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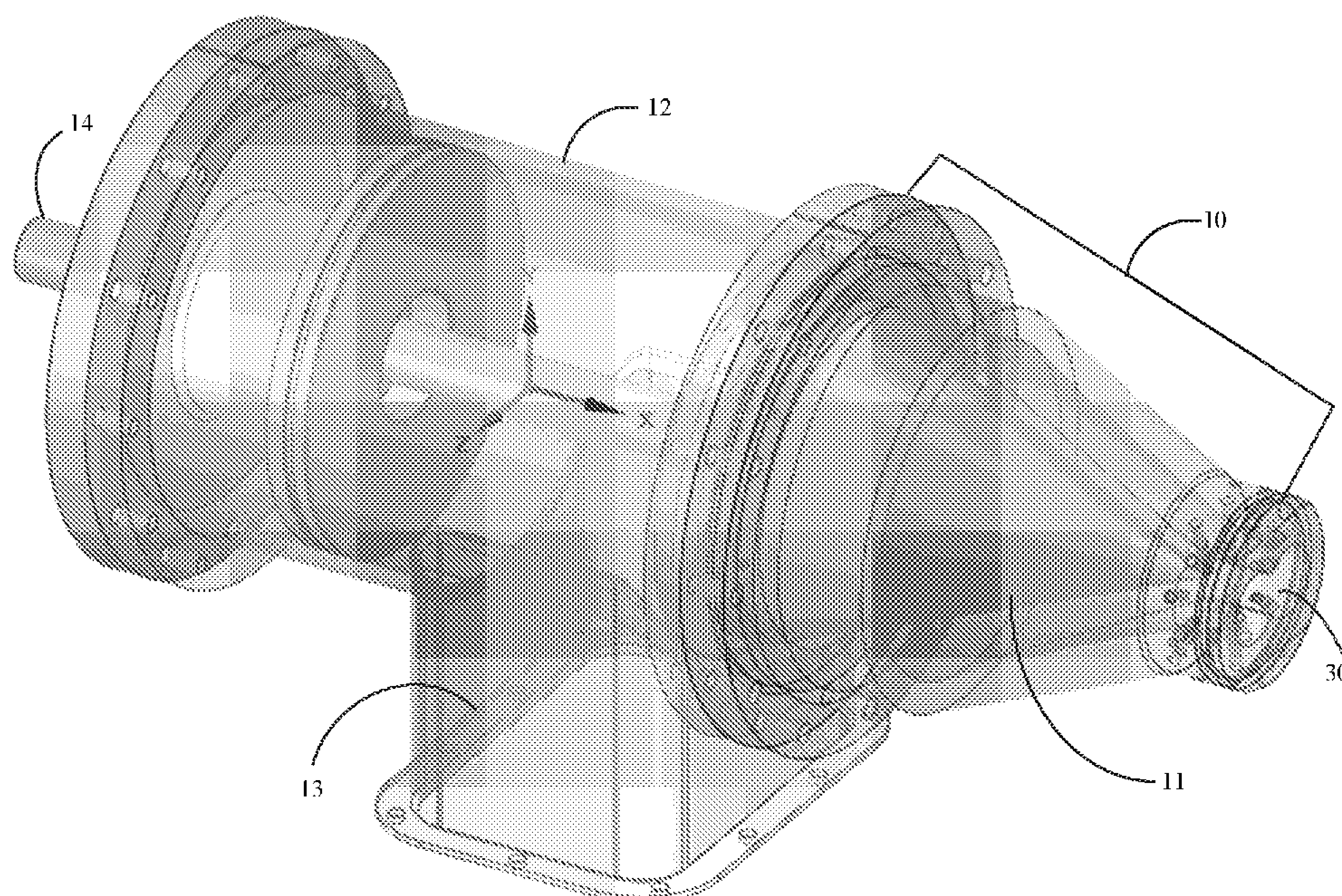
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FIG. 1



(57) Abstract: A valve assembly wherein the inner wall of the valve body comprises at least one opening for the entry of a liquid under pressure following output of a slurry or liquid from a tube or pipe. The valve assembly is particularly useful in maintaining a semi-continuous or continuous pressurized flow of biomass from an extruder and extending the reaction zone downstream from the extruder. An advantage of having an extended reaction zone allows for a complete treatment of materials without further wear on the extruder and also allows manipulation of the upstream treatment of materials in the tube or pipe.

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## **PRESSURE VALVE PROCESSING**

### **CROSS-REFERENCE**

[0001] This application claims the benefit of U.S. Provisional Application No. 63/087,077, filed on October 2, 2020, U.S. Provisional Application No. 63/146,608, filed on February 6, 2021, and U.S. Provisional Application No. 63/153,740, filed on February 25, 2021, each of which is incorporated herein by reference in its entirety.

### **BACKGROUND**

[0002] Valves are used to control the flow of materials in many industrial processes. The inside of a relief valve contains a plug that blocks or reduces the output of a source of material when the valve is pressurized. When the pressure behind the plug is released the plug is pushed back by the force of the pressure from this output. This allows the valve to be opened until the pressure behind the plug is equal or greater than the force of the output. If a valve is coupled to an actuator operating in response to the output, precise continuous movement is possible rather than with just a manual-operated or spring-operated valve.

[0003] When moving materials under pressure it can be difficult to control the pressure in the container through which they are transported. This is difficult for continuous or semi-continuous flow of a slurry of materials moving in one direction in critical operating states resulting from treatment of the media. In order to maintain a constant pressure and velocity of the moving material, a valve must be designed to operate to hold the pressure in the pipe or barrel at a constant while allowing for a certain velocity. This is especially true of particulate substances such as biomass moving in a liquid under high pressure where the valve is involved in further treatment and the flow of materials is rapid and surging. Such severe operating conditions can induce premature failure and leakage of the valve assembly, resulting in blowouts and extreme wear. Further, slurry particles can become trapped in the valve sealing cycle, resulting in performance degradation of the valve assembly. In general, pressure relief valves are not designed to handle such operations.

### **SUMMARY**

[0004] In one aspect, provided herein is a system for pretreating a biomass comprising: an extruder comprising one or more screws, wherein an internal plug of the biomass is formed due to action of the one or more screws, thereby forming an upstream end of a pressurized reaction zone for pretreatment of the biomass; and a valve assembly attached at an output

end of the extruder, wherein the valve assembly forms a downstream end of the reaction zone and adds a liquid to the reaction zone.

[0005] In another aspect, provided herein is a system for pretreating a biomass comprising: an extruder comprising one or more screws, wherein an internal plug of the biomass is formed due to action of the one or more screws, thereby forming an upstream end of a pressurized reaction zone for pretreatment of the biomass; and a valve assembly attached at an output end of the extruder, wherein the valve assembly comprises: a valve body comprising a large circular section, an intercalary conical section, and a small circular collar containing one or more nozzles for liquid input, the valve body having a chamber formed therein that connects an input end and a discharge end of the valve body, wherein the small circular collar is smaller in inner diameter than the large circular section; a valve needle axially displaceable within the chamber of the valve body; and a housing attached to the discharge end of the valve body and enclosing the valve needle when the valve needle is disengaged with the valve body.

[0006] In some embodiments, the biomass is selected from the group consisting of: silage, agricultural residues, corn stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits. In some embodiments, the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone. In some embodiments, temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and pressure in the reaction zone is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI. In some embodiments, the system further comprises a mean for supplying steam and one or more chemicals to the reaction zone. In some embodiments, the one or more chemicals comprise an acid. In some embodiments, the acid is sulfuric acid.

[0007] In some embodiments, the valve assembly comprises: a valve body comprising a large circular section, an intercalary conical section, and a small circular collar containing one or more nozzles for liquid input, the valve body having a chamber formed therein that connects an input end and a discharge end of the valve body, wherein the small circular collar is smaller in inner diameter than the large circular section; a valve needle axially

displaceable within the chamber of the valve body; and a housing attached to the discharge end of the valve body and enclosing the valve needle when the valve needle is disengaged with the valve body. In some embodiments, the housing contains a removable discharge ring. In some embodiments, the discharge ring is tapered. In some embodiments, the valve body contains an annular ring. In some embodiments, the annular ring is removable. In some embodiments, there is an annular space formed in the chamber between the valve body and the valve needle when the valve needle is closed on the valve body. In some embodiments, the nozzles for liquid input transfer water into the chamber. In some embodiments, the nozzles for liquid input transfer a liquid other than water into the chamber. In some embodiments, the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof. In some embodiments, an inner diameter of the housing at an end of the housing abutting the valve body is at least 7% larger than an inner diameter of the valve body at its discharge end. In some embodiments, an inner diameter of the housing at an end of the housing abutting the valve body is about 7% larger than an inner diameter of the valve body at its discharge end. In some embodiments, the valve needle has a cone with a wide end opposing to its conical tip. In some embodiments, the cone is tapered in a range of from 45 degrees to 75 degrees. In some embodiments, the cone is tapered about 45 degrees. In some embodiments, the valve needle has a diameter at the wide end that is at least 4% larger than an inner diameter of the valve body at its discharge end. In some embodiments, the valve needle has a diameter at the wide end that is about 4% larger than an inner diameter of the valve body at its discharge end. In some embodiments, the extruder is a twin screw extruder. In some embodiments, the extruder has ports for adding steam and/or acid.

[0008] In another aspect, provided herein is a method of pretreating a biomass through the system disclosed herein.

[0009] In another aspect, provided herein is a method of pretreating a biomass, the method comprising: conveying the biomass through an extruder from a feeder zone of the extruder to a reaction zone of the extruder, wherein the feeder zone and the reaction zone are separated by a biomass plug formed downstream of the input zone and upstream from the reaction zone; adding steam and/or a chemical to the biomass in the reaction zone to partially treat the biomass; conveying the partially-treated biomass into a valve assembly attached to an output end of the extruder, and treating the partially-treated biomass in the valve assembly, thereby producing a pretreated biomass; and discharging the pretreated biomass through the valve assembly.

[00010] In some embodiments of the method, the biomass is conveyed through the extruder at a velocity same as a velocity at which the partially-treated biomass is conveyed through the

valve assembly. In some embodiments, temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and pressure in the reaction zone is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI. In some embodiments, the biomass is selected from the group consisting of: silage, agricultural residues, corn stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits. In some embodiments, the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone. In some embodiments, the chemical is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof. In some embodiments, the extruder comprises one or more screws. In some embodiments, the extruder comprises two screws.

[00011] In another aspect, provided herein is a method of pretreating a biomass, the method comprising: conveying the biomass through an extruder from a feeder zone of the extruder to a reaction zone of the extruder, wherein the feeder zone and the reaction zone are separated by a biomass plug formed downstream of the input zone and upstream from the reaction zone; adding steam and/or a chemical to the biomass in the reaction zone to partially treat the biomass; conveying the partially-treated biomass into an extension compartment attached to an output end of the extruder, and treating the partially-treated biomass in the extension compartment, thereby producing a pretreated biomass.

[00012] In some embodiments, the method further comprising adding an acid at a downstream end of the extruder as the biomass exits the extruder. In some embodiments, the extension compartment is formed by a tube. In some embodiments, the extension compartment is formed by a vessel. In some embodiments, the extension compartment is formed by a valve assembly. In some embodiments, the extension compartment is capable of discharging the pretreated biomass in a continuous manner. In some embodiments, the extension compartment is capable of discharging the pretreated biomass in a semi-continuous manner. In some embodiments, the extension compartment is capable of discharging the pretreated biomass in batches. the biomass is conveyed through the extruder at a velocity same as a velocity at which the partially-treated biomass is conveyed through the extension compartment. In some

embodiments, the extension compartment is pressurized. In some embodiments, the extension compartment is equipped with one or more nozzles for liquid input. In some embodiments, the nozzles for liquid input transfer water into the chamber. In some embodiments, the nozzles for liquid input transfer a liquid other than water into the chamber. In some embodiments, the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof. In some embodiments, temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and pressure in the reaction zone is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI. In some embodiments, the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits. In some embodiments, the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone. In some embodiments, the chemical is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof. In some embodiments, the extruder comprises one or more screws. In some embodiments, the extruder comprises two screws.

[00013] In one aspect, a system for treating biomass through an extruder and a valve assembly is provided, comprising: an extruder comprising one or more screws wherein an internal plug of biomass is formed due to action of the screws, thereby forming one end of a pressurized reaction zone; a method of supplying steam and one or more chemicals to the reaction zone; a valve assembly attached at the output end of the extruder that forms the downstream end of the reaction zone and adds a liquid to the reaction zone; and the valve assembly capable of rapidly discharging pressurized treated biomass into a non-pressurized discharge area.

[00014] In some embodiments, the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers,

yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits. In a further aspect, the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 seconds in the reaction zone. In another embodiment, the temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and the pressure is elevated by steam to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI. In another aspect, the chemical is an acid. In another aspect, the acid is sulfuric acid. In a further embodiment, the valve assembly comprises: a housing; a valve body comprising: a large circular section; a middle conical section; a smaller circular collar containing one or more nozzles for liquid input; and a valve needle.

[00015] In another embodiment, there is a space between the valve body and the valve needle when the valve needle is seated. In one aspect, the nozzles for liquid input transfer water into the space between the valve body and the valve needle. In another aspect, the nozzles for liquid input transfer a liquid other than water into the space between the valve body and the valve needle. In one embodiment, the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.

[00016] In one aspect, there is a method for treating a slurry or liquid in a pipe or barrel attached to a valve assembly, the method comprising: the pipe or barrel having a plug forming one end of a reaction zone; conveying a liquid or slurry through the pipe or barrel; having a valve assembly attached to the output end of the pipe or barrel forming the downstream end of the reaction zone while maintaining pressure in the reaction zone through the input of steam; adding a substance into the upstream end of the valve assembly as the liquid or slurry enters the valve assembly; and using the valve assembly to discharge the treated liquid or slurry into a non-pressurized area. In one aspect, the liquid or slurry comprises biomass. In another aspect, the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum,

bamboo, corncobs, and peels and pits. In another aspect, the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 seconds in the reaction zone.

[00017] In one embodiment, the temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and the pressure is elevated by steam to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI. In another embodiment, the substance is an acid. In a further embodiment, the acid is sulfuric acid.

[00018] In one aspect, a system is provided to extend a reaction zone downstream of an extruder, comprising: an extruder comprising a reaction zone section, wherein said extruder reaction zone section is attached to a downstream valve assembly comprising an adjacent inner space; wherein the reaction zone section in the extruder is combined with the adjacent inner space of the valve assembly to extend the reaction zone downstream of the extruder. In another aspect, the velocity of the materials moving through the reaction zone section of the extruder is kept constant with the velocity of the materials moving through the valve assembly.

[00019] In one embodiment, the valve assembly has an annular ring that is part of the valve body. In another embodiment, the annular ring is replaceable. In one embodiment, the valve body contains nozzles for the input of a liquid. In one embodiment, a valve needle seats at a discharge ring when closed in the valve body. In a further aspect, the valve needle is attached to an actuator. In one embodiment, the actuator maintains a pressure on the valve needle, said pressure which is maintained over 1,800 lbf on the valve needle. In another embodiment, the actuator maintains a pressure of between 50,000 to 500,000 lbf on the valve needle.

[00020] In one embodiment, the extruder is a twin screw extruder. In another embodiment, the extruder has ports for adding steam and/or acid.

[00021] In one aspect, a method to extend a reaction zone downstream of an extruder is provided, the method comprising processing biomass in a reaction zone wherein the reaction zone extends from an extruder into an attached downstream valve assembly. In one embodiment, the valve assembly comprises: a housing, a valve body further comprising a large circular section, a middle conical section, a smaller circular collar containing one or more nozzles for liquid input, and a valve needle.

[00022] In one embodiment, the housing contains a removable discharge ring. In another embodiment, the discharge ring is tapered. In a further embodiment, the valve body contains an annular ring. In a further embodiment, the annular ring is removable. In one

aspect, there is a space between the valve body and the valve needle when the valve needle is seated. In another aspect, the nozzles for liquid input transfer water into the space between the valve body and the valve needle. In a further aspect, the nozzles for liquid input transfer a liquid other than water into the space between the valve body and the valve needle. In another embodiment, the liquid in the nozzles is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof. In another embodiment, the liquid is an acid. In a further embodiment, the acid is sulfuric acid. In another embodiment, steam and one or more chemicals are added to the reaction zone of the extruder. In a further embodiment, the temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C. The pressure is elevated by steam to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI. In another embodiment, the velocity is kept constant throughout the reaction zone.

[00023] In one aspect, a method of processing biomass is provided comprising: conveying biomass through an extruder wherein the extruder is divided into two zones, an input zone and a reaction zone, separated by a biomass plug formed downstream of the input zone and upstream from the reaction zone; adding steam and/or a chemical to biomass in the reaction zone to partially treat the biomass; conveying the partially-treated biomass into an attached valve assembly for a time to continue treatment; and discharging the biomass through the valve assembly. In another aspect, the velocity of the biomass being conveyed is the same in the extruder and in the valve assembly. In a one embodiment, the temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C. The pressure is elevated by steam to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI. In a further embodiment, the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits. In one aspect, the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone. In another aspect, the chemical

is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.

### INCORPORATION BY REFERENCE

[00024] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

### BRIEF DESCRIPTION OF THE DRAWINGS

[00025] The novel features of the disclosure are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present disclosure will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the disclosure are utilized, and the accompanying drawings of which:

[00026] **FIG 1** is a diagram depicting the modified pressure valve assembly.

[00027] **FIG 2** is a diagram showing a longitudinal view of the valve and its housing.

[00028] **FIGS 3A and 3B** are diagrams depicting longitudinal views of the valve assembly from the top (**3A**) and side (**3B**).

[00029] **FIG 4** is a longitudinal drawing of the valve assembly from in a view from the top.

[00030] **FIG 5** is a larger drawing of section A seen in Figure 4.

[00031] **FIG 6** is a drawing of a cross section of the valve body without the valve needle.

[00032] **FIGS 7A-7D** depict cross sections of the valve at the annulus at: a closed position (**7A**); with a 0.5 mm stroke (**7B**); with a 1.0 mm stroke (**7C**); and with a 1.5 mm stroke (**7D**).

### DETAILED DESCRIPTION

[00033] As used in the specification and the appended claims, the singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a purified monomer" includes mixtures of two or more purified monomers. The term "comprising" as used herein is synonymous with "including," "containing," or "characterized by," and is inclusive or open-ended and does not exclude additional, unrecited elements or method steps.

[00034] "About" means a referenced numeric indication plus or minus 10% of that referenced numeric indication. For example, the term about 4 would include a range of 3.6 to 4.4. All numbers expressing quantities of ingredients, reaction conditions, and so forth used in the specification are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth herein are approximations that can vary depending upon the desired properties sought to be obtained. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of any claims in any application claiming priority to the present application, each numerical parameter should be construed in light of the number of significant digits and ordinary rounding approaches.

[00035] Wherever the phrase "for example," "such as," "including" and the like are used herein, the phrase "and without limitation" is understood to follow unless explicitly stated otherwise. Therefore, "for example ethanol production" means "for example and without limitation ethanol production."

[00036] In this specification and in the claims that follow, reference will be made to a number of terms which shall be defined to have the following meaning.

#### **Definitions**

[00037] "Optional" or "optionally" means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where said event or circumstance occurs and instances where it does not. For example, the phrase "the medium can optionally contain glucose" means that the medium may or may not contain glucose as an ingredient and that the description includes both media containing glucose and media not containing glucose.

[00038] Unless characterized otherwise, technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art.

[00039] The term "biomass" as used herein has its ordinary meaning as known to those skilled in the art and can include one or more carbonaceous biological materials that can be converted into a biofuel, chemical or other product. Biomass as used herein is synonymous with the term "feedstock" and includes silage, agricultural residues (corn stalks, grass, straw, grain hulls, bagasse, etc.), nuts, nut shells, coconut shells, animal waste (manure from cattle, poultry, and hogs), Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles, Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials (wood or bark, sawdust, wood chips, wood pellets, timber

slash, and mill scrap), municipal waste (waste paper, recycled toilet papers, yard clippings, etc.), and energy crops (poplars, willows, switchgrass, alfalfa, prairie bluestem, algae, including macroalgae such as members of the Chlorophyta, Phaeophyta, Rhodophyta, etc.). One exemplary source of biomass is plant matter. Plant matter can be, for example, woody plant matter, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, sugar cane, grasses, sorghum, high biomass sorghum, bamboo, algae and material derived from these. Plants can be in their natural state or genetically modified, *e.g.*, to increase the cellulosic or hemicellulosic portion of the cell wall, or to produce additional exogenous or endogenous enzymes to increase the separation of cell wall components. Plant matter can be further described by reference to the chemical species present, such as proteins, polysaccharides and oils. Polysaccharides include polymers of various monosaccharides and derivatives of monosaccharides including glucose, fructose, lactose, galacturonic acid, rhamnose, etc. Plant matter also includes agricultural waste byproducts or side streams such as pomace, corn steep liquor, corncobs, corn fiber, corn steep solids, distillers' grains, peels, pits, fermentation waste, straw, lumber, sewage, garbage and food leftovers. Peels can be citrus which include, but are not limited to, tangerine peel, grapefruit peel, orange peel, tangerine peel, lime peel and lemon peel. These materials can come from farms, forestry, industrial sources, households, etc. Another non-limiting example of biomass is animal matter, including, for example milk, bones, meat, fat, animal processing waste, and animal waste. "Feedstock" is frequently used to refer to biomass being used for a process, such as those described herein.

[00040] "Pretreatment" or "pretreated" is used herein to refer to any mechanical, chemical, thermal, biochemical process or combination of these processes whether in a combined step or performed sequentially, that achieves disruption or expansion of the biomass so as to render the biomass more susceptible to attack by enzymes and/or microbes, and can include the enzymatic hydrolysis of released carbohydrate polymers or oligomers to monomers. In one embodiment, pretreatment includes removal or disruption of lignin so as to make the cellulose and hemicellulose polymers in the plant biomass more available to cellulolytic enzymes and/or microbes, for example, by treatment with acid or base. In one embodiment, pretreatment includes disruption or expansion of cellulosic and/or hemicellulosic material. In another embodiment, it can refer to starch release and/or enzymatic hydrolysis to glucose. Steam explosion, and ammonia fiber

expansion (or explosion) (AFEX) are well known thermal/chemical techniques.

Hydrolysis, including methods that utilize acids, bases, and/or enzymes can be used.

Other thermal, chemical, biochemical, enzymatic techniques can also be used.

[00041] "Steam explosion" as used herein is a physicochemical method that uses high-pressure steam to disrupt bonding between polymeric components and decompression to break the lignocellulose structure. In this method, the lignocellulose slurry is treated with high-pressure steam for some time and then rapidly depressurized to atmospheric pressure.

[00042] As intended herein, a "liquid" composition may contain solids and a "solids" composition may contain liquids. A liquid composition refers to a composition in which the material is primarily liquid, and a solids composition is one in which the material is primarily solid. A "slurry" refers to solids dissolved or undissolved in a liquid.

### **Description**

[00043] The following description and examples illustrate some exemplary embodiments of the disclosure in detail. Those of skill in the art will recognize that there are numerous variations and modifications of this disclosure that are encompassed by its scope. Accordingly, the description of a certain exemplary embodiment should not be deemed to limit the scope of the present disclosure.

[00044] In one aspect, the valve assembly described herein has a structure and design that addresses degradative stresses encountered in high pressure flows of treated liquids or slurries of materials flowing through a tube or pipe. The valve assembly is designed to incorporate part of the treatment of such liquids or slurries as the flow passes from the attached tube or pipe upstream into the valve assembly, through the valve assembly and downstream into a discharge area.

[00045] Another major advantage of using a valve assembly such as one described herein is the ability to reduce the time materials are processed in the extruder barrel. The pressure and velocity of materials moving through the reaction zone is held fairly constant no matter the size of the extruder and end valve assembly. Because the annular space in the valve adds reaction zone length when increasing the size of the valve, the reaction zone volume increases, thereby increasing the time of materials processing without extending the retention period in the extruder barrel.

[00046] In one embodiment, valve assemblies for use in fluid ends are provided. In another aspect, the valve assembly disclosed herein can be used to continuously or semi-continuously process liquids, a slurry of materials, a thick liquid, or any liquified matter

under pressure. By process, it is understood that materials can be modified alone by means of heat, pressure, and/or the addition of chemicals, or mixed under pressure, heated, chemically reacted by means of combining two or more components (simultaneously or through subsequent addition), by the addition of chemical components such as acids, bases, bleaching components, dyes, and the like. Examples of such components include plastics, plant materials, foodstuffs, polymers, polyurethanes, and the like.

[00047] In one aspect, a slurry of materials can include pretreated biomass or partially-hydrolyzed biomass. This arrangement can be used to obtain a constant velocity and pressure as material is moved through a passageway such as a tube or pipe. Water or steam can be added to increase and maintain a constant pressure in the passageway by means of an intercalary plug and the valve assembly at the output. The section between the plug and through the valve assembly is the reaction zone wherein modifications to the materials occur. This zone includes the flashing of materials through the end of the valve needle.

[00048] In one embodiment, an extruder and valve assembly can be used to process materials. Extruders move liquids, slurries, solid and viscous materials through a barrel by means of screw elements. Depending on the shape of the elements, materials may be slowed, mixed, or pushed through the barrel. The extruder can be a single screw extruder, a twin-screw extruder, or a triple-screw extruder. Preferably, for biomass materials, a twin-screw extruder is used. Extruders having specially configured screws designed to permit the addition of very high quantities of steam for increased pressure make it possible to pretreat biomass at high velocities. A rapid extruder pretreatment system, such as described in US 2016/0273009 A1 or WO2018/151833 (A1), each incorporated herein by reference in its entirety, offers a unique pathway for the deconstruction of biomass and release of cellulose and lignin from other biomass components. The combination of mechanical fibrillation, dilute acid hydrolysis, and steam explosion, all accomplished in under 20 seconds, yields a very clean slurry of soluble sugars, microcrystalline cellulose, and lignin. The short, yet intense, treatment duration yields a unique cellulose, hemicellulose and lignin products that have been rendered into a highly reactive states without the overcooking or sulfonation that occurs in most other processes.

[00049] Restriction and relief devices for liquids and materials moving through pipes or barrels have been proposed in the past. Several of these have involved intercalary valves in

an extruder barrel itself. One such device described in US 2007/0237022A1 is a mid-barrel adjustable valve assembly. Others are end valves such as those found in US2009/0053800A1, WO2010/056940A2, or US10,344,757B1. None of these function as a part of the treatment system and are not capable of high velocity continuous processing.

[00050] Extrusion may be continuous or semi-continuous and the process can be done with the material hot or cold. Commonly extruded materials include metals, polymers, ceramics, concrete, modelling clay, and foodstuffs; however, biomass can be processed in an extruder as well. Extruders can have one or more shafts. A twin-screw extruder is a machine having two co-penetrating and self-cleaning identical screws which are mounted on shafts and rotate in the same direction in a fixed closed housing called "barrel". The twin-screw extruders can operate continuously with very short residence times under high temperatures and pressures.

[00051] In one embodiment, an acid, heat and explosion pretreatment process to extract biomass components is a rapid treatment process that includes steam explosion. The treatment is carried out as reduced-size particles of biomass are treated to pressurized acid hydrolysis and high temperatures through steam, then subjected to steam explosion. Because the whole process is uniform throughout and only takes seconds, it requires an effective and rapidly moving valve system to maintain pressures for continuous processing.

[00052] In processing biomass, steam is injected into the barrel to increase temperature and pressure. In one embodiment, the screw elements also function to slow down the flow of materials to form an intercalary plug that functions to seal materials in the barrel after input and further build pressure within the barrel. See, *e.g.*, U.S. application No. 15/932,340, incorporated herein by reference.

[00053] The example of the valve assembly is not meant to be limiting to an extruder but is provided as an illustration of demonstrating its functional value. In this system, one functional embodiment of the pressure valve assembly is to help initiate and maintain constant pressure in the extruder and through the valve body. This is the reaction zone through which much of the treatment of the biomass takes place. The intercalary plug in the extruder facilitates slowdown through the use of particular screws and steam is used to build the pressure in the reaction zone. An actuator sets the pressure on the valve needle to keep the required pressure in the extruder and within the valve body. If a valve is coupled to an actuator operating in response to the internal pressure at the end of the pipe or barrel instead of a manual or spring-operated valve, precise continuous movement is possible.

[00054] Preferably, the actuator is a hydraulic or pneumatic actuator such as those manufactured by Kyntronics (Solon, OH 44139, U.S.A.). The actuator keeps the valve needle

moving in and out endlessly and quickly with very small movements along the longitudinal axis. The actual force the needle valve must maintain for biomass in the reaction zone of the body of the extruder barrel can range from 1,800 lbf to 82,000 lbf and much higher (over 500,000 lbf). Constant force is achieved by controlling the annular space through which treated biomass material or liquid flows. An actuator system takes an electrical signal directly to the actuation mechanism. It is set to work at a particular pressure and react to the force exerted by the material flowing out of the tube or extruder.

[00055] In one aspect, because the reaction zone encompasses the area between the plug, through the valve body, and the steam explosion area as liquid or slurry flashes outside the annular ring (the interface between the annular and discharge ring -see *infra*), a shorter reaction zone length is required in the tube or pipe. In the example of biomass processing in an extruder, this shortens the length of the extruder reaction zone and reduces the cost of the metallurgy necessary for extruder processing.

[00056] In one example of a pressure valve assembly, as shown in **FIG. 1**, the valve has a valve body **10** fitted with a conical valve needle **11** and a housing **12** fitted with a discharge pipe **13**. The valve body and needle can be made of any material that can withstand the wear and tear of liquids or slurries of different chemicals passing through from upstream input **30** through the valve body and housing to the discharge pipe **13**, but it is constructed of an inert metal or metal with an inert coating. The valve needle is attached to a shaft **14**. The valve body **10** as shown in a longitudinal section in **FIG. 2**, has a cylindrical-shaped section **15**, an intercalary conical section **16**, and another generally cylindrical-shaped collar **17** of smaller diameter than the first section **15**. The valve body includes an annular (wear) ring **19** at its widest part. It sits into a recessed cavity in the valve body section **15**. The annular ring **19** internal surface aligns with the rest of the valve body **10** and functions as a wear part that can be replaced. The annular ring **19** sits inside the reaction zone of the valve and extends to the minimum annular space **21** (see **FIG. 7A**) after which the flash to atmosphere (steam explosion) occurs.

[00057] The tapered discharge ring **20** sits outside the valve body **10** in the housing **12** and is not a part of the reaction zone. It is a means to ensure liquids or slurry are channeled to the discharge pipe **13** and into the flash tank (not shown). It is also made a wear part so that it is easily changed. The taper on the discharge ring **20** (see **Figs. 3A and 3B**) avoids a right angle connection to the valve body that could result in material build up and interfere with movement of substances flowing from the needle tip to the output.

[00058] **FIGS. 3A and 3B** are longitudinal sections of the top and side view, respectively, of the valve and its housing. Materials flow upstream under pressure from a

tube, barrel or pipe (**FLUID FORCE**) into section **17** through the valve body and are discharged downstream into the housing **12**. Force from the actuator is applied to the valve needle through the shaft **14**.

[00059] There is an annular space **21** between the valve body **10** and the valve needle **11**. There is also a 7% increase in the diameter of the cavity **22** of the housing **12** where discharged liquid or slurries (materials) are received as compared to the internal diameter of the valve body **10** where materials flash out.

[00060] In operation, differential pressure acting on the valve needle **11** causes the valve needle **11** to be displaced along its longitudinal axis **75**. The pressure behind the valve shaft **14** causes the valve to seat into the valve body section **15** just before the widest end of the needle **11**.

[00061] The widest part of the needle valve **11** is slightly larger than the widest part of the valve body **10** so that it seats in the valve body section **15** at the annular ring **19** when closed. In one embodiment, the diameter of the wide end of the needle is at least 4% larger than the diameter of the valve body at the discharge end. In one embodiment, the diameter of the wide end of the needle is about 4% larger than the diameter of the valve body at the discharge end. In one embodiment, the diameter of the wide end of the needle is 416 mm while the diameter at the discharge end of the valve body is 400 mm. It can be made larger or smaller. In one embodiment, the cone is tapered 45 degrees from its widest diameter to the needle tip **18**. In other embodiments, the taper of the cone can range from 45 degrees to 75 degrees. This measurement will be based on materials, feedstock, process requirements, space requirements, and the force necessary to move the needle valve.

[00062] The collar **17** is the means by which the pressure relief valve is connected to an extruder or other tube. When the valve is fully seated and an extruder is attached, the valve needle tip **18** extends just to the beginning of the collar at the end of the conical section **16** and there is a space between the tip of the needle and the discharge end of the pipe or extruder **35** and the end of any screws **38**. In the process of pretreating biomass in an extruder, water is injected through injection nozzles **36** in the collar **17** after the materials leave the extruder but before they reach the valve needle tip **18** (see **FIGS. 4 and 5**). The water is used to thin the material, improve rheology through steam explosion and therefore reduces torque on the extruder to push through the valve. With processing, materials, especially slurries, do not often flow, but surge a bit as they are processed through a pipe or barrel. The flow at exit is turbulent and as it mixes with the water, it smooths into a laminar flow traveling downstream in the space of the valve **21**. Any

liquid can be added just prior to output from the tube to facilitate the flow of materials through the valve system and/or to further process materials. In one embodiment, liquids such as water, acid, bases, alcohols, solvents, aldehydes, ketones, and the like can be used for this purpose.

[00063] In the closing position of the valve, the valve needle tip **18** comes to rest in the inner space of the valve body **10** and about at the interface of the intercalary conical section **16** and smaller cylindrical-shaped collar **17**. See **Fig. 5**. The valve needle tip **18** is about 3-6 mm downstream of liquid injection.

[00064] **FIG. 6** is a cross section diagram of the valve body **10** without the valve needle **18** looking towards the discharge end of an extruder with twin screws **38**. The input nozzles **36** eject liquid into the collar **17** after materials exit the extruder.

[00065] **FIG. 7A** is a cross section diagram of the seal between the conical needle **11** and the conical valve body **15** at the annular ring **19**. At this point, the pressure behind the valve shaft **14** is equal to or greater than the pressure of the fluids and/or materials flowing out of the pipe and serves to stop the flow. **FIG. 7B** depicts the movement of the valve needle **11** when the pressure inside the pipe increases and the valve needle **11** moves approximately 0.5mm towards the housing. The valve needle **11** is separated from its seated position in the annular ring **19** so that the fluids and/or materials can flow around the valve needle **11** through the passageway (space) **21** towards the discharge area **22** (shown in **FIG. 3**). An increase in pressure from the pipe results in further movement of the valve needle **11** towards the discharge area, widens the gap between the needle and the annular ring **19**, and allows a greater flow of fluids and/or materials; *i.e.*, movement at 1.0 mm (**FIG. 7C**), and 1.5 mm (**FIG. 7D**).

[00066] In operation, the valve needle **18** moves in and out several times per second to maintain the setpoint pressure required, and therefore moves between fully closed and allowing a maximum annular space of 2mm. The hydraulic actuator attached to the valve needle keeps the valve needle moving in and out endlessly, very quickly and with very small movements along the longitudinal axis.

[00067] The passageway offers a unique opportunity to extend the reaction zone beyond the end of the extruder barrel. In some embodiments, the reaction zone is extended by an extension chamber other than the passageway of the valve assembly disclosed herein. For instance, the extension compartment is formed by a vessel or a tube that is attached to the output end of the extruder. Processing is continuous through the extruder and the passageway **21** and the volume of the space **21** has to be taken into consideration when measuring pretreatment times. The barrel sections of the extruder and manifold and injection assemblies

are designed so they can be repositioned and/or flipped around. Thus, if a change of reaction zone length is required, for example, the steam injection and acid injection ports can be moved so that the injection of steam and acid is accomplished further downstream towards the end of the extruder barrel, shortening the period of time materials are pretreated in the extruder section but maintaining the same volume of space in the passageway **21**. This results in less wear and tear on expensive extruder sections and coatings, reducing the cost of pretreatment overall.

[00068] In another embodiment, increasing the volume space of the passageway, by increasing the size of the valve assembly, would result in lengthening of the pretreatment period without increasing wear and tear on the extruder. In a further embodiment, if a longer steam period was required with a shorter acid treatment, the acid barrel can be moved downstream, thereby increasing the time in contact with the steam and theoretically reducing the amount of acid required vs having the acid further downstream. Similarly, if there is too long a contact time with acid at reaction temperatures such that inhibitors are generated, the acid barrel can be moved downstream and/or added later in the passageway **21**, thereby generating fewer inhibitors.

[00069] Depending on the size of the extruder system, stable, continuous biomass pretreatment operations have been carried out with a 30mm valve, a 63mm valve, a 98 mm valve, and a 400 mm valve. In other embodiments, valves of 500-600 mm and larger can be used.

[00070] This system, comprised of the injectors together with the barrels and the end valve sizing provides a significant amount of flexibility and almost finite control over injection possibilities and the duration of pretreatment. The velocity of materials moving through and flashing out of the valve is kept constant so that as the size of the valve is increased, residence time of the materials in the space **21** increases.

[00071] From the above examples, it is apparent to one skilled in the art that a multitude of combinations of barrel sections, combined with different volumes of the passageway **21** can be attained to maximize the efficiency of biomass pretreatment while minimizing the costs of pretreatment. Temperatures and chemicals can vary as the velocity of materials moving through the system is maintained.

[00072] Under certain circumstances, it is desirable to have a continuous processing of materials, liquids, or both under a constant pressure. For example, the pretreatment of biomass is uneconomical in batches. It is time-consuming and wastes materials. The problem is how to keep a constant precise pressure during treatment while moving substances through a pipe or barrel and discharging pressurized materials to atmospheric

pressure simultaneously. Further, it is difficult to do this when working with slurries because the nature of the heterogeneous mixture can cause pulsing.

[00073] The valve described herein can be used at high velocities. For example, continuous biomass processing as measured at the annular ring 19 is 185-190 m/s at a 0.5 mm stroke. Potential ranges are about 90 m/s to 250 m/s. In other embodiments, velocities of 95 m/s, 100 m/s, 110 m/s, 120 m/s, 130 m/s, 140 m/s, 150 m/s, 160 m/s, 170 m/s, 180 m/s, 190 m/s, 200 m/s, 210 m/s, 220 m/s, 230 m/s, 240 m/s, and higher are possible.

[00074] The rate of biomass materials moving through the system has been established from 55 kg/hr for a 30 mm valve to over 96 DMT/day for a 400 mm valve. Higher rates can be achieved for larger valves.

[00075] In some embodiments, the liquid or slurry is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 seconds in the reaction zone. In some embodiments, biomass is treated for about 5 to 15 seconds in the reaction zone; in larger systems, the biomass is treated for 30 seconds or less, or is treated for 60 seconds or less.

[00076] In another embodiment, a liquid or slurry can be treated at an elevated pressure. In one embodiment biomass is pretreated at a pressure range of about 1psi to about 30psi. In another embodiment biomass is pretreated at a pressure or about 50psi, 100psi, 150psi, 200psi, 250psi, 300psi, 350psi, 400psi, 450psi, 500psi, 550psi, 600psi, 650psi, 700psi, 750psi, 800psi or more up to 900 psi. In some embodiments, biomass can be treated with elevated pressures by the injection of steam into a biomass containing vessel. In one embodiment, the biomass can be treated to vacuum conditions prior or subsequent to alkaline or acid treatment or any other treatment methods provided herein.

### **Exemplary Embodiments**

Embodiment 1. A system for treating biomass through an extruder and a valve assembly comprising:

- (a) an extruder comprising one or more screws wherein an internal plug of biomass is formed due to action of the screws, thereby forming one end of a pressurized reaction zone;
- (b) a method of supplying steam and one or more chemicals to the reaction zone;
- (c) a valve assembly attached at the output end of the extruder that forms the downstream end of the reaction zone and adds a liquid to the reaction zone; and
- (d) said valve assembly capable of rapidly discharging pressurized treated biomass into a non-pressurized discharge area.

Embodiment 2. The system of Embodiment 1, wherein the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits.

Embodiment 3. The system of Embodiment 1, wherein the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone.

Embodiment 4. The system of Embodiment 1, wherein the temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and the pressure is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.

Embodiment 5. The system of Embodiment 1, wherein one chemical is an acid.

Embodiment 6. The system of Embodiment 1, wherein the acid is sulfuric acid.

Embodiment 7. The system of Embodiment 1, wherein the valve assembly comprises:

Embodiment 8. A housing;

(a) a valve body comprising:

- i. a large circular section;
- ii. a middle conical section;
- iii. a smaller circular collar containing one or more nozzles for liquid input; and

(b) a valve needle.

Embodiment 9. The valve assembly of Embodiment 7, wherein there is a space between the valve body and the valve needle when the valve needle is seated.

Embodiment 10. The valve assembly of Embodiment 7, wherein the nozzles for liquid input transfer water into the space between the valve body and the valve needle.

Embodiment 11. The valve assembly of Embodiment 7, wherein the nozzles for liquid input transfer a liquid other than water into the space between the valve body and the valve needle.

Embodiment 12. The nozzles of Embodiment 10, wherein the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.

Embodiment 13. A method for treating a slurry or liquid in a pipe or barrel attached to a valve

assembly, the method comprising:

- a. said pipe or barrel having a plug forming one end of a reaction zone;
- b. conveying a liquid or slurry through the pipe or barrel;
- c. having a valve assembly attached to the output end of the pipe or barrel forming the downstream end of the reaction zone while maintaining pressure in the reaction zone through the input of steam;
- d. adding a substance into the upstream end of the valve assembly as the liquid or slurry enters the valve assembly; and
- e. using the valve assembly to discharge the treated liquid or slurry into a non-pressurized area.

Embodiment 14. The method of Embodiment 12, wherein the liquid or slurry comprises biomass.

Embodiment 15. The method of Embodiment 13, wherein the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits.

Embodiment 16. The method of Embodiment 14, wherein the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 seconds in the reaction zone.

Embodiment 17. The method of Embodiment 14, wherein the temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and the pressure is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.

Embodiment 18. The method of Embodiment 14, wherein the substance is an acid.

Embodiment 19. The method of Embodiment 14, wherein the acid is sulfuric acid.

Embodiment 20. A system to extend a reaction zone downstream of an extruder comprising:

- (a) an extruder comprising a reaction zone section, wherein said extruder reaction zone section is attached to a downstream valve assembly comprising an adjacent inner space;
- (b) wherein the reaction zone section in the extruder is combined with the adjacent inner space of the valve assembly to extend the reaction zone downstream of the

extruder.

Embodiment 21. The system of Embodiment 19, wherein the velocity of the materials moving through the reaction zone section of the extruder is kept constant with the velocity of the materials moving through the valve assembly.

Embodiment 22. The valve assembly of Embodiment 19, wherein an annular ring is part of the valve body.

Embodiment 23. The valve assembly of Embodiment 19, wherein the annular ring is replaceable.

Embodiment 24. The valve assembly of Embodiment 19, wherein the valve body contains nozzles for the input of a liquid.

Embodiment 25. The valve assembly of Embodiment 19, wherein a valve needle seats when closed in the valve body at a discharge ring.

Embodiment 26. The valve assembly of Embodiment 24, wherein the valve needle is attached to an actuator.

Embodiment 27. The actuator of Embodiment 25, wherein the actuator maintains a pressure on the valve needle.

Embodiment 28. The actuator of Embodiment 25, wherein the actuator maintains a pressure of over 1,800 lbf on the valve needle.

Embodiment 29. The actuator of Embodiment 25, wherein the actuator maintains a pressure of between 50,000 to 500,000 lbf on the valve needle.

Embodiment 30. The extruder of Embodiment 19, wherein the extruder is a twin screw extruder.

Embodiment 31. The extruder of Embodiment 19, wherein the extruder has ports for adding steam and/or acid.

Embodiment 32. A method to extend a reaction zone downstream of an extruder comprising:  
(a) processing biomass in a reaction zone wherein the reaction zone extends from an extruder into an attached downstream valve assembly.

Embodiment 33. The method of Embodiment 31, wherein the valve assembly comprises:

- (a) a housing;
- (b) a valve body comprising:
  - iv. a large circular section;
  - v. a middle conical section;
  - vi. a smaller circular collar containing one or more nozzles for liquid input; and
- (c) a valve needle.

Embodiment 34. The valve assembly of Embodiment 32, wherein the housing contains a removable discharge ring.

Embodiment 35. The valve assembly of Embodiment 33, wherein the discharge ring is tapered.

Embodiment 36. The valve assembly of Embodiment 32, wherein the valve body contains an annular ring.

Embodiment 37. The valve assembly of Embodiment 35, wherein the annular ring is removable.

Embodiment 38. The valve assembly of Embodiment 32, wherein there is a space between the valve body and the valve needle when the valve needle is seated.

Embodiment 39. The valve assembly of Embodiment 32, wherein the nozzles for liquid input transfer water into the space between the valve body and the valve needle.

Embodiment 40. The valve assembly of Embodiment 38, wherein the nozzles for liquid input transfer a liquid other than water into the space between the valve body and the valve needle.

Embodiment 41. The nozzles of Embodiment 39, wherein the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.

Embodiment 42. The method of Embodiment 31, wherein steam and one or more chemicals are added to the reaction zone of the extruder.

Embodiment 43. The method of Embodiment 31, wherein the temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and the pressure is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.

Embodiment 44. The method of Embodiment 41, wherein the liquid is an acid.

Embodiment 45. The method of Embodiment 41, wherein the acid is sulfuric acid.

Embodiment 46. The method of Embodiment 31, wherein the velocity is kept constant throughout the reaction zone.

Embodiment 47. A method of processing biomass comprising:

- (a) conveying biomass through an extruder wherein the extruder is divided into two zones, an input zone and a reaction zone, separated by a biomass plug formed downstream of the input zone and upstream from the reaction zone;
- (b) adding steam and/or a chemical to biomass in the reaction zone to partially treat the biomass;
- (c) conveying the partially-treated biomass into an attached valve assembly for a time to continue treatment; and
- (d) discharging the biomass through the valve assembly.

Embodiment 48. The method of Embodiment 46, wherein the velocity of the biomass being

conveyed is the same in the extruder and in the valve assembly.

Embodiment 49. The method of Embodiment 46, wherein the temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and the pressure is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.

Embodiment 50. The method of Embodiment 46, wherein the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits.

Embodiment 51. The method of Embodiment 46, wherein the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone.

Embodiment 52. The method of Embodiment 46, wherein the chemical is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.

[1] A system for pretreating a biomass comprising:

- (a) an extruder comprising one or more screws, wherein an internal plug of the biomass is formed due to action of the one or more screws, thereby forming an upstream end of a pressurized reaction zone for pretreatment of the biomass; and
- (b) a valve assembly attached at an output end of the extruder, wherein the valve assembly forms a downstream end of the reaction zone and adds a liquid to the reaction zone.

[2] The system of paragraph [1], wherein the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows,

switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits.

- [3] The system of paragraph [1] or [2], wherein the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone.
- [4] The system of any one of paragraphs [1]-[3], wherein temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and pressure in the reaction zone is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.
- [5] The system of any one of paragraphs [1]-[4], wherein the system further comprises a mean for supplying steam and one or more chemicals to the reaction zone.
- [6] The system of paragraph [5], wherein the one or more chemicals comprise an acid.
- [7] The system of paragraph [6], wherein the acid is sulfuric acid.
- [8] The system of any one of paragraphs [1]-[7], wherein the valve assembly comprises:  
a valve body comprising a large circular section, an intercalary conical section, and a small circular collar containing one or more nozzles for liquid input, the valve body having a chamber formed therein that connects an input end and a discharge end of the valve body, wherein the small circular collar is smaller in inner diameter than the large circular section;  
a valve needle axially displaceable within the chamber of the valve body; and  
a housing attached to the discharge end of the valve body and enclosing the valve needle when the valve needle is disengaged with the valve body.
- [9] The system of paragraph [8], wherein the housing contains a removable discharge ring.
- [10] The system of paragraph [9], wherein the discharge ring is tapered.
- [11] The system of any one of paragraphs [8]-[10], wherein the valve body contains an annular ring.
- [12] The system of paragraph [11], wherein the annular ring is removable.
- [13] The system of any one of paragraphs [8]-[12], wherein there is an annular space formed in the chamber between the valve body and the valve needle when the valve needle is closed on the valve body.

- [14] The system of any one of paragraphs [8]-[13], wherein the nozzles for liquid input transfer water into the chamber.
- [15] The system of any one of paragraphs [8]-[14], wherein the nozzles for liquid input transfer a liquid other than water into the chamber.
- [16] The system of paragraph [15], wherein the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.
- [17] The system of any one of paragraphs [8]-[16], wherein an inner diameter of the housing at an end of the housing abutting the valve body is at least 7% larger than an inner diameter of the valve body at its discharge end.
- [18] The system of any one of paragraphs [8]-[17], wherein an inner diameter of the housing at an end of the housing abutting the valve body is about 7% larger than an inner diameter of the valve body at its discharge end.
- [19] The system of any one of paragraphs [8]-[18], wherein the valve needle has a cone with a wide end opposing to its conical tip.
- [20] The system of paragraph [19], wherein the cone is tapered in a range of from 45 degrees to 75 degrees.
- [21] The system of paragraph [19], wherein the cone is tapered about 45 degrees.
- [22] The system of any one of paragraphs [19]-[21], wherein the valve needle has a diameter at the wide end that is at least 4% larger than an inner diameter of the valve body at its discharge end.
- [23] The system of any one of paragraphs [19]-[22], wherein the valve needle has a diameter at the wide end that is about 4% larger than an inner diameter of the valve body at its discharge end.
- [24] The system of any one of paragraphs [1]-[23], wherein the extruder is a twin screw extruder.
- [25] The system of any one of paragraphs [1]-[24], wherein the extruder has ports for adding steam and/or acid.
- [26] A system for pretreating a biomass comprising:
- (a) an extruder comprising one or more screws, wherein an internal plug of the

biomass is formed due to action of the one or more screws, thereby forming an upstream end of a pressurized reaction zone for pretreatment of the biomass; and

(b) a valve assembly attached at an output end of the extruder, wherein the valve assembly comprises:

a valve body comprising a large circular section, an intercalary conical section, and a small circular collar containing one or more nozzles for liquid input, the valve body having a chamber formed therein that connects an input end and a discharge end of the valve body, wherein the small circular collar is smaller in inner diameter than the large circular section;

a valve needle axially displaceable within the chamber of the valve body;  
and

a housing attached to the discharge end of the valve body and enclosing the valve needle when the valve needle is disengaged with the valve body.

[27] The system of paragraph [26], wherein the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits.

[28] The system of paragraph [26] or [27], wherein the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone.

[29] The system of any one of paragraphs [26]-[28], wherein the temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and the pressure is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.

[30] The system of any one of paragraphs [26]-[29], wherein the chamber of the valve body forms a downstream part of the pressurized reaction zone.

- [31] The system of any one of paragraphs [26]-[30], wherein the system further comprises a mean for supplying steam and one or more chemicals to the reaction zone.
- [32] The system of paragraph [31], wherein the one or more chemicals comprise an acid.
- [33] The system of paragraph [32], wherein the acid is sulfuric acid.
- [34] The system of any one of paragraphs [26]-[33], wherein the housing contains a removable discharge ring.
- [35] The system of paragraph [34], wherein the discharge ring is tapered.
- [36] The system of any one of paragraphs [26]-[35], wherein the valve body contains an annular ring.
- [37] The system of paragraph [36], wherein the annular ring is removable.
- [38] The system of any one of paragraphs [26]-[37][29], wherein there is an annular space formed in the chamber between the valve body and the valve needle when the valve needle is closed on the valve body.
- [39] The system of any one of paragraphs [26]-[38][37], wherein the nozzles for liquid input transfer water into the chamber.
- [40] The system of any one of paragraphs [26]-[39], wherein the nozzles for liquid input transfer a liquid other than water into the chamber.
- [41] The system of paragraph [40], wherein the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.
- [42] The system of any one of paragraphs [26]-[41][37], wherein an inner diameter of the housing at an end of the housing abutting the valve body is at least 7% larger than an inner diameter of the valve body at its discharge end.
- [43] The system of any one of paragraphs [26]-[42], wherein an inner diameter of the housing at an end of the housing abutting the valve body is about 7% larger than an inner diameter of the valve body at its discharge end.
- [44] The system of any one of paragraphs [26]-[43], wherein the valve needle has a cone with a wide end opposing to its conical tip.
- [45] The system of paragraph [44], wherein the cone is tapered in a range of from 45 degrees to 75 degrees.

- [46] The system of paragraph [44], wherein the cone is tapered about 45 degrees.
- [47] The system of any one of paragraphs [44]-[46], wherein the valve needle has a diameter at the wide end that is at least 4% larger than an inner diameter of the valve body at its discharge end.
- [48] The system of any one of paragraphs [44]-[46], wherein the valve needle has a diameter at the wide end that is about 4% larger than an inner diameter of the valve body at its discharge end.
- [49] The system of any one of paragraphs [26]-[48], wherein the extruder is a twin screw extruder.
- [50] The system of any one of paragraphs [26]-[49], wherein the extruder has ports for adding steam and/or acid.
- [51] A method of pretreating a biomass through the system of any one of paragraphs [1]-[50].
- [52] A method of pretreating a biomass, the method comprising:
- (a) conveying the biomass through an extruder from a feeder zone of the extruder to a reaction zone of the extruder, wherein the feeder zone and the reaction zone are separated by a biomass plug formed downstream of the input zone and upstream from the reaction zone;
  - (b) adding steam and/or a chemical to the biomass in the reaction zone to partially treat the biomass;
  - (c) conveying the partially-treated biomass into a valve assembly attached to an output end of the extruder, and treating the partially-treated biomass in the valve assembly; and
  - (d) discharging the biomass through the valve assembly.
- [53] The method of paragraph [52], wherein the biomass is conveyed through the extruder at a velocity same as a velocity at which the biomass is conveyed through the valve assembly.
- [54] The method of paragraph [52] or [53], wherein temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and pressure in the reaction zone is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.
- [55] The method of any one of paragraphs [52]-[54], wherein the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains,

Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits.

- [56] The method of any one of paragraphs [52]-[55], wherein the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone.
- [57] The method of any one of paragraphs [52]-[56], wherein the chemical is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.
- [58] The method of any one of paragraphs [52]-[57], wherein the extruder comprises one or more screws.
- [59] The method of paragraph [58], wherein the extruder comprises two screws.
- [60] The method of any one of paragraphs [52]-[59], wherein the valve assembly comprises: a valve body comprising a large circular section, an intercalary conical section, and a small circular collar containing one or more nozzles for liquid input, the valve body having a chamber formed therein that connects an input end and a discharge end of the valve body, wherein the small circular collar is smaller in inner diameter than the large circular section;  
a valve needle axially displaceable within the chamber of the valve body; and  
a housing attached to the discharge end of the valve body and enclosing the valve needle when the valve needle is disengaged with the valve body.
- [61] The method of paragraph [60], wherein the housing contains a removable discharge ring.
- [62] The method of paragraph [61], wherein the discharge ring is tapered.
- [63] The method of any one of paragraphs [60]-[62][63], wherein the valve body contains an annular ring.
- [64] The method of paragraph [63], wherein the annular ring is removable.
- [65] The method of any one of paragraphs [60]-[64], wherein there is an annular space

formed in the chamber between the valve body and the valve needle when the valve needle is closed on the valve body.

[66] The method of any one of paragraphs [60]-[65], wherein the nozzles for liquid input transfer water into the chamber.

[67] The method of any one of paragraphs [60]-[66], wherein the nozzles for liquid input transfer a liquid other than water into the chamber.

[68] The method of paragraph [67], wherein the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.

[69] The method of any one of paragraphs [60]-[68], wherein an inner diameter of the housing at an end of the housing abutting the valve body is at least 7% larger than an inner diameter of the valve body at its discharge end.

[70] The method of any one of paragraphs [60]-[69], wherein an inner diameter of the housing at an end of the housing abutting the valve body is about 7% larger than an inner diameter of the valve body at its discharge end.

[71] The method of any one of paragraphs [60]-[70], wherein the valve needle has a cone with a wide end opposing to its conical tip.

[72] The system of paragraph [71], wherein the cone is tapered in a range of from 45 degrees to 75 degrees.

[73] The method of paragraph [72], wherein the cone is tapered about 45 degrees.

[74] The method of any one of paragraphs [71]-[73], wherein the valve needle has a diameter at the wide end that is at least 4% larger than an inner diameter of the valve body at its discharge end.

[75] The method of any one of paragraphs [71]-[73], wherein the valve needle has a diameter at the wide end that is about 4% larger than an inner diameter of the valve body at its discharge end.

[76] The method of any one of paragraphs [52]-[75], wherein the treatment of the partially-treated biomass in the valve assembly comprises subjecting the partially-treated biomass to an elevated pressure and/or temperature same to the reaction zone.

[77] The method of any one of paragraphs [52]-[76], wherein the treatment of the partially-

treated biomass in the valve assembly comprises adding a substance at an upstream end of the valve assembly to the partially-treated biomass.

- [78] The method of paragraph [77], wherein the substance comprises an acid.
- [79] The method of paragraph [78], wherein the acid comprises sulfuric acid.
- [80] The method of any one of paragraphs [52]-[79], wherein the extruder is a twin screw extruder.
- [81] The method of any one of paragraphs [52]-[80], wherein the extruder has ports for adding steam and/or acid.
- [82] A method of pretreating a biomass, the method comprising:
- (a) conveying the biomass through an extruder from a feeder zone of the extruder to a reaction zone of the extruder, wherein the feeder zone and the reaction zone are separated by a biomass plug formed downstream of the input zone and upstream from the reaction zone;
  - (b) adding steam and/or a chemical to the biomass in the reaction zone to partially treat the biomass;
  - (c) conveying the partially-treated biomass into an extension compartment attached to an output end of the extruder, and
  - (d) treating the partially-treated biomass in the extension compartment, thereby producing a pretreated biomass.
- [83] The method of paragraph [82], wherein the method further comprising adding an acid at a downstream end of the extruder as the biomass exits the extruder.
- [84] The method of paragraph [82] or [83], wherein the extension compartment is formed by a tube.
- [85] The method of paragraph [82] or [83], wherein the extension compartment is formed by a vessel.
- [86] The method of paragraph [82] or [83], wherein the extension compartment is formed by a valve assembly.
- [87] The method of any one of paragraphs [82]-[86], wherein the extension compartment is capable of discharging the pretreated biomass in a continuous manner.
- [88] The method of any one of paragraphs [82]-[86], wherein the extension compartment is capable of discharging the pretreated biomass in a semi-continuous manner.

- [89] The method of any one of paragraphs [82]-[86], wherein the extension compartment is capable of discharging the pretreated biomass in batches.
- [90] The method of any one of paragraphs [82]-[89], wherein the biomass is conveyed through the extruder at a velocity same as a velocity at which the partially-treated biomass is conveyed through the extension compartment.
- [91] The method of any one of paragraphs [82]-[89], wherein the extension compartment is pressurized.
- [92] The method of any one of paragraphs [82]-[89], wherein the extension compartment is equipped with one or more nozzles for liquid input.
- [93] The method of paragraph [92], wherein the nozzles for liquid input transfer water into the chamber.
- [94] The method of paragraph [92], wherein the nozzles for liquid input transfer a liquid other than water into the chamber.
- [95] The method of paragraph [94], wherein the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.
- [96] The method of any one of paragraphs [82]-[95], wherein temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and pressure in the reaction zone is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.
- [97] The method of any one of paragraphs [82]-[96], wherein the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits.
- [98] The method of any one of paragraphs [82]-[97], wherein the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone.

[99] The method of any one of paragraphs [82]-[98], wherein the chemical is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.

[100] The method of any one of paragraphs [82]-[99], wherein the extruder comprises one or more screws.

[101] The method of paragraph [100], wherein the extruder comprises two screws.

[00077] While preferred embodiments of the present disclosure have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the disclosure. It should be understood that various alternatives to the embodiments of the disclosure described herein may be employed in practicing the disclosure. It is intended that the following claims define the scope of the disclosure and that methods and structures within the scope of these claims and their equivalents be covered thereby.

## CLAIMS

### WHAT IS CLAIMED IS:

1. A system for pretreating a biomass comprising:
  - (a) an extruder comprising one or more screws, wherein an internal plug of the biomass is formed due to action of the one or more screws, thereby forming an upstream end of a pressurized reaction zone for pretreatment of the biomass; and
  - (b) a valve assembly attached at an output end of the extruder, wherein the valve assembly forms a downstream end of the reaction zone and adds a liquid to the reaction zone.
2. The system of claim 1, wherein the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits.
3. The system of claim 1, wherein the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone.
4. The system of claim 1, wherein temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and pressure in the reaction zone is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.
5. The system of claim 1, wherein the system further comprises a mean for supplying steam and one or more chemicals to the reaction zone.
6. The system of claim 5, wherein the one or more chemicals comprise an acid.
7. The system of claim 6, wherein the acid is sulfuric acid.
8. The system of claim 1, wherein the valve assembly comprises:
  - a valve body comprising a large circular section, an intercalary conical section, and a

small circular collar containing one or more nozzles for liquid input, the valve body having a chamber formed therein that connects an input end and a discharge end of the valve body, wherein the small circular collar is smaller in inner diameter than the large circular section;

a valve needle axially displaceable within the chamber of the valve body; and

a housing attached to the discharge end of the valve body and enclosing the valve needle when the valve needle is disengaged with the valve body.

9. The system of claim 8, wherein the housing contains a removable discharge ring.
10. The system of claim 9, wherein the discharge ring is tapered.
11. The system of claim 8, wherein the valve body contains an annular ring.
12. The system of claim 11, wherein the annular ring is removable.
13. The system of claim 8, wherein there is an annular space formed in the chamber between the valve body and the valve needle when the valve needle is closed on the valve body.
14. The system of claim 8, wherein the nozzles for liquid input transfer water into the chamber.
15. The system of claim 8, wherein the nozzles for liquid input transfer a liquid other than water into the chamber.
16. The system of claim 15, wherein the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.
17. The system of claim 8, wherein an inner diameter of the housing at an end of the housing abutting the valve body is at least 7% larger than an inner diameter of the valve body at its discharge end.
18. The system of claim 8, wherein an inner diameter of the housing at an end of the housing abutting the valve body is about 7% larger than an inner diameter of the valve body at its discharge end.
19. The system of claim 8, wherein the valve needle has a cone with a wide end opposing to its conical tip.
20. The system of claim 19, wherein the cone is tapered in a range of from 45 degrees to 75 degrees.
21. The system of claim 19, wherein the cone is tapered about 45 degrees.

22. The system of claim 19, wherein the valve needle has a diameter at the wide end that is at least 4% larger than an inner diameter of the valve body at its discharge end.
23. The system of claim 19, wherein the valve needle has a diameter at the wide end that is about 4% larger than an inner diameter of the valve body at its discharge end.
24. The system of claim 1, wherein the extruder is a twin screw extruder.
25. The system of claim 1, wherein the extruder has ports for adding steam and/or acid.
26. A system for pretreating a biomass comprising:
- (a) an extruder comprising one or more screws, wherein an internal plug of the biomass is formed due to action of the one or more screws, thereby forming an upstream end of a pressurized reaction zone for pretreatment of the biomass; and
  - (b) a valve assembly attached at an output end of the extruder, wherein the valve assembly comprises:
    - a valve body comprising a large circular section, an intercalary conical section, and a small circular collar containing one or more nozzles for liquid input, the valve body having a chamber formed therein that connects an input end and a discharge end of the valve body, wherein the small circular collar is smaller in inner diameter than the large circular section;
    - a valve needle axially displaceable within the chamber of the valve body;
    - and
    - a housing attached to the discharge end of the valve body and enclosing the valve needle when the valve needle is disengaged with the valve body.
27. The system of claim 26, wherein the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits.

28. The system of claim 26, wherein the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone.
29. The system of claim 26, wherein the temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and the pressure is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.
30. The system of claim 26, wherein the chamber of the valve body forms a downstream part of the pressurized reaction zone.
31. The system of claim 26, wherein the system further comprises a mean for supplying steam and one or more chemicals to the reaction zone.
32. The system of claim 31, wherein the one or more chemicals comprise an acid.
33. The system of claim 32, wherein the acid is sulfuric acid.
34. The system of claim 26, wherein the housing contains a removable discharge ring.
35. The system of claim 34, wherein the discharge ring is tapered.
36. The system of claim 26, wherein the valve body contains an annular ring.
37. The system of claim 36, wherein the annular ring is removable.
38. The system of claim 26, wherein there is an annular space formed in the chamber between the valve body and the valve needle when the valve needle is closed on the valve body.
39. The system of claim 26, wherein the nozzles for liquid input transfer water into the chamber.
40. The system of claim 26, wherein the nozzles for liquid input transfer a liquid other than water into the chamber.
41. The system of claim 40, wherein the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.
42. The system of claim 26, wherein an inner diameter of the housing at an end of the housing abutting the valve body is at least 7% larger than an inner diameter of the valve body at its discharge end.
43. The system of claim 26, wherein an inner diameter of the housing at an end of the housing abutting the valve body is about 7% larger than an inner diameter of the valve body at its discharge end.

44. The system of claim 26, wherein the valve needle has a cone with a wide end opposing to its conical tip.
45. The system of claim 44, wherein the cone is tapered in a range of from 45 degrees to 75 degrees.
46. The system of claim 44, wherein the cone is tapered about 45 degrees.
47. The system of claim 44, wherein the valve needle has a diameter at the wide end that is at least 4% larger than an inner diameter of the valve body at its discharge end.
48. The system of claim 44, wherein the valve needle has a diameter at the wide end that is about 4% larger than an inner diameter of the valve body at its discharge end.
49. The system of claim 26, wherein the extruder is a twin screw extruder.
50. The system of claim 26, wherein the extruder has ports for adding steam and/or acid.
51. A method of pretreating a biomass through the system of any one of claims 1-50.
52. A method of pretreating a biomass, the method comprising:
  - (a) conveying the biomass through an extruder from a feeder zone of the extruder to a reaction zone of the extruder, wherein the feeder zone and the reaction zone are separated by a biomass plug formed downstream of the input zone and upstream from the reaction zone;
  - (b) adding steam and/or a chemical to the biomass in the reaction zone to partially treat the biomass;
  - (c) conveying the partially-treated biomass into a valve assembly attached to an output end of the extruder, and treating the partially-treated biomass in the valve assembly, thereby producing a pretreated biomass; and
  - (d) discharging the pretreated biomass through the valve assembly.
53. The method of claim 52, wherein the biomass is conveyed through the extruder at a velocity same as a velocity at which the partially-treated biomass is conveyed through the valve assembly.
54. The method of claim 52, wherein temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and pressure in the reaction zone is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.
55. The method of claim 52, wherein the biomass is selected from the group consisting of:

silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits.

56. The method of claim 52, wherein the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone.
57. The method of claim 52, wherein the chemical is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.
58. The method of claim 52, wherein the extruder comprises one or more screws.
59. The method of claim 58, wherein the extruder comprises two screws.
60. The method of claim 52, wherein the valve assembly comprises:
  - a valve body comprising a large circular section, an intercalary conical section, and a small circular collar containing one or more nozzles for liquid input, the valve body having a chamber formed therein that connects an input end and a discharge end of the valve body, wherein the small circular collar is smaller in inner diameter than the large circular section;
  - a valve needle axially displaceable within the chamber of the valve body; and
  - a housing attached to the discharge end of the valve body and enclosing the valve needle when the valve needle is disengaged with the valve body.
61. The method of claim 60, wherein the housing contains a removable discharge ring.
62. The method of claim 61, wherein the discharge ring is tapered.
63. The method of claim 60, wherein the valve body contains an annular ring.
64. The method of claim 63, wherein the annular ring is removable.
65. The method of claim 60, wherein there is an annular space formed in the chamber between the valve body and the valve needle when the valve needle is closed on the valve body.

66. The method of claim 60, wherein the nozzles for liquid input transfer water into the chamber.
67. The method of claim 60, wherein the nozzles for liquid input transfer a liquid other than water into the chamber.
68. The method of claim 67, wherein the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.
69. The method of claim 60, wherein an inner diameter of the housing at an end of the housing abutting the valve body is at least 7% larger than an inner diameter of the valve body at its discharge end.
70. The method of claim 60, wherein an inner diameter of the housing at an end of the housing abutting the valve body is about 7% larger than an inner diameter of the valve body at its discharge end.
71. The method of claim 60, wherein the valve needle has a cone with a wide end opposing to its conical tip.
72. The system of claim 71, wherein the cone is tapered in a range of from 45 degrees to 75 degrees.
73. The method of claim 71, wherein the cone is tapered about 45 degrees.
74. The method of claim 71, wherein the valve needle has a diameter at the wide end that is at least 4% larger than an inner diameter of the valve body at its discharge end.
75. The method of claim 71, wherein the valve needle has a diameter at the wide end that is about 4% larger than an inner diameter of the valve body at its discharge end.
76. The method of claim 52, wherein the treatment of the partially-treated biomass in the valve assembly comprises subjecting the partially-treated biomass to an elevated pressure and/or temperature same to the reaction zone.
77. The method of claim 52, wherein the treatment of the partially-treated biomass in the valve assembly comprises adding a substance at an upstream end of the valve assembly to the partially-treated biomass.
78. The method of claim 77, wherein the substance comprises an acid.
79. The method of claim 78, wherein the acid comprises sulfuric acid.

80. The method of claim 52, wherein the extruder is a twin screw extruder.
81. The method of claim 52, wherein the extruder has ports for adding steam and/or acid.
82. A method of pretreating a biomass, the method comprising:
- (a) conveying the biomass through an extruder from a feeder zone of the extruder to a reaction zone of the extruder, wherein the feeder zone and the reaction zone are separated by a biomass plug formed downstream of the input zone and upstream from the reaction zone;
  - (b) adding steam and/or a chemical to the biomass in the reaction zone to partially treat the biomass;
  - (c) conveying the partially-treated biomass into an extension compartment attached to an output end of the extruder, and
  - (d) treating the partially-treated biomass in the extension compartment, thereby producing a pretreated biomass.
83. The method of claim 82, wherein the method further comprising adding an acid at a downstream end of the extruder as the biomass exits the extruder.
84. The method of claim 82, wherein the extension compartment is formed by a tube.
85. The method of claim 82, wherein the extension compartment is formed by a vessel.
86. The method of claim 82, wherein the extension compartment is formed by a valve assembly.
87. The method of claim 82, wherein the extension compartment is capable of discharging the pretreated biomass in a continuous manner.
88. The method of claim 82, wherein the extension compartment is capable of discharging the pretreated biomass in a semi-continuous manner.
89. The method of claim 82, wherein the extension compartment is capable of discharging the pretreated biomass in batches.
90. The method of claim 82, wherein the biomass is conveyed through the extruder at a velocity same as a velocity at which the partially-treated biomass is conveyed through the extension compartment.
91. The method of claim 82, wherein the extension compartment is pressurized.
92. The method of claim 82, wherein the extension compartment is equipped with one or more nozzles for liquid input.

93. The method of claim 92, wherein the nozzles for liquid input transfer water into the chamber.
94. The method of claim 92, wherein the nozzles for liquid input transfer a liquid other than water into the chamber.
95. The method of claim 94, wherein the liquid is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.
96. The method of claim 82, wherein temperature in the reaction zone is elevated to 50-500 °C, 75-400 °C, 100-350°C, 150-300°C, 200-250°C, or 150-300°C, and pressure in the reaction zone is elevated to 50-1000 PSI, 100-750 PSI, 200-600 PSI, 300-500 PSI or 350-450 PSI.
97. The method of claim 82, wherein the biomass is selected from the group consisting of: silage, agricultural residues, com stover, bagasse, sorghum, nuts, nut shells, coconut shells, Distillers Dried Solubles, Distillers Dried Grains, Condensed Distillers Solubles Distillers Wet Grains, Distillers Dried Grains with Solubles, woody materials, sawdust, wood chips, wood pellets, timber slash, mill scrap, municipal waste, waste paper, recycled toilet papers, yard clippings, and energy crops such as poplars, willows, switchgrass, alfalfa, and prairie bluestem, non-woody plant matter, cellulosic material, lignocellulosic material, hemicellulosic material, carbohydrates, corn, sugar cane, grasses, high biomass sorghum, bamboo, corncobs, and peels and pits.
98. The method of claim 82, wherein the biomass is treated for less than 60, 55, 50, 45, 40, 35, 30, 25, 20, 19, 18, 17, 16, 15, 14, 13, 12, 10, 9, 8, 7, 6, 5, 4, 3, 2, or 1 second in the reaction zone.
99. The method of claim 82, wherein the chemical is selected from the group consisting of: an acid, a base, an alcohol, a ketone, an aldehyde, a solvent, or a combination thereof.
100. The method of claim 82, wherein the extruder comprises one or more screws.
101. The method of claim 100, wherein the extruder comprises two screws.

FIG. 1

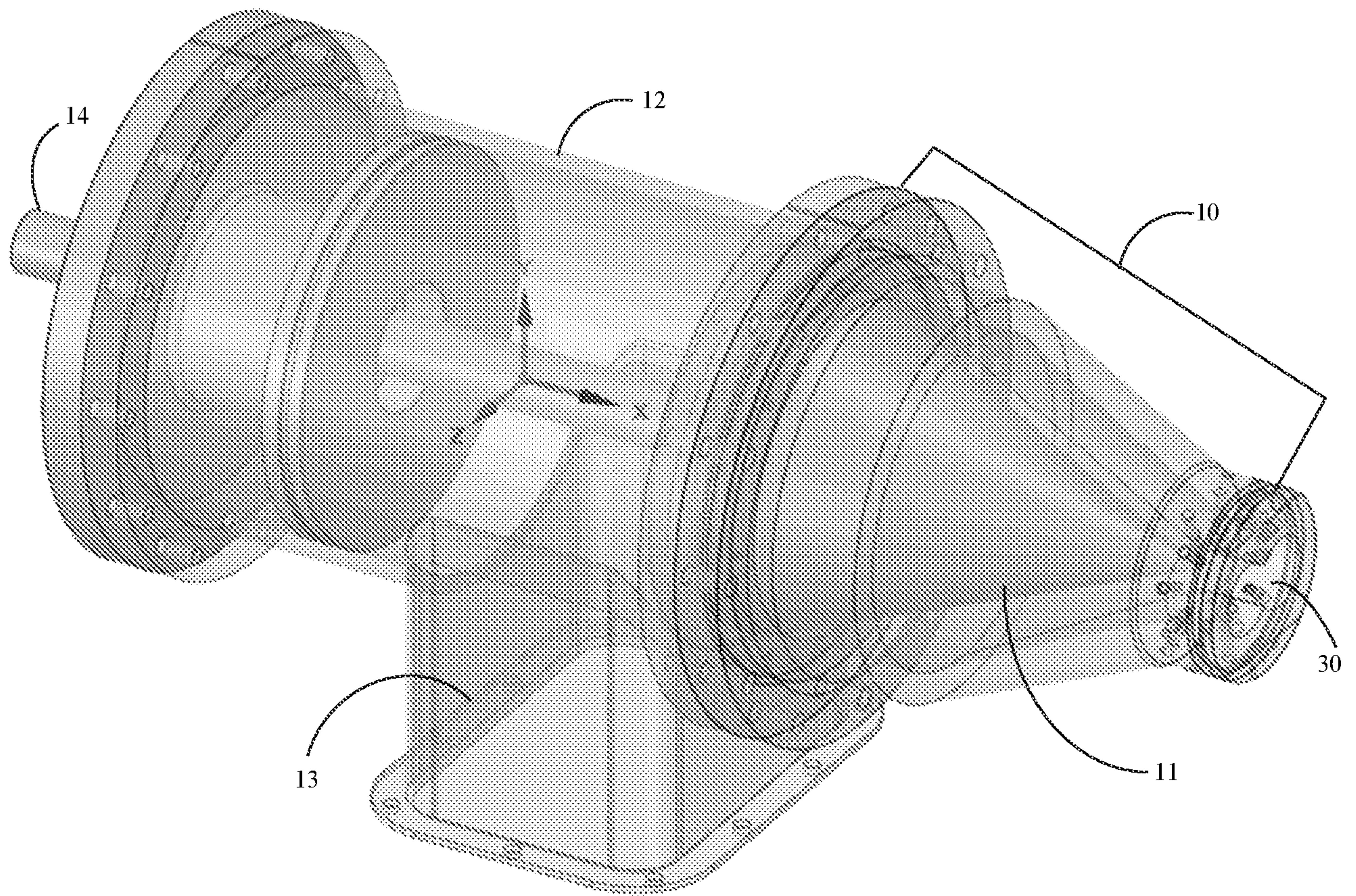
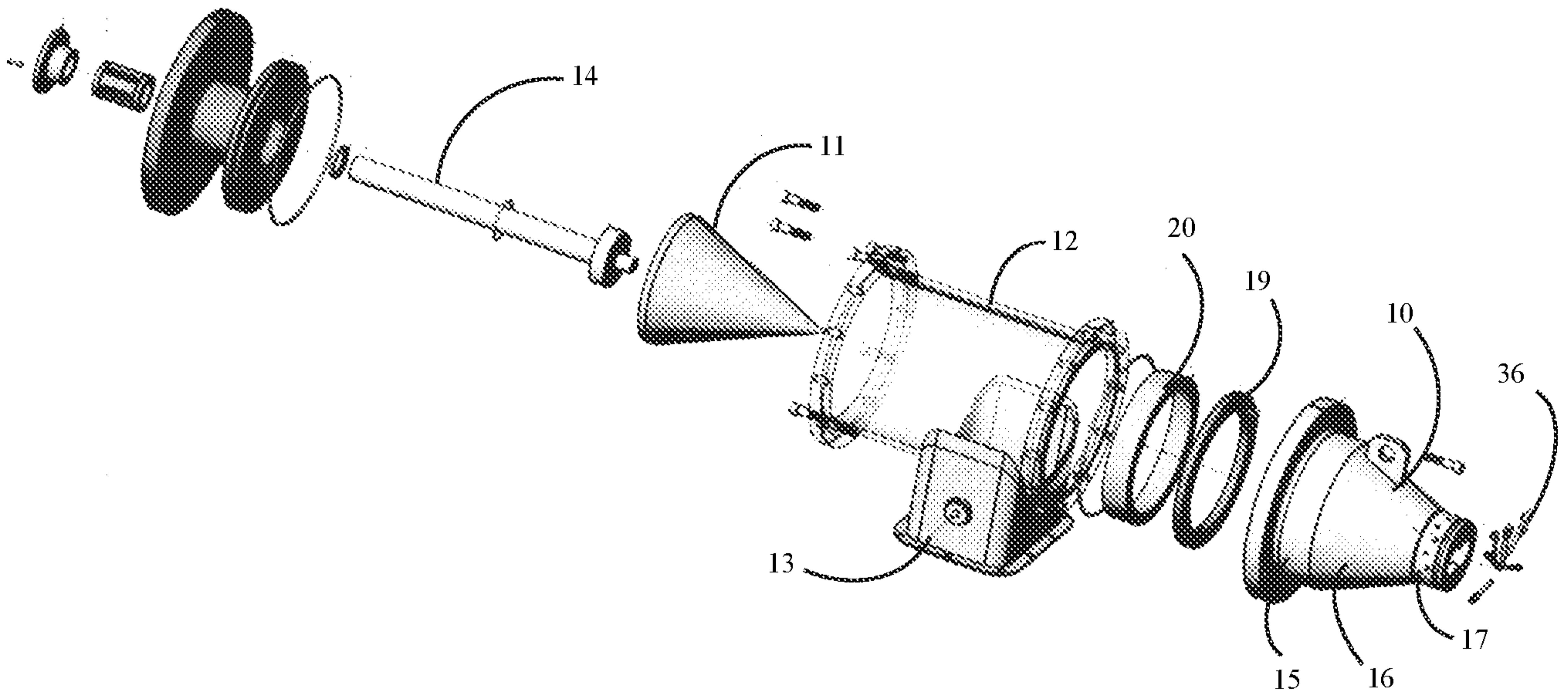


FIG. 2



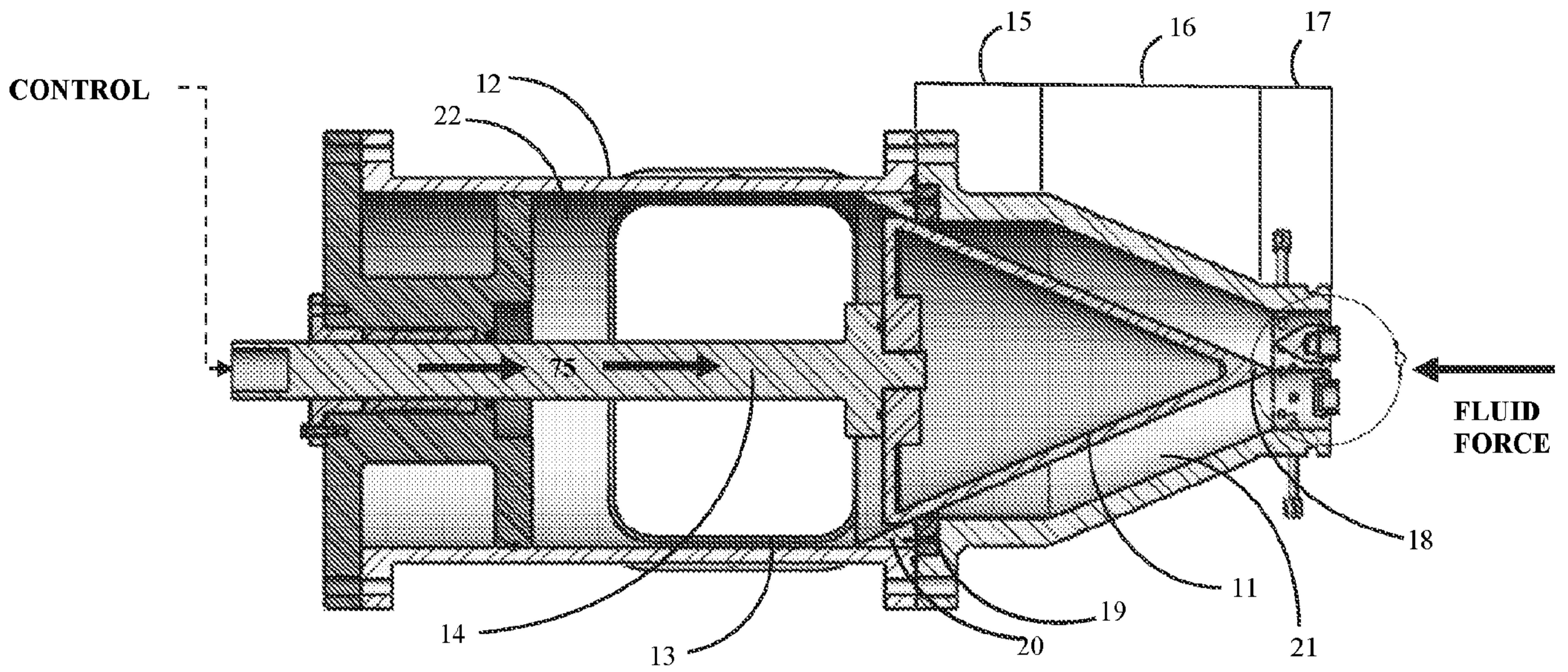


FIG. 3A

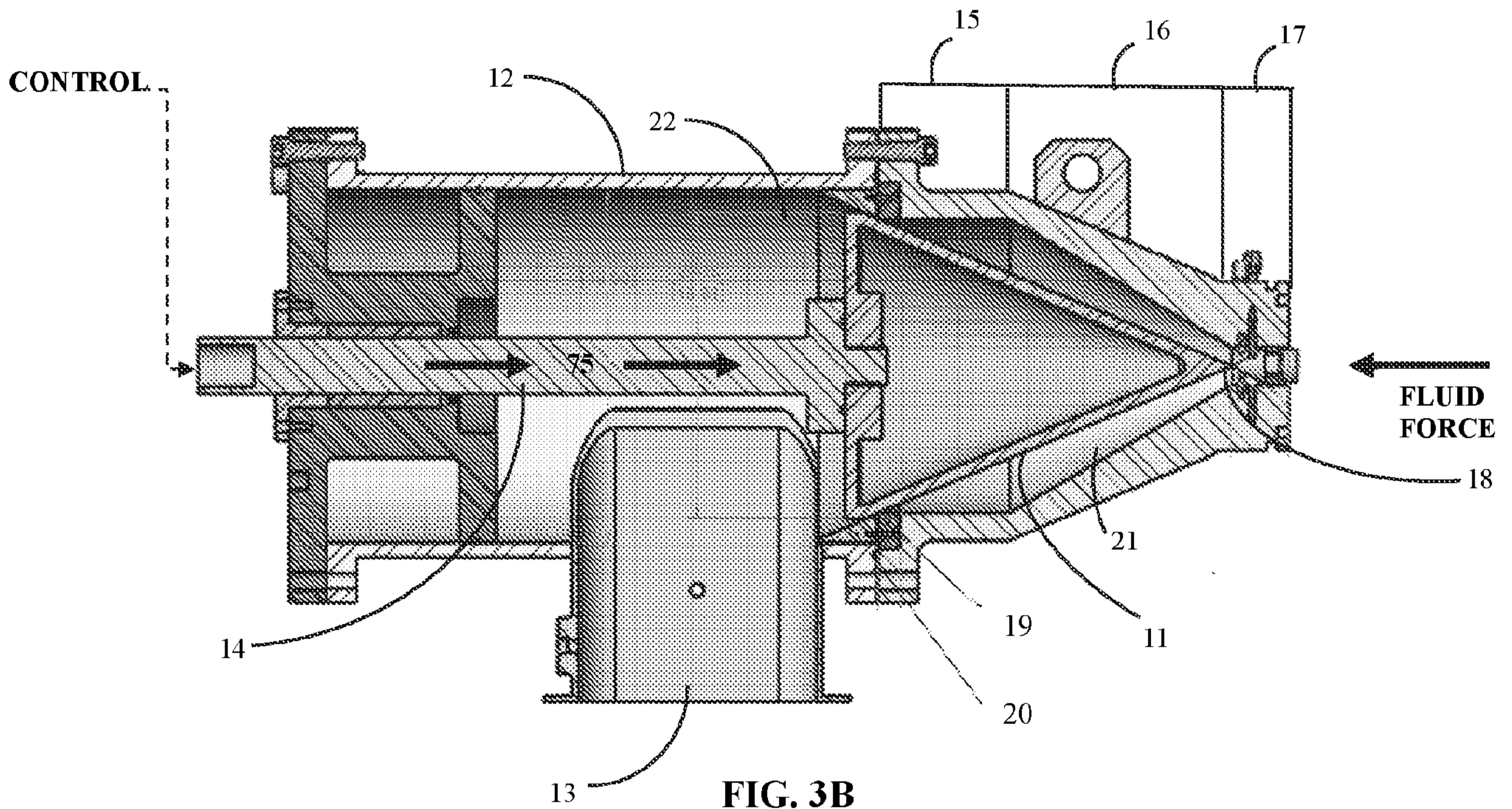


FIG. 3B

FIG. 4

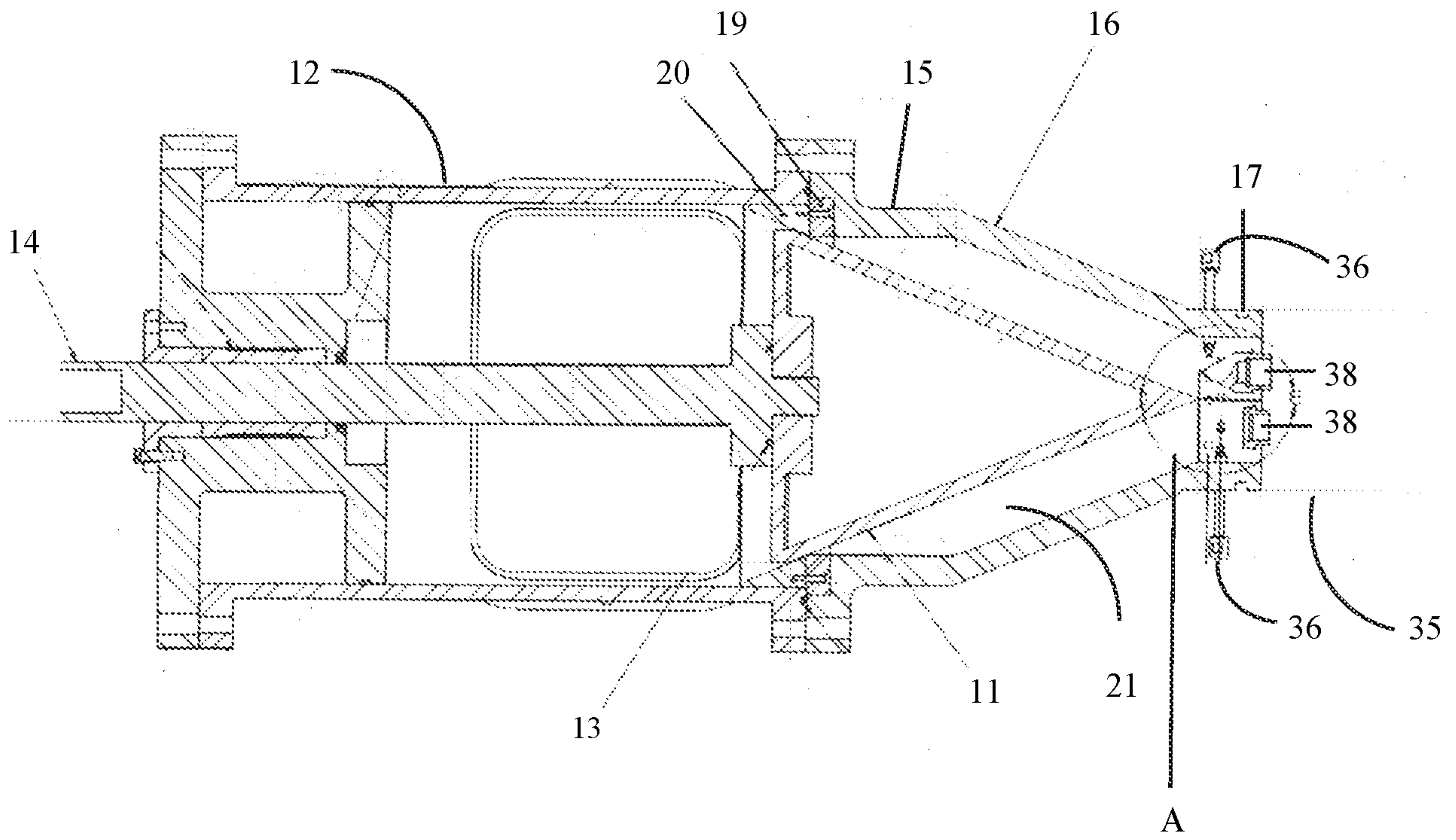


FIG. 5

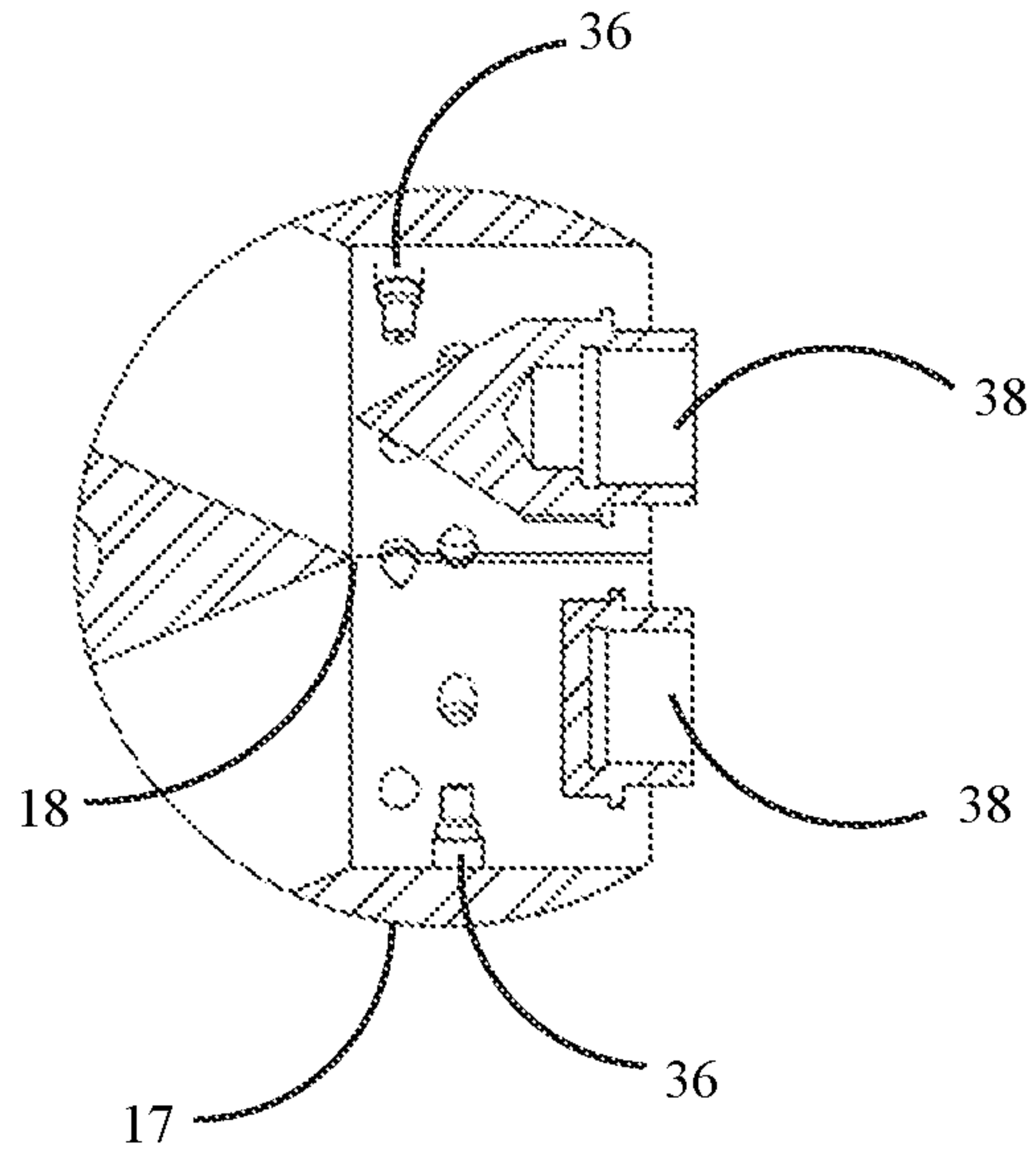
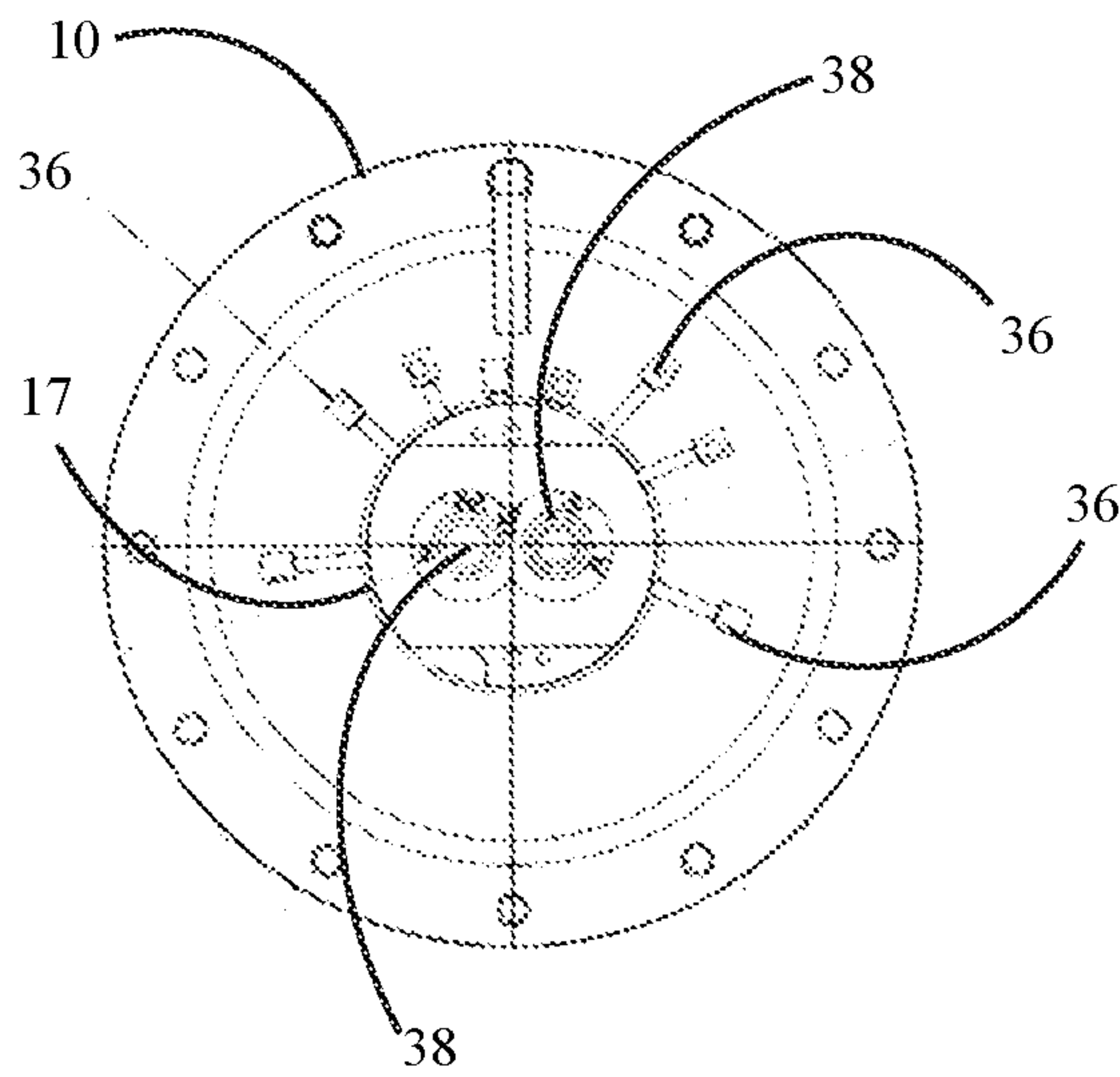


FIG. 6



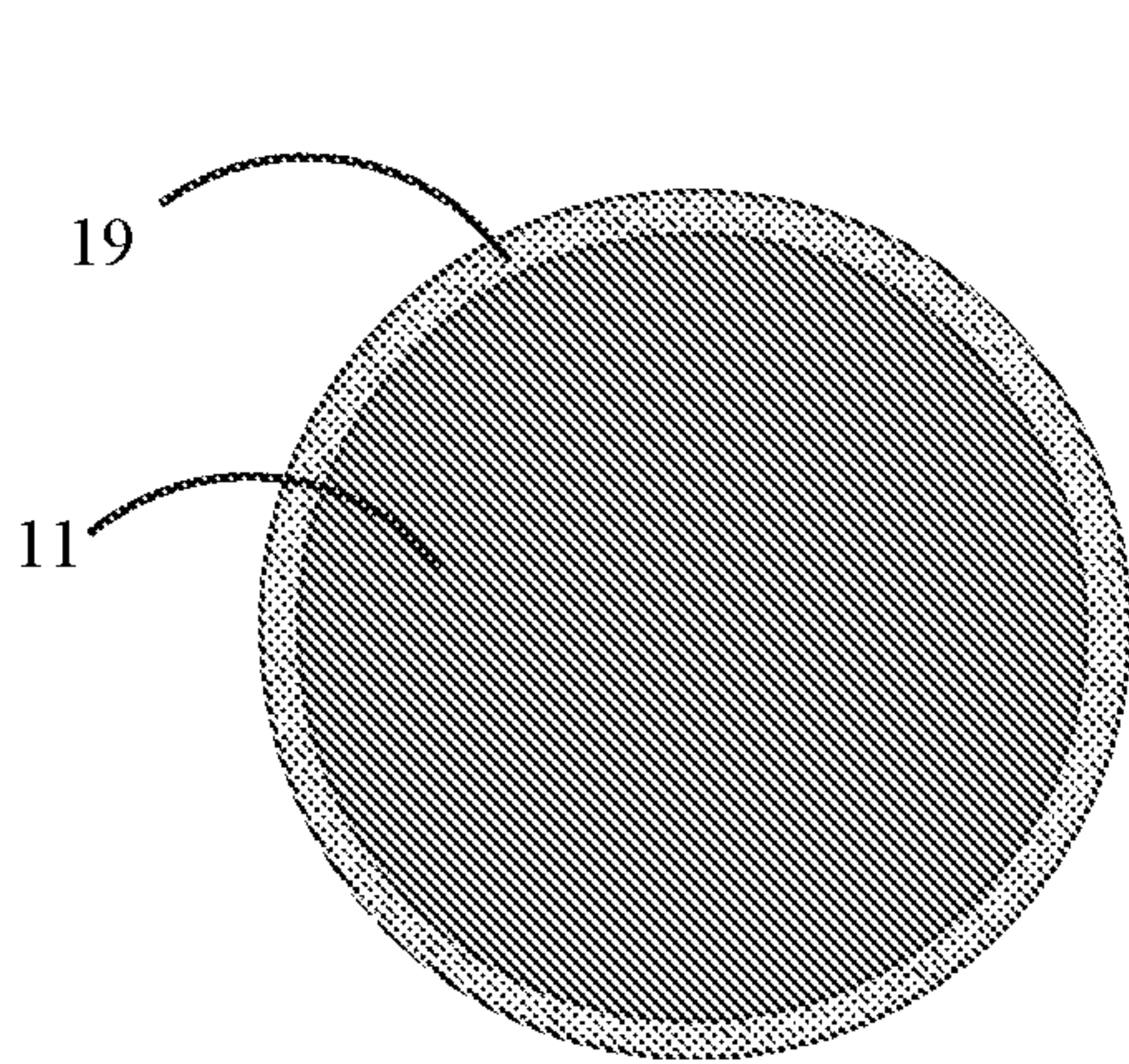


FIG. 7A

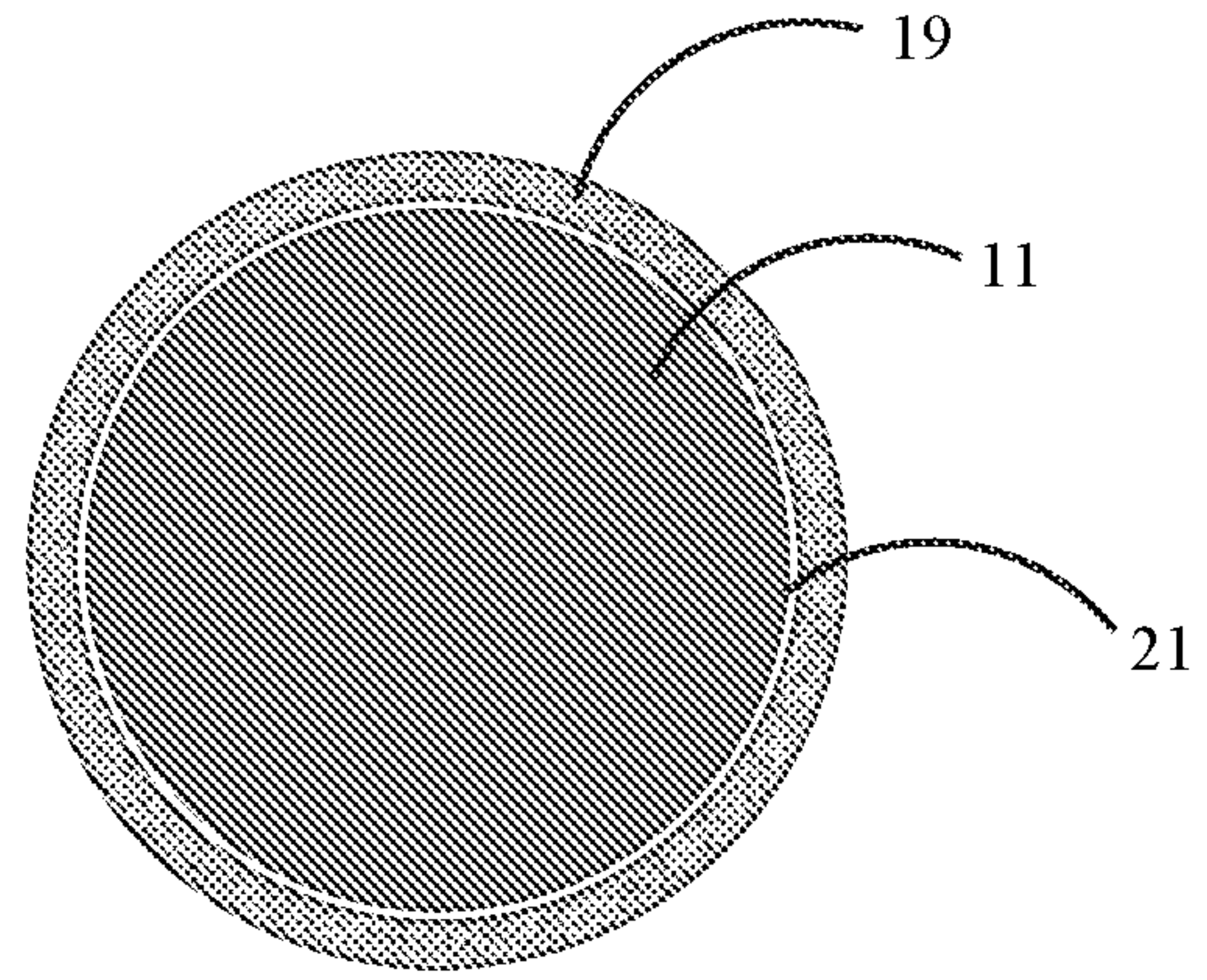


FIG. 7B

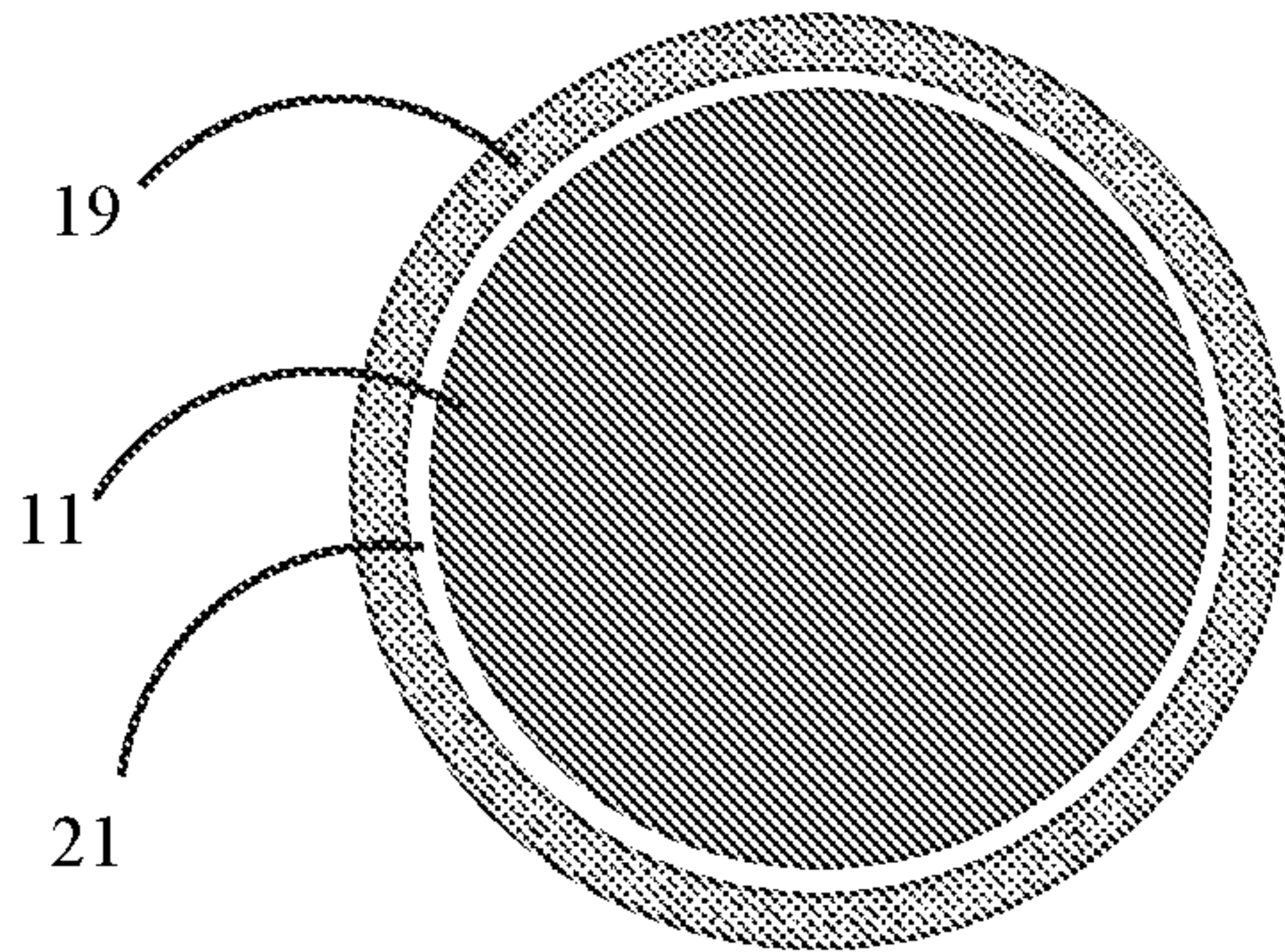


FIG. 7C

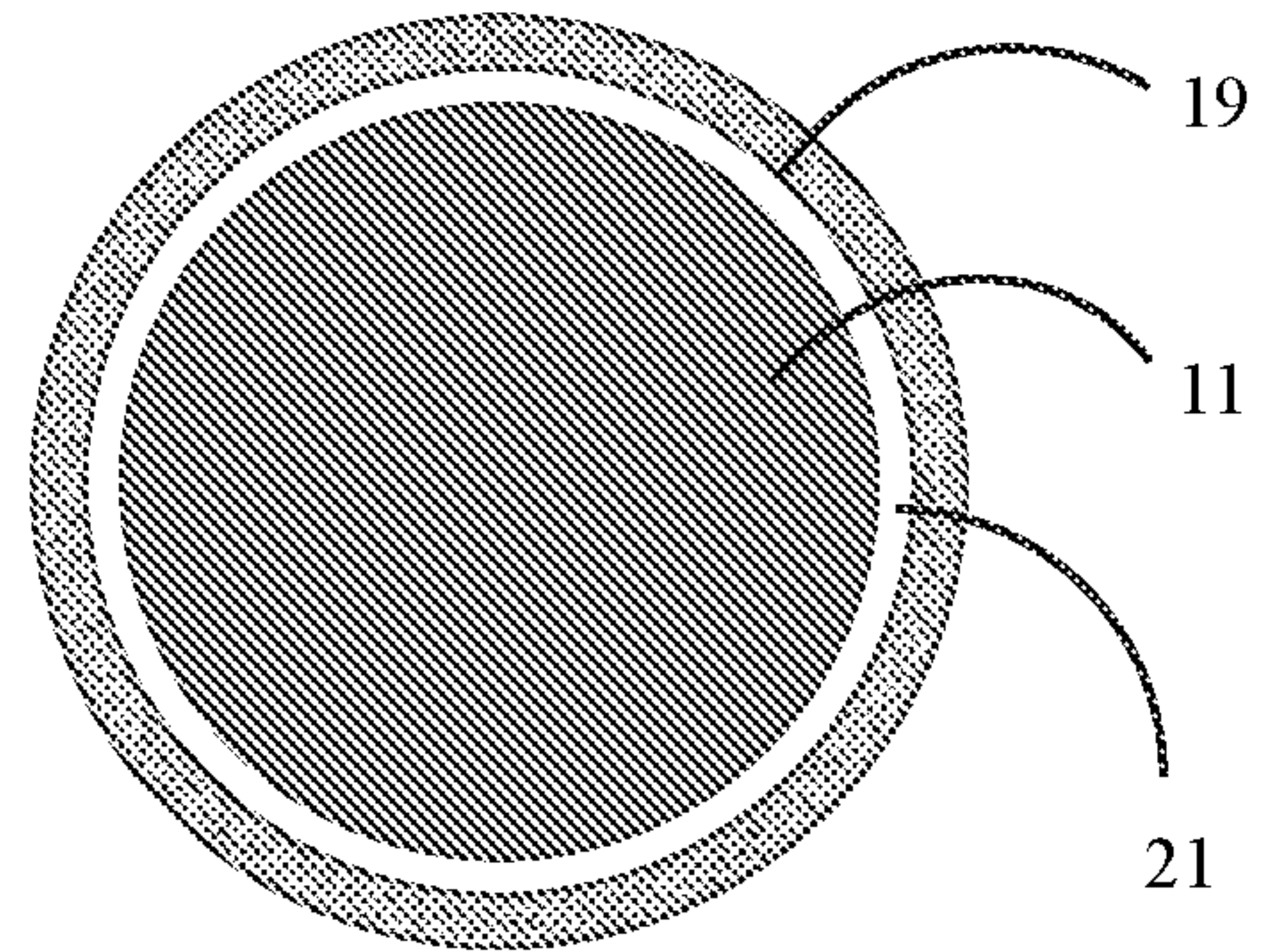


FIG. 7D