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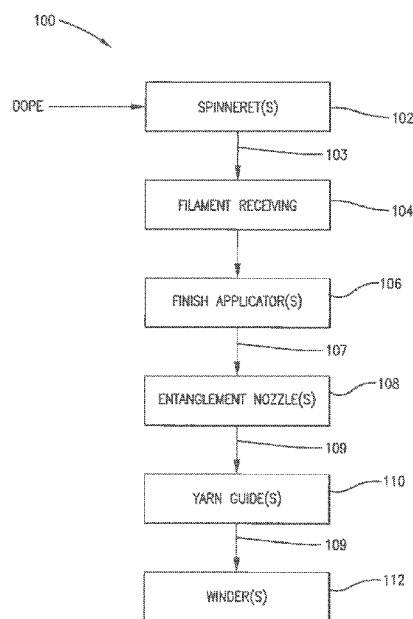


Fig. 1.

(57) Abstract: A method of producing cellulosic yarn packages. The method comprises passing at least a first and a second group of filaments through a common cabinet, entangling the first group of filaments at a first location to form a first yarn, entangling the second group of filaments at a second location to form a second yarn, and winding at least the first and second yarns around a common core. The yarns may be wound around different sections, or around at least one common section of the core. The yarns are not entangled or twisted with one another on the core, which enables the yarns to be unwindable from the core individually.



PROCESS FOR MAKING MULTI-END YARN PACKAGES

BACKGROUND

[001] The present application is generally related to cellulosic yarn and, more particularly, to systems and methods for use in increasing cellulosic yarn production.

[002] Textile fabrics consisting of yarns are widely used in a variety of applications. These fabrics may be formed by weaving, knitting, crocheting, knotting, or felting yarn made of materials, such as, for example, polyesters, polyamides, acrylics, polyurethanes, glass, polypropylene, silk, and a variety of cellulosic materials. Cellulose acetate fibers are one type of cellulosic material known for their sustainability, biodegradability, and renewability. Traditionally, cellulose acetate fibers are formed by extruding dope from a spinneret to produce multiple filaments, which may then be joined to create multi-filament yarns. The possibility of increasing fiber production has been explored as the market for cellulose-based textiles has grown. However, there is a limit to the number of spinnerets that can be accommodated in existing spinning machine cabinets. Also, adding more spinning machines to a production facility or additional winders to an existing spinning machine is a time-consuming and expensive endeavor.

[003] Thus, it is desirable to increase cellulose acetate fiber production using existing equipment and processes without the need to invest in additional and expensive equipment.

SUMMARY

[004] Provided herein is a method of producing cellulosic yarn packages. The method comprises passing at least a first and a second group of filaments through a common cabinet, entangling the first group of filaments at a first location to form a first yarn, entangling the second group of filaments at a second location to form a second yarn, and winding at least the first and second yarns around a common core.

[005] Also provided herein is a method of producing cellulosic yarn packages. The method comprises entangling a first group of filaments at a first location to form a first yarn, entangling a second group of filaments at a second location to form a second yarn, and winding the first and second yarns around a common core. No more than four yarns are wound around the common core.

[006] Also provided herein is a method of producing cellulosic yarn packages. The method comprises entangling a first group of filaments at a first location to form a first yarn having a denier of less than 300, entangling a second group of filaments at a second location to form a second yarn having a denier of less than 300, and winding the first and second yarns around a common core.

BRIEF DESCRIPTION OF THE FIGURES

[007] FIG. 1 is a schematic illustration of an example yarn production system.

[008] FIG. 2 illustrates one embodiment of the yarn guide and winding sub-assemblies shown in FIG. 1.

[009] FIG. 3 and 3A are side view illustrations of an example yarn package that may be produced as shown in FIG. 2.

[0010] FIG. 4 and 4A are side view illustrations of another example yarn package that may be produced as shown in FIG. 2.

[0011] FIG. 5 illustrates another example of the yarn guide and winding sub-assemblies shown in FIG. 1.

[0012] FIG. 6 and FIG. 6A are side view illustrations of an example yarn package that may be produced as shown in FIG. 5.

[0013] FIG. 7 illustrates another example of the yarn guide and winding sub-assemblies shown in FIG. 1.

[0014] FIG. 8 is a side view illustration of an example yarn package that may be produced as shown in FIG. 7.

[0015] FIG. 9 illustrates another example of the yarn guide and winding sub-assemblies shown in FIG. 1.

[0016] FIG. 10 and FIG. 10A are side view illustrations of an example yarn package that may be produced as shown in FIG. 9.

[0017] FIG. 11 is a schematic illustration of an example portion of the yarn production system shown in FIG. 1.

[0018] FIG. 12 is a schematic illustration of another example portion of the yarn production system shown in FIG. 1.

5 [0019] FIG. 13 is a schematic illustration of another example portion of the yarn production system shown in FIG. 1.

DETAILED DESCRIPTION

10 [0020] The present application generally relates to systems and methods for use in increasing cellulosic yarn production, and yarn packages produced therefrom. Yarn production is increased by expanding the production capabilities of existing fiber spinning machines and/or by converting other assets (e.g., tow production assets) to yarn production assets. Such yarns can be utilized in expanded application opportunities in downstream fiber converting and end use apparel applications, for example. The yarns can be produced by
15 any type of dry or wet spinning processes known in the art. In one embodiment, wet spinning is defined as a process whereby at least one polymer is dissolved in at least one solvent to create a liquid solution. The solution is forced through a spinneret, and then comes into contact with a coagulating bath, which causes
20 the liquid to solidify into fibers. In another embodiment, dry spinning is defined as a process whereby at least one polymer is dissolved in at least one solvent and then extruded. As fibers emerge through the spinneret, the solvent is evaporated.

[0021] Fiber spinning machines often include multiple spinnerets per cabinet, and the spinnerets each produce a yarn end that is then wound onto its own distinct core. As disclosed herein, the various sub-assemblies (i.e., spinning, finish application, entanglement, yarn guide, and/or winding) of an example production system are modified to facilitate increasing the yarn output thereof. Specifically, in one embodiment, at least one of the spinnerets used to form the
25 filaments is modified to output more than one distinct filament grouping that each produces an individually-entangled yarn therefrom. Multiple yarns are then wound around the same core in a winding configuration that enables the
30

respective yarn ends to be unwindable from the core individually. By winding more than one yarn around the same core, the winding capacity of the existing spinning machine is increased without having to modify the winding system, such as by increasing the number of winders, to accommodate the additional
5 cores needed to receive any additional yarn ends.

[0022] Thus, the yarn package configurations disclosed herein enable yarn output to be increased on a per cabinet basis while still producing a package of distinct yarn ends that are easily separable from one another when being unwound from the common core. The yarn packages disclosed herein also
10 provide enhanced versatility to meet customer needs for varying package sizes and configurations. In addition, it should be understood that even though embodiments herein are disclosed in the context of cellulosic yarn production, the embodiments may also be applied to non-cellulosic yarn and fiber production.

[0023] The fibers, filaments, and/or yarns as described herein may be formed from one or more cellulose esters including, but not limited to, cellulose acetate, cellulose propionate, cellulose butyrate, cellulose acetate formate, cellulose acetate propionate, cellulose acetate butyrate, cellulose propionate butyrate, and mixtures thereof. Although described herein with reference to “cellulose
20 acetate,” it should be understood that one or more of the above cellulose acid esters or mixed esters may also be used to form the fibers, nonwovens, and articles as described herein. Various types of cellulose esters are described, for example, in U.S. Patent Nos. 1,698,049; 1,683,347; 1,880,808; 1,880,560; 1,984,147, 2,129,052; and 3,617,201, each of which is incorporated herein by
25 reference to the extent not inconsistent with the present disclosure. In some cases, other types of treated or regenerated cellulose (*e.g.*, viscose, rayon, cupro, model, or lyocell) may or may not be used in forming fibers as described herein. In some cases, other types of recycle content material may or may not be used in forming fibers as described herein. Example recycle content material
30 includes, but is not limited to, woven, knitting, or non-woven fabrics, thread, yarns, fiber fills, and various other plastic articles.

[0024] When the fibers described herein are formed from cellulose acetate, it may be formed from cellulose diacetate, cellulose triacetate, or mixtures thereof. The cellulose acetate (or other cellulose ester) useful in embodiments of the present invention can have a degree of substitution in the range between 2.2 and 3, between 2.25 and 2.8, between 2.35 and 2.8, or between 2.4 and 2.7. As used herein, the term “degree of substitution” or “DS” refers to the average number of acetyl substituents per anhydroglucose ring of the cellulose polymer, wherein the maximum degree of substitution is 3.0. In some cases, the cellulose acetate used to form fibers as described herein may have an average degree of substitution of at least about 1.95, 2.0, 2.05, 2.1, 2.15, 2.2, 2.25, or 2.3 and/or not more than about 2.9, 2.85, 2.8, 2.75, 2.7, 2.65, 2.6, 2.55, 2.5, 2.45, 2.4, or 2.35, with greater than 90, 91, 92, 93, 94, 95, 96, 97, 98, or 99 percent of the cellulose acetate having a degree of substitution greater than 2.15, 2.2, or 2.25. In some cases, greater than 90 percent of the cellulose acetate can have a degree of substitution greater than 2.2, 2.25, 2.3, or 2.35.

[0025] The cellulose acetate may have a weight-average molecular weight (M_w) of not more than 90,000, measured using gel permeation chromatography with N-methyl-2-pyrrolidone (NMP) as the solvent. In some case, the cellulose acetate may have a molecular weight of at least about 10,000, at least about 20,000, 25,000, 30,000, 35,000, 40,000, or 45,000 and/or not more than about 90,000, 85,000, 80,000, 75,000, 70,000, 65,000, 60,000, or 50,000, and/or between 10,000 and 90,000, between 20,000 and 80,000, between 30,000 and 70,000, or between 40,000 and 60,000.

[0026] Referring now to the drawings, FIG. 1 is a schematic illustration of an example yarn production system 100. The cellulose acetate or other cellulose ester used in the production of the fibers and/or yarns described herein may be formed by any suitable method known in the art. The process can be batch or continuous. In some cases, cellulose acetate may be formed by reacting a cellulosic material such as wood pulp with acetic anhydride and a catalyst in an acidic reaction medium to form a cellulose acetate flake. The cellulosic material and/or acetic anhydride can contain recycle content from multiple sources as disclosed in U.S. Patent Application 63/374,127, entitled “Cellulose The flake

may then be dissolved in a solvent, such as acetone or methyl ethyl ketone, to form a solvent “dope” which can be filtered and sent through at least one spinneret 102, as shown in FIG. 1, to form continuous cellulose acetate filaments or fibers 103. In some cases, up to about 1 weight percent or more of titanium dioxide or other delusterant may be added to the dope prior to filtration, depending on the desired properties and ultimate end use of the fibers. In other embodiments less than 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0.01 of titanium dioxide and/or other delusterant is added. In other embodiments, there is a substantial absence of titanium dioxide and/or other delusterant.

[0027] In some cases, the solvent dope or flake used to form the cellulose acetate fibers may include few or no additives in addition to the cellulose acetate. Such additives can include, but are not limited to, pigments, colorants, antimicrobials, UV stabilizers, flame retardants, antioxidants, thermal stabilizers, pro-oxidants, acid scavengers, inorganics, photodegradation agents, biodegradation agents, decomposition accelerating agents, polyesters, enzymes, microorganisms, water soluble polymers, modified cellulose acetate, water-dispersible additives, nitrogen-containing compounds, hydroxy-functional compounds, oxygen-containing heterocyclic compounds, sulfur-containing heterocyclic compounds, anhydrides, and monoepoxides, or combinations thereof. In some cases, the cellulose acetate fibers as described herein can include at least about 90, 90.5, 91, 91.5, 92, 92.5, 93, 93.5, 94, 94.5, 95, 95.5, 96, 96.5, 97, 97.5, 98, 98.5, 99, 99.5, 99.9, 99.99, 99.995, or 99.999 percent cellulose acetate, based on the total weight of the fiber. Fibers formed according to the present invention may include not more than about 10, 9.5, 9, 8.5, 8, 7.5, 7, 6.5, 6, 5.5, 5, 4.5, 4, 3.5, 3, 2.5, 2, 1.5, 1, 0.5, 0.1, 0.01, 0.005, or 0.001 weight percent of additives other than cellulose acetate, including the specific additives listed herein.

[0028] Cellulose acetate fibers can achieve higher levels of biodegradability and/or compostability without use of additives that have traditionally been used to facilitate environmental non-persistence of similar fibers. Such additives can include, for example, photodegradation agents, biodegradation agents, decomposition accelerating agents, and various types of other additives.

Despite being substantially free of these types of additives, the cellulose acetate fibers and articles produced therefrom have unexpectedly been found to exhibit enhanced biodegradability and compostability when tested under industrial, home, and/or soil conditions.

5 **[0029]** In some embodiments, the cellulose acetate fibers described herein may be substantially free of photodegradation agents. For example, the fibers may include not more than about 1, 0.75, 0.50, 0.25, 0.10, 0.05, 0.025, 0.01, 0.005, 0.0025, or 0.001 weight percent of photodegradation agent, based on the total weight of the fiber, or the fibers may include no photodegradation agents.

10 Examples of such photodegradation agents include, but are not limited to, pigments which act as photooxidation catalysts and are optionally augmented by the presence of one or more metal salts, oxidizable promoters, and combinations thereof. Pigments can include coated or uncoated anatase or rutile titanium dioxide, which may be present alone or in combination with one

15 or more of the augmenting components such as, for example, various types of metals. Other examples of photodegradation agents include benzoin, benzoin alkyl ethers, benzophenone and its derivatives, acetophenone and its derivatives, quinones, thioxanthenes, phthalocyanine and other photosensitizers, ethylene-carbon monoxide copolymer, aromatic ketone-metal salt sensitizers, and combinations thereof.

20 **[0030]** In some embodiments, the cellulose acetate fibers described herein may be substantially free of biodegradation agents and/or decomposition agents. For example, the fibers may include not more than about 1, 0.75, 0.50, 0.25, 0.10, 0.05, 0.025, 0.01, 0.005, 0.0025, 0.0020, 0.0015, 0.001, 0.0005

25 weight percent of biodegradation agents and/or decomposition agents, based on the total weight of the fiber, or the fibers may include no biodegradation and/or decomposition agents. Examples of such biodegradation and decomposition agents include, but are not limited to, salts of oxygen acid of phosphorus, esters of oxygen acid of phosphorus or salts thereof, carbonic acids or salts thereof, oxygen acids of phosphorus, oxygen acids of sulfur,

30 oxygen acids of nitrogen, partial esters or hydrogen salts of these oxygen acids, carbonic acid and its hydrogen salt, sulfonic acids, and carboxylic acids.

5 [0031] Other examples of such biodegradation and decomposition agents include an organic acid selected from the group consisting of oxo acids having 2 to 6 carbon atoms per molecule, saturated dicarboxylic acids having 2 to 6 carbon atoms per molecule, and lower alkyl esters of the oxo acids or the saturated dicarboxylic acids with alcohols having from 1 to 4 carbon atoms. Biodegradation agents may also comprise enzymes such as, for example, a lipase, a cellulase, an esterase, and combinations thereof. Other types of biodegradation and decomposition agents can include cellulose phosphate, starch phosphate, calcium secondary phosphate, calcium tertiary phosphate, 10 calcium phosphate hydroxide, glycolic acid, lactic acid, citric acid, tartaric acid, malic acid, oxalic acid, malonic acid, succinic acid, succinic anhydride, glutaric acid, acetic acid, and combinations thereof.

15 [0032] Cellulose acetate fibers described herein may also be substantially free of several other types of additives that have been added to other fibers to encourage environmental non-persistence. Examples of these additives can include, but are not limited to, polyesters, including aliphatic and low molecular weight (e.g., less than 5000) polyesters, enzymes, microorganisms, water soluble polymers, modified cellulose acetate, water-dispersible additives, nitrogen-containing compounds, hydroxy-functional compounds, oxygen- 20 containing heterocyclic compounds, sulfur-containing heterocyclic compounds, anhydrides, monoepoxides, and combinations thereof. In some cases, the fibers described herein may include not more than about 0.5, 0.4, 0.3, 0.25, 0.1, 0.075, 0.05, 0.025, 0.01, 0.0075, 0.005, 0.0025, or 0.001 weight percent of these types of additives, or the cellulose acetate fibers may not include any of 25 these types of additives.

30 [0033] Turning back to FIG. 1, the dope can be extruded through a plurality of holes in spinneret 102 into a vertical spinning cabinet 104 to form continuous cellulose acetate filaments. At spinneret 102, filaments 103 may be drawn to several hundred, or even thousand, individual filaments. Each spinneret face may have one or more cluster of holes to produce a group of filaments, and an individually-entangled cellulosic yarn is produced from each group of filaments. Each of these clusters may include between 2 and 300, between 4 and 300,

between 8 and 150, between 12 and 75, between 15 and 30 holes, which produces a yarn having the corresponding number of fibers. That is, each group of filaments may include between 2 and 300, 4 and 300, between 8 and 150, between 12 and 75, between 15 and 30 individual fibers. Spinneret 102 may be operated at any speed suitable to produce filaments having desired size and shape.

[0034]As used herein, “entangle” refers to physically attaching a group of filaments to one another via filament deformation and intertwining. For example, filaments can be entangled by twisting and/or air jetting. Thus, respective individually-entangled yarns are not entangled with one another. Rather, only the group of filaments in these individually-entangled, or separately-entangled, yarns are entangled with one another.

[0035]Individual bundles may be assembled into a filament yarn, as will be described in more detail below. As used herein, a “filament yarn” or “tow yarn” refers to a yarn formed from a plurality of continuous, untwisted individual filaments. The filament yarn may be of any suitable size and, in some embodiments, may have a total denier between 10 and 300, between 10 to 800, between 20 and 500, between 30 and 300, between 40 and 150, or between 50 and 100.

[0036]The individual filaments, which are extruded in a generally longitudinally aligned manner and which ultimately form the filament yarn, may also be of any suitable size. For example, each filament may have a linear denier per filament (weight in g of 9000m fiber length) between 0.25 and 50, between 0.5 and 25, between 1 and 10, between 2 and 6, or between 3 and 5, measured according to ASTM D1577-01 using the FAVIMAT vibroscope procedure. As used herein, the term “filament” refers to an elongated, continuous single strand fiber and is distinguished from a staple fiber, which has been cut to a specified length.

[0037]The individual filaments discharged from the spinneret may have any suitable transverse cross-sectional shape. Exemplary cross-sectional shapes include, but are not limited to, circular or any shape other than circular (irregular), such as Y-shaped, I-shaped (dog bone), ribbon or stripped, closed C-shaped, tri-lobal, multi-lobal, X-shaped, or crenulated. When a filament has

a multi-lobal cross-sectional shape, it may have at least 4, 5, or 6 or more lobes. In some cases, the filaments may be symmetric along one or more, two or more, three or more, or four or more axes, and, in other embodiments, the filaments may be asymmetrical. As used herein, the term “cross-section” generally refers to the transverse cross-section of the filament relative to the longitudinal axis of the filament. The cross-section of the filament may be determined and measured using Quantitative Image Analysis (QIA).

[0038] In some embodiments, the cross-sectional shape of an individual filament may be characterized according to its deviation from a round cross-sectional shape. In some cases, this deviation can be characterized by the shape factor of the filament or fiber, which is determined by the following formula: $\text{Shape Factor} = \text{Perimeter} / (4\pi \times \text{Cross-Sectional Area})^{1/2}$. In some embodiments, the shape factor of the individual cellulose acetate (or other cellulose ester) filaments or fibers can be at least about 1, 1.01, 1.1, 1.15, 1.2, 1.25, 1.3, 1.35, 1.4, 1.45, 1.5, 1.55, 1.6, 1.65, 1.7, 1.75, 1.8, 1.85, 1.9, 1.95, 2, 2.25, 2.5, 2.75, 3, or 3.25 and/or not more than about 5, 4.8, 4.75, 4.5, 4.25, 4, 3.75, 3.5, 3.25, 3, 2.75, 2.5, 2.25, 2, 1.75, 1.5, or 1.25. (Note: these values may also be expressed as ratios of the listed numbers to 1 – e.g., 1.45:1). The shape factor of filament or fiber having a round cross-sectional shape is 1. The shape factor can be calculated from the cross-sectional area of a filament or fiber, which can be measured using QIA.

[0039] Additionally, the cross-sectional shape of the filament or fiber may also be compared to a round cross-section according to its equivalent diameter, which is the equivalent diameter of a round filament or fiber having a cross-sectional area equal to a given filament or fiber. In some embodiments, cellulose acetate filaments or fibers according to embodiments of the present invention can have an equivalent diameter of at least about 0.0022, 0.0023, 0.0024, 0.0025, 0.0030, 0.0033, 0.0035, 0.0040, 0.0045, 0.0050, 0.0055, 0.0060, 0.0065, 0.0070, 0.0073, 0.0075, 0.0080, 0.0085, 0.0090, 0.0095, 0.0100, 0.0103, 0.0104, 0.0105, 0.0110, 0.0112, 0.0115, 0.0120, 0.0125, 0.0126, 0.013, 0.014, or 0.015 mm. Alternatively, or in addition, the cellulose acetate filaments or fibers may have an equivalent diameter of not more than

about 0.0400, 0.0375, 0.036, 0.0359, 0.0350, 0.0033, 0.0327, 0.0325, 0.0300, 0.0275, 0.0250, 0.0232, 0.0225, 0.0200, 0.0179, 0.0175, 0.016, 0.0150, 0.0127, 0.0125, or 0.0120 mm. The equivalent diameter is calculated from the cross-section of a filament or fiber, measured using QIA.

5 **[0040]** In another embodiment of the invention, the cross-section of a cellulose acetate fiber is shaped with many lobes. Although not wishing to be bound by theory, after the dope is spun through the spinneret, it can take on a round-shaped cross-section. After rapid evaporation of the solvent from the surface, a skin layer on the surface of the fiber can form. After that, evaporation of the solvent from the inside of the fiber can cause the skin layer to cave in toward the fiber cross-section, giving rise to the final multi-lobal cross-section. In yet another embodiment, the cross-section can be crenulated, which is defined as having an irregularly wavy or serrated outline.

10 **[0041]** According to some embodiments, the filaments or fibers 103 discharged from cabinet 104 may be at least partially coated with at least one fiber finish by at least one finish applicator 106 to produce coated filaments 107. As used herein, the terms “fiber finish” and “finish” refer to any suitable type of coating that, when applied to a fiber, modifies friction exerted by and on the fiber, and alters the ability of the fibers to move relative to one another and/or relative to a surface. Finishes are not the same as adhesives, bonding agents, or other similar chemical additives which, when added to fibers, prevent movement between the fibers by adhering them to one another. Finishes, when applied, continue to permit the movement of the fibers relative to one another and/or relative to other surfaces, but may modify the ease of this movement by increasing or decreasing the frictional forces. In some cases, finishes may not modify the frictional forces between fibers, but can, instead, impart one or more other desirable properties to the final coated fiber.

20 **[0042]** In some embodiments, the filaments or yarns may include at least two finishes applied to all or a portion of its surface at one or more points during the fiber production process. In other cases, the fibers may only include one finish while, in other cases, the fibers may not include any finish at all. When two or more finishes are applied to the fibers, the finishes may be applied as a blend

of two or more different finishes, or the finishes may be applied separately at different times during the process. For example, in some cases, the fibers may be at least partially coated with a spinning or spin finish applied to the filament yarn at one or more points during the process of forming the fibers. For example, in some embodiments, the spinning finish may be added to the fiber just after spinning. Alternatively, or in addition, the spinning finish may be added to the filament yarn just prior to subsequent fiber processing, such as texturing or crimping, if applicable. In some cases, no spinning finish may be applied.

[0043] Any suitable method of applying the spinning finish may be used and can include, for example, spraying, wick application, dipping, or use of squeeze, lick, or kiss rollers. When used, the spinning finish may be of any suitable type and can be present on the filaments or fibers in an amount of at least about 0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.50, 0.55, 0.60, 0.70, 0.80, 0.90, or 1 percent finish-on-yarn (FOY). Alternatively, or in addition, the spinning finish may be present in an amount of not more than about 10.0, 9.0, 8.0, 7.0, 6.0, 5.0, 4.0, 3.0, 2.0, 1.5, 1.4, 1.3, 1.2, 1.1, 1.0, 0.90, 0.80, 0.75, 0.70, 0.65, 0.60, or 0.50 percent finish-on-yarn (FOY) based on the total weight of the dried fiber. As used herein “FOY” or “finish on yarn” refers to the amount of finish on the fiber or filament, less any added water. One or two or more types of spinning finishes may be used. In some cases, the spinning finish may be hydrophobic.

[0044] Further, in some embodiments, the top-coat (and/or spinning) finish may include other additives such as, for example, an anti-static agent. In addition, the finish may also include one or more other additives such as a wetting agent, antioxidants, biocides, anti-corrosion agents, pH control agents, emulsifiers, and combinations thereof. It is also possible that one or more additives may be added to a fiber as a coating, but without additional friction-modifying properties.

[0045] When present, any suitable anti-static agent may be used and, in some cases, the anti-static agent may include polar and/or hydrophilic compounds. When used, such additives may be present in any suitable amount such as, for example, at least about 0.10, 0.15, 0.20, 0.25, 0.30, or 0.35 weight percent

and/or not more than about 3, 2.9, 2.8, 2.7, 2.6, 2.5, 2.4, 2.3, 2.2, 2.1, 2.0, 1.9, 1.8, 1.7, 1.6, 1.5, 1.4, 1.3, 1.2, 1.1, 1, 0.90, 0.80, 0.70, 0.60, or 0.50 weight percent, based on the total weight of the fiber.

[0046] When the fibers are coated with an anti-static finish, the coated fiber may exhibit a static half-life of not more than about 100, 90, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 22, 20, 17, 15, 12, 10, 8, 5, 3, 2, 1.5, or 1 second, measured according to AATCC 84-2011. In some embodiments, the fibers may have a static half-life of not more than about 30, 25, 20, 18, 15, 12, 10, or 8 minutes. In other embodiments, the static half-life of the coated fiber may be at least about 30 seconds, at least about 1 minute, at least about 5, 8, 10, 15, 20, 30, 40, 50, 60, 75, 90, or 100 minutes and/or not more than about 120, 110, 100, 90, 75, 60, 45, 40, 35, 30, 20, 15, or 12 minutes, measured according to AATCC 84-2011.

[0047] In some embodiments, this may be not more than 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10, or 5 percent of the static half-life of an identical but uncoated fiber. In some cases, the static half-life of the coated fiber may be at least 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, or 95 percent less than the static half-life of an identical but uncoated fiber.

[0048] Alternatively, or in addition, the coated fibers described herein may have a surface resistivity (Log R) of at least about 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, or 9 and/or not more than about 11, 10.5, 10, 9.75, 9.5, 9.25, 9, 8.75, 8.5, 8.25, 8, 7.75, 7.5 measured according to AATCC TM76-2011. The surface resistivity was measured using a Monroe Electronics resistivity meter (Model No. 272A) connected to a Keithley Instruments isolation box (Model No. 6104) using an isolation cup for measuring the resistivity of the fibers. The surface resistivity (Log R) is calculated by multiplying the surface resistance by the ratio of the length of the area being tested to its width and expressing the result as the base 10 logarithm of the calculated value.

[0049] In some embodiments, the fibers or filament yarns may be at least partially coated with at least one spinning finish and at least one top-coat finish. The total amount of all finishes present on the fibers or filament yarns according

to embodiments of the present invention can be at least about 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.50, 0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90, 0.95, 1.0, or 1.05 percent FOY and/or not more than about 10, 9, 8, 7, 6, 5, 4, 3, 2, 1.5, 1.4, 1.3, 1.2, 1.1, 1.0, 0.90, 0.80, 0.75, 0.70, 0.65, 0.60, 0.55, 0.50, or 0.45 percent FOY, based on the total weight of the dried fiber. The amount of finish on the fibers as expressed by weight percent may be determined by solvent extraction according to ASTM D2257.

[0050] In some cases, when the filament yarn is coated with a spinning and/or top-coat finish, the filament yarn may exhibit a fiber-to-fiber (F/F) coefficient of friction (COF) of at least about 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, or 0.40 and/or not more than about 0.55, 0.50, 0.45, 0.42, 0.40, 0.35, 0.33, 0.30, 0.25, 0.20, 0.15, 0.14, 0.13, 0.12, 0.11, 0.10, 0.09, 0.08, 0.07, or 0.06. Values for the F/F coefficient of friction (COF) of continuous filaments can be determined according to ASTM D3412 with the specified yarn parameters, a speed of 100 m/min, an input tension of 10 grams, and a single twist applied to the filament.

[0051] In another embodiment, yarns described herein may have a F/F coefficient of friction value within one or more of the above ranges measured using a continuous tension tester electronic device (CTT-E) according to ASTM D3412 with the specified yarn parameters, a speed of 20 m/min, an input tension of 10 grams, and a single twist applied to the filament.

[0052] Additionally, filament yarns coated with a spinning and/or top-coat finish according to embodiments of the present invention may exhibit a fiber-to-metal (F/M) coefficient of friction of at least about 0.01, 0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.50, 0.55, 0.57, 0.60, or 0.65 and/or not more than about 0.80, 0.75, 0.70, 0.65, 0.60, 0.55, 0.50, 0.45, or 0.40. Values for the F/M coefficient of friction of continuous filaments can be determined according to ASTM D3108 with the specified yarn parameters, a speed of 100m/min, and an input tension of 48 grams.

[0053] In another embodiment, yarns described herein may have a F/M coefficient of friction value within one or more of the above ranges measured using a continuous tension tester electronic device (CTT-E) according to ASTM

D3108 with the specified yarn parameters, a speed of 100 m/min, and an input tension of 10 grams.

[0054] The coated fibers as described herein may also exhibit higher-than-expected strength. For example, in some embodiments, the coated fibers may be formed from filaments that exhibit a tenacity of at least about 0.5, 0.55, 0.60, 0.65, 0.70, 0.75, 0.80, 0.85, 0.90, 0.95, 1.0, 1.05, 1.1, 1.15, 1.20, 1.25, 1.30, or 1.35 grams-force/denier (g/denier) and/or not more than 2.50, 2.45, 2.40, 2.35, 2.30, 2.25, 2.20, 2.15, 2.10, 2.05, 2.00, 1.95, 1.90, 1.85, 1.80, 1.75, 1.70, 1.65, 1.60, 1.55, 1.50, 1.47, 1.45, or 1.40 g/denier, and/or between 0.5 and 3.0, between 1 and 2, or between 1.25 and 1.5 g/denier, as measured according to ASTM D3822. Additionally, in some embodiments, the elongation at break of the coated fibers can be at least about 5, 6, 10, 15, 20, or 25 percent and/or not more than about 50, 45, 40, 35, or 30 percent, and/or between 5 and 50, between 10 and 40, or between 20 and 30, as measured according to ASTM D3822.

[0055] In one embodiment of the invention, fibers and filament yarns described herein include little or no plasticizer and have unexpectedly been shown to exhibit enhanced biodegradability under industrial, home, and soil conditions, even as compared to cellulose acetate fibers with higher levels of plasticizer.

[0056] In some embodiments, the fibers described herein can include less than about 50, 30, 27, 25, 22, 20, 17, 15, 12, 10, 9.5, 9, 8.5, 8, 7.5, 7, 6.5, 6, 5.5, 5, 4.5, 4, 3.5, 3, 2.5, 2, 1.5, 1, 0.5, 0.25, or 0.10 percent plasticizers, based on the total weight of the fiber and/or yarns, or the fibers may include no plasticizer. When present, the plasticizer may be incorporated into the fiber itself by being blended with the solvent dope or cellulose acetate flake, or the plasticizer may be applied to the surface of the fiber or filament by spraying, by centrifugal force from a rotating drum apparatus, or by an immersion bath.

[0057] Examples of plasticizers that may or may not be present in or on the fibers can include, but are not limited to, aromatic polycarboxylic acid esters, aliphatic polycarboxylic acid esters, lower fatty acid esters of polyhydric alcohols, and phosphoric acid esters. Further examples can include, but are not limited to, dimethyl phthalate, diethyl phthalate, dibutyl phthalate, dihexyl

phthalate, dioctyl phthalate, dimethoxyethyl phthalate, ethyl phthalylethyl glycolate, butyl phthalylbutyl glycolate, tetraoctyl pyromellitate, trioctyl trimellitate, dibutyl adipate, dioctyl adipate, dibutyl sebacate, dioctyl sebacate, diethyl azelate, dibutyl azelate, dioctyl azelate, glycerol, trimethylolpropane, pentaerythritol, sorbitol, glycerin triacetate (triacetin), diglycerin tetracetate, triethyl phosphate, tributyl phosphate, tributoxyethyl phosphate, triphenyl phosphate, and tricresyl phosphate, and combinations thereof. In some embodiments, the fibers of the present invention may not include any type of plasticizer or other additive, and can consist essentially of, or consist of, cellulose acetate and not more than 1 percent FOY of a spinning finish.

[0058] Additionally, the cellulose acetate fibers described herein may not have undergone additional treatment steps designed to enhance the biodegradability of the fibers. For example, the fibers may not have been hydrolyzed or treated with enzymes or microorganisms. The fibers may include not more than about 1, 0.75, 0.5, 0.25, 0.1, 0.05, or 0.01 weight percent of an adhesive or bonding agent and may include less than 1, 0.75, 0.5, 0.25, 0.1, 0.05, or 0.01 weight percent of modified or substituted cellulose acetate. In some embodiments, the fibers may not include any adhesive or bonding agent and may not be formed from any substituted or modified cellulose acetate. Substituted or modified cellulose acetate may include cellulose acetate that has been modified with a polar substituent, such as a substituent selected from the group consisting of sulfates, phosphates, borates, carbonates, and combinations thereof.

[0059] In one embodiment, after the finish is applied, the cellulose acetate fibers are passed through at least one entanglement (TF) jet or discharged from at least one entanglement nozzle 108. The TF jets expose the cellulose acetate fibers to turbulent air such that one or more nodes are formed along the length of the yarn. Formation of these nodes helps with spinning, weaving, knitting, and processability of the yarn. In one embodiment or in combination with any other mentioned embodiments, the TF jets may be blown at a pressure between 10 and 30 pounds per square inch (psi). In one embodiment or in combination with any other mentioned embodiments, the yarn has an entanglement node

density within a range between 1 and 50, between 2 and 30, between 4 and 20, or between 6 and 15 nodes per foot.

[0060] In some embodiments, the resulting individually-entangled yarns formed from the cellulose acetate fibers have a moisture content within a range between 3.5 and 30 percent, 3.5 and 25 percent, 3.5 and 20 percent, 3.5 and 15 percent, 4 and 10 percent, 4 and 8 percent, or 5 and 7 percent based on the total weight of the yarn. Additionally or alternatively, in some embodiments, the resulting individually-entangled yarns formed from the cellulose acetate fibers have a residual solvent content within a range between 0 and 30 percent, between 2 and 20 percent, or between 4 and 15 percent based on the total weight of the yarn.

[0061] In some embodiments, after the entanglement, the resulting individually-entangled yarns 109 are routed, via at least one yarn guide 110, towards at least one winder 112. As will be described in more detail below, the newly-formed yarns may be accumulated onto cores or tubes and the cores or tubes may be removable from winders 112, with the resulting individually-entangled yarns wound around the cores or tubes, as individual yarn packages of cellulosic material.

[0062] Referring now to FIGS. 2-10, yarn guide 110 receives a plurality of individually-entangled yarns 109 entangled by entanglement nozzle 108 (shown in FIG. 1), and then routes yarns 109 towards winders 112 to produce one or more yarn packages. Specifically, each yarn guide 110 includes a guide arm 116 that is individually capable of routing one or more yarns 109 towards winders 112. Each winder 112 includes a rotatable spool 118, and at least one core 120 is removably coupled to and rotatable with rotatable spool 118 such that yarns 109 may be wound or co-wound thereon. As will be described in more detail below, each spool 118 may receive more than one core 120 thereon. Thus, a plurality of individually-entangled yarns 109 may be wound around each common core 120. In one embodiment or in combination with any other mentioned embodiments, the number of yarns wound or co-wound on core 120 is not more than 20, not more than 15, not more than 10, not more than 5, or not more than 4.

[0063]As used herein, “co-wound” refers to the winding of more than one yarns 109 around a common core at the same time.

[0064]As described above, spinnerets 102 (shown in FIG. 1) are modified to output more than one distinct filament grouping that each produces an individually-entangled yarn 109. Thus, in one embodiment or in combination with any other mentioned embodiments, yarns 109 derived from the same spinneret.

[0065]In one embodiment or in combination with any other mentioned embodiments, core 120 has a substantially cylindrical shape. In other words, core 120 does not include flanges, or any other structure that provides lateral support to yarns wound on core 120, defined at terminal ends of core 120.

[0066]In one embodiment or in combination with any other mentioned embodiments, core 120 has a length between 2 and 24, between 4 and 12, or between 5 and 8 inches.

[0067]In one embodiment or in combination with any other mentioned embodiments, core 120 is made of a non-metallic material. Exemplary non-metallic materials can include a cardboard material and/or a plastic material.

[0068]In one embodiment, at least two individually-entangled yarns 109 are wound around a common core 120 to define one or more yarn sections on the core. Each yarn section can include one or more individually-entangled yarns co-wound around core 120. These yarns 109 are not twisted with each other on core 120. That is, even when more than one yarn 109 is routed towards a winder 112 from a single guide arm 116, these yarns 109 are combined and co-wound on core 120 without being permanently twisted or entangled with one another before reaching the winder 112. Thus, the respective yarns 109 are unwindable from core 120 individually.

[0069]As used herein, “unwound individually,” “unwindable individually,” and variations thereof means yarns can be simultaneously and/or sequentially unwound from their core and separated from one another. As used herein, “unwound simultaneously,” “unwindable simultaneously,” and variations thereof means yarns can be simultaneously unwound from their core and separated from one another. As used herein, “unwound sequentially,” “unwindable

sequentially,” means one yarn can be unwound from the core without unwinding another yarn from the same core.

[0070] For example, referring specifically to FIGS. 2, 3, and 4, a first guide arm 122 routes a first yarn 124 towards a first core 126 on a first spool 127, a second guide arm 128 routes a second yarn 130 towards a second core 129 on first spool 127, a third guide arm 132 routes a third yarn 134 towards a third core 131 on a second spool 133, and a fourth guide arm 138 routes a fourth yarn 140 towards a fourth core 135 on second spool 133. Thus, yarns 124, 130, 134, and 140 are wound around their respective cores 126, 129, 131, and 135 to produce four yarn packages 142 simultaneously.

[0071] Referring to FIGS. 3 and 4, first spool 127 having two yarn packages 142 formed thereon is illustrated. For example, one yarn package 142 includes first core 126 and a first yarn section 144 formed from first yarn 124, and another yarn package 142 includes second core 129 and a second yarn section 146 formed from second yarn 130. Thus, each yarn package 142 is individually removable from first spool 127. For example, yarn package 142 associated with first core 126 may be removed, and then yarn package 142 associated with second core 129 may be removed afterwards. Accordingly, the packages have a reduced size and weight, which may enhance the processability of yarn 109 wound thereon.

[0072] In one embodiment, yarns 124 and 130 may be wound around a common core to form yarn sections 144 and 146 thereon that are similar to those illustrated in FIGS. 3 and 4. For example, and with reference to FIG. 3A, such multi-section yarn packages may include yarn sections 144 and 146 spaced from one another on the common core. Alternatively, and with reference to FIG. 4A, such multi-section yarn packages may include yarn sections 144 and 146 adjacent to and in substantial contact with one another on the common core to enhance the stability of the yarn package.

Thus, yarns 109 may be wound around separate sections of the common core to increase the winding capacity of cabinet 104 (shown in FIG. 1) while still enabling yarns 109 to be unwound therefrom individually.

[0073] As used herein, a “separate section” of the core is defined as the volume of fiber? between two parallel planes extending perpendicular to the longitudinal axis of the core.

[0074] Referring now to FIGS. 5 and 6, in one embodiment, first guide arm 122 routes first yarn 124 towards first core 126, second guide arm 128 routes second yarn 130 towards first core 126, third guide arm 132 routes third yarn 134 towards second core 129, and fourth guide arm 138 routes fourth yarn 140 towards second core 129. Yarns 124 and 130 are wound around separate sections of first core 126, and yarns 134 and 140 are wound around separate sections of second core 129 to produce two multi-section yarn packages 150. For example, one yarn package 150 includes first core 126, a first yarn section 152 formed from first yarn 124, and a second yarn section 154 formed from second yarn 130. The other yarn package 150 includes second core 129, a third yarn section 156 formed from third yarn 134, and a fourth yarn section 158 formed from fourth yarn 140. Yarn sections 152, 154, 156, and 158 may be spaced from one another, or may be adjacent to and in substantial contact with one another, on their respective cores 126 and 129.

[0075] Thus, yarns 109 are wound around separate sections of first core 126, second core 129, or the common core to increase the winding capacity of cabinet 104 (shown in FIG. 1) while still enabling yarns 109 to be unwound from core 126 and core 129 individually.

[0076] In an alternative embodiment, yarns 124, 130, 134, and 140 may be wound around a common core 120 to form one package 155 with yarn sections 152, 154, 156, and 158 thereon that are similar to those illustrated in FIG. 6A.

[0077] Referring now to FIGS. 7 and 8, in one embodiment, first guide arm 122 routes first yarn 124 and second yarn 130 towards a fifth core 157, and second guide arm 128 routes third yarn 134 and fourth yarn 140 towards a sixth core 159. Specifically, the yarn pairs are combined at the respective guide arms 122 and 128, but are not twisted or not permanently entangled before being wound on the respective cores 157 and 159. Accordingly, the yarn pairs define a combined yarn 160 that is wound around the respective cores 157 and 159 to enable two yarn packages 162 to be produced simultaneously. For example,

referring to FIG. 8, yarn package 162 includes combined yarn 160 wound around at least one common section of first core 126. In one embodiment, combined yarn 160 is co-wound around core 157 along the length thereof. Accordingly, yarn package 162 has a section wound thereon formed from more than one yarn.

[0078]As used herein, “combined” refers to two or more yarns occupying at least one common section of a core. Combined yarns are capable of being individually unwound from a core (i.e., unwound at the same time as separate yarns, but not unwound sequentially).

[0079]Referring now to FIGS. 9 and 10, in one embodiment, first guide arm 122 routes first yarn 124 and second yarn 130 towards first core 129, and second guide arm 128 routes third yarn 134 and fourth yarn 140 towards second core 126. Specifically, the yarn pairs are combined at the respective guide arms 122 and 128, but are not twisted or not permanently entangled before being wound on first core 129 and second core 126. The yarn pairs define combined yarns 164 and 166 that are wound around the respective cores 126 and 129 to produce multiple yarn packages 168 simultaneously. For example, referring to FIG. 10, one yarn package 168 includes first core 129 and a first yarn section 172 formed from combined yarn 166, and the other yarn package 168 includes second core 126 and a second yarn section 170 formed from combined yarn 164. Accordingly, each yarn package 168 has a yarn section wound thereon that is formed from more than one yarn (i.e., a combined yarn).

[0080]In one embodiment, yarns 164 and 166 can be wound around a common core to form yarn sections 170 and 172 thereon that are similar to those illustrated in FIG. 10A. Similar to the embodiments illustrated in FIGS. 3A and 4A, yarn sections 170 and 172 may be spaced from one another on the common core, or may be adjacent to and in substantial contact with one another on the common core.

[0081]The above embodiments are for example purposes only. The systems and methods described herein may be used to produce yarn packages having any number of yarns, combined yarns, and/or yarn sections.

[0082] In one embodiment or in combination with any other mentioned embodiments, yarns 109 are wound around a respective core 120 in a helical pattern. For example, each core may have a longitudinal axis 174, and yarns 109 may be wound on the core at an angle between 0.1 and 89.9, between 1 and 30, between 2 and 20, or between 5 and 12 degrees relative to longitudinal axis 174. Accordingly, yarn may be collected along the length of the core.

[0083] In one embodiment or in combination with any other mentioned embodiments, the yarn packages produced as described above may have a combined weight, including at least the core and yarn wound thereon, between 1 and 40, between 2 and 3, between 4 and 20, or between 5 and 15 pounds.

[0084] In one embodiment or in combination with any other mentioned embodiments, each wound yarn section has a width, as defined relative to longitudinal axis 174, between 1 and 12 inches, between 1.5 and 6 inches, or between 2 and 3 inches on the core.

[0085] Cellulose acetate fibers, filaments, and/or yarns as described herein can be used to form nonwoven webs that can be used in several types of fibrous articles. For example, in some cases, coated fibers as described herein may be suitable for use in forming nonwoven fabrics that exhibit unexpected and improved properties, such as strength, durability, flexibility, softness, and absorbency. Additionally, the fibers as described herein exhibit unique properties such as lower friction, higher strength, and more durability, which facilitate faster, more efficient, and more uniform processing of the fibers into nonwoven webs.

[0086] The fibers, filaments, and/or yarns, and the nonwovens formed therefrom, can be biodegradable, meaning that such fibers are expected to decompose under certain environmental conditions. The degree of degradation can be characterized by the weight loss of a sample over a given period of exposure to certain environmental conditions. In some cases, the material used to form the fibers, or the nonwoven webs or articles produced from the fibers can exhibit a weight loss of at least about 5, 10, 15, or 20 percent after burial in soil for 60 days and/or a weight loss of at least about 15, 20, 25, 30, or 35 percent after 15 days of exposure to a typical municipal composter. However,

the rate of degradation may vary depending on the particular end use of the fibers, as well as the composition of the remaining article, and the specific test. Exemplary test conditions are provided in U.S. Patent No. 5,970,988 and U.S. Patent No. 6,571,802.

5 **[0087]** In some embodiments, the cellulose acetate fibers may be biodegradable fibers and such fibers may be used to form fibrous articles such as textiles, nonwoven fabrics, filters, and yarns. Unexpectedly, it has been found that cellulose acetate fibers as described herein exhibit enhanced levels of environmental non-persistence, characterized by better-than-expected
10 degradation under various environmental conditions. Fibers and fibrous articles described herein may meet or exceed passing standards set by international test methods and authorities for industrial compostability, home compostability, and/or soil biodegradability.

[0088] To be considered “compostable,” a material must meet the following four
15 criteria: (1) the material must be biodegradable; (2) the material must be disintegrable; (3) the material must not contain more than a maximum amount of heavy metals; and (4) the material must not be ecotoxic. As used herein, the term “biodegradable” generally refers to the tendency of a material to chemically decompose under certain environmental conditions.
20 Biodegradability is an intrinsic property of the material itself, and the material can exhibit different degrees of biodegradability, depending on the specific conditions to which it is exposed. The term “disintegrable” refers to the tendency of a material to physically decompose into smaller fragments when exposed to certain conditions. Disintegration depends both on the material itself, as well as
25 the physical size and configuration of the article being tested. Ecotoxicity measures the impact of the material on plant life, and the heavy metal content of the material is determined according to the procedures laid out in the standard test method.

[0089] The cellulose acetate fibers can exhibit a biodegradation of at least 70
30 percent in a period of not more than 50 days, when tested under aerobic composting conditions at ambient temperature ($28^{\circ}\text{C} \pm 2^{\circ}\text{C}$) according to ISO 14855-1 (2012). In some cases, the cellulose acetate fibers can exhibit a

biodegradation of at least 70 percent in a period of not more than 49, 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, or 37 days when tested under these conditions, also called "home composting conditions." These conditions may not be aqueous or anaerobic. In some cases, the cellulose acetate fibers can exhibit a total biodegradation of at least about 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, or 88 percent, when tested under according to ISO 14855-1 (2012) for a period of 50 days under home composting conditions. This may represent a relative biodegradation of at least about 95, 97, 99, 100, 101, 102, or 103 percent, when compared to cellulose subjected to identical test conditions.

[0090] To be considered "biodegradable," under home composting conditions according to the French norm NF T 51-800 and the Australian standard AS 5810, a material must exhibit a biodegradation of at least 90 percent in total (*e.g.*, as compared to the initial sample), or a biodegradation of at least 90 percent of the maximum degradation of a suitable reference material after a plateau has been reached for both the reference and test item. The maximum test duration for biodegradation under home composting conditions is 1 year. The cellulose acetate fibers as described herein may exhibit a biodegradation of at least 90 percent within not more than 1 year, measured according 14855-1 (2012) under home composting conditions. In some cases, the cellulose acetate fibers may exhibit a biodegradation of at least about 91, 92, 93, 94, 95, 96, 97, 98, 99, or 99.5 percent within not more than 1 year, or the fibers may exhibit 100 percent biodegradation within not more than 1 year, measured according 14855-1 (2012) under home composting conditions.

[0091] Additionally, or in the alternative, the fibers described herein may exhibit a biodegradation of at least 90 percent within not more than about 350, 325, 300, 275, 250, 225, 220, 210, 200, 190, 180, 170, 160, 150, 140, 130, 120, 110, 100, 90, 80, 70, 60, or 50 days, measured according 14855-1 (2012) under home composting conditions. In some cases, the fibers can be at least about 97, 98, 99, or 99.5 percent biodegradable within not more than about 70, 65, 60, or 50 days of testing according to ISO 14855-1 (2012) under home composting conditions. As a result, the cellulose acetate fibers may be

considered biodegradable according to, for example, French Standard NF T 51-800 and Australian Standard AS 5810 when tested under home composting conditions.

[0092] The cellulose acetate fibers can exhibit a biodegradation of at least 60 percent in a period of not more than 45 days, when tested under aerobic composting conditions at a temperature of 58°C ($\pm 2^\circ\text{C}$) according to ISO 14855-1 (2012). In some cases, the fibers can exhibit a biodegradation of at least 60 percent in a period of not more than 44, 43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, or 27 days when tested under these conditions, also called "industrial composting conditions." These may not be aqueous or anaerobic conditions. In some cases, the fibers can exhibit a total biodegradation of at least about 65, 70, 75, 80, 85, 87, 88, 89, 90, 91, 92, 93, 94, or 95 percent, when tested under according to ISO 14855-1 (2012) for a period of 45 days under industrial composting conditions. This may represent a relative biodegradation of at least about 95, 97, 99, 100, 102, 105, 107, 110, 112, 115, 117, or 119 percent, when compared to cellulose fibers subjected to identical test conditions.

[0093] To be considered "biodegradable," under industrial composting conditions according to ASTM D6400 and ISO 17088, at least 90 percent of the organic carbon in the whole item (or for each constituent present in an amount of more than 1% by dry mass) must be converted to carbon dioxide by the end of the test period when compared to the control or in absolute. According to European standard ED 13432 (2000), a material must exhibit a biodegradation of at least 90 percent in total, or a biodegradation of at least 90 percent of the maximum degradation of a suitable reference material after a plateau has been reached for both the reference and test item. The maximum test duration for biodegradability under industrial composting conditions is 180 days. The cellulose acetate fibers described herein may exhibit a biodegradation of at least 90 percent within not more than 180 days, measured according 14855-1 (2012) under industrial composting conditions. In some cases, the cellulose acetate fibers may exhibit a biodegradation of at least about 91, 92, 93, 94, 95, 96, 97, 98, 99, or 99.5 percent within not more than 180 days, or the fibers may

exhibit 100 percent biodegradation within not more than 180 days, measured according 14855-1 (2012) under industrial composting conditions.

[0094] Additionally, or in the alternative, cellulose acetate fibers described herein may exhibit a biodegradation of least 90 percent within not more than about 175, 170, 165, 160, 155, 150, 145, 140, 135, 130, 125, 120, 115, 110, 105, 100, 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, or 45 days, measured according 14855-1 (2012) under industrial composting conditions. In some cases, the cellulose acetate fibers can be at least about 97, 98, 99, or 99.5 percent biodegradable within not more than about 65, 60, 55, 50, or 45 days of testing according to ISO 14855-1 (2012) under industrial composting conditions. As a result, the cellulose acetate fibers described herein may be considered biodegradable according to ASTM D6400 and ISO 17088 when tested under industrial composting conditions.

[0095] The fibers or fibrous articles may exhibit a biodegradation in soil of at least 60 percent within not more than 130 days, measured according to ISO 17556 (2012) under aerobic conditions at ambient temperature. In some cases, the fibers can exhibit a biodegradation of at least 60 percent in a period of not more than 130, 120, 110, 100, 90, 80, or 75 days when tested under these conditions, also called "soil composting conditions." These may not be aqueous or anaerobic conditions. In some cases, the fibers can exhibit a total biodegradation of at least about 65, 70, 72, 75, 77, 80, 82, or 85 percent, when tested under according to ISO 17556 (2012) for a period of 195 days under soil composting conditions. This may represent a relative biodegradation of at least about 70, 75, 80, 85, 90, or 95 percent, when compared to cellulose fibers subjected to identical test conditions.

[0096] In order to be considered "biodegradable," under soil composting conditions according the OK biodegradable SOIL conformity mark of Vinçotte and the DIN Geprüft Biodegradable in soil certification scheme of DIN CERTCO, a material must exhibit a biodegradation of at least 90 percent in total (e.g., as compared to the initial sample), or a biodegradation of at least 90 percent of the maximum degradation of a suitable reference material after a plateau has been reached for both the reference and test item. The maximum

test duration for biodegradability under soil composting conditions is 2 years. The cellulose acetate fibers as described herein may exhibit a biodegradation of at least 90 percent within not more than 2 years, 1.75 years, 1 year, 9 months, or 6 months measured according to ISO 17556 (2012) under soil composting conditions. In some cases, the cellulose acetate fibers may exhibit a biodegradation of at least about 91, 92, 93, 94, 95, 96, 97, 98, 99, or 99.5 percent within not more than 2 years, or the fibers may exhibit 100 percent biodegradation within not more than 2 years, measured according to ISO 17556 (2012) under soil composting conditions.

[0097] Additionally, or in the alternative, cellulose acetate fibers described herein may exhibit a biodegradation of at least 90 percent within not more than about 700, 650, 600, 550, 500, 450, 400, 350, 300, 275, 250, 240, 230, 220, 210, 200, or 195 days, measured according to ISO 17556 (2012) under soil composting conditions. In some cases, the cellulose acetate fibers can be at least about 97, 98, 99, or 99.5 percent biodegradable within not more than about 225, 220, 215, 210, 205, 200, or 195 days of testing according to ISO 17556 (2012) under soil composting conditions. As a result, the cellulose acetate fibers described herein may meet the requirements to receive The OK biodegradable SOIL conformity mark of Vinçotte and to meet the standards of the DIN Geprüft Biodegradable in soil certification scheme of DIN CERTCO.

[0098] In some embodiments, cellulose acetate fibers (or fibrous articles) of the present invention may include less than 1, 0.75, 0.50, or 0.25 weight percent of components of unknown biodegradability. In some cases, the fibers or fibrous articles described herein may include no components of unknown biodegradability.

[0099] In addition to being biodegradable under industrial and/or home composting conditions, cellulose acetate fibers or fibrous articles as described herein may also be compostable under home and/or industrial conditions. As described previously, a material is considered compostable if it meets or exceeds the requirements set forth in EN 13432 for biodegradability, ability to disintegrate, heavy metal content, and ecotoxicity. The cellulose acetate fibers or fibrous articles described herein may exhibit sufficient compostability under

home and/or industrial composting conditions to meet the requirements to receive the OK compost and OK compost HOME conformity marks from Vinçotte.

[00100] In some cases, the cellulose acetate fibers and fibrous articles described herein may have a volatile solids concentration, heavy metals and fluorine content that fulfill all of the requirements laid out by EN 13432 (2000). Additionally, the cellulose acetate fibers may not cause a negative effect on compost quality (including chemical parameters and ecotoxicity tests).

[00101] In some cases, the cellulose acetate fibers or fibrous articles can exhibit a disintegration of at least 90 percent within not more than 26 weeks, measured according to ISO 16929 (2013) under industrial composting conditions. In some cases, the fibers or fibrous articles may exhibit a disintegration of at least about 91, 92, 93, 94, 95, 96, 97, 98, 99, or 99.5 percent under industrial composting conditions within not more than 26 weeks, or the fibers or articles may be 100 percent disintegrated under industrial composting conditions within not more than 26 weeks. Alternatively, or in addition, the fibers or articles may exhibit a disintegration of at least 90 percent under industrial composting conditions within not more than about 26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11, or 10 weeks, measured according to ISO 16929 (2013). In some cases, the cellulose acetate fibers or fibrous articles described herein may be at least 97, 98, 99, or 99.5 percent disintegrated within not more than 12, 11, 10, 9, or 8 weeks under industrial composting conditions, measured according to ISO 16929 (2013).

[00102] In some cases, the cellulose acetate fibers or fibrous articles can exhibit a disintegration of at least 90 percent within not more than 26 weeks, measured according to ISO 16929 (2013) under home composting conditions. In some cases, the fibers or fibrous articles may exhibit a disintegration of at least about 91, 92, 93, 94, 95, 96, 97, 98, 99, or 99.5 percent under home composting conditions within not more than 26 weeks, or the fibers or articles may be 100 percent disintegrated under home composting conditions within not more than 26 weeks. Alternatively, or in addition, the fibers or articles may exhibit a disintegration of at least 90 percent within not more than about 26, 25,

24, 23, 22, 21, 20, 19, 18, 17, 16, or 15 weeks under home composting conditions, measured according to ISO 16929 (2013). In some cases, the cellulose acetate fibers or fibrous articles described herein may be at least 97, 98, 99, or 99.5 percent disintegrated within not more than 20, 19, 18, 17, 16, 15, 14, 13, or 12 weeks, measured under home composting conditions according to ISO 16929 (2013).

[00103] The cellulose acetate fibers may be used to form textiles for agricultural, medical, food, and other applications, for example. In some embodiments, the textile fabric can be prepared from yarns comprising the cellulose acetate, as described herein. As used herein, textile fabrics are materials made from yarns and that are either woven, knitted, crocheted, knotted, embroidered, braided/plaited, laced, or carpet piled. Textile fabrics can include geotextile fabrics, carpet pilings, and fabrics (which includes cloth). The geotextile fabrics as used in the context of a textile fabric herein are those that are woven or knitted. Examples of suitable types of textile fabrics formable from the cellulose acetate fibers can include, but are not limited to, clothing (undergarments, socks, hats, shirts, pants, dresses, scarves, gloves, etc.), bags, baskets, upholstered furnishings, window shades, towels, table cloths, bed coverings, flat surface coverings, in art work, filters, flags, backpacks, tents, handkerchiefs, rags, balloons, kites, sails, parachutes, automotive upholstery, protective clothing such as against heat for firefighters and welders, protective clothing for bullet armor or stab protection, medical textile fabrics such as implants, and agrotextile fabrics for crop protection.

[00104] Referring now to FIGS. 11-13, yarn production system 100 further includes at least one dope mixer 176 and a solvent recovery system 178. In the example embodiments, dope mixer 176 receives fresh solvent 179 and/or solvent 180 from solvent recovery system 178, and receives solids 182, such as the cellulose acetate flake described above. Dope mixer 176 dissolves solids 182 in solvent 180 to produce a dope mixture 184. In some embodiments, dope mixture 184 has between about 15 and 40 percent dissolved solids, and between about 60 and 85 percent solvent, by weight of dope mixture 184.

[00105] Dope mixture 184 is then provided to spinnerets 102 in a common cabinet 104 to produce cellulose acetate filaments 103 therefrom. In some embodiments, spinnerets 102 can spin dope mixture 184 at a rate of between 200 and 2000, between 250 and 1000, or between 300 and 500 meters per minute when forming filaments 103. The spinning rate is determined by the surface speed of the godet roll. In addition, an outlet temperature of spinnerets 102 may be maintained at between about 30 °C and about 120 °C during the spinning. These process conditions enable continuous filaments as described herein to be produced for forming into continuous yarn.

[00106] For example, as illustrated in FIG. 11, two single-cluster spinnerets 186 spin dope mixture 184 to form filaments 103 therefrom. Specifically, each spinneret 186 forms a group of filaments, such that a first group 188 and a second group 190 of filaments are formed and passed through common cabinet 104. In some embodiments, cabinet 104 further includes an air inlet 192 and an air outlet 194. Air inlet 192 receives a stream of air 196, which is channeled through cabinet 104 as first and second groups 188 and 190 of filaments are passed through cabinet 104. Air 196 is passed by the filaments to remove at least a portion of the solvent therefrom. In some embodiments, first and second groups 188 and 190 of filaments are passed through cabinet for a residence time of between about 0.1 and 2.0 seconds. The residence time is selected to remove a desired amount of solvent from filaments 103. The removed solvent entrained in air may then be discharged from outlet 194 in the form of an air-solvent stream 198. Air-solvent stream 198 may then be provided to solvent recovery system 178 to recover solvent therefrom. The recovered solvent may then be recycled towards dope mixer 176 to enable additional filaments to be formed therefrom.

[00107] In some embodiments, the cabinet air 196 may be introduced at or near the top of the cabinet and pass down the cabinet before discharge at or near the bottom of the cabinet. Or, alternatively, the air may be introduced and discharged at multiple locations along the length of the cabinet. The configuration used will depend on several control criteria, including the solvent recovery rate, filament tensions, or air turbulence.

[00108] In the example embodiments, filaments 103 discharged from cabinet 104 are routed towards finish applicator 106 to apply a finish to filaments 103. In some embodiments, yarn production system 100 includes a first finish applicator 200 and a second finish applicator 202 positioned at separate locations outside cabinet 104. For example, first finish applicator 200 applies a finish to first group 188 of filaments at a first location, and second finish applicator 202 applies a finish to second group 190 of filaments at a second location that is positioned a distance from the first location. Thus, this arrangement of finish applicators 106 facilitates the production of distinct yarns from the respective groups of filaments.

[00109] In some embodiments, the finish is applied to filaments 103 before being entangled into yarns. For example, coated filaments 107 routed from finish applicators 200 and 202 may be entangled by entanglement nozzles 108. In the example embodiment, filaments 107 are entangled by air jets discharged from nozzles 108 to produce, for example, first yarn 124 and second yarn 130. For example, a first nozzle 204 at a first location entangles filaments 107 to produce first yarn 124, and a second nozzle 232 at a second location entangles filaments 107 to produce second yarn 130. The first and second locations are positioned a distance from each other to facilitate the production of distinct yarns from the respective groups of filaments.

[00110] In some embodiments, first and second yarns 124 and 130 may be routed from entanglement nozzles 108 towards a driven godet roll 208 for optional further processing of the yarns. For example, godet roll 208 is rotatable at a controlled speeds to stretch first and/or second yarns 124 and 130 wound thereabout. In some embodiments when acetone is utilized as the solvent, godet roll 208 is rotatable to stretch first and/or second yarns 124 and 130 to a draw ratio of less than 2 to 0.8, 1.7 to 0.8, 1.5 to 0.8, 1.3 to 0.8, 1.2 to 0.8, 1 to 0.8, 2 to 1, 1.7 to 1, 1.5 to 1, 1.3 to 1, 1.2 to 1, 1.1 to 1 and 1.1 to 1. Draw ratio is defined as the ratio of the yarn speed at the godet roll to the extrusion velocity of solids at the spinneret orifice.

[00111] The individually-entangled yarns 124 and 130 are then routed from godet roll 208 towards yarn guides 110 and winders 112 as described

above to produce cellulosic yarn packages, such as those illustrated in FIGS. 3, 4, and 8. Although yarns 124 and 130 are illustrated as being combined on godet roll 208, it should be understood that separation between yarns 124 and 130 is maintained prior to and/or during winding around the at least one core.

5 **[00112]** Referring now to FIG. 12, yarn production system 100 includes two multi-cluster spinnerets 210 within common cabinet 104. Spinnerets 210 spin dope mixture 184 to form filaments 103 therefrom. Specifically, each spinneret 210 forms two distinct groups of filaments, such that a first group 212 and a second group 214 of filaments are formed by one spinneret 210, and a
10 third group 216 and a fourth group 218 of filaments are formed by the other spinneret 210.

[00113] Each group 212, 214, 216, and 218 passed through common cabinet 104 may then be routed towards finish applicator 106 to apply a finish to filaments 103. In some embodiments, yarn production system 100 includes
15 a first finish applicator 220, a second finish applicator 222, a third finish applicator 224, and a fourth finish applicator 226 each positioned at separate locations outside cabinet 104. For example, first finish applicator 220 applies a finish to first group 212 of filaments at a first location, second finish applicator 222 applies a finish to second group 214 of filaments at a second location, third
20 finish applicator 224 applies a finish to third group 216 of filaments at a third location, and fourth finish applicator 226 applies a finish to fourth group 218 of filaments at a fourth location. Each respective location is positioned a distance from each of the other locations. Thus, this arrangement of finish applicators 106 facilitates the production of distinct yarns from the respective groups of
25 filaments.

[00114] Coated filaments 107 routed from finish applicators 220, 222, 224, and 226 may then be entangled by entanglement nozzles 108. In the example embodiment, filaments 107 are entangled by air jets discharged from nozzles 108 to produce, for example, first yarn 124, second yarn 130, third yarn
30 134, and fourth yarn 140. For example, a first nozzle 228 at a first location entangles first group 212 of filaments to produce first yarn 124, a second nozzle 230 at a second location entangles second group 214 of filaments to produce

second yarn 130, a third nozzle 232 at a third location entangles third group 216 of filaments to produce third yarn 134, and a fourth nozzle 234 at a fourth location entangles fourth group 218 of filaments to produce fourth yarn 140. Each respective location is positioned a distance from each of the other locations. Thus, this arrangement of nozzles 108 facilitates the production of distinct and individually-entangled yarns from the respective groups of filaments.

[00115] Yarns 124, 130, 134, and 140 may then be routed towards godet roll 208 for optional further processing of the yarns, as described above. The individually-entangled yarns 124, 130, 134, and 140 may then be routed towards yarn guides 110 and winders 112 as described above to produce cellulosic yarn packages, such as those illustrated in FIGS. 6 and 10.

[00116] Referring now to FIG. 13, yarn production system 100 includes two single-cluster spinnerets 186 within common cabinet 104. Yarn production system 100 also includes a first dope mixer 236 and a second dope mixer 238. Both dope mixers 236 and 238 receive solvent 180 from solvent recovery system 178, for example. In addition, first dope mixer 236 receives first solids 240 to form a first dope mixture 242, and second dope mixer 238 receives second solids 244 to form a second dope mixture 246. First and second solids 240 and 244 may both include cellulose acetate flake as described above. However, first and second dope mixtures 242 and 246 may be different from one another in terms of composition based on any of the variables disclosed herein. Accordingly, one spinneret 186 may spin first dope mixture 242 to produce first yarn 124, and the other spinneret 186 may spin second dope mixture 246 to produce second yarn 130 made of a different material than first yarn 124.

[00117] The individually-entangled yarns 124 and 130 may then be routed towards yarn guides 110 and winders 112 as described above to produce cellulosic yarn packages, such as those illustrated in FIGS. 3, 4, and 8, having yarn sections of different material wound thereon.

[00118] In some embodiments the godet roll 208 may be a single driven roll as shown in Figure 11-13 or it may be multiple driven rolls, with the yarn

threaded around the rolls in various patterns. Or in another embodiment, no godet roll may be used with the yarns routed directly to the winder. Those skilled in the art will know several methods of receiving the yarns from the spinning cabinet and controlling the spinning tensions, the draft ratios, and the tension at winding.

[00119] In some embodiments, the TF devices may be placed after the godet roll and before the winder or, alternatively, before the finish applicator but still outside of the cabinet. Those skilled in the art will know the advantages of various TF device placement, depending on the need to control yarn tension and fiber finish level to ensure adequate and consistent entanglement.

[00120] Additional advantages of the various embodiments will be apparent to those skilled in the art upon review of the disclosure herein. It will be appreciated that the various embodiments described herein are not necessarily mutually exclusive unless otherwise indicated herein. For example, a feature described or depicted in one embodiment may also be included in other embodiments but is not necessarily included. Thus, the present disclosure encompasses a variety of combinations and/or integrations of the specific embodiments described herein.

DEFINITIONS

[00121] As used herein, the terms “comprising,” “comprises,” and “comprise” are open-ended transition terms used to transition from a subject recited before the term to one or more elements recited after the term, where the element or elements listed after the transition term are not necessarily the only elements that make up the subject.

[00122] As used herein, the terms “including,” “includes,” and “include” have the same open-ended meaning as “comprising,” “comprises,” and “comprise.”

[00123] As used herein, the terms “having,” “has,” and “have” have the same open-ended meaning as “comprising,” “comprises,” and “comprise.”

[00124] As used herein, the terms “containing,” “contains,” and “contain” have the same open-ended meaning as “comprising,” “comprises,” and “comprise.”

[00125] As used herein, the terms “a,” “an,” “the,” and “said” mean one or more.

[00126] As used herein, the term “and/or,” when used in a list of two or more items, means that any one of the listed items can be employed by itself or any combination of two or more of the listed items can be employed. For example, if a composition is described as containing components A, B, and/or C, the composition can contain A alone; B alone; C alone; A and B in combination; A and C in combination; B and C in combination; or A, B, and C in combination.

[00127] The preferred forms of the invention described above are to be used as illustration only, and should not be used in a limiting sense to interpret the scope of the present invention. Obvious modifications to the exemplary embodiments, set forth above, could be readily made by those skilled in the art without departing from the spirit of the present invention.

[00128] The inventors hereby state their intent to rely on the Equivalents to determine and assess the reasonably fair scope of the present invention as pertains to any apparatus not materially departing from but outside the literal scope of the invention as set forth in the following claims.

NUMERICAL RANGES

[00129] The present description uses numerical ranges to quantify certain parameters relating to the invention. It should be understood that when numerical ranges are provided, such ranges are to be construed as providing literal support for claim limitations that only recite the lower value of the range as well as claim limitations that only recite the upper value of the range. For example, a disclosed numerical range of 10 to 100 provides literal support for a claim reciting “greater than 10” (with no upper bounds) and a claim reciting “less than 100” (with no lower bounds).

[00130] Additionally, it should be understood that a listing of numerical values following a descriptor, such as “at least” and “not more than,” provides literal support for a range based on all of the numerical values following that descriptor. For example, a statement specifying “at least 2, 5, or 10 and/or not more than 100, 50, or 25” would provide literal support for ranges of “at least 25,” “not more than 50,” and “at least 10 and not more than 25.”

EXAMPLES

[00131] In the conventional process of extruding filaments and making yarn packages, each group of yarn is extruded from one spinneret, passes through the cabinet, then is threaded through a set of auxiliary devices before being wound onto separate cores to form a package on the winder. To increase yarn production capacity, multiple groups of openings? can be incorporated into one spinneret, enabling the extrusion of multiple groups of filaments or yarns from a single spinneret. Without increasing the number of existing winders, multiple yarn groups can be wound onto one core using different methods. Example One to Four describe the production processes, respectively, of making conventional packages, conventional packages with increased capacity, combined packages with increased capacity, and sectional packages with increased capacity, using two spinnerets in one cabinet as the basic unit.

Example One

[00132] A first yarn was produced from the 1st spinneret in one cabinet, and a second yarn was produced from the 2nd spinneret in the same cabinet. The two yarns were kept separate in the cabinet through two yarn guides at the exit. After exiting the cabinet, two yarns were individually lubricated before taken up by a shared godet roll. Then each yarn was entangled before being wound onto separate cores on a common winder spool. The throughput of this conventional set up establishes the baseline capacity.

Example Two

[00133] A first and a second yarn were produced from the 1st spinneret in one cabinet, and a third and fourth yarn were produced from the 2nd spinneret in the same cabinet. The four yarns were kept separate in the cabinet through four yarn guides at the exit. After exiting the cabinet, the yarns were individually lubricated before taken up by a shared godet roll. Then each yarn was entangled before wounding onto cores. The first and second yarns were wound separately onto two cores on a common spool on the first winder. Similarly, the third and fourth yarns were wound by using a second winder. Compared to the conventional process, this example doubled the throughput of one cabinet while maintaining the same output per winder.

Example Three

[00134] A first and a second yarn were produced from the 1st spinneret in one cabinet, and a third and fourth yarn were produced from the 2nd spinneret in the same cabinet. The four groups of yarns were kept separate in the cabinet through four yarn guides at the exit. After exiting the cabinet, the yarns were individually lubricated before taken up by a shared godet roll. Then each yarn was entangled before winding. The first and second yarns were then combined and threaded through a first yarn guide, co-wound on the same section of the first core on a winder spool. Similarly, the third and fourth yarns were co-wound on the same section of the second core on the same winder spool using a second yarn guide. Compared to the conventional process, this example doubled the throughput for both the cabinet and the winder.

Example Four

[00135] A first and a second yarn were produced from the 1st spinneret in one cabinet, and a third and fourth yarn were produced from the 2nd spinneret in the same cabinet. The four groups of yarns were kept separate in the cabinet through four yarn guides at the exit. After exiting the cabinet, the yarns were individually lubricated before taken up by a shared godet roll. Then each yarn was entangled before winding. The first yarn was wound on the first section

of the first core on a winder spool, and the second yarn was co-wound on the second section of the same core. The third and fourth yarns were co-wound in the same manner on two sections of the second core on the same winder spool. Compared to the conventional process, this example doubled the throughput for both the cabinet and the winder.

[00136] Table 1 summarizes the production setups, throughputs, and yarn package parameters of Example One to Four. All the examples were based on the same production conditions including the dope solids, dope temperature, draw ratio, and spinning speed in the ranges described in this disclosure. The yarn specifications were 75 denier/19 filaments, 2.0% FOY, 1.3 gpd tenacity, 21% elongation, and 11 entanglement nodes per foot. The package dimensions were measured using a ruler, and the package weight was obtained by weighing the package on a calibrated scale and subtracting the core weight. The helix angle was calculated from the known the winder speeds in the traverse and spool rotating directions. Examples 2-4 doubled the throughput compared to Example One due to the increase in the number of groups resulting from the change from conventional spinnerets to spinnerets with multiple hole groupings. Example 3 and Example 4 doubled the number of yarns per winder compared to Example One and Two by winding multiple yarns per core. In Example 4, due to the sectional structure of the package, there is a small gap between sections defined as the section-to-section distance. As a result, the package weight in Example 4 is lower, and the helix angle is set higher to ensure package stability.

TABLE 1

Comparison of Cellulose Acetate Yarn Production Setups, Throughputs, and Yarn Package Parameters					
Settings (One Cabinet)	Example	Example One	Example Two	Example Three	Example Four
		Conventional Package	Conventional Package with Increased Capacity	Combined Package with Increased Capacity	Sectional Package with Increased Capacity
Number of Spinnerets		2	2	2	2
Number Clusters/ of Spinneret		1	2	2	2
Number of Yarn Groups		2	4	4	4
Number of Lube Applicators		2	4	4	4
Number of TF Applicators		2	4	4	4
Number of Tension Guides		2	4	4	4
Number of Winders		1	2	1	1
Number of Cores/Winder		2	2	2	2
Number of Sections/Core		1	1	1	2
Number of Yarns/Section		1	1	2	1
Number of Yarns/Winder		2	2	4	4
Throughput (kg/hr)		0.74	1.47	1.47	1.47
Core Length (cm)		17.4	17.4	17.4	17.4
Section Length (cm)		14.6	14.6	14.6	6.7
Section to Section Distance (mm)		--	--	--	1.6
Helix Angle (°)		9.0	9.0	9.0	9.2
Package Weight (not including core) (kg)		5.3	5.3	5.3	4.6

What is claimed is:

1. A method of producing cellulosic yarn packages, the method comprising:

5 passing at least a first and a second group of filaments through a common cabinet;

 entangling the first group of filaments at a first location to form a first yarn;

10 entangling the second group of filaments at a second location to form a second yarn;

 routing the first and second yarns towards at least one common spool; and

 winding the first and second yarns around at least one core on the common spool; wherein at least two yarns are wound on one core.

15 2. The method in accordance with Claim 1 further comprising:

 passing at least the first, the second, a third, and a fourth group of filaments through the common cabinet;

 entangling the third group of filaments at a third location to form a third yarn; and

20 entangling the fourth group of filaments at a fourth location to form a fourth yarn.

3. The method in accordance with Claim 1 further comprising spinning at least one dope mixture from at least one multi-cluster spinnerets to form the first and second group of filaments.

25

4. The method in accordance with Claim 2 further comprising spinning at least one dope mixture from at least one multi-cluster spinnerets to form the first, second, third, and fourth group of filaments.

5 5. The method in accordance with Claim 1 further comprising channeling air through the common cabinet to remove solvent from the first and second groups of filaments.

6. The method in accordance with Claim 5 further comprising:
discharging an air-solvent stream from the common cabinet;
recovering solvent from the air-solvent stream; and
10 recycling the recovered solvent to form additional filaments.

7. The method in accordance with Claim 1 further comprising passing at least the first and second groups of filaments through the common cabinet for a residence time of between about 0.1 and 2.0 seconds.

8. A method of producing cellulosic yarn packages, the method comprising:
15 entangling a first group of filaments at a first location to form a first yarn;
entangling a second group of filaments at a second location to form a second yarn;

routing the first and second yarns towards a common spool; and
winding the first and second yarns around at least one core on the
20 common spool,

wherein no more than four yarns are wound on the at least one core; and

wherein at least two yarns are wound on one core.

9. A method of producing cellulosic yarn packages, the method comprising:
25 entangling a first group of filaments at a first location to form a first yarn having a denier of less than 300;

entangling a second group of filaments at a second location to form a second yarn having a denier of less than 300;

routing the first and second yarns towards a common spool; and

winding the first and second yarns around at least one core on the common spool wherein at least two yarns are wound on one core.

10. The method in accordance with Claim 1 further comprising winding at least the first and second yarns around different cores on the common spool.

11. The method in accordance with Claim 1 further comprising winding at least the first and second yarns helically around the at least one core.

12. The method in accordance with Claim 1, wherein the routing further comprises maintaining separation between the first and second yarns prior to or during winding around the at least one core.

13. The method in accordance with Claim 1 further comprising winding at least the first and second yarns around separate sections of the common core.

14. The method in accordance with Claim 1, wherein the winding further comprises forming a first yarn section from the first yarn, and a second yarn section from the second yarn, on the common core, wherein the first and second yarn sections are spaced from one another on the common core.

15. The method in accordance with Claim 1, wherein the winding further comprises forming a first yarn section from the first yarn, and a second yarn section from the second yarn, on the common core, wherein the first and second yarn sections are adjacent to and in substantial contact with one another on the common core.

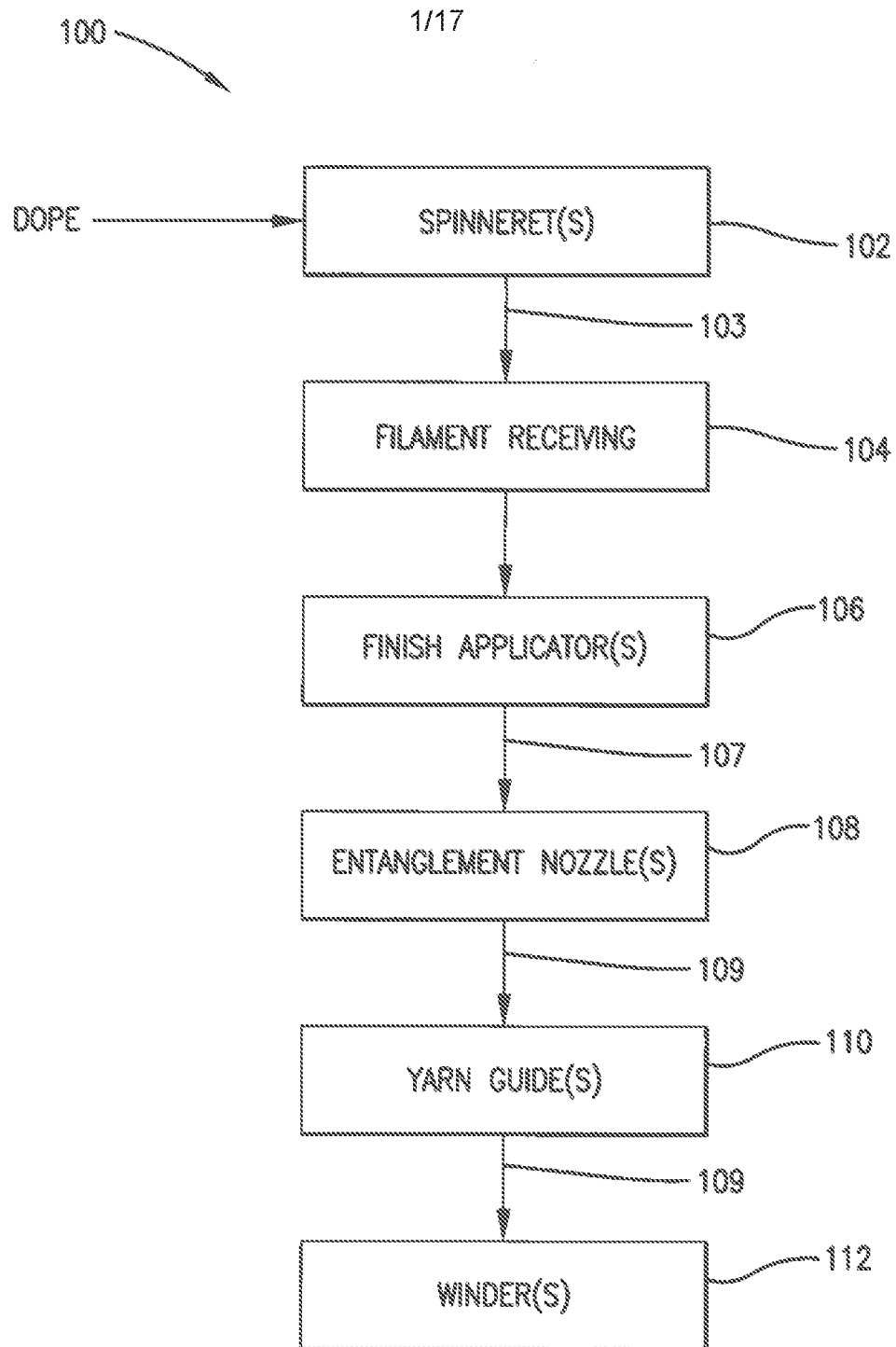
16. The method in accordance with Claim 1 further comprising winding at least the combined first and second yarns around one common section of the at least one core.
17. The method in accordance with Claim 1 further comprising applying a finish to the first and second groups of filaments at separate locations.
18. The method in accordance with Claim 17 further comprising applying the finish before the filaments are entangled.
19. The method in accordance with Claim 1 further comprising entangling the first and second groups of filaments with air jets.
20. The method in accordance with Claim 1 further comprising forming the first and second groups of filaments via dry spinning or wet spinning.
21. The method in accordance with Claim 1 further comprising spinning a dope mixture to form the first and second groups of filaments.
22. The method in accordance with Claim 21 further comprising spinning the dope mixture at a rate of between about 200 and 2000 meters per minute.
23. The method in accordance with Claim 21 further comprising maintaining the dope temperature at the spinneret outlet of between about 30 °C and about 120 °C during the spinning.
24. The method in accordance with Claim 21, wherein the dope mixture comprises dissolved solids and a solvent.
25. The method in accordance with Claim 21, wherein the dope mixture has between about 15 and 40 percent dissolved solids, and between about 60 and 85 percent solvent, by weight of the dope mixture.
26. The method in accordance with Claim 25 wherein the dissolved solids comprise a material selected from the group consisting of cellulose material, acetylated cellulose material, cellulose acetate material,

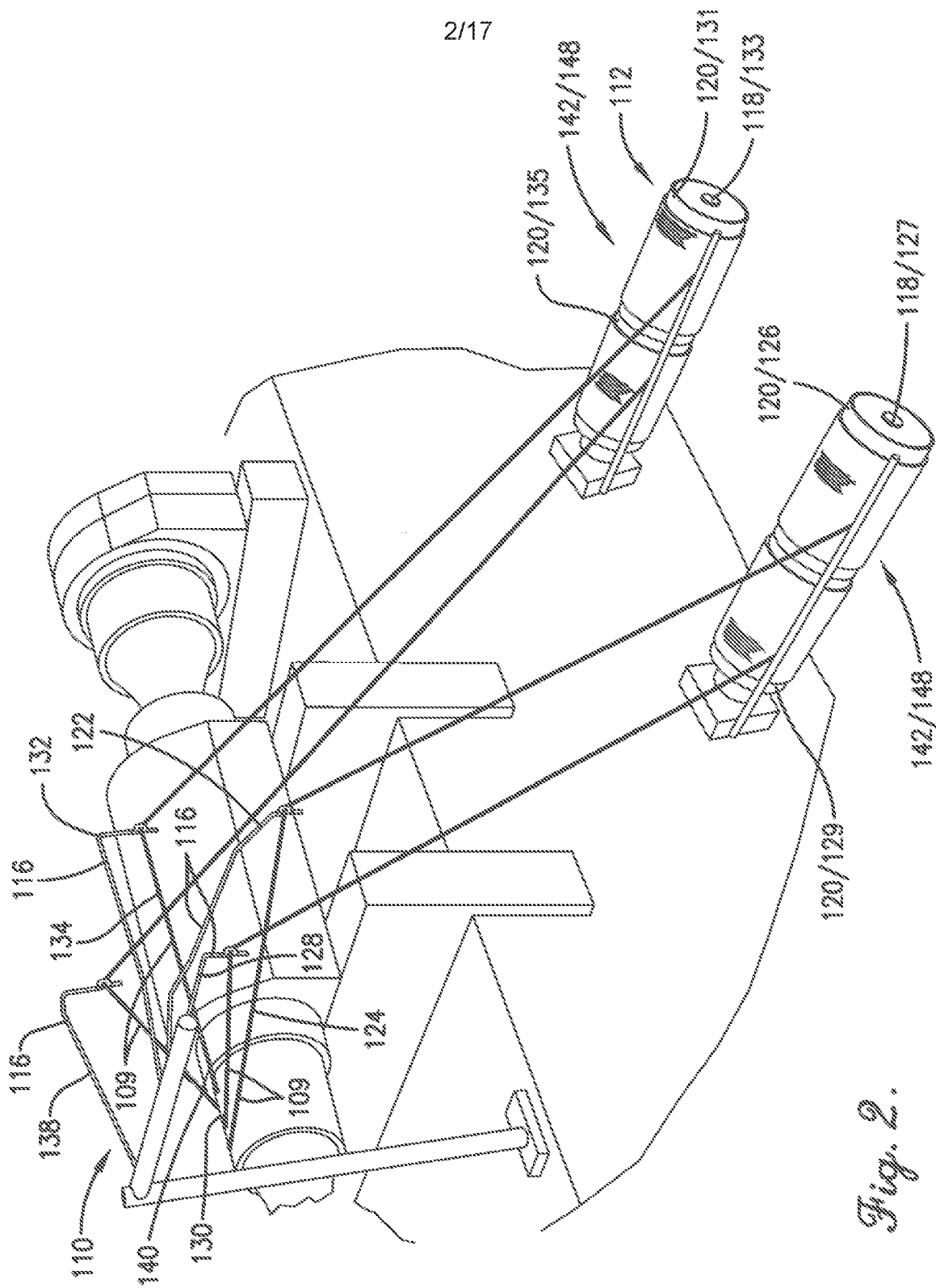
cellulose diacetate material, recycle content material, biodegradable material, and combinations thereof.

27. The method in accordance with Claim 25, wherein the solvent is selected from the group consisting of acetone, methylene chloride, dimethylformamide (DMF), dimethylacetamide (DMAC), dimethyl sulfoxide (DMSO), and combinations thereof.

28. The method in accordance with Claim 1 further comprising spinning a first dope mixture to form the first group of filaments, and spinning a second dope mixture to form the second group of filaments.

29. The method in accordance with Claim 1 further comprising stretching the first and second yarns to a draw ratio of less than about 2 to 0.8.

*Fig. 1.*



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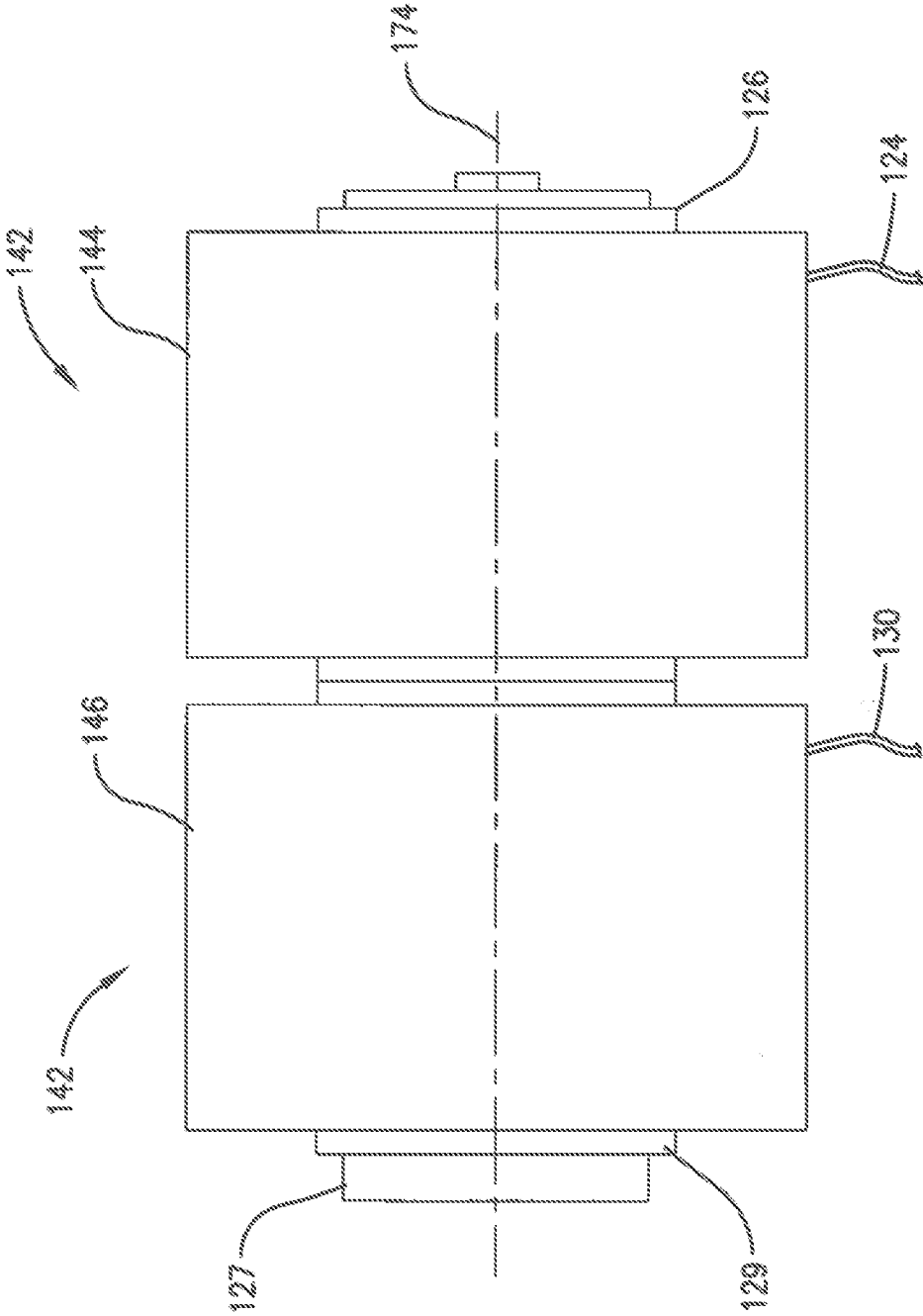


Fig. 3.

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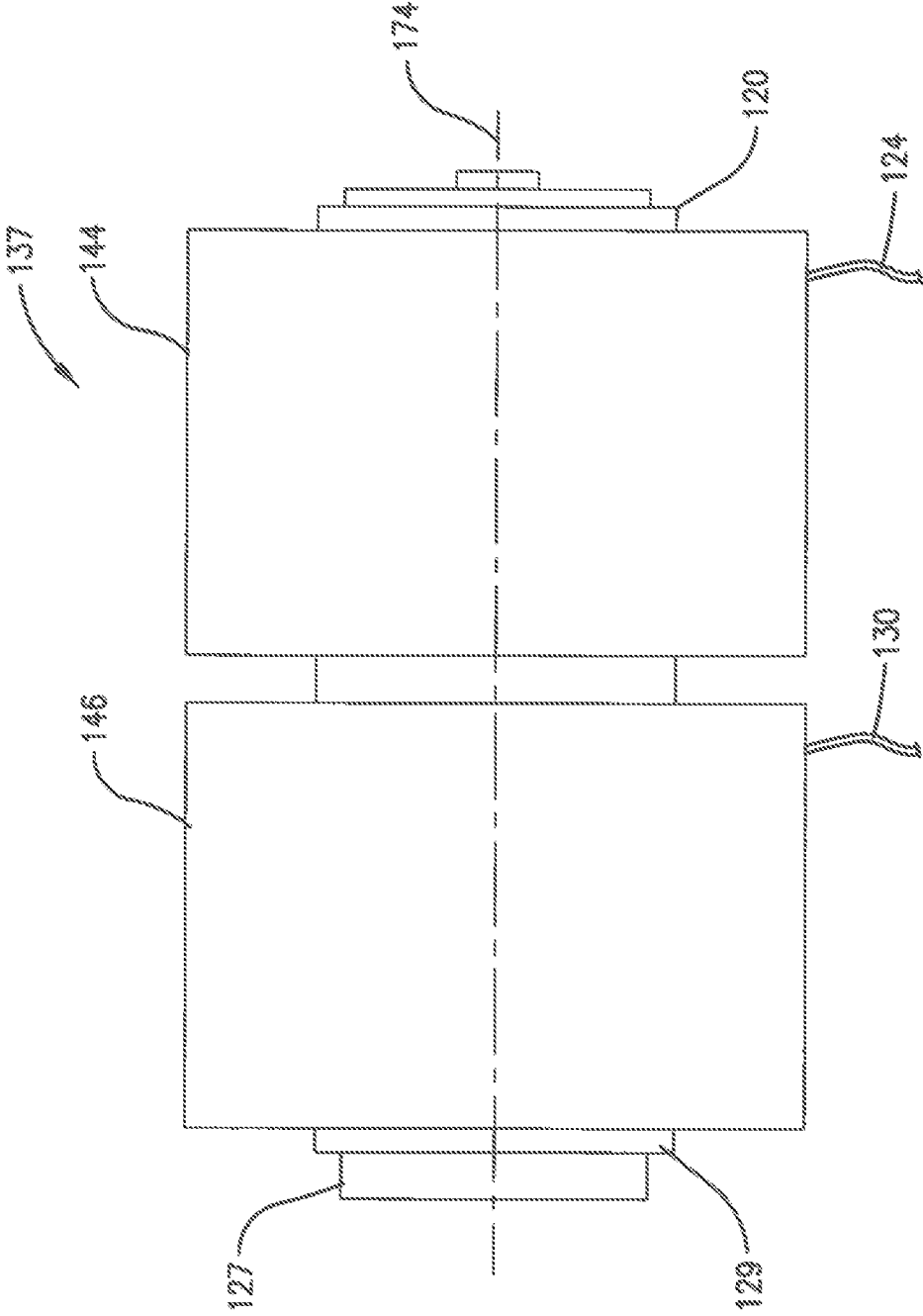


Fig. 3A.

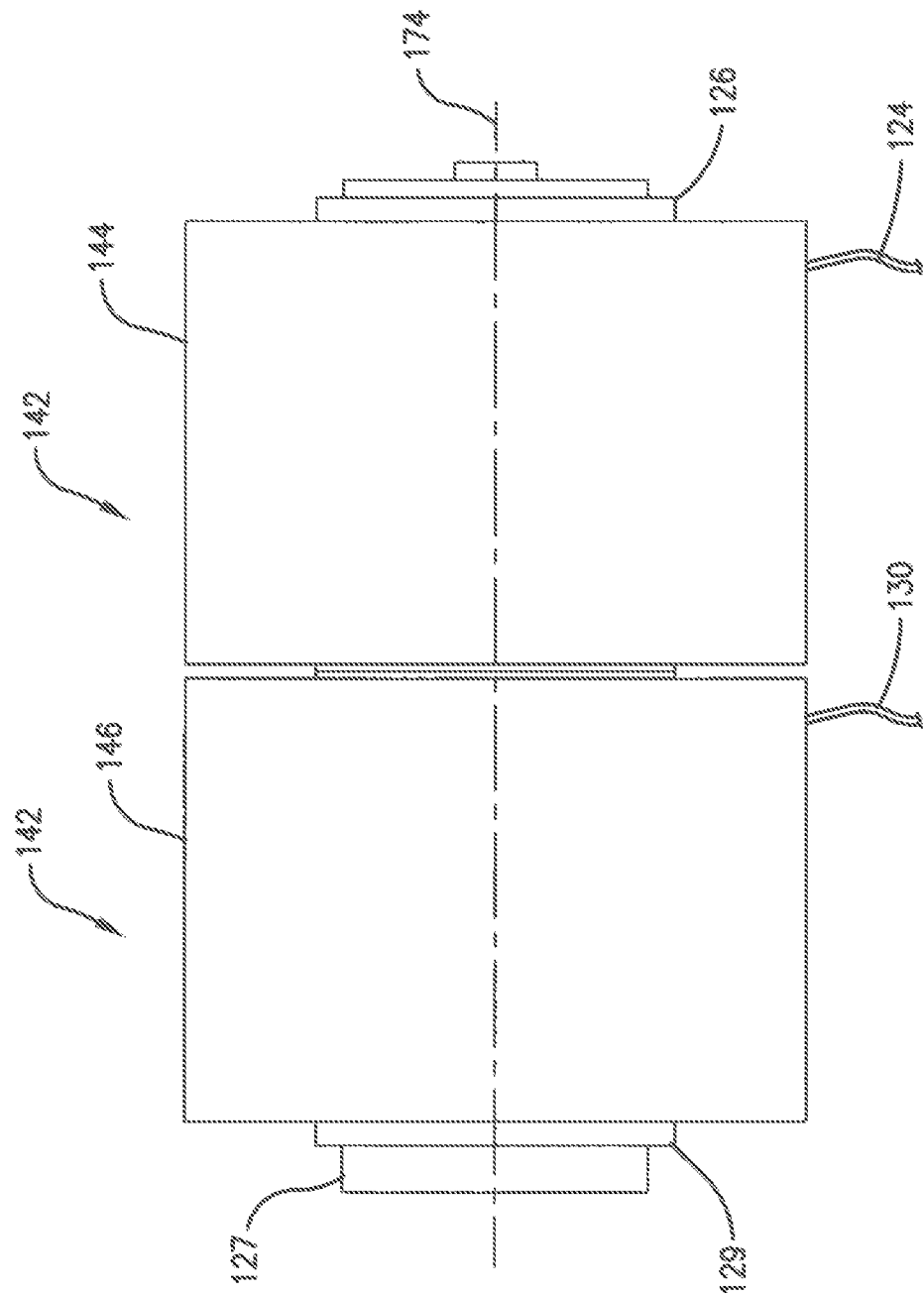


Fig. 4.

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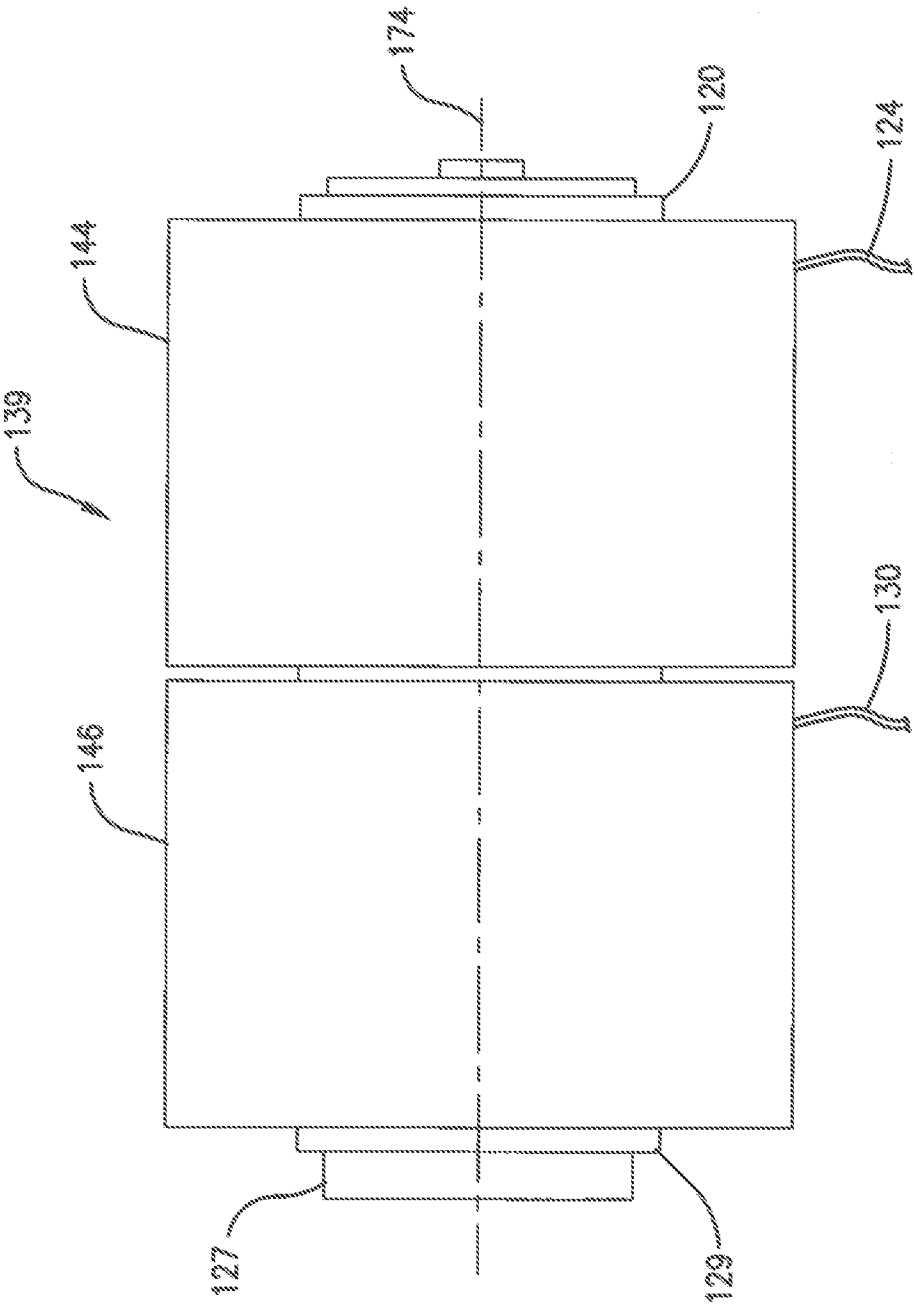


Fig. 4A.

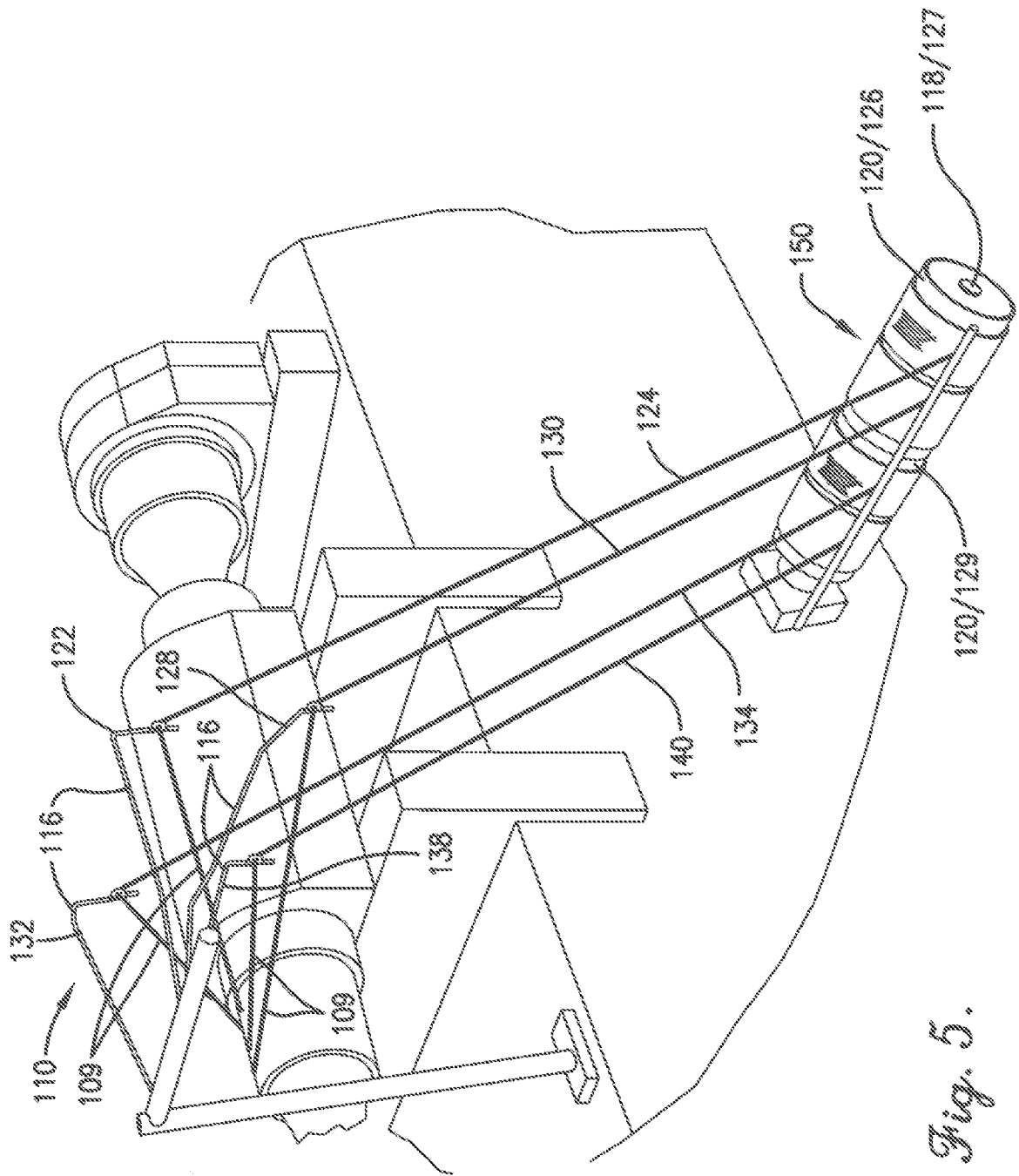


Fig. 5.

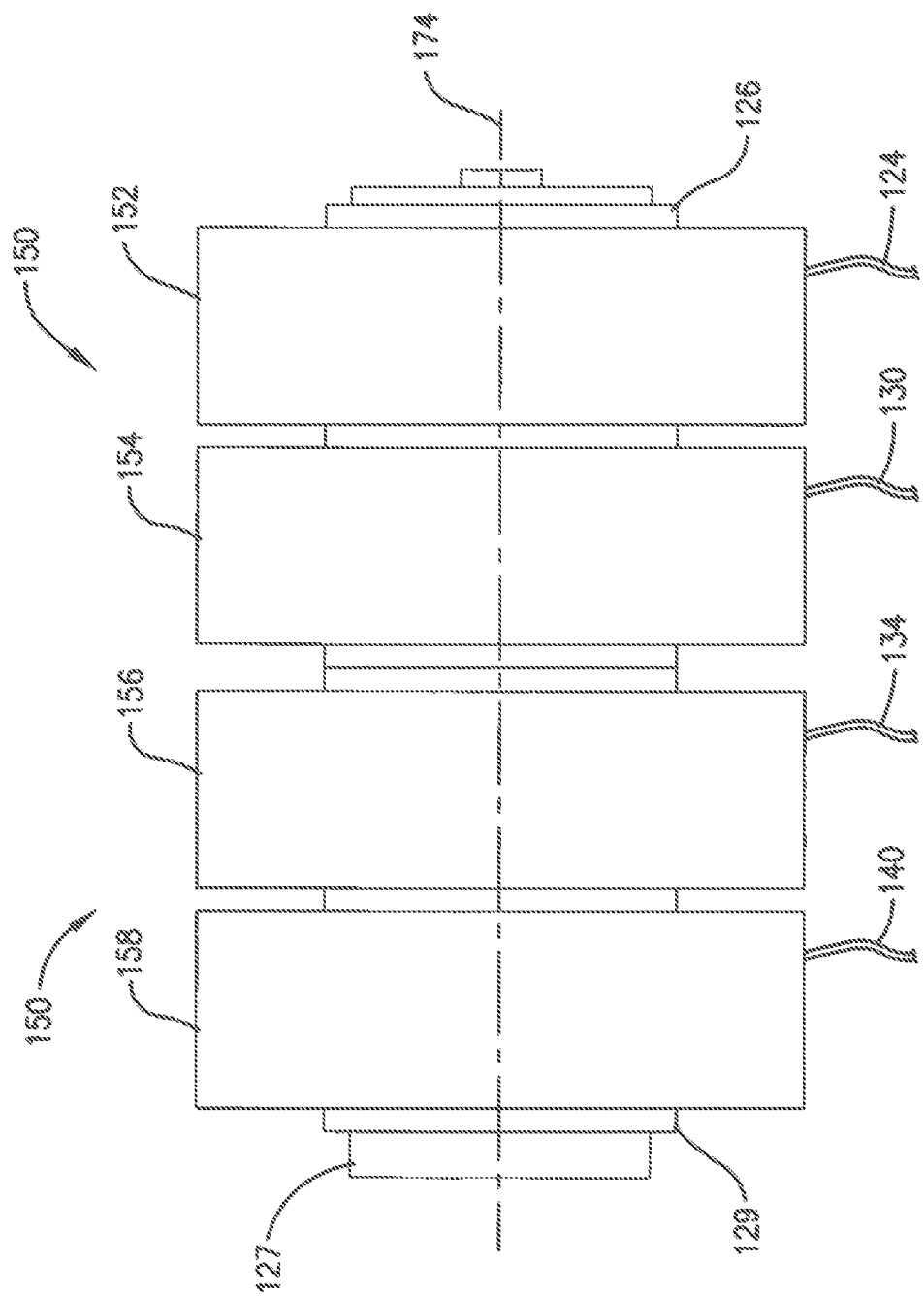


Fig. 6.

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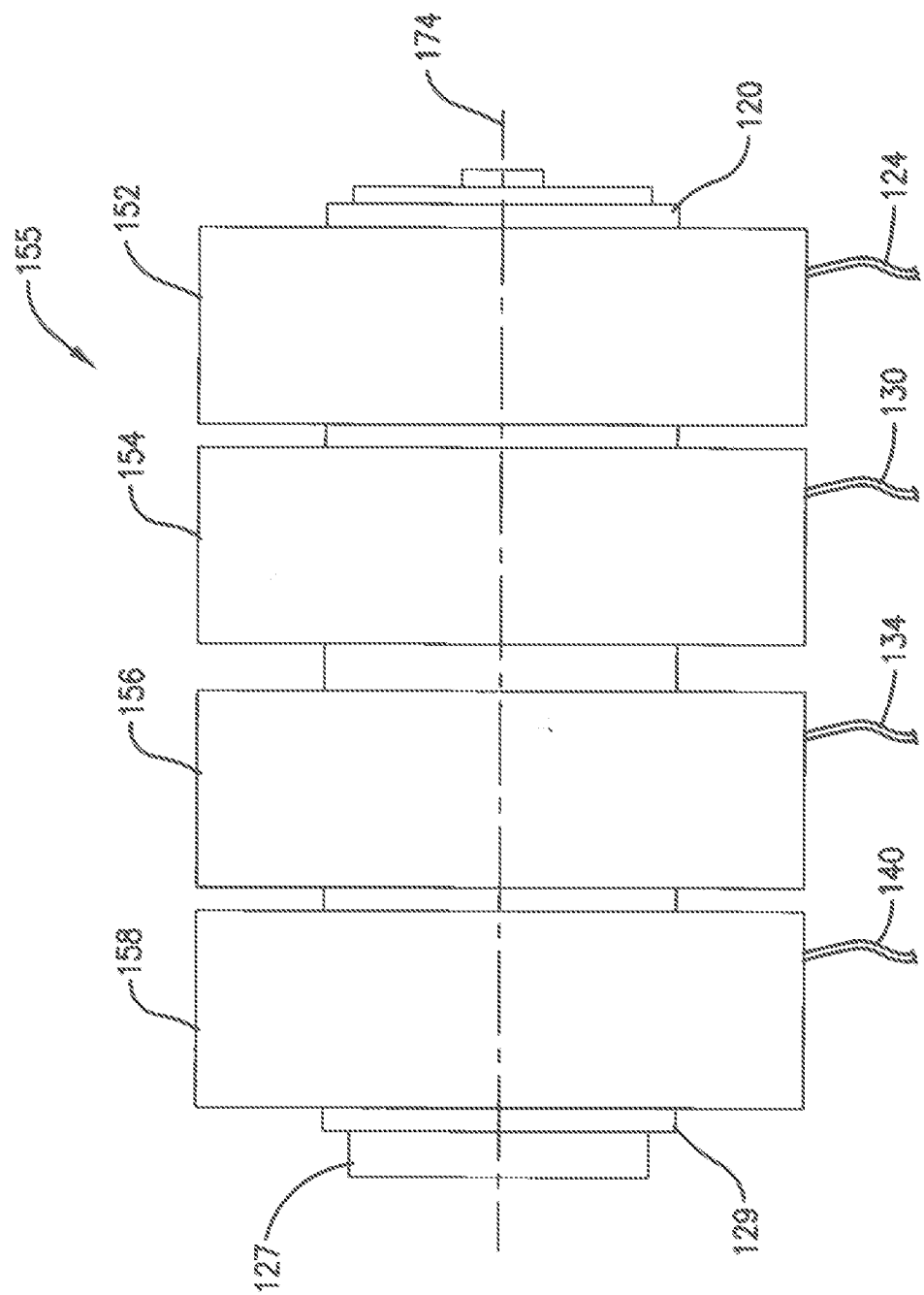


Fig. 6A.

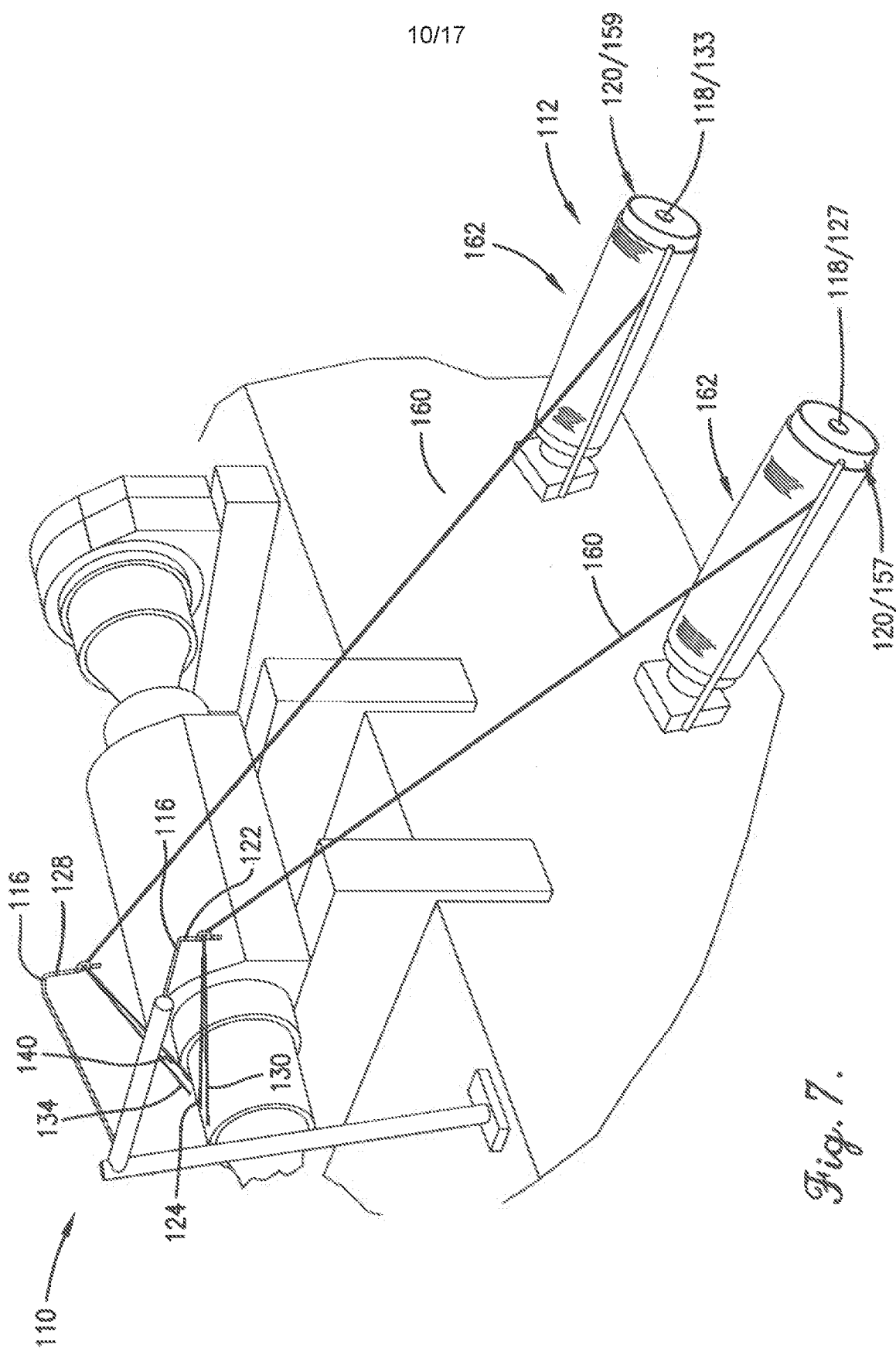


Fig. 7.

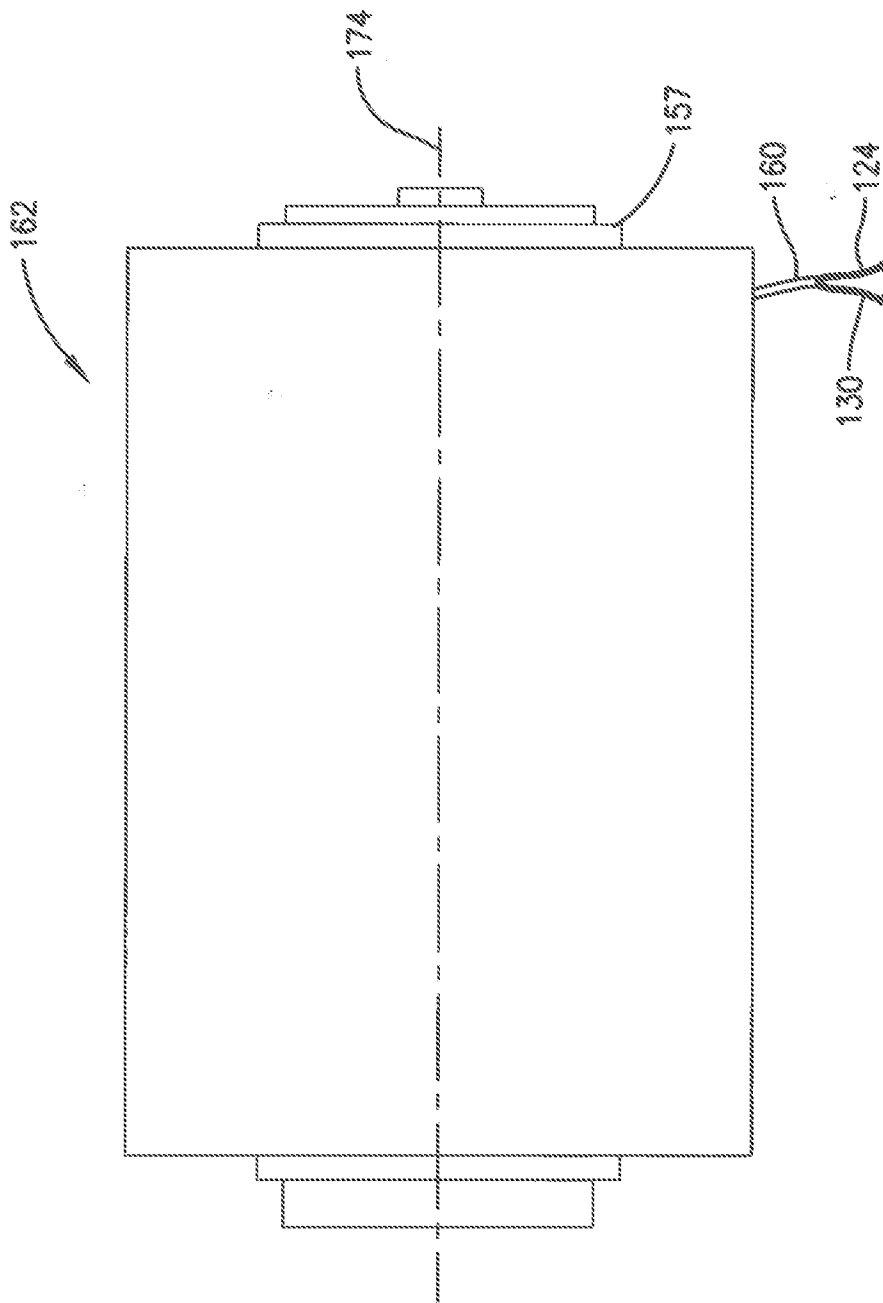


Fig. 8.

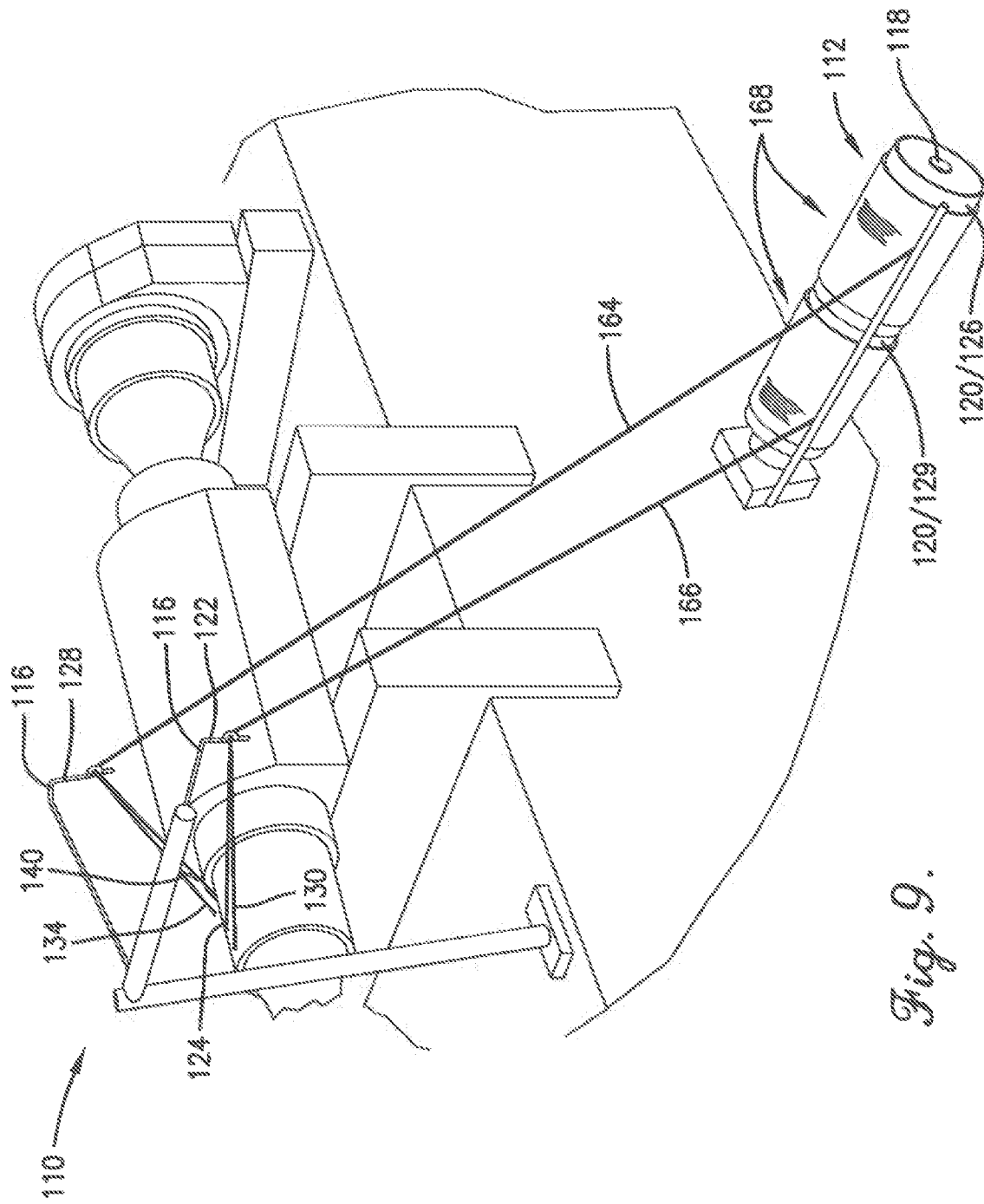


Fig. 9.

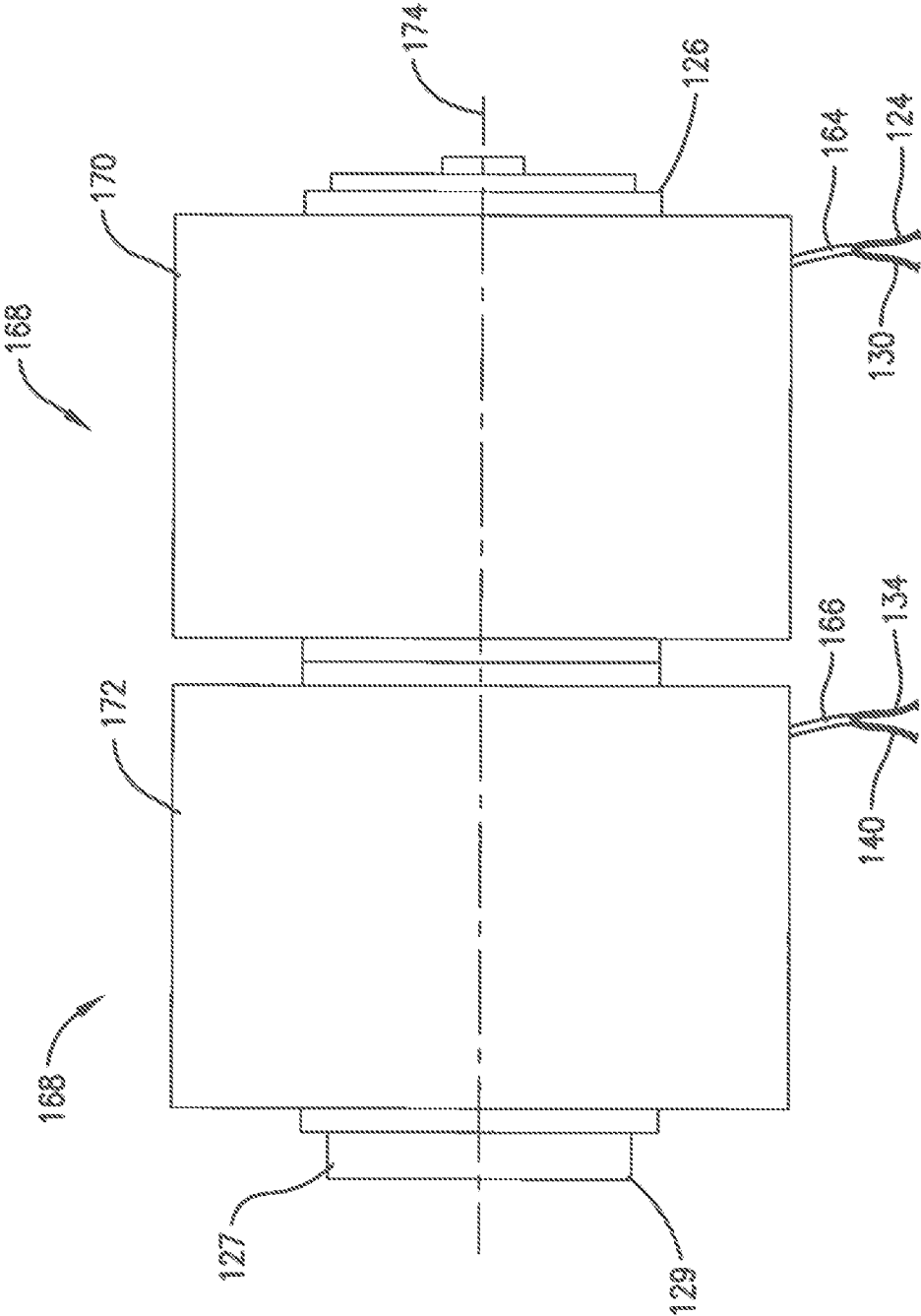


Fig. 10.

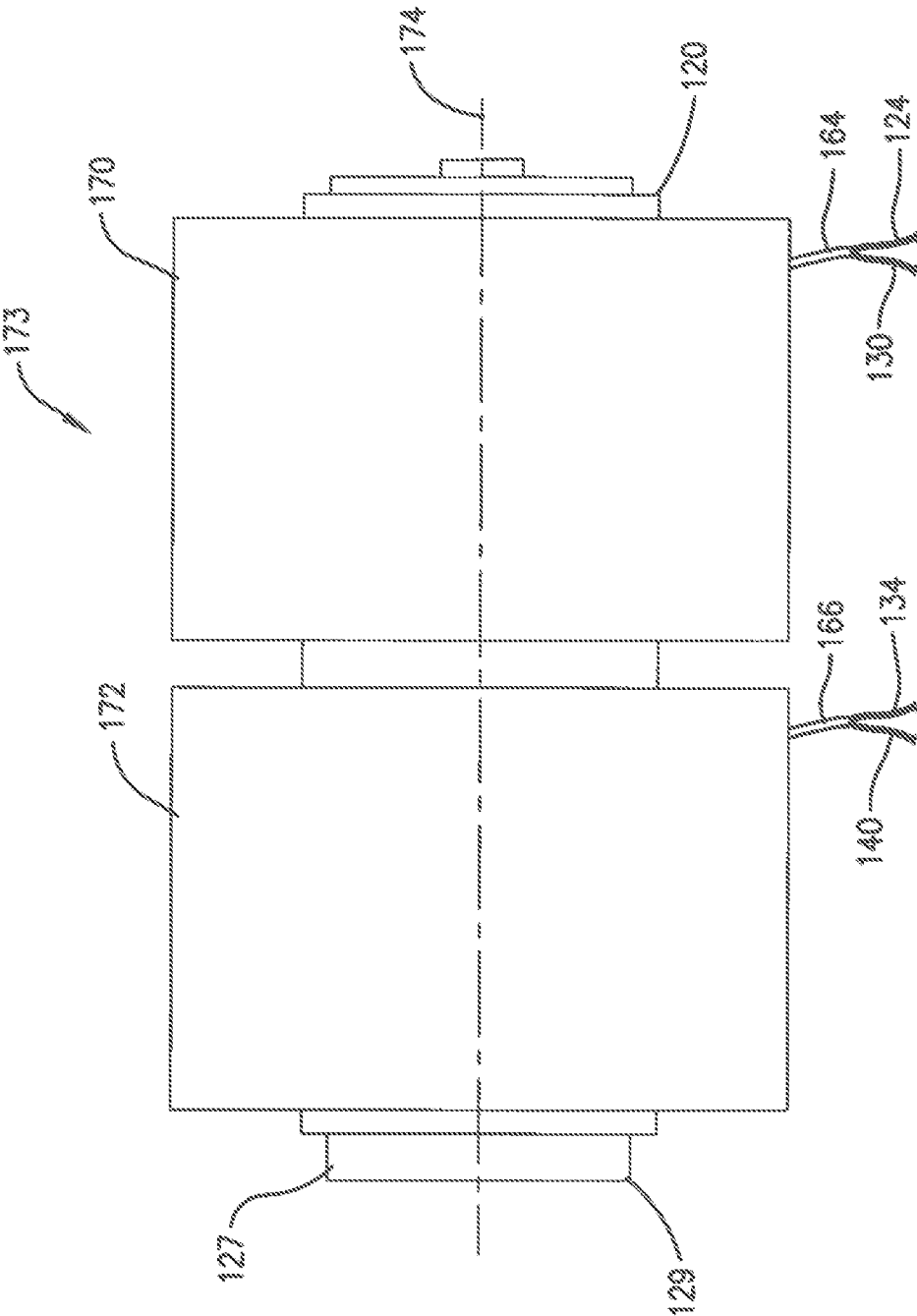
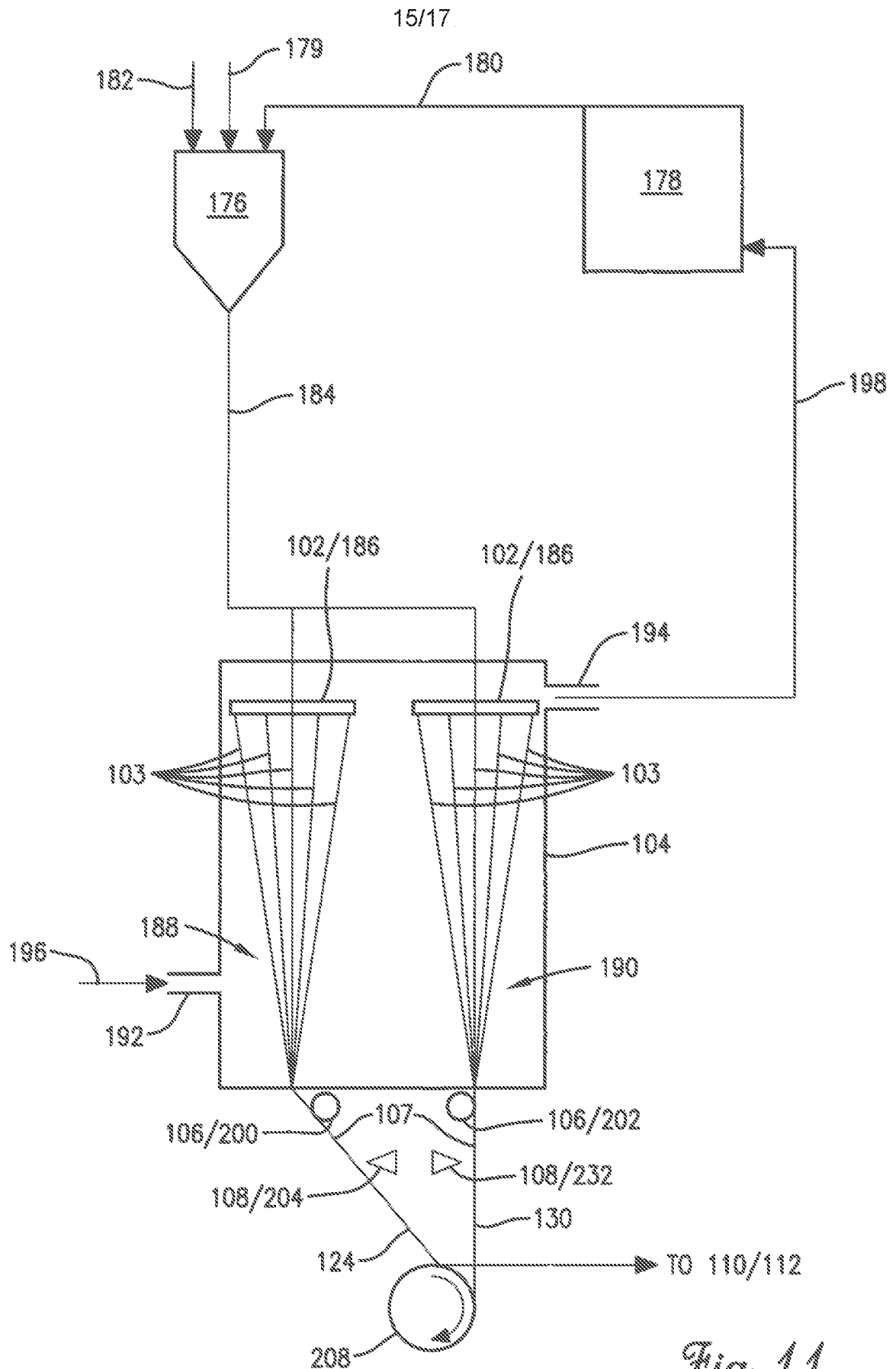


Fig. 10A.



Sp. 11.

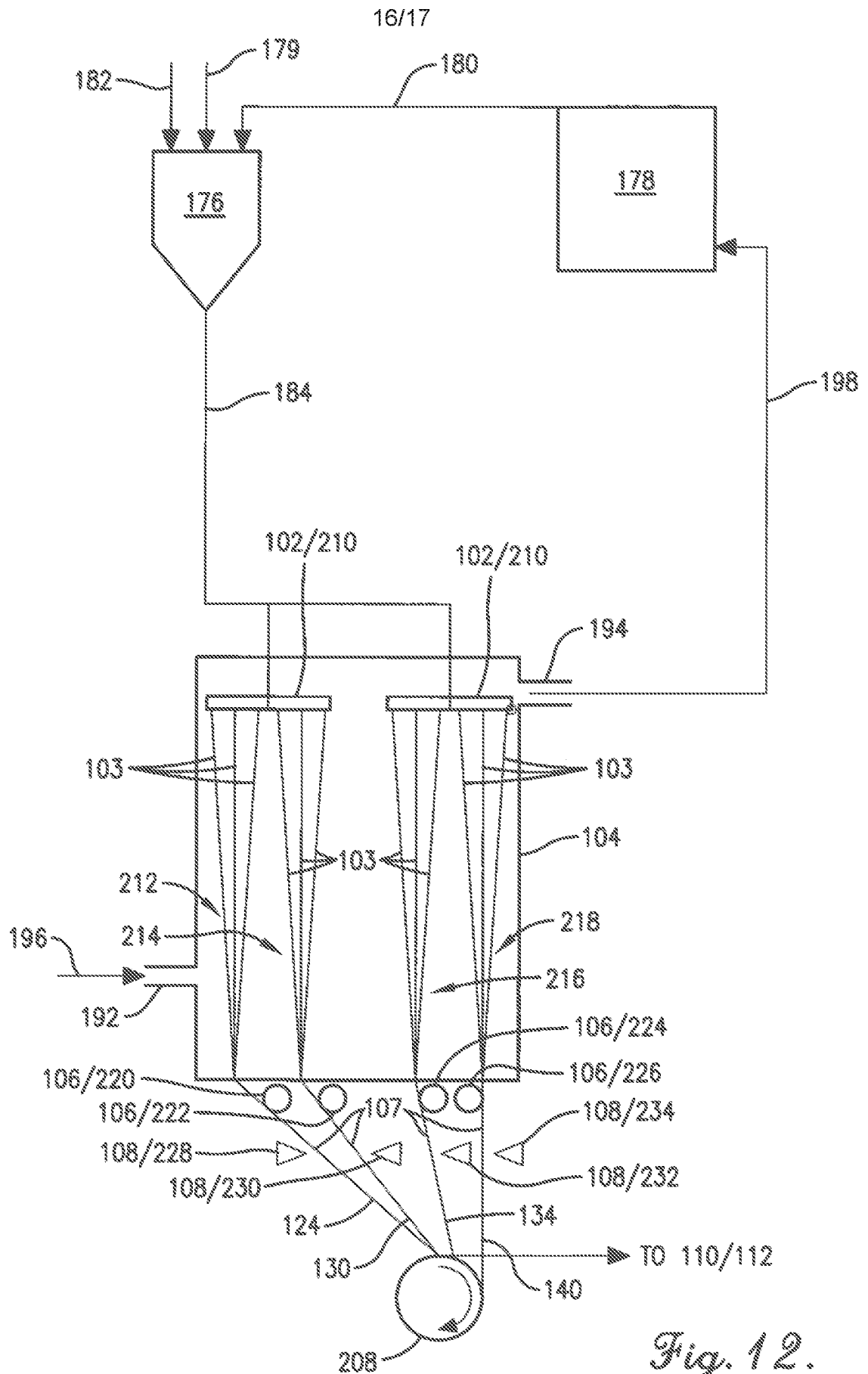


Fig. 12.

