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(54) **CONTINUOUS SOLID FILTRATION FOR SOLID-LIQUID SEPARATIONS**

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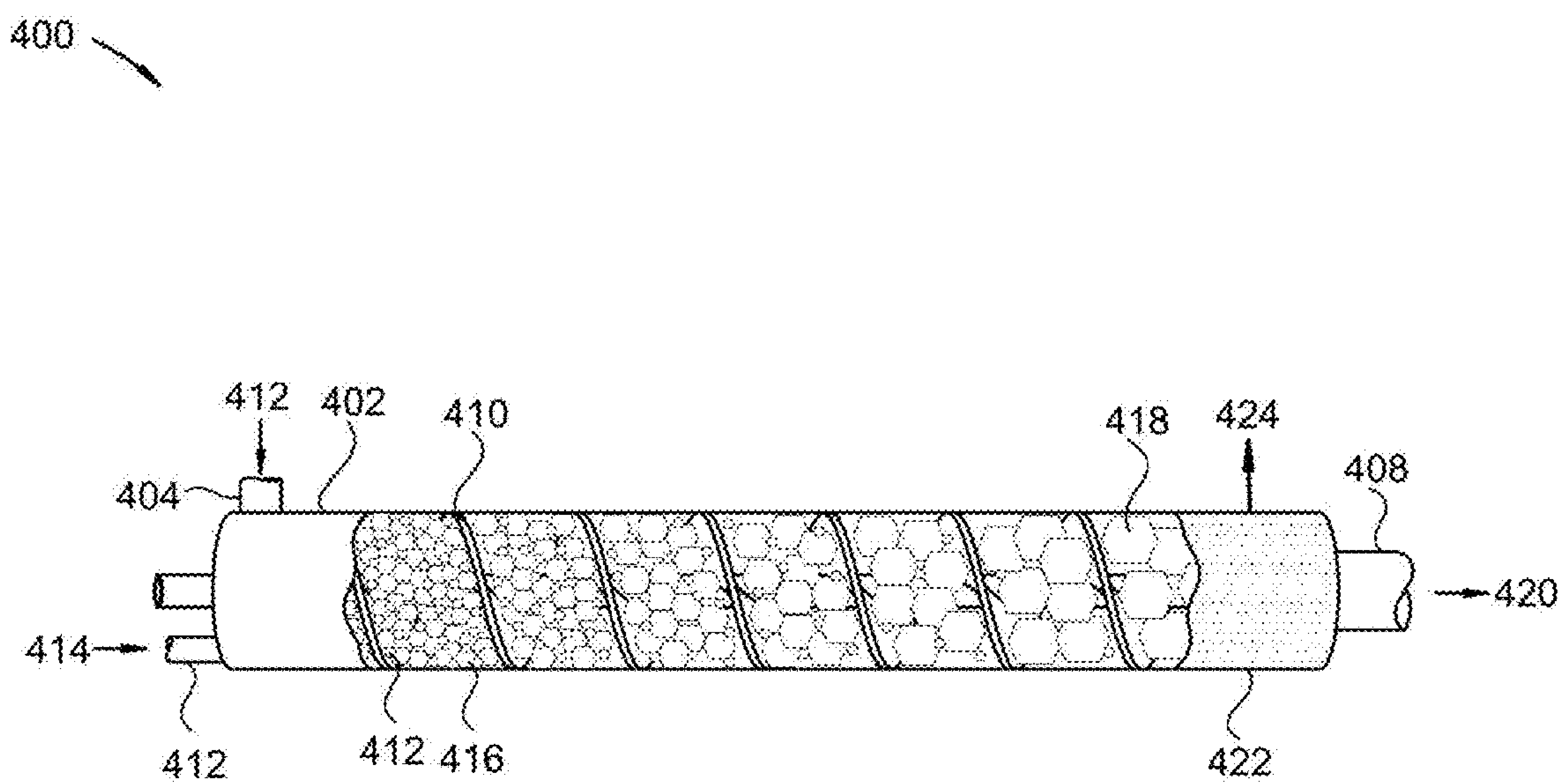
(57) **ABSTRACT**

A method for clarifying a process fluid is disclosed. The process fluid is provided to a transport device. The process fluid comprises a process liquid that entrains a first solid of a first average particle size. A second solid of a second average particle size is provided to the transport device. The second average particle size is larger than the first average particle size. The process fluid passes through the second solid. The first solid adsorbs to, deposits on, fuses with, or is trapped by the second solid, producing a first solid-depleted process fluid and a first solid-loaded second solid. The first solid-loaded second solid is removed from the transport device continuously. The second solid is reconstituted from a portion of the first solid-loaded second solid. The second solid is recycled to the transport device. In this manner, the process fluid is clarified.



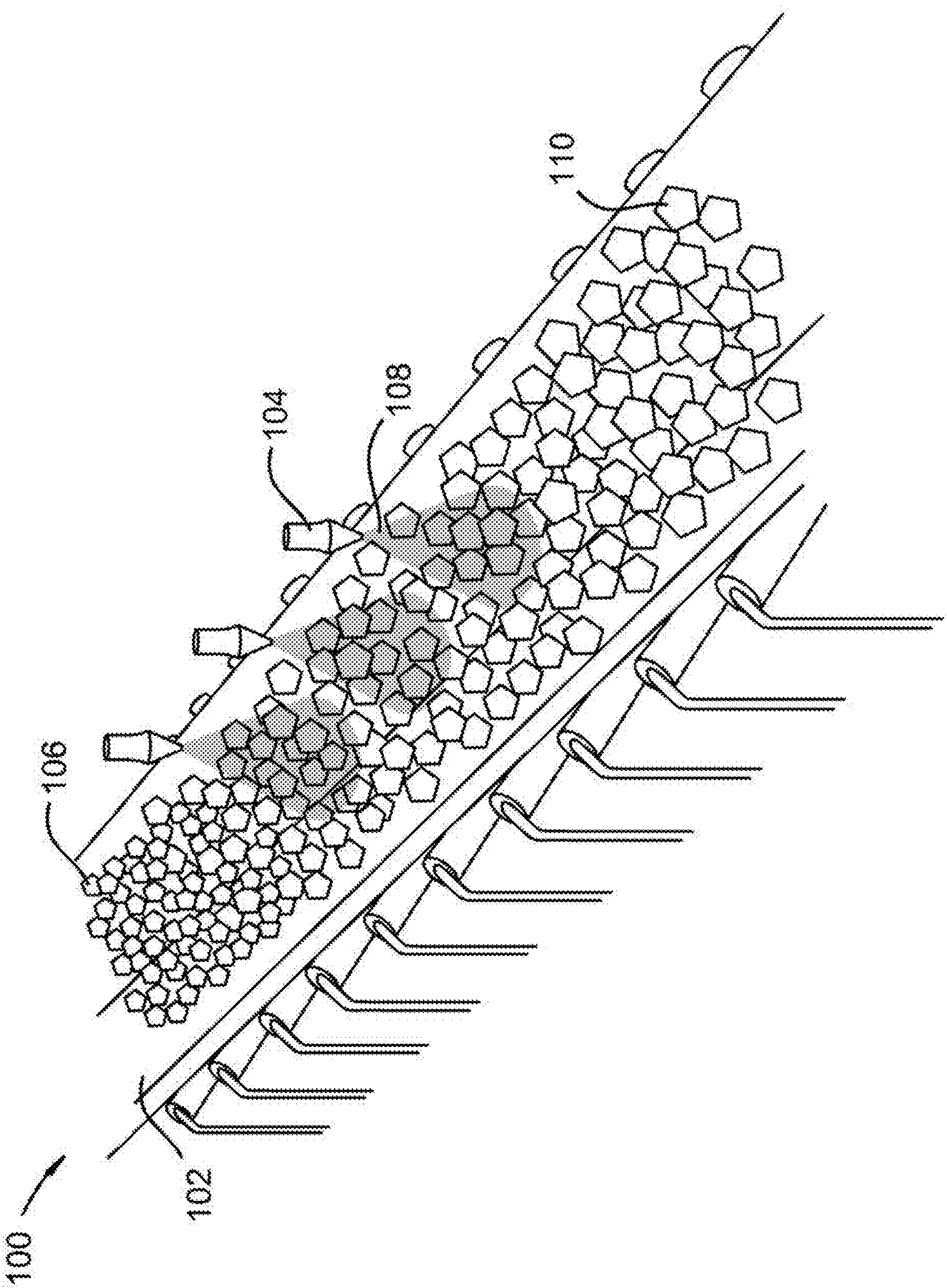


FIG. 1A

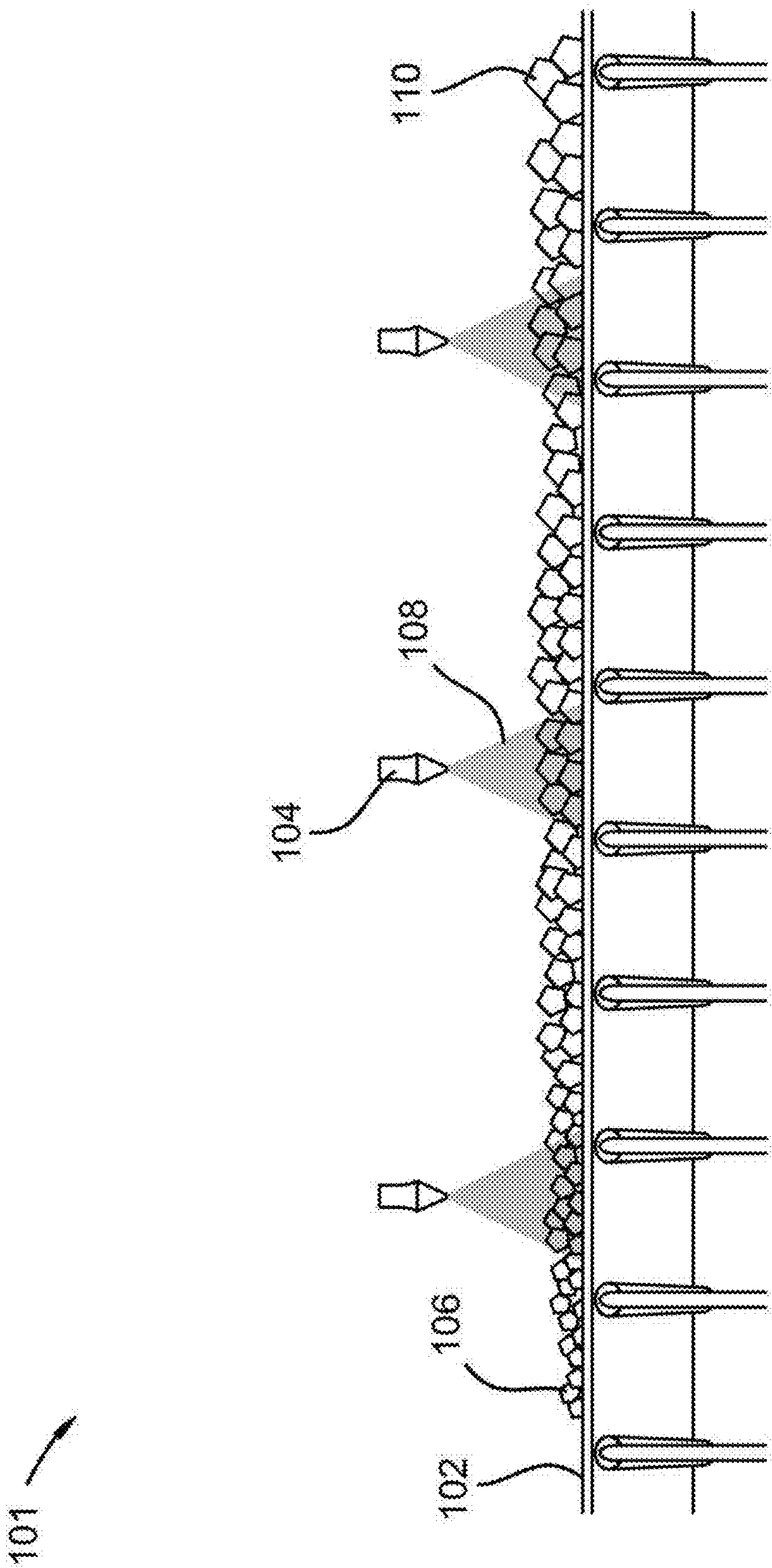


FIG. 1B

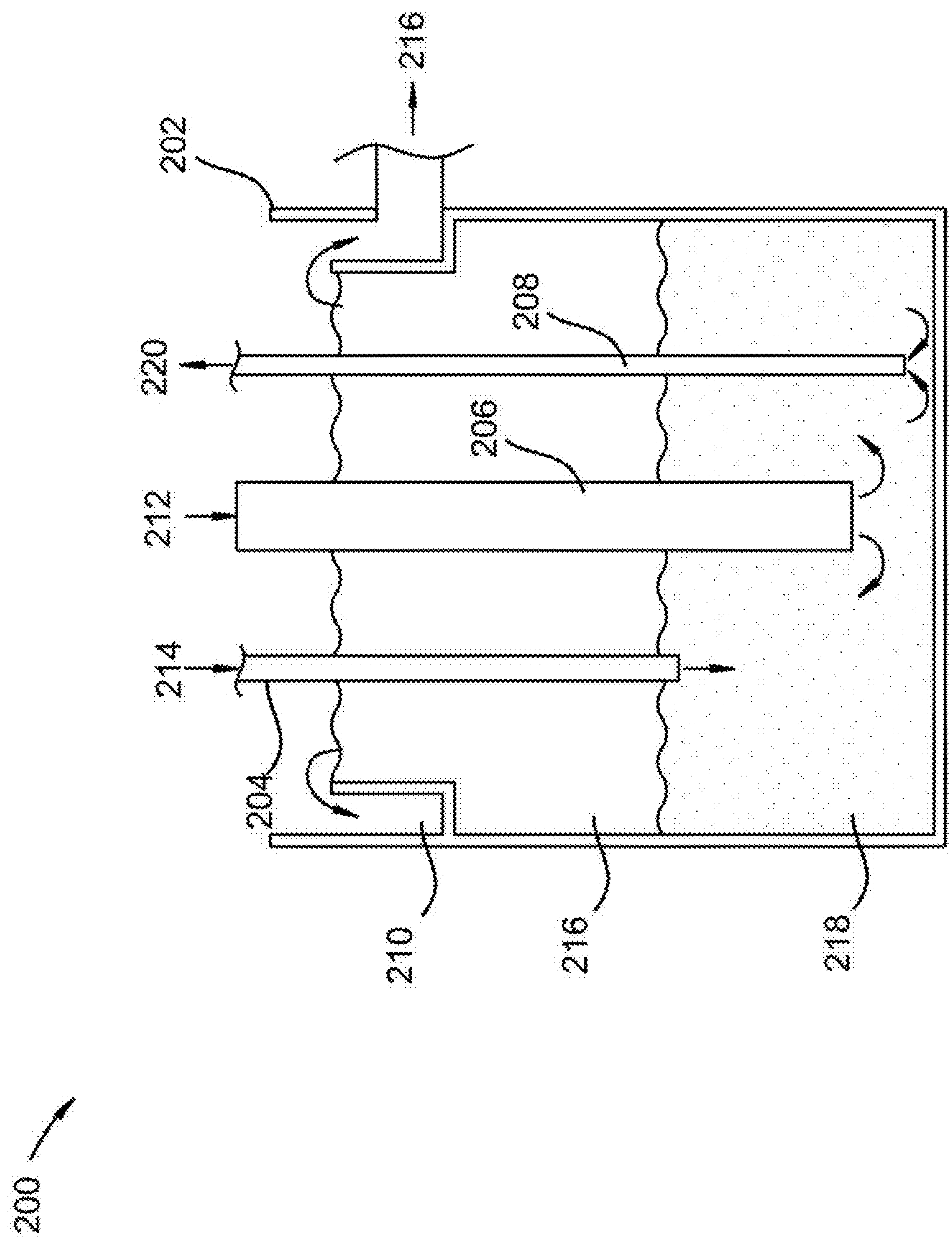


FIG. 2

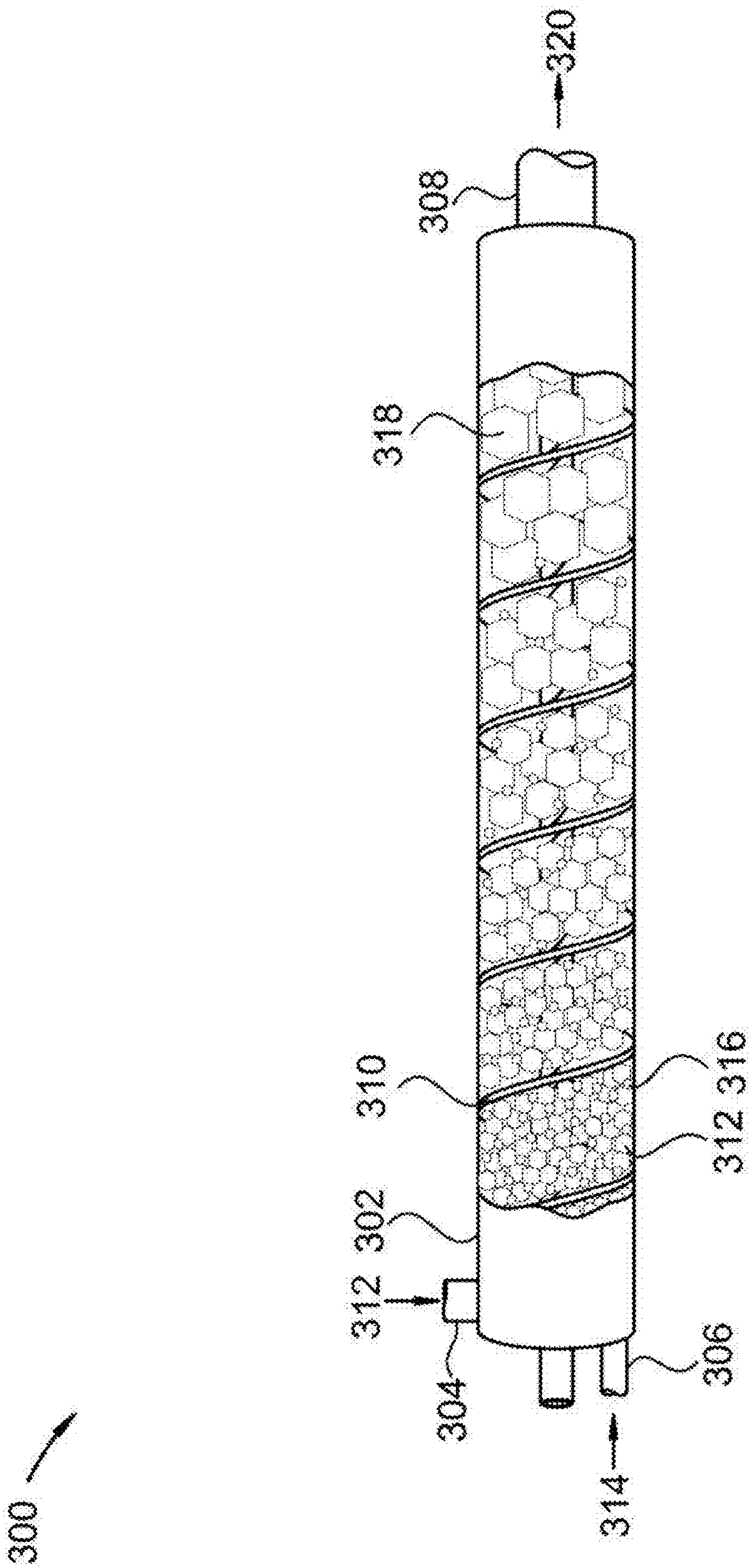


FIG. 3

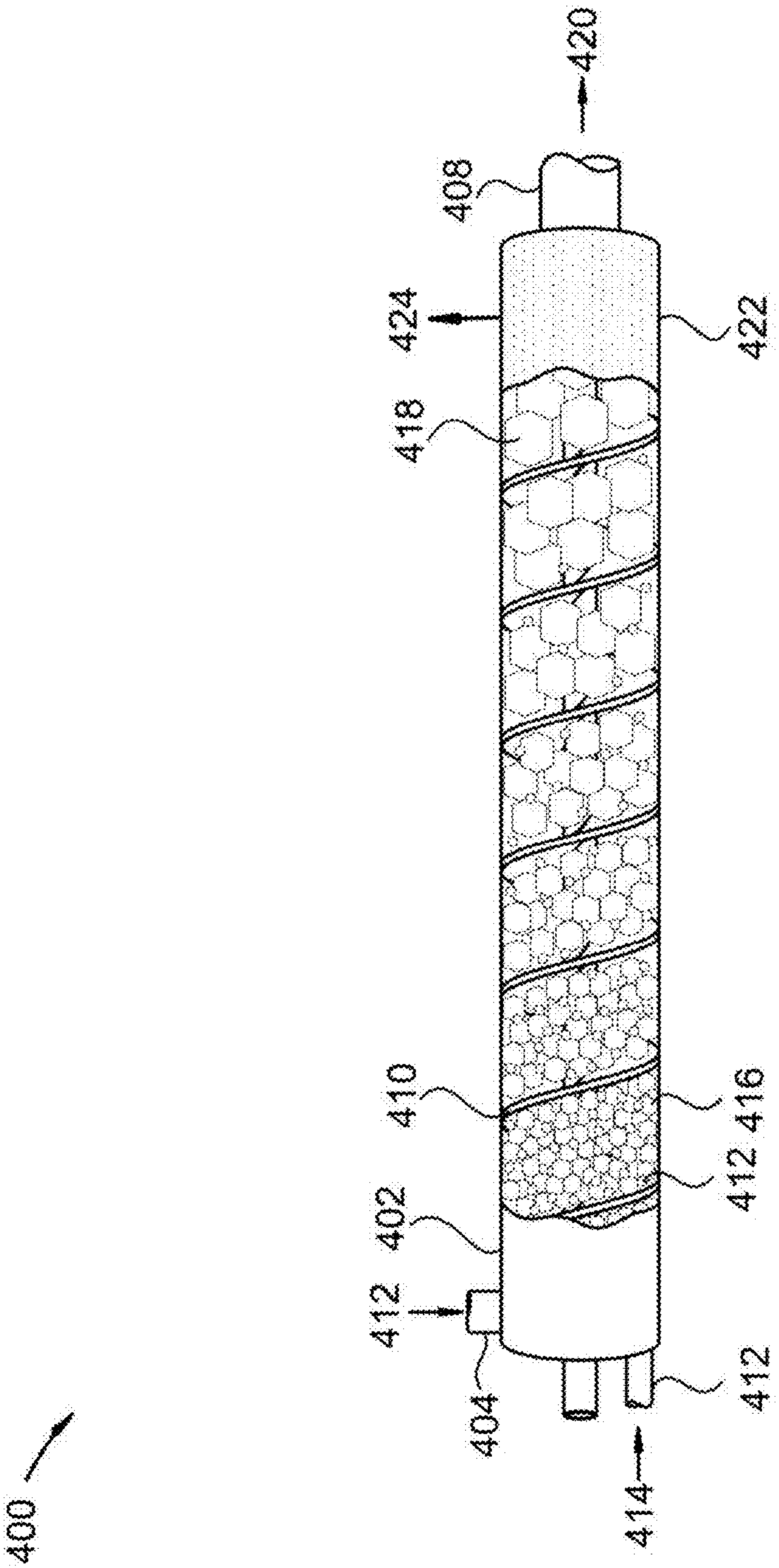


FIG. 4

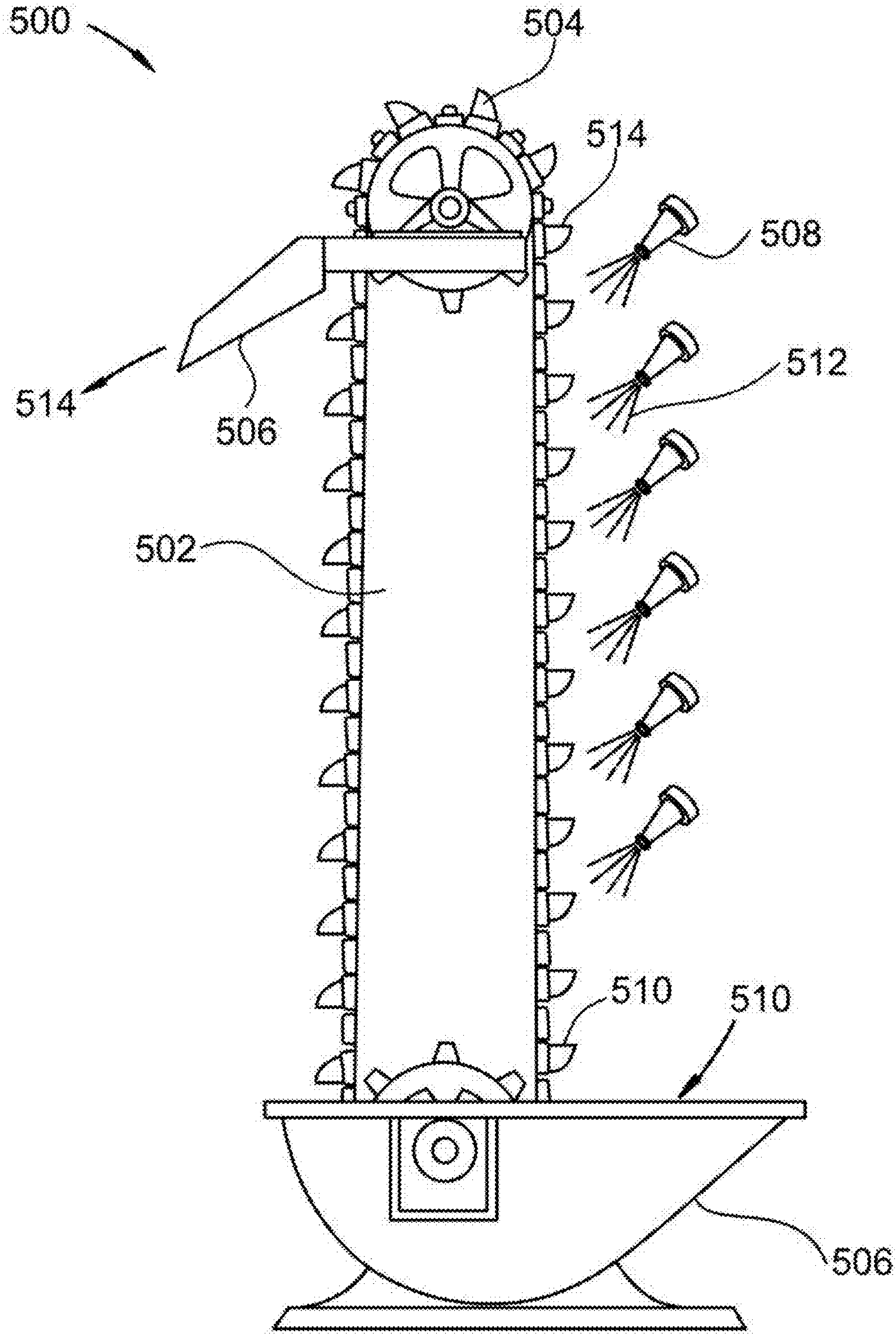


FIG. 5

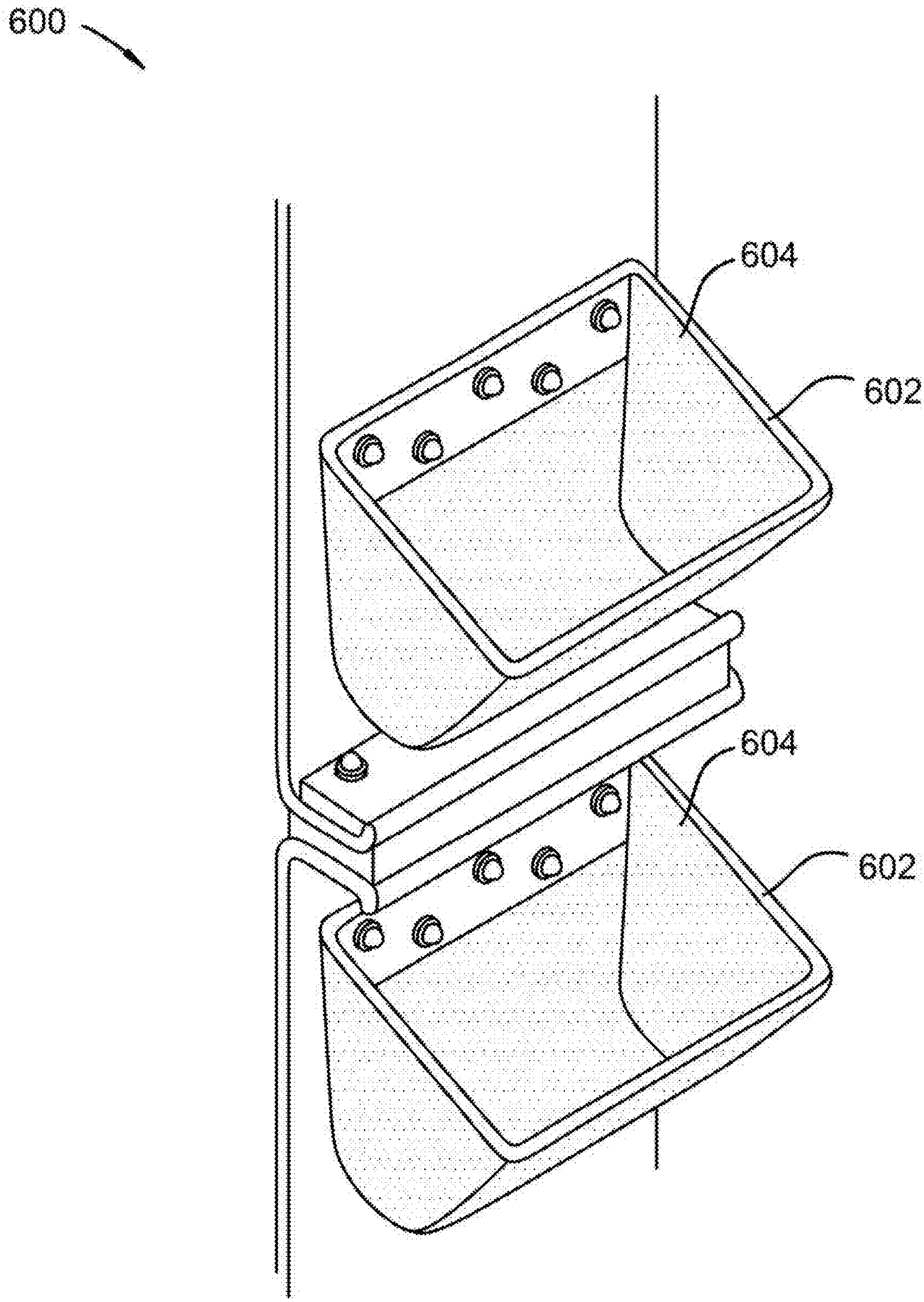


FIG. 6

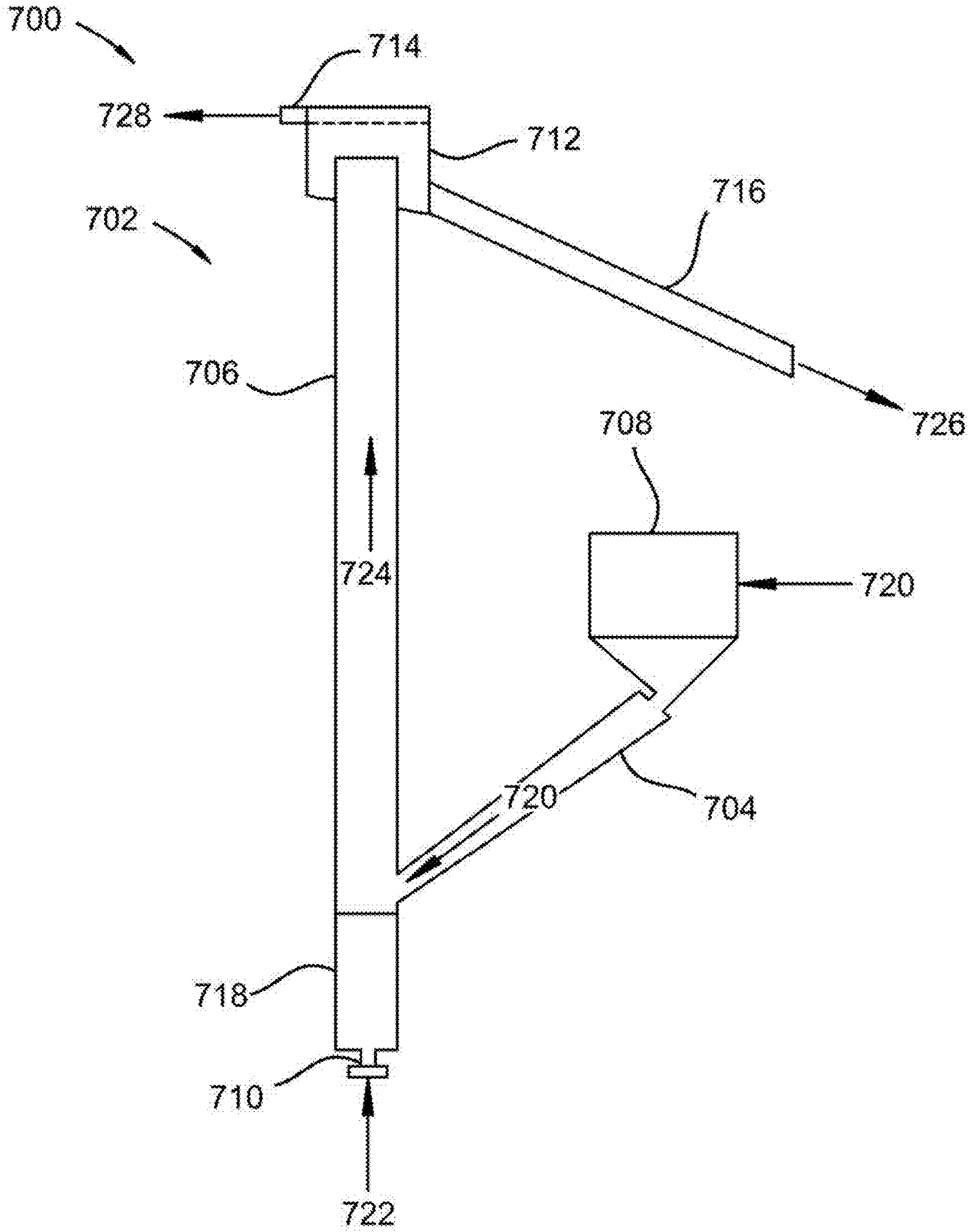


FIG. 7

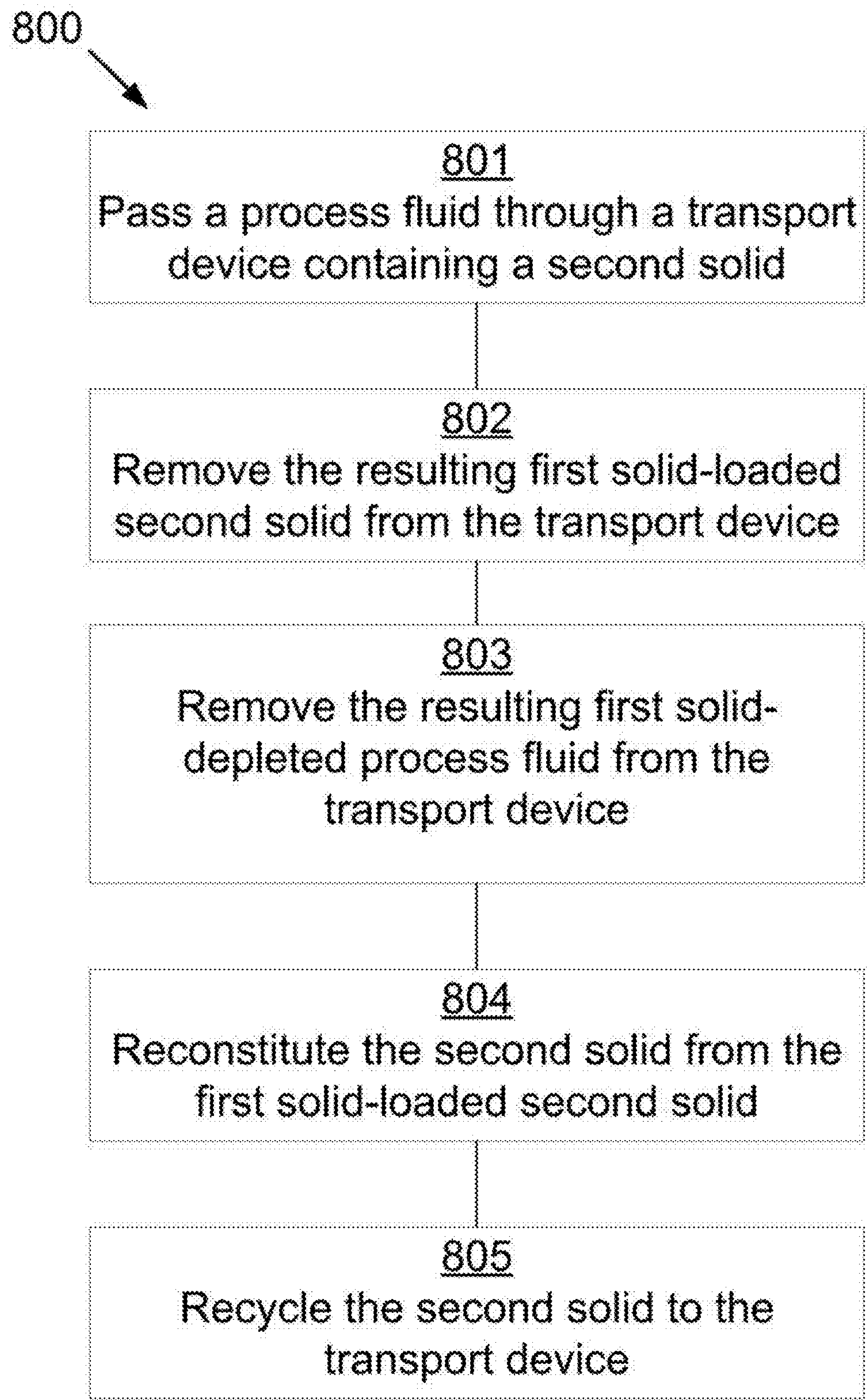

800
801
Pass a process fluid through a transport device containing a second solid
802
Remove the resulting first solid-loaded second solid from the transport device
803
Remove the resulting first solid-depleted process fluid from the transport device
804
Reconstitute the second solid from the first solid-loaded second solid
805
Recycle the second solid to the transport device

FIG. 8

CONTINUOUS SOLID FILTRATION FOR SOLID-LIQUID SEPARATIONS

[0001] This invention was made with government support under DE-FE0028697 awarded by The Department of Energy. The government has certain rights in the invention.

FIELD OF THE INVENTION

[0002] This invention relates generally to solid/liquid separation. More particularly, we are interested in removing solids from liquids continuously.

BACKGROUND

[0003] Removing solids from liquids is a unit operation common to almost all heavy industries. Whether the process requires the removal of biomass and dirt from water, solid carbon dioxide from a cryogenic liquid, or dust from oil, solid/liquid separation is a constant. Filter presses, thickeners, clarifiers, and other devices all separate solids. A common technique for removing fine solids is sedimentation filtration. The filtering media is exclusively sand or similar granular bulk materials.

[0004] U.S. Pat. No. 6,143,186, to Van Unen, teaches a device for continuous filtration of liquids. A liquid with dirt to remove is fed through one wall of a vertical sedimentation filter using bulk material as a filter media, and is removed from the opposite wall of the sedimentation filter. The bulk material, now with dirt entrained on it, is suctioned into a separations device which recycles the bulk material into the chamber and discharges the dirt. The present disclosure differs from this disclosure in that the chamber is required to be rectangular, inlets and outlet are required to be in the walls, a portion of the liquid being filtered is used to remove the bulk material and dirt during the suction step, and the entire process is limited to ambient conditions. This disclosure is pertinent and may benefit from the methods disclosed herein and is hereby incorporated for reference in its entirety for all that it teaches.

[0005] U.S. patent Ser. No. 13/409,856, to Self, et al., teaches various methods for lowering levels of carbon dioxide and other atmospheric pollutants. Gravity separation of carbonates or bicarbonates is conducted gravity separation, mechanical separation, and thermal evaporation. Optionally, flocculation and other methods of crystal growth are utilized. The present disclosure differs from this disclosure in that no sedimentation filtration or similar utilized. Further, there is no process to separate the larger carbonates and bicarbonates from their flocculants or similar, to reuse them for further separation. This disclosure is pertinent and may benefit from the methods disclosed herein and is hereby incorporated for reference in its entirety for all that it teaches.

[0006] U.S. Pat. No. 6,942,807, to Meng, et al., teaches a water filtration device and method for removing heavy metals and organic compounds from water. An iron filter is provided for precipitating the heavy metals and a sand filter for removing the heavy metals and organic compounds. The iron filter is vibrated or otherwise agitated to cause the precipitates to be removed from the iron. The present disclosure differs from this disclosure in that two stages of filtration are required, the sand filter is not continually recycled for reuse, and vibration is required. This disclosure is pertinent and may benefit from the methods disclosed herein and is hereby incorporated for reference in its entirety for all that it teaches.

[0007] In Microfiltration (Martin, J. F. et al. 1991. J. Air Waste Manage. Assoc. 41:1653-1657) and adsorption and magnetic filtration (Chen, W. Y. et al. 1991. Res. J. Water Pollut. Control Fed. 63:958-964), an adsorption and magnetic filtration process is disclosed. Heavy metals are adsorbed onto fine magnetic particles coated with ferrihydrite. The magnetic particles are then collected using a magnetic filter. Finally, the magnetic particles are regenerated by metal desorption and then reused. The present disclosure differs from this disclosure in that magnetic filtration and metal desorption are required in order to accomplish the filtration and recycling. This disclosure is pertinent and may benefit from the methods disclosed herein and is hereby incorporated for reference in its entirety for all that it teaches.

[0008] U.S. Pat. No. 7,247,245, to Proulx, et al., teaches a filtration cartridge and process for filtering a slurry. A filter cartridge is used for filtering solids from a slurry. The present disclosure differs from this disclosure in that the filter cartridge has to be replaced when full. This disclosure is pertinent and may benefit from the methods disclosed herein and is hereby incorporated for reference in its entirety for all that it teaches.

[0009] U.S. Pat. No. 5,900,159, to Engel, et al., teaches a method for separating a liquid from a slurry in the presence of a gas. The slurry is degasified and then separated through a cross-flow filter. The present disclosure differs from this disclosure in that a cross-flow filter is required. This disclosure is pertinent and may benefit from the methods disclosed herein and is hereby incorporated for reference in its entirety for all that it teaches.

SUMMARY

[0010] A method for clarifying a process fluid is disclosed. The process fluid is provided to a transport device. The process fluid comprises a process liquid that entrains a first solid of a first average particle size. A second solid of a second average particle size is provided to the transport device. The second average particle size is larger than the first average particle size. The process fluid passes through the second solid. The first solid adsorbs to, deposits on, fuses with, or is trapped by the second solid, producing a first solid-depleted process fluid and a first solid-loaded second solid. The first solid-loaded second solid is removed from the transport device continuously. The second solid is reconstituted from a portion of the first solid-loaded second solid. The second solid is recycled to the transport device. In this manner, the process fluid is clarified.

[0011] The first solid and the second solid may comprise the same compound. The second solid may be reconstituted from the first solid-loaded second solid by a sizing process comprising crushing, grinding, screening, extruding, stamping, shaping, or a combination thereof.

[0012] The first solid may comprise a frozen condensable or absorbed gas or gases and the second solid may comprise a frozen condensable or absorbed gas or gases. The frozen condensable or absorbed gas may comprise carbon dioxide, nitrogen oxide, sulfur dioxide, nitrogen dioxide, sulfur trioxide, hydrogen sulfide, hydrogen cyanide, or combinations thereof. The frozen condensable or absorbed gas or gases derive from vitiated flows, producer gases, or other industrial flows, wherein the vitiated flows are produced from coal, biomass, natural gas, oil, and other common fuels. The first solid may further comprise particulates, mercury, other heavy metals, condensed organics, soot, inorganic ash components, other impurities common to the vitiated flows, the producer gases, or the other industrial flows, or combinations thereof

[0013] The transport device may comprise a conveyor belt, bucket elevator, circulating fluidized-bed, hail tower, screw conveyor, leach tank, flow channel, tube, porous filter, screen filter, or channel.

[0014] The process liquid may comprise any compound or mixture of compounds with a freezing point above a temperature at which the first solid solidifies.

[0015] The process fluid may further comprise a third solid of a third average particle size, the third average particle size being smaller than the second average particle size.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] In order that the advantages of the invention will be readily understood, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the invention and are not therefore to be considered limiting of its scope, the invention will be described and explained with additional specificity and detail through use of the accompanying drawings, in which:

[0017] FIGS. **1**A-B show an isometric view and a side view of a conveyor belt for clarifying a process fluid.

[0018] FIG. **2** shows a cross-sectional view of a leach tank for clarifying a process fluid.

[0019] FIG. **3** shows a cutaway isometric side view of a screw conveyor for clarifying a process fluid.

[0020] FIG. **4** shows a cutaway isometric side view of a screw conveyor for clarifying a process fluid.

[0021] FIG. **5** shows a bucket elevator for clarifying a process fluid.

[0022] FIG. **6** shows buckets for use in the bucket elevator of FIG. **5**.

[0023] FIG. **7** shows a lift pipe system for clarifying a process fluid.

[0024] FIG. **8** shows a method for clarifying a process fluid.

DETAILED DESCRIPTION

[0025] It will be readily understood that the components of the present invention, as generally described and illustrated in the Figures herein, could be arranged and designed in a wide variety of different configurations. Thus, the following more detailed description of the embodiments of the invention, as represented in the Figures, is not intended to limit the scope of the invention, as claimed, but is merely representative of certain examples of presently contemplated embodiments in accordance with the invention.

[0026] Referring to FIGS. **1**A-B, an isometric view and a side view of a conveyor belt for clarifying a process fluid are shown at **100** and **101**, respectively, as per one embodiment of the present invention. Second solids **106** are provided to porous conveyor belt **102** and are conveyed through process fluid stream **108**. Process fluid stream **108** comprises a process liquid and first solids. Process fluid stream **108**, provided by sprayers **104**, is sprayed onto porous conveyor belt **102**. Process fluid stream **108** passes through second solids **106**. The first solids adsorb to, deposit on, fuse with, or are trapped by second solid **106**. This produces a first solid-depleted process fluid that passes through conveyor belt **102** and first solid-loaded second solid **110**, that is removed continuously from porous conveyor belt **102**. A portion of first solid-loaded second solid **110** is processed to reconstitute second solid **102**, which is recycled to porous conveyor belt **102**. The first solid is of a first average particle size and the second solid is of a second average particle size. The first average particle size is smaller than the second average particle size. The entire process is conducted in a continuous manner.

[0027] Referring to FIG. **2**, a cross-sectional view of a leach tank for clarifying a process fluid is shown at **200**, as per one embodiment of the present invention. Second solid carbon dioxide **214** is provided through solid inlet **204** to leach tank **202**. Process fluid **212**, comprising a process liquid and a first solid carbon dioxide, is provided to leach tank **202** through process inlet **206**. Process fluid **212** passes through solid bed **218**, causing the first solid carbon dioxide to adsorb to, deposit on, fuse with, and become trapped by second solid carbon dioxide **214**, producing first solid-loaded second solids and first solid-depleted process fluid **216**. Solid bed **218** consists of second solids **214** and the first solid-loaded second solids. First solid-loaded second solids are removed through **220** with a portion of first solid-depleted process fluid **216** as product stream **220**. Product stream **220** is separated through a solid-liquid separator, resulting in a first portion of a clarified process fluid being removed from the first solid-loaded second solids. A portion of the first solid-loaded second solids are sized by a comminution process comprising crushing, grinding, and screening to reconstitute second solid carbon dioxide **214** for recycling to leach tank **202**. First solid-depleted process fluid **216** overflows into weir **210** and is drained from leach tank **202** as a second portion of the clarified process fluid. The first solid carbon dioxide is of a first average particle size and second solid carbon dioxide **214** is of a second average particle size. The first average particle size is smaller than the second average particle size. The entire process is conducted in a continuous manner. In some embodiments, leach tank **202** has a mixing apparatus to stir solid bed **218**. In some embodiments, the solid-liquid separator for product stream **220** comprises a filter press, screw press, rollers, mangle, or combinations thereof.

[0028] Referring to FIG. **3**, a cutaway isometric side view of a screw conveyor for clarifying a process fluid is shown at **300**, as per one embodiment of the present invention. Screw conveyor **302** comprises process inlet **306**, solid inlet **304**, and product outlet **308**. Second solids **312** are provided to screw conveyor **302** through solid inlet **304**. Process fluid **314**, comprising a process liquid and first solid **316**, is provided to screw conveyor **302** through process inlet **306**. Screw **310** advances process fluid **314** and second solids **312** through screw conveyor **302**. First solids **316** adsorbs to, deposits on, fuses with, or is trapped by second solid **312**, producing a first solid-depleted process fluid and first solid-loaded second solid **318**. First solid-loaded second solid **318** is removed with the first solid-depleted process fluid as product stream **320**. Product stream **320** is separated through a solid-liquid separator, resulting in a first portion of a clarified process fluid being removed from first solid-loaded second solids **318**. A portion of first solid-loaded second solid **318** is processed to reconstitute second solids **312**, which is recycled to screw conveyor **302**. First solids **316** is of a first average particle size and second solids **312** is of a second average particle size. The first average particle size is smaller than the second average particle size. The entire process is conducted in a continuous manner. In some embodiments, the solid-liquid separator for product stream **320** comprises a filter press, screw press, rollers, mangle, or combinations thereof.

[0029] Referring to FIG. **4**, a cutaway isometric side view of a screw conveyor for clarifying a process fluid is shown at **400**, as per one embodiment of the present invention. Screw conveyor **402** comprises process inlet **406**, solid inlet **404**, product outlet **408**, and filter **422**. Second solids **412** are provided to screw conveyor **402** through solid inlet **404**. Process fluid **414**, comprising a process liquid and first solid **416**, is provided to screw conveyor **402** through process inlet **406**. Screw **410** advances process fluid **414** and second solids **412** through screw conveyor **402**. First solids **416** adsorbs to, deposits on, fuses with, or is trapped by second solid **412**, producing first solid-depleted process fluid **424** and first solid-loaded second solid **418**. First solid-depleted process fluid **424** is removed through filter **422**. First solid-loaded second solid **418** is removed as product stream **420**. A portion of product stream **420** is processed to reconstitute second solids **412**, which is recycled to screw conveyor **402**. First solids **416** is of a first average particle size and second solids **412** is of a second average particle size. The first average particle size is smaller than the second average particle size. The entire process is conducted in a continuous manner.

[0030] Referring to FIG. **5**, a bucket elevator for clarifying a process fluid is shown at **500**, as per one embodiment of the present invention. Bucket elevator **502** comprises buckets **504**, inlet bin **506**, and outlet chute **506**. Second solids **510** is provided to inlet bin **506** and is picked up by buckets **504**. Buckets **504** ascend with second solids **510** and are sprayed by nozzles **508** with process fluid **512**. Process fluid **512** comprises a process liquid and a first solid. The first solids adsorb to, deposit on, fuse with, or are trapped by second solid **510**, producing a first solids-depleted process fluid and first solid-loaded second solid **514**. Buckets **504** and inlet bin **506** comprise holes through which the first solid-depleted process fluid drains. First solid-loaded second solid **514** is dumped by buckets **504** into outlet chute **506** and is removed. The first solids are of a first average particle size and second solids **510** are of a second average particle size. The first average particle size is smaller than the second average particle size. The entire process is conducted in a continuous manner.

[0031] Referring to FIG. **6**, buckets for use in bucket elevator **502**, as per FIG. **5**, are shown at **600**, as per one embodiment of the present invention. Buckets **602** have holes **604** that are smaller than the second average particle size. In some embodiments, holes **604** are smaller than the first average particle size.

[0032] Referring to FIG. **7**, a lift pipe system for clarifying a process fluid is shown at **700**, as per one embodiment of the present invention. Lift pipe system **702** comprises lift pipe **706**, solid-liquid mix chamber **718**, liquid inlet **710**, solids injection pipe **704**, solids hopper **708**, solid-liquid separator **712**, liquid outlet **714**, and solids outlet **716**. Second solids **720** are provided to solids hopper **708** and pass into solid-liquid mix chamber **718** via solids injection pipe **704**. Process fluid **722** is provided to solid-liquid mix chamber **718** through liquid inlet **710**. Process fluid **722** comprises a process liquid and a first solid. Process fluid **722** mixes with second solids **720** and passes through lift pipe **706** as mix stream **724**. The first solids adsorb to, deposit on, fuse with, or are trapped by second solids **720** in lift pipe **706**, producing first solid-depleted process fluid **728** and first solid-loaded second solid **726**, which are separated in solid-liquid separator **712**. First solid-depleted process fluid **728** is removed through liquid outlet **714**. First solid-loaded second solid **726** is removed through solids outlet **716** and a portion is processed to produce second solids **720**. The first solids are of a first average particle size and second solids **720** are of a second average particle size. The first average particle size is smaller than the second average particle size. The entire process is conducted in a continuous manner.

[0033] Referring to FIG. **8**, a method for clarifying a process fluid is shown at **800**, as per one embodiment of the present invention. A process fluid is passed through a transport device containing a second solid **801**. The resulting first solid-loaded second solid is removed from the transport device **802**. The resulting first solid-depleted process fluid is removed from the transport device **803**. The second solid is reconstituted from the first solid-loaded second solid **804**. The second solid is recycled to the transport device **805**.

[0034] In some embodiments, the first solid comprises a frozen condensable or absorbed gas or gases and the second solid comprises a frozen condensable or absorbed gas or gases. Frozen condensable and absorbed gases includes frozen condensable and absorbed vapors. In some embodiments, the frozen condensable gas, the frozen condensable or absorbed gas or gases comprise carbon dioxide, nitrogen oxide, sulfur dioxide, nitrogen dioxide, sulfur trioxide, hydrogen sulfide, hydrogen cyanide, or combinations thereof. In some embodiments, the frozen condensable or absorbed gas or gases, derive from vitiated flows, producer gases, or other industrial flows, wherein the vitiated flows are produced from coal, biomass, natural gas, oil, and other common fuels. In some embodiments, the first solid further comprises particulates, mercury, other heavy metals, condensed organics, soot, inorganic ash components, biomass, salts, water ice, frozen condensable gases, other impurities common to the vitiated flows, the producer gases, or the other industrial flows, or combinations thereof.

[0035] In some embodiments, the transport device comprises a conveyor belt, bucket elevator, circulating fluidized-bed, hail tower, screw conveyor, leach tank, flow channel, tube, porous filter, screen filter, or channel. In some embodiments, the transport device comprises a porous lower section allowing passage of the process liquid out of the transport device but preventing passage of the first solid. In some embodiments, the transport device comprises a surface material inhibiting adsorption of gases, preventing deposition of solids, or a combination thereof.

[0036] In some embodiments, the process liquid comprises any compound or mixture of compounds with a freezing point above a temperature at which the first solid solidifies. In some embodiments, the process fluid further comprises a third solid of a third average particle size, the third average particle size being smaller than the second average particle size. The third solid comprises particulates, mercury, other heavy metals, condensed organics, soot, inorganic ash components, biomass, salts, water ice, frozen condensable or absorbed gases, other impurities common to the vitiated flows, the producer gases, or the other industrial flows, or combinations thereof.

[0037] In some embodiments, the process liquid comprises water, brine, hydrocarbons, liquid ammonia, liquid carbon dioxide, other cryogenic liquids, other hydrocarbons, and combinations thereof. In some embodiments, the cryogenic liquid comprises 1,1,3-trimethylcyclopentane, 1,4-pentadiene, 1,5-hexadiene, 1-butene, 1-methyl-1-ethylcyclopentane, 1-pentene, 2,3,3,3-tetrafluoropropene, 2,3-dimethyl-1-butene, 2-chloro-1,1,1,2-tetrafluoroethane, 2-methylpentane, 3-methyl-1,4-pentadiene, 3-methyl-1-butene, 3-methyl-1-pentene, 3-methylpentane, 4-methyl-1-hexene, 4-methyl-1-pentene, 4-methylcyclopentene, 4-methyl-trans-2-pentene, bromochlorodifluoromethane, bromodifluoromethane, bromotrifluoroethylene, chlorotrifluoroethylene, cis 2-hexene, cis-1,3-pentadiene, cis-2-hexene, cis-2-pentene, dichlorodifluoromethane, difluoromethyl ether, trifluoromethyl ether, dimethyl ether, ethyl fluoride, ethyl mercaptan, hexafluoropropylene, isobutane, isobutene, isobutyl mercaptan, isopentane, isoprene, methyl isopropyl ether, methylcyclohexane, methylcyclopentane, methylcyclopropane, n,n-diethylmethylamine, octafluoropropane, pentafluoroethyl trifluorovinyl ether, propane, sec-butyl mercaptan, trans-2-pentene, trifluoromethyl trifluorovinyl ether, vinyl chloride, bromotrifluoromethane, chlorodifluoromethane, dimethyl silane, ketene, methyl silane, perchloryl fluoride, propylene, vinyl fluoride, or combinations thereof.

[0038] In some embodiments, the second solid comprises a material that melts at a temperature above a melting temperature of the first solid. The second solid may be reconstituted in these embodiments by compressing the first solids-loaded second solids to force the process liquid retained on the first solids-loaded second solids out, warming the first-solids loaded second solids to melt the first solids to form a product liquid, and separating the second solids from the product liquid.

1. A method for clarifying a process fluid comprising:

providing the process fluid to a transport device, wherein the process fluid comprises a process liquid and a first solid of a first average particle size, the first solid entrained in the process liquid;

providing a second solid of a second average particle size to the transport device, wherein the second average particle size is larger than the first average particle size;

passing the process fluid through the second solid, wherein the first solid adsorbs to, deposits on, fuses with, or is trapped by the second solid, producing a first solid-depleted process fluid and a first solid-loaded second solid;

removing the first solid-loaded second solid from the transport device continuously;

reconstituting the second solid from a portion of the first solid-loaded second solid; and,

recycling the second solid to the transport device;

whereby the process fluid is clarified.

2. The method of claim **1**, providing the first solid and the second solid comprising the same compound.

3. The method of claim **2**, reconstituting the first solid-loaded second solid from the transport device continuously by a sizing process comprising crushing, grinding, screening, extruding, stamping, shaping, or a combination thereof.

4. The method of claim **3**, providing the first solid and the second solid comprising carbon dioxide.

5. The method of claim **4**, providing the process fluid comprising any compound or mixture of compounds with a freezing point above a temperature at which the carbon dioxide solidifies.

6. The method of claim **5**, providing the process fluid comprising water, brine, hydrocarbons, liquid ammonia, liquid carbon dioxide, other cryogenic liquids, other hydrocarbons, and combinations thereof.

7. The method of claim **6**, providing the process fluid comprising 1,1,3-trimethylcyclopentane, 1,4-pentadiene, 1,5-hexadiene, 1-butene, 1-methyl-1-ethylcyclopentane, 1-pentene, 2,3,3,3-tetrafluoropropene, 2,3-dimethyl-1-butene, 2-chloro-1,1,1,2-tetrafluoroethane, 2-methylpentane, 3-methyl-1,4-pentadiene, 3-methyl-1-butene, 3-methyl-1-pentene, 3-methylpentane, 4-methyl-1-hexene, 4-methyl-1-pentene, 4-methylcyclopentene, 4-methyl-trans-2-pentene, bromochlorodifluoromethane, bromodifluoromethane, bromotrifluoroethylene, chlorotrifluoroethylene, cis 2-hexene, cis-1,3-pentadiene, cis-2-hexene, cis-2-pentene, dichlorodifluoromethane, difluoromethyl ether, trifluoromethyl ether, dimethyl ether, ethyl fluoride, ethyl mercaptan, hexafluoropropylene, isobutane, isobutene, isobutyl mercaptan, isopentane, isoprene, methyl isopropyl ether, methylcyclohexane, methylcyclopentane, methylcyclopropane, n,n-diethylmethylamine, octafluoropropane, pentafluoroethyl trifluorovinyl ether, propane, sec-butyl mercaptan, trans-**2**-pentene, trifluoromethyl trifluorovinyl ether, vinyl chloride, bromotrifluoromethane, chlorodifluoromethane, dimethyl silane, ketene, methyl silane, perchloryl fluoride, propylene, vinyl fluoride, or combinations thereof.

8. The method of claim **1**, providing the first solid comprising particulates, mercury, other heavy metals, condensed organics, soot, inorganic ash components, biomass, salts, water ice, frozen condensable gases, frozen absorbed gases, impurities common to vitiated flows, impurities common to producer gases, impurities common to other industrial flows, or combinations thereof.

9. The method of claim **8**, providing the first solid comprising frozen condensable gases or frozen absorbed gases comprising carbon dioxide, nitrogen oxide, sulfur dioxide, nitrogen dioxide, sulfur trioxide, hydrogen sulfide, hydrogen cyanide, hydrocarbons, or combinations thereof.

10. The method of claim **1**, providing the second solid comprising particulates, mercury, other heavy metals, condensed organics, soot, inorganic ash components, biomass, salts, water ice, frozen condensable gases, frozen absorbed gases, impurities common to vitiated flows, impurities common to producer gases, impurities common to other industrial flows, or combinations thereof.

11. The method of claim **10**, providing the first solid comprising frozen condensable gases or frozen absorbed gases comprising carbon dioxide, nitrogen oxide, sulfur dioxide, nitrogen dioxide, sulfur trioxide, hydrogen sulfide, hydrogen cyanide, hydrocarbons, or combinations thereof.

12. The method of claim **1**, providing the transport device comprising a conveyor belt, bucket elevator, circulating fluidized-bed, hail tower, screw conveyor, leach tank, flow channel, tube, porous filter, screen filter, or channel.

13. The method of claim **1**, providing the transport device comprising a porous lower section wherein the porous lower section allows passage of the process liquid out of the transport device but prevents passage of the first solid.

14. The method of claim **13**, providing the transport device a surface material inhibiting adsorption of gases, preventing deposition of solids, or a combination thereof.

15. The method of claim **1**, providing the process fluid comprising any compound or mixture of compounds with a freezing point above a temperature at which the first solid solidifies.

16. The method of claim **1**, providing the process fluid further comprising a third solid of a third average particle size, the third average particle size being smaller than the second average particle size.

17. The method of claim **16**, providing the third solid comprising particulates, mercury, other heavy metals, condensed organics, soot, inorganic ash components, biomass, salts, water ice, frozen condensable gases, frozen absorbed gases, impurities common to vitiated flows, impurities common to producer gases, impurities common to other industrial flows, or combinations thereof.

18. The method of claim **17**, passing the process fluid through the second solid, the third solid absorbing to, depositing on, fusing with, or becoming trapped by the second solid.

19. The method of claim **1**, providing the second solid comprising a material that melts at a temperature above a melting temperature of the first solid.

20. The method of claim **19**, reconstituting the second solid by compressing the first solids-loaded second solids to force the process liquid retained on the first solids-loaded second solids out, warming the first-solids loaded second solids to melt the first solids to form a product liquid, and separating the second solids from the product liquid.

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