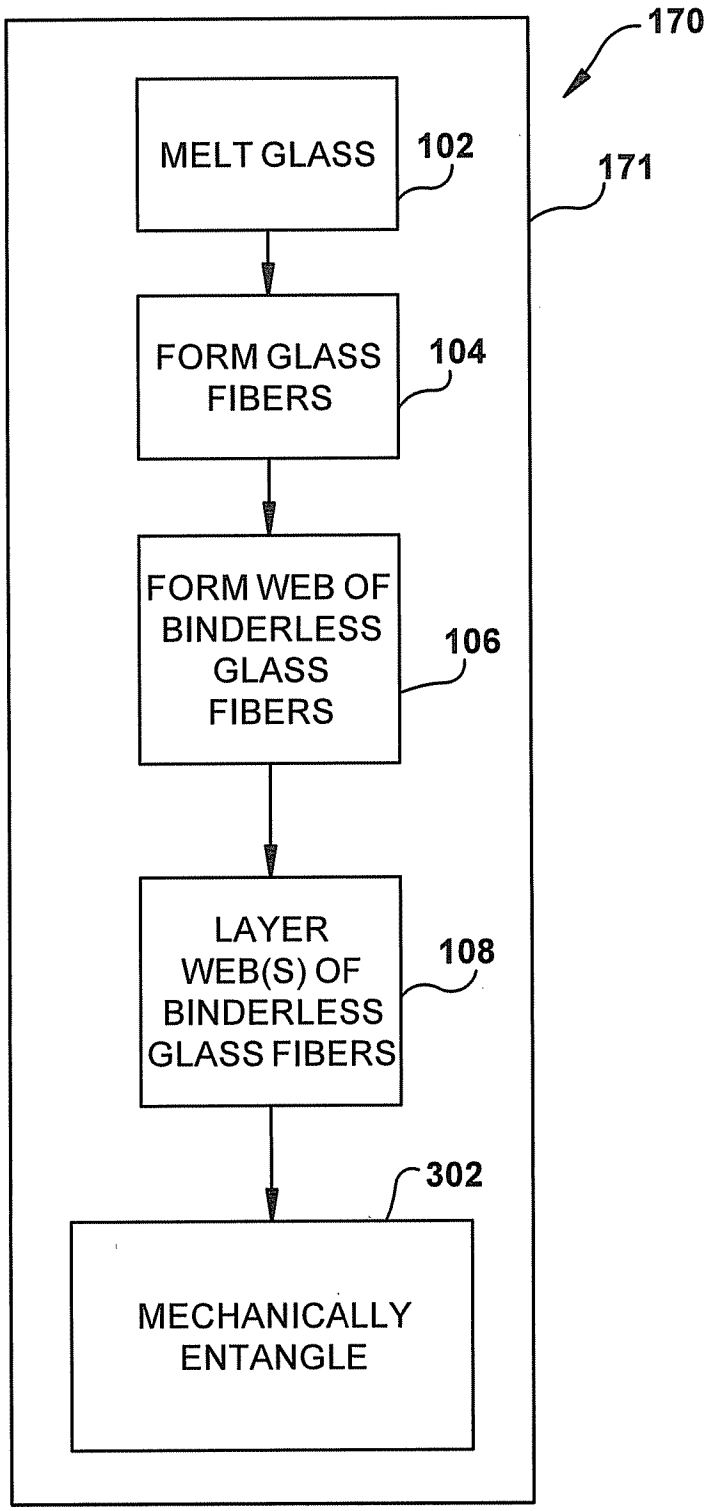

170
171
MELT GLASS
102
FORM GLASS FIBERS
104
FORM WEB OF BINDERLESS GLASS FIBERS
106
LAYER WEB(S) OF BINDERLESS GLASS FIBERS
108
302
MECHANICALLY ENTANGLE

FIG. 1C

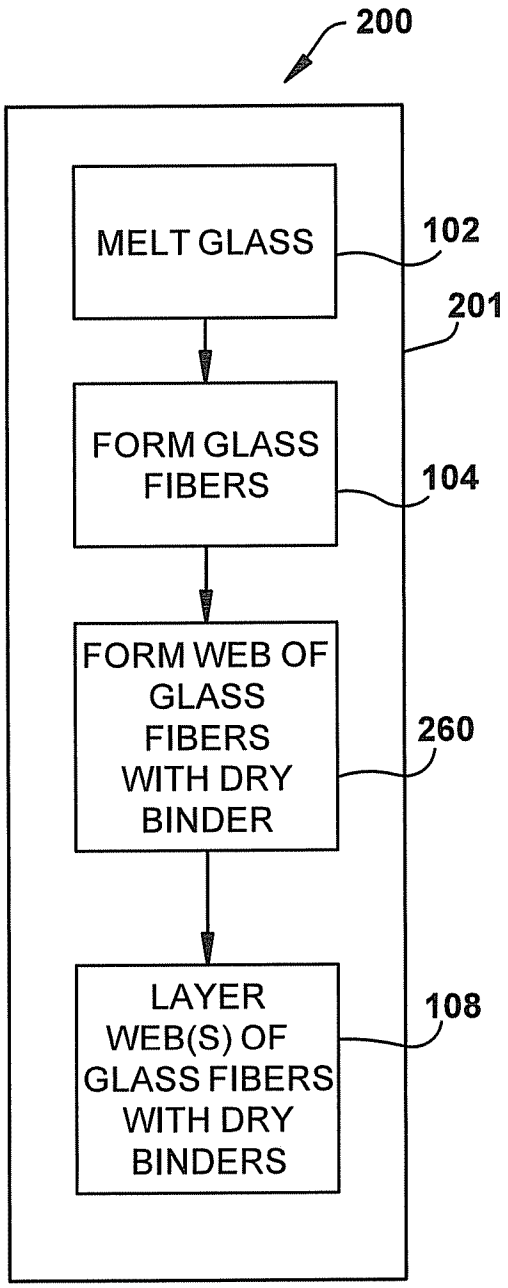

200
MELT GLASS
102
201
FORM GLASS FIBERS
104
FORM WEB OF GLASS FIBERS WITH DRY BINDER
260
LAYER WEB(S) OF GLASS FIBERS WITH DRY BINDERS
108

FIG. 2A

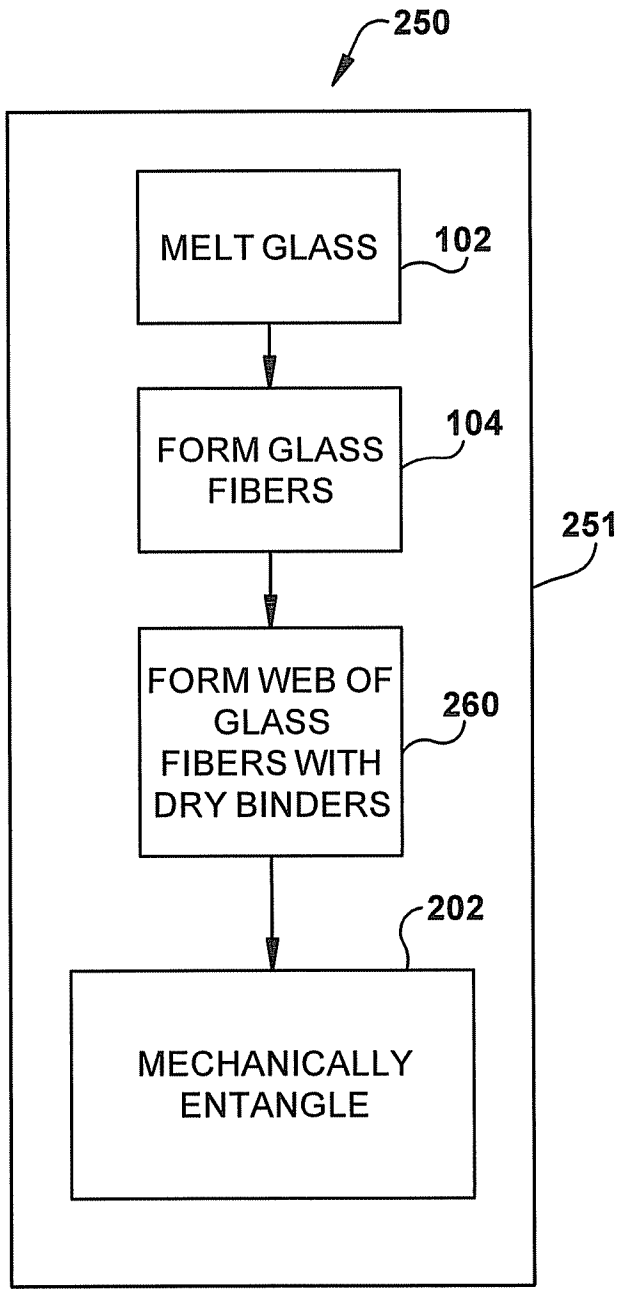

250
MELT GLASS
102
FORM GLASS FIBERS
104
251
FORM WEB OF GLASS FIBERS WITH DRY BINDERS
260
202
MECHANICALLY ENTANGLE

FIG. 2B

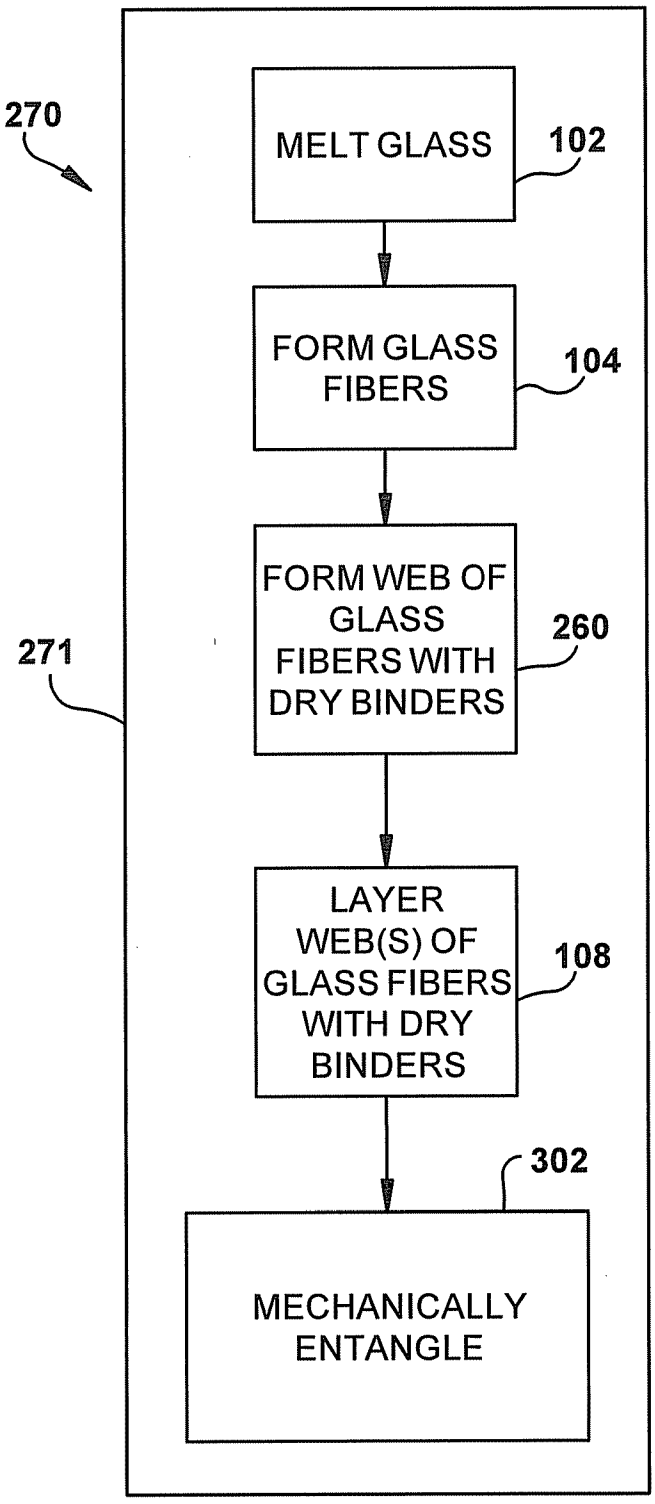

270
MELT GLASS
102
FORM GLASS FIBERS
104
FORM WEB OF GLASS FIBERS WITH DRY BINDERS
260
271
LAYER WEB(S) OF GLASS FIBERS WITH DRY BINDERS
108
302
MECHANICALLY ENTANGLE

FIG. 2C

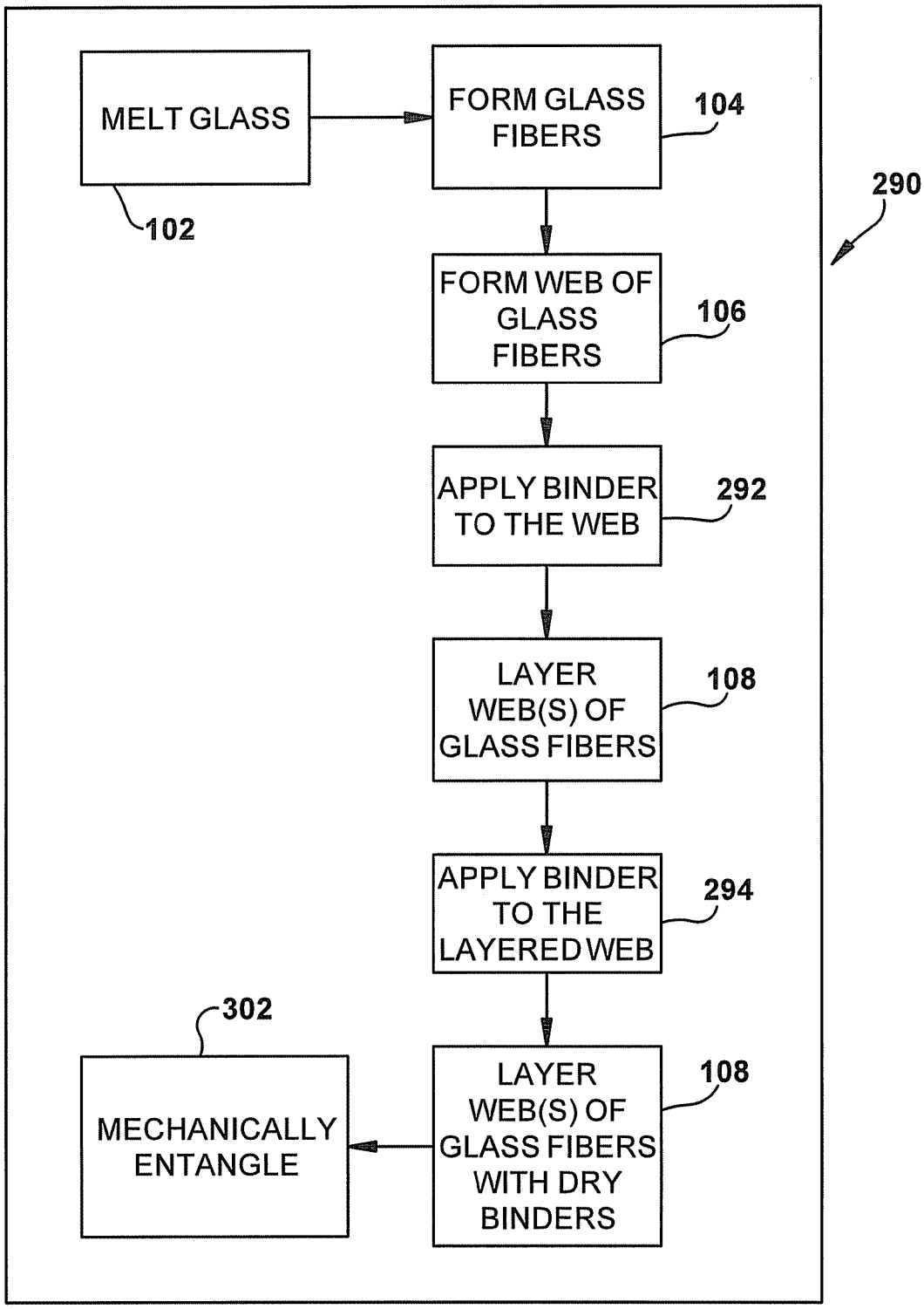

MELT GLASS
102
FORM GLASS FIBERS
104
290
FORM WEB OF GLASS FIBERS
106
APPLY BINDER TO THE WEB
292
LAYER WEB(S) OF GLASS FIBERS
108
APPLY BINDER TO THE LAYERED WEB
294
302
MECHANICALLY ENTANGLE
LAYER WEB(S) OF GLASS FIBERS WITH DRY BINDERS
108

FIG. 2D

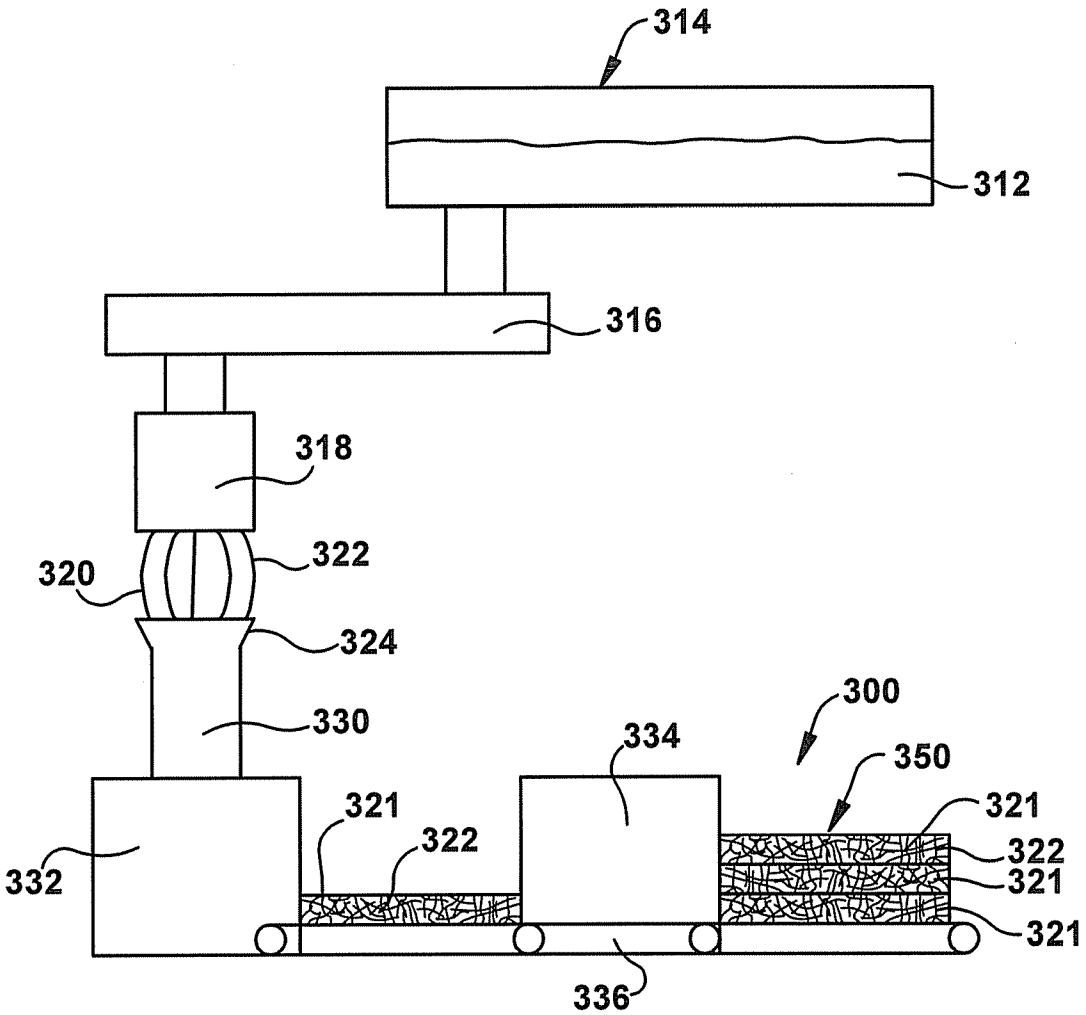

314
312
316
318
320
322
324
330
300
334
350
321
322
321
322
321
332
321
336

FIG. 3A

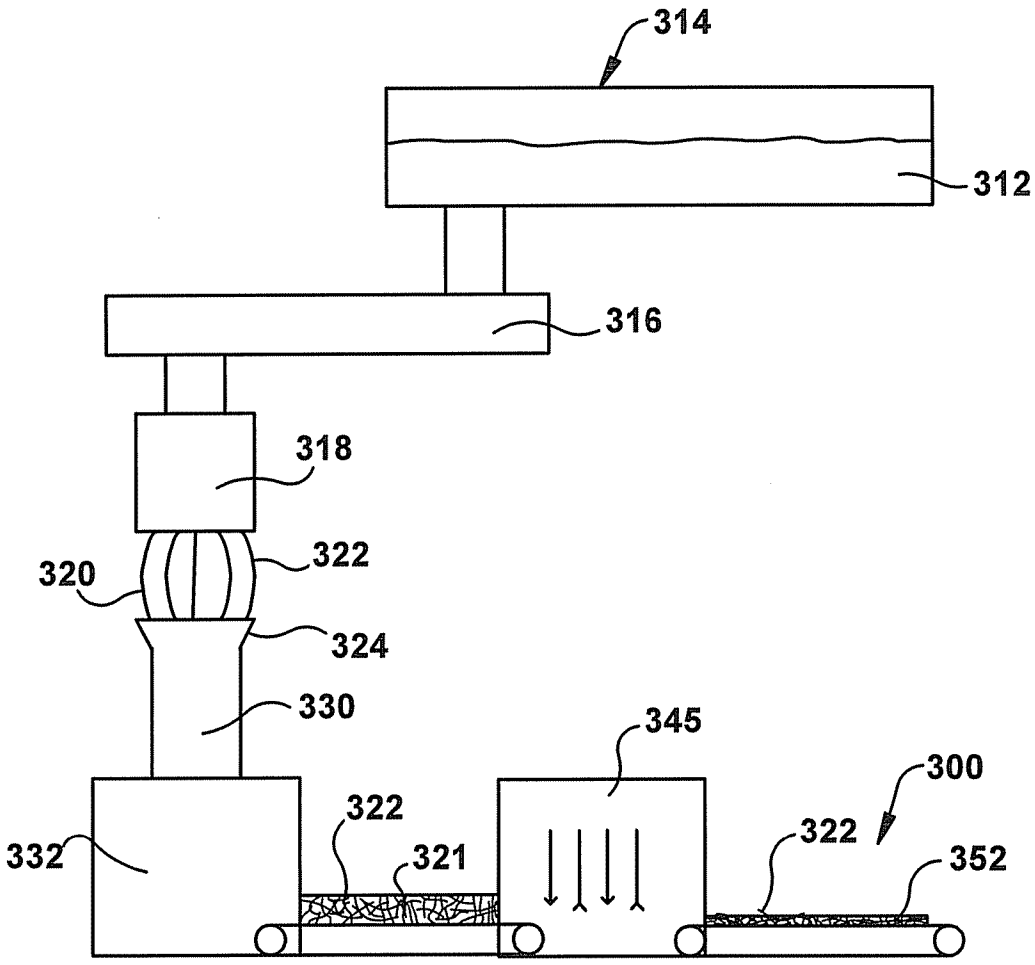


FIG. 3B

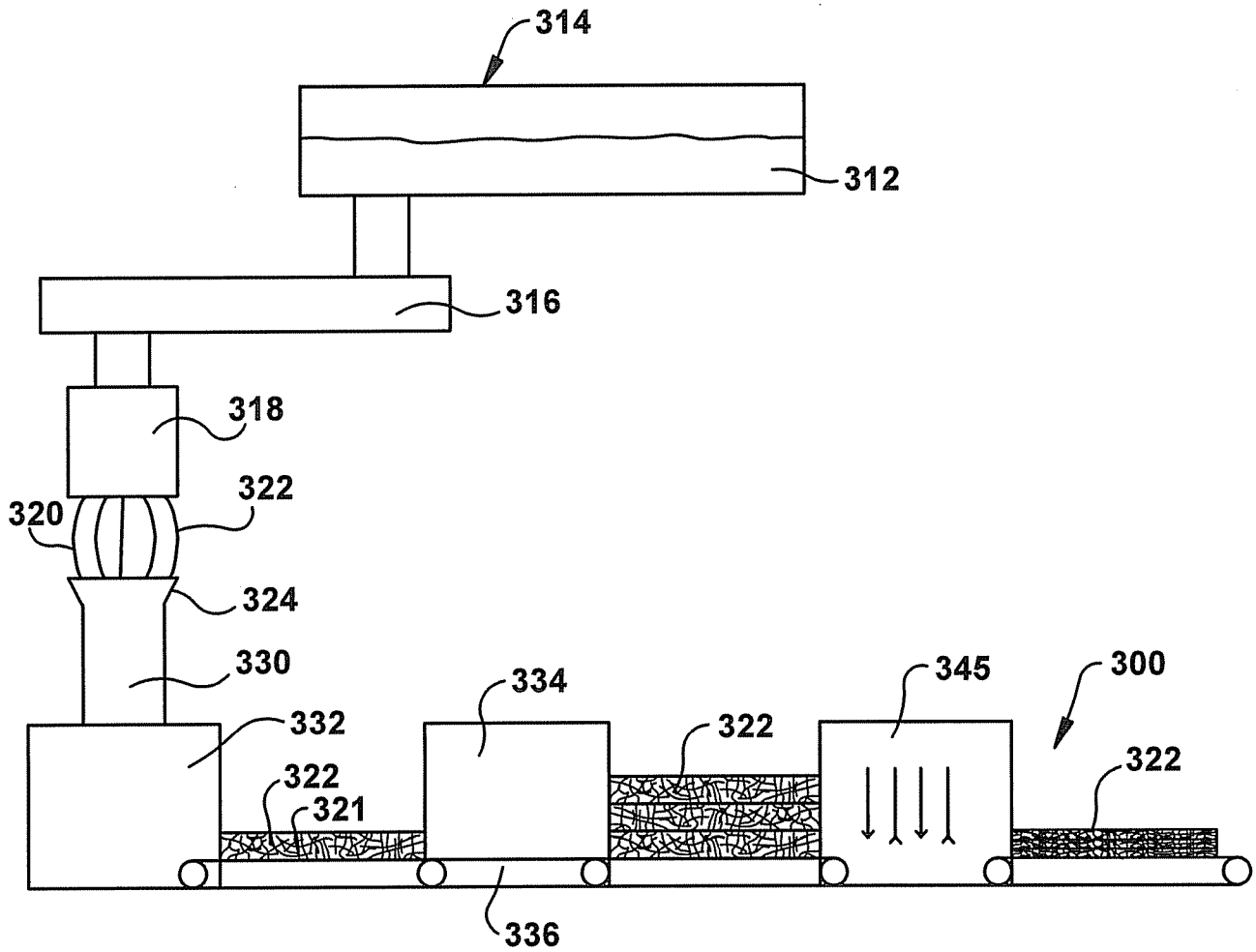

314
312
316
318
322
320
324
330
332
322
321
334
322
345
300
322
336

FIG. 3C

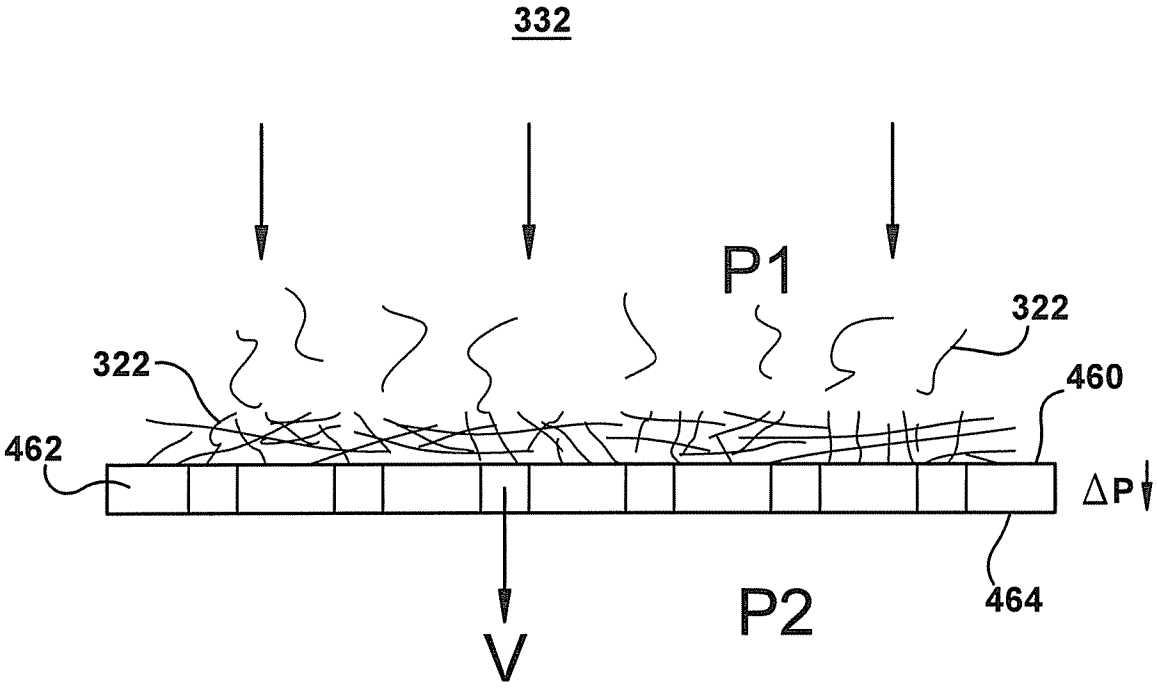


FIG. 4

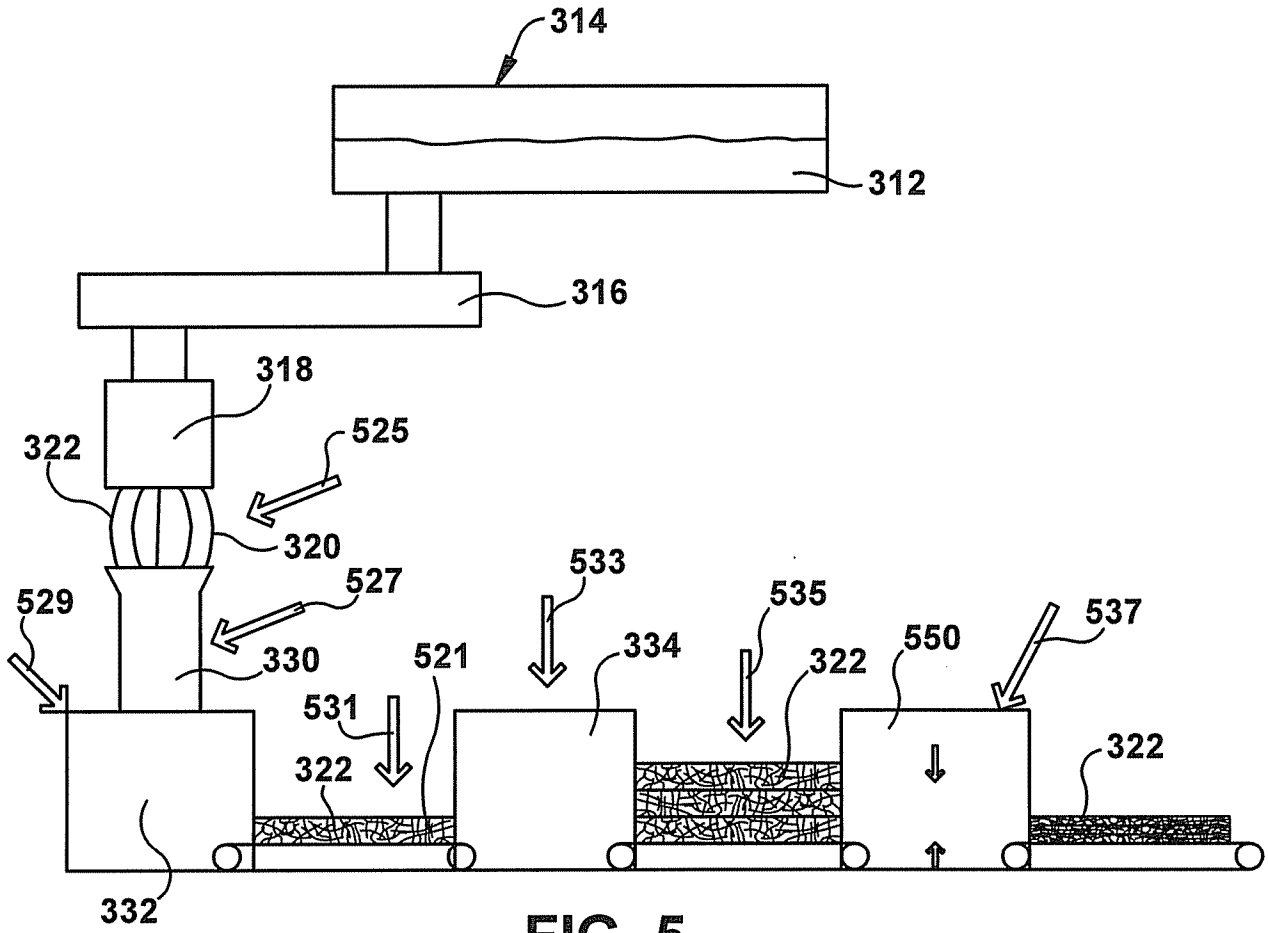

314
312
316
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322
525
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527
529
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533
521
334
531
322
535
322
550
537
322
332

FIG. 5

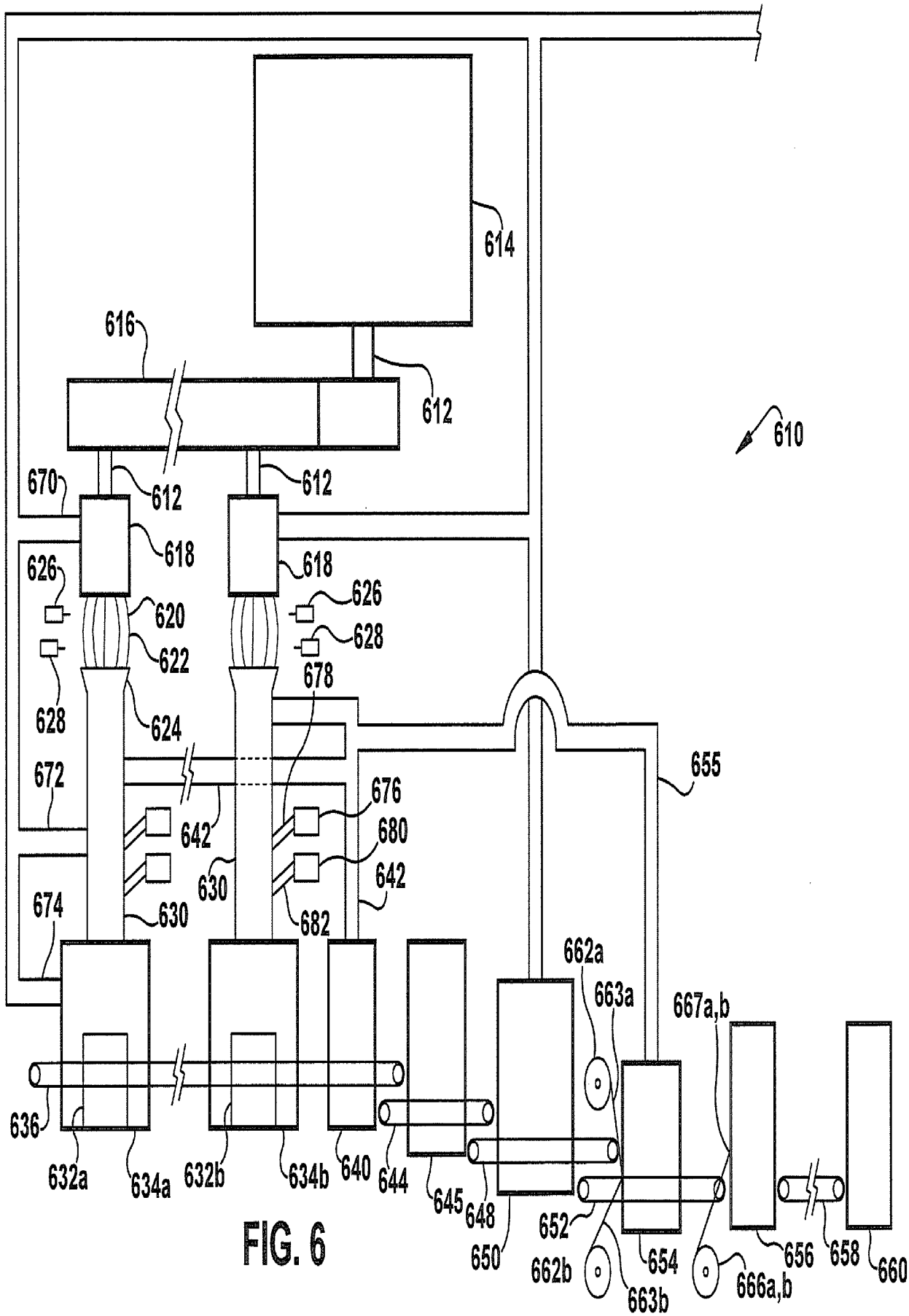

614
616
612
610
670
612
612
618
618
626
626
620
628
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628
678
624
672
655
676
642
680
630
642
674
630
682
662a
663a
667a,b
636
632a
634a
632b
634b
640
644
645
648
650
652
662b
654
663b
666a,b
656
658
660

FIG. 6

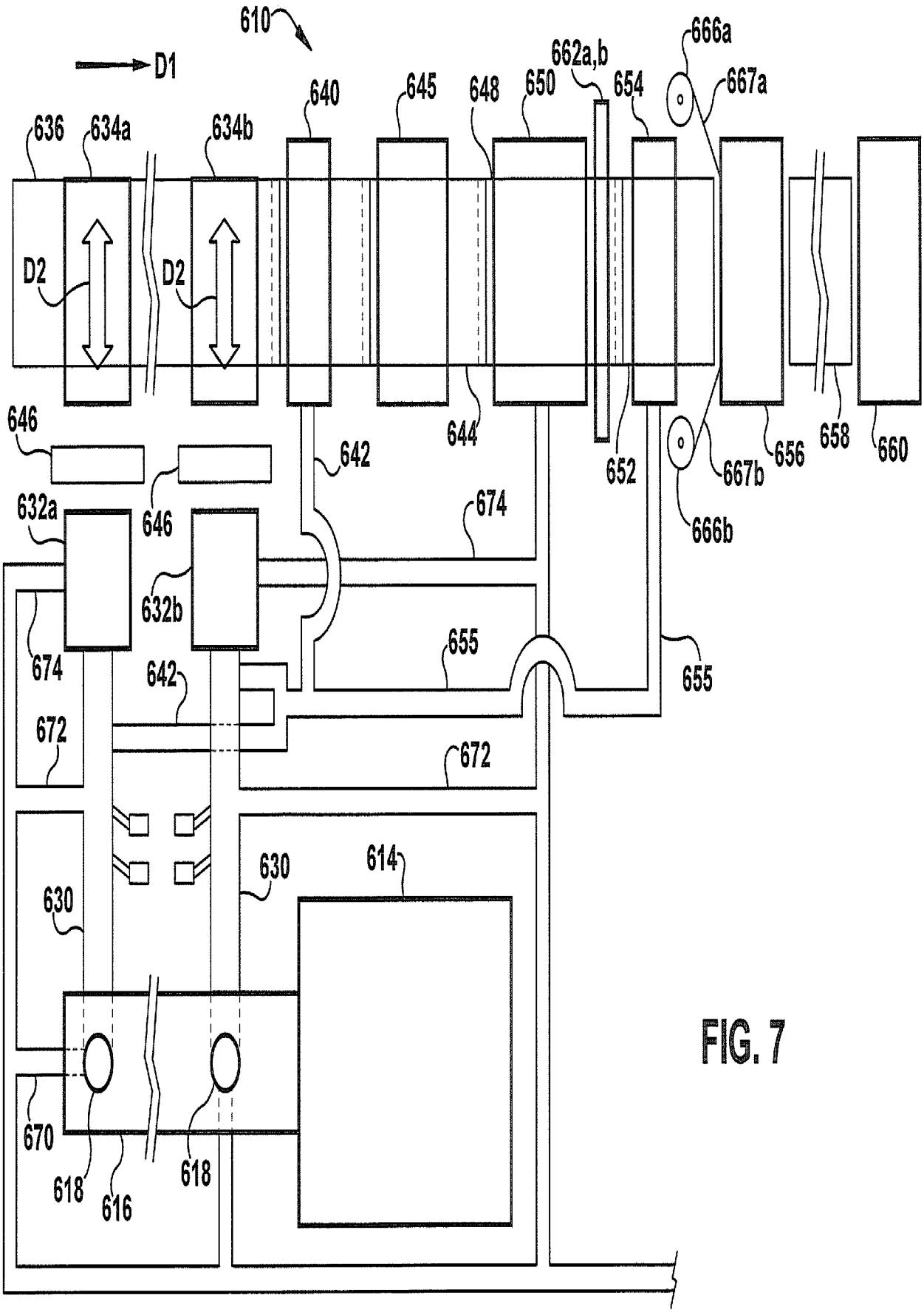

610
D1
636
634a
634b
640
645
648
650
662a,b
654
666a
667a
D2
D2
646
644
642
652
667b
656
658
660
646
632a
646
674
666b
632b
655
674
655
642
672
672
630
614
630
670
618
618
616

FIG. 7