(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
3 April 2008 (03.04.2008)

PCT

(10) International Publication Number
WO 2008/039936 A2

(51) International Patent Classification:
G06F 1/16 (2006.01)

(21) International Application Number:
PCT/US2007/079762

(22) International Filing Date:
27 September 2007 (27.09.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/847,384	27 September 2006 (27.09.2006)	US
60/847,383	27 September 2006 (27.09.2006)	US
60/847,374	27 September 2006 (27.09.2006)	US
60/847,372	27 September 2006 (27.09.2006)	US
60/847,382	27 September 2006 (27.09.2006)	US
60/847,373	27 September 2006 (27.09.2006)	US

(71) Applicant and
(72) Inventor: **CORT, Steven L.** [US/US]; 411 Bathgate Lane, Cary, North Carolina 27513 (US).

(74) Agent: **COATS & BENNETT, PLLC**; 1400 Crescent Green, Suite 300, Cary, North Carolina 27518 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

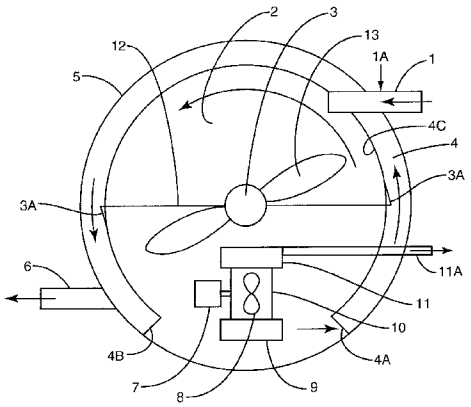
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *without international search report and to be republished upon receipt of that report*

(54) **Title:** MAGNETIC SEEDING AND SEPARATION TECHNOLOGY FOR TREATING WATER



(57) **Abstract:** A system and process for utilizing magnetic seeding and separation in a water treatment system. The invention relates to the use of magnetic seeding and separation technology where a magnetic seed is added to water along with a flocculating polymer. The flocculating polymer binds the non magnetic pollutant particles to the magnetic seed yielding magnetic floc. Collectors with magnetized surfaces attract magnetic floc. The magnetically collected magnetic floc are sheared to form sludge, which is discharged as waste, and cleaned magnetic seed, which is recycled and reused in the water treatment system. Magnetic seeding and magnetic separation technology are employed in various types of water treatment systems to remove dissolved pollutants, suspended solids and scalants. Moreover, using magnetic seeding and magnetic separation in conjunction with polymers or biological treatment to remove dissolved pollutants and suspended solids from water.

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MAGNETIC SEEDING AND SEPARATION TECHNOLOGY FOR TREATING WATER

FIELD OF THE INVENTION

The present invention relates to water treatment, particularly to the use of magnetic seeding and separation to treat water.

SUMMARY OF THE INVENTION

A method of treating water utilizing magnetic seeding and magnetic separation is disclosed. The method includes mixing magnetic seed and a flocculant with the water to be treated to form magnetic floc. The magnetic floc is collected on a magnetic collector that extends substantially around an upper perimeter portion of a tank that contains the water to be treated and the formed magnetic floc. After the floc has been collected by the magnetic collector, the magnetic floc is removed from the magnetic collector.

Additionally, the present invention relates to a water treatment system including seeded floc which comprises a horizontally disposed collector and a horizontally extending shear tank. Disposed within the shear tank are a horizontally extending tank, a horizontally disposed shearing device mounted in the tank and an outlet formed in the horizontally extending tank for discharging the sheared slurry of seeds and sludge.

Moreover, the present invention entails a moving magnetic collector, a shear device and a removal device used in a water treatment system. The magnetic collector collects magnetic floc from water being treated. The magnetic floc is removed from the magnetic collector and sheared, producing sheared slurry

of magnetic seeds and sludge. The same magnetic collector that collected the magnetic floc then collects the separated magnetic seed.

The present invention also relates to a method of clarifying water in a batch type water treatment system employing a magnetic separation technique. The method includes mixing magnetic seed with a flocculant to yield magnetic floc. Thereafter, the magnetic floc is settled to a lower portion of the tank and clarified water is decanted from the tank. Then, the magnetic floc are sheared producing magnetic seed and sludge. A magnetic field retains the magnetic seed in the lower portion of the tank, while the sludge is discharged from the tank. The retained magnetic seed are reused to treat subsequent batches of water.

The invention includes a water treatment system for treating water including magnetic floc, and includes a moving magnetic collector for collecting the magnetic floc from the water. A removal device for removing magnetic floc from the moving magnetic collector is included, and the removal device is magnetically held adjacent the moving magnetic collector.

In addition, a method of retrofitting an existing biological wastewater treatment system is disclosed. The existing wastewater treatment system includes one or more biological reactors and one or more gravity clarifiers. The method includes converting the one or more gravity clarifiers of the existing water treatment system to one or more biological reactors. In addition, a high rate clarifier is added to the existing water treatment system.

Furthermore, the invention relates to a ballasted flocculation process for treating water where the ballast comprises a magnetic ballast or seed such as magnetite. Magnetic floc are formed in a flocculation zone or tank by mixing the magnetic seed and a flocculant in the water to be treated. A magnetic collector

collects at least some of the magnetic floc from the flocculation zone thereby performing a seed cleaning function in the flocculation zone. Water and other magnetic floc move downstream to a settling tank or zone where at least some of the remaining magnetic floc settle. The settled magnetic floc is transferred or moved from the settling zone or tank back upstream to a point ahead of the settling tank where the magnetic floc is collected.

Additionally, the present invention relates to a multi-stage process of removing dissolved contaminants and suspended solids from water employing a magnetic separation technique. The process includes, in a first stage, directing water into a first tank and mixing the water with magnetic seed and flocculant. The flocculant binds suspended solids in the water to the magnetic seed forming magnetic floc. A magnetic collector collects the magnetic floc, which are then removed from the collector. In a second stage, water is directed into a second tank and mixed with magnetic seed. The magnetic seed may be coated, for example with a polymer. The magnetic seed or the coated magnetic seed sorb dissolved contaminants in the water. A magnetic collector collects the magnetic seed with the sorbed contaminants to allow the contaminants to be removed from the water.

A method of treating cooling water to remove scalants is also disclosed. The method includes directing the cooling water into a chamber and mixing magnetic seed, such as magnetite, with the water such that scalants attach to the magnetic seed to form magnetic particles. These magnetic particles are collected on a magnetic collector, and after being collected on the magnetic collector, are removed therefrom.

Finally, a biological nitrification-denitrification and clarification process is also provided by the present invention. The process utilizes magnetic seeding and magnetic separation to treat water containing ammonia. The process includes directing the water into a vessel and mixing the water with a first magnetic bed media in the vessel. The conditions in the vessel are maintained to result in a biofilm forming on the first magnetic bed media. The process includes utilizing the biofilm formed on the first magnetic bed media to nitrify the water. Further, the process provides separating the first magnetic bed media from the nitrified water and transferring the nitrified water from the vessel. The process includes mixing a second magnetic bed media with the nitrified water and forming magnetic floc where the magnetic floc comprise magnetic bed media, suspended solids, and a biofilm. The biofilm comprised in the magnetic floc is utilized to denitrify the nitrified water. The process also includes utilizing the second magnetic bed media to clarify the nitrified water and collecting the magnetic floc with a magnetic collector.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic plan view of a flocculation tank with a final magnetic collector disposed about an upper perimeter of the tank.

Figure 2 is a schematic plan view of a flocculation tank with an alternate embodiment of a magnetic collector disposed about an upper perimeter of the tank.

Figure 3 is a schematic side elevation view of apparatus according to one aspect of the invention, with a magnetic separator device mounted in the upper portion of a flocculation tank.

Figure 4 is a schematic plan view of an apparatus according to one embodiment with a stationary continuous cleaner and a moving magnetic collector bed.

Figure 5 is a schematic plan view of an apparatus according to one embodiment with a moving continuous cleaner and a stationary magnetic collector bed.

Figure 6 is a schematic side elevation of an apparatus according to one embodiment with a moving magnetic belt collector.

Figure 7 is a front elevation view of the moving magnetic belt collector.

Figure 8 is a side elevation view of an apparatus according to one embodiment where the final collector comprises a bed of magnets supported on a screen in an annular trough extending around an upper portion of a tank.

Figure 9 is a side elevation view of an apparatus according to one embodiment where the final collector comprises a buoyant bed of magnets supported in an annular trough extending around an upper portion of a tank

Figure 10 is a schematic end view of one embodiment of the magnetic separator device.

Figure 11 is a more detailed schematic view of Fig. 10 showing a portion of a magnetic drum and scraper assembly used to first separate magnetic floc from the water stream and then to return cleaned magnetic seed to the floc tank for reuse.

Figure 12 is a perspective view of the horizontally-extending shear tank.

Figure 13 is an end view of the horizontally-extending shear tank juxtaposed with a floc collector and a seed extractor.

Figure 14 is a perspective view of the horizontally-extending shear tank juxtaposed with a floc collector and a seed extractor in a treatment tank.

Figure 15a, 15b and 15c show details of scraper designs.

Figure 16 is a schematic side view of a tank and related equipment for carrying out the method of the invention.

Figure 17 is a schematic illustration of a batch treatment system showing a flocculation phase of a magnetic separation process.

Figure 18 is a schematic illustration showing magnetic floc settled to the lower portion of the tank.

Figure 19 is a schematic illustration showing clarified water being decanted from the tank.

Figure 20 is a schematic illustration showing magnetic floc being sheared yielding magnetic seed and sludge.

Figure 21 is a schematic illustration showing sludge being drained from the tank, while the magnetic field retains the magnetic seed in the tank.

Figure 22 shows the magnetic seed retained in the tank after the sludge has been drained.

Figure 23 is a schematic illustration of an existing wastewater treatment system.

Figure 24 is a schematic illustration showing a retrofit for an existing wastewater treatment system.

Figure 25 is a schematic illustration of a ballasted flocculation process.

Figure 26 is a schematic illustration of a ballasted flocculation process where the ballast comprises magnetic seed that are utilized to form magnetic floc.

Figure 27 is a schematic illustration of the multistage process of the present invention that utilizes magnetic sorption and magnetic clarification.

Figure 28 is a schematic diagram of a system for cleaning water according to the invention.

Figure 29 is a side elevation view of the equipment according to one embodiment of the invention.

Figure 30 shows a schematic cross-sectional view of a first embodiment of apparatus for practice of the invention.

Figure 31 shows a detail of the apparatus of Figure 30.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is in the technical field of removing fine particles from water. The fine particles can include metal precipitates, organic solids, inorganic solids, clays, silts, oil and grease and any other hard to remove fine solids. The invention is applicable to industrial wastewater, municipal wastewater, potable water, combined sewer overflow, storm water, process water, cooling water, ground water, and any other waters that require clarification to remove fine particles. The term "water" as used herein includes water and all forms of wastewater.

The invention relates to the use of magnetic seeding and separation technology where a fine magnetic seed material is added to the water along with an organic flocculating polymer. The organic flocculating polymer binds the non-magnetic pollutant particles to the magnetic seed material and then the composite particle, or magnetic floc. In some embodiments, a flocculating polymer may not be used but rather the sorption properties of the magnetic

particles are employed to extract pollutants from the water and attaché the pollutants to the magnetic particles. In some cases, certain scalants may be removed by employing magnetic particles whose surfaces provide sites for sacrificial scaling thus preventing or reducing scaling on downstream equipment. In any case, the invention includes utilizing the magnetic properties of the magnetic particles, bound with pollutants -- be they in the form of flocs, particles with pollutants sorbed therewith, or scaled magnetic particles -- to magnetically remove the pollutants from the water.

Collectors employing magnetized surfaces are used to attract magnetic particles and their burden of pollutants. The magnetized surfaces are generally moving magnetized surfaces to facilitate continuous transport of collected particles out of the water. The surfaces are equipped with permanent magnets or electromagnets to provide the required magnetic strength to remove the magnetic particles. The magnetic strength of the magnets used ranges approximately 0.1 to 10 tesla. Permanent magnets may be more commonly 0.5 to 1.5 tesla while electromagnets may be configured with a strength up to about 10 tesla.

The magnetically collected magnetic floc are further processed to form separate streams of sludge to be ejected as a waste product and cleaned magnetic seed to be recycled and reused in the water treatment system.

The process of using magnetic seeding and separation technology for removing fine pollutant particles sometimes involves attaching the fine pollutant particles to the magnetic seed material with a flocculating polymer. In a traditional flocculation process, the aim is to produce a large floc that will settle rapidly by gravity. To assure this floc formation, it is important to have the proper mixing energy. The measure of this mixing energy is referred to as the root-mean-square

velocity gradient G measured in negative seconds (sec^{-1}). For optimum floc formation in a gravity separation situation, the G value should generally not exceed approximately 50 sec^{-1}. Exceeding this level increases the speed of mixing and the formation of microfloc, but will shear the floc and prevent the development of large macroflocs that will settle rapidly.

Magnetic seeding and separation is different. Since the size of floc is not important because gravity settling is not employed, the G value can be greatly increased because all that is needed is for the magnetic and non-magnetic particles to collide quickly in the presence of the flocculating polymer. Therefore the G value can be increased to about 100 $sec^{-1}$and higher, which will speed the flocculation and therefore clarification process. The G value should generally be greater than about 50 sec^{-1} and less than about 1000 sec^{-1}but more preferably in the range of about 100 to about 500 sec^{-1} in magnetic seeding and separation.

Various forms of magnetic seed material may be used. Among the forms is magnetite, a ferromagnetic form of ferric oxide. Other forms include but are not limited to zero valent iron, ferrosilicon, maghemite, jacobsite, trevorite, magnesioferrite, magnetic sulfides like pyrrohotite and greigite, and any other ferromagnetic and ferremagnetic materials that show strong attraction to a magnetic field.

Magnetic seed particle sizes in the range of 30 to 50 microns, as would be characteristic of 90% of material passing a 355 mesh, may be commonly used as magnetic seed for binding or sorbing pollutant particles for removal. Further, for various sorption processes, those that for example may be useful for removing very fine or nano pollutant particles, magnetic seed sizes may range down to approximately 20 nanometers. Magnetic seeding in treatment vessels such as

flocculation tanks is typically done at a concentration by weight of magnetic seed of about 0.5 to 1% and which in some cases may up to about 3-5%.

Reference is made to the magnetic seeding and subsequent separation techniques and devices disclosed in application Ser. Nos. 11/503,951 (the '951 application), 11/135,644 (the '644 application), and U.S. Patent No. 7,255,793. The disclosures of the '951 and '644 applications and U.S. Patent No. 7,255,793 are expressly incorporated herein by reference.

As used herein the term "water" includes all forms water and of wastewater. "High rate clarifiers" are defined as clarifiers that have a surface overflow rate greater than five gallons per minute per square foot of surface area. The terms "absorption" and "adsorption" are used interchangeably and are not intended to be limiting. "Sorb" and "sorption" are used to refer to both absorption and adsorption.

TANK DESIGN

Turning now to the drawings and the design of the tank and final magnetic collector, a final magnetic collector 4 is configured to maintain a substantial residence time in a tank or flocculation chamber while providing a substantial surface area for the final magnetic collector. One way to accomplish this is to locate the floc chamber or zone in the center and bottom of a cylindrical tank and then to extend the final collector around the perimeter of the upper regions of the tank, as illustrated in Figure 1. In this way, the floc chamber occupies a substantial volume of the tank, increasing the residence time during which the flocculent effectively attaches fine pollutant particles to magnetic seed, such as magnetite, to form composite particles or magnetic floc. This allows the use of

magnetic techniques for removal of the fine pollutant particles from the water stream.

The tank can be a cylindrical tank with a circular final magnetic collector 4 extending around the perimeter of an upper portion of a treatment tank 5, as illustrated in Figures 1-5. Disposing final magnetic collector 4 around the perimeter of tank 5 increases the surface area of the collector, effectively slowing the motion of the composite particles to less than about 18 inches per second while increasing their residence time in the collector. A speed greater than about 18 inches per second may tend to dislodge the magnetic particles from magnetized surfaces of final magnetic collector 4.

Scaling up the tank design for high flow rate applications requires a larger final magnetic collector 4 which is can be accommodated by placing the collector in proximity to the perimeter of the tank 5. The efficiency of final magnetic collector 4 is reported as the Surface Overflow Rate (SOR) which is measured in gallons per minute per square foot (gpm/ft^2) of surface area. The SOR for a traditional gravity clarifier is about 0.25 to 1.00 gpm/ft^2. The SOR for the present process ranges from about 10 gpm/ft^2 to 300 gpm/ft^2 which tends to make magnetic separation technology attractive.

Figure 1 shows a typical layout for positioning of key treatment elements. The features include the cylindrical tank 5 which is strong and easy to construct, whereby a large portion of the tank volume is dedicated to a flocculation zone 2 where the flocculation of pollutants to magnetic seed material, and provision of a long flow path in final magnetic collector 4. In some applications, a square or rectangular tank may be utilized in the process since the final magnetic collector 4 can be configured such that it can be disposed along one or more sides of the

tank. See, for example, Figures 6 and 7 and the description below of a magnetic belt collector used in conjunction with the final magnetic collector. While generally more expensive to construct, a square tank has some improved flocculation characteristics because of improved mixing in that it does not require baffles to increase turbulence as may sometimes be the case with circular tanks.

Referring in particular to Figure 1, water flows into the tank through a pipe 1 where a flocculating polymer is added at 1A. The water flows into the central flocculation chamber or zone 2 that contains magnetic seed particles (typically magnetite), so that composite magnetic particles, or magnetic floc, are formed and are made up of the pollutant particles bound by the flocculent to the magnetic seed. A flocculation mixer motor 3 and mixer blade 13 are provided to ensure thorough mixing. Water then flows through an opening 4A into an outer shell which contains the final magnetic collector 4 that extends about the perimeter of the tank 5. In this space any of a variety of different types of final magnetic collectors 4 can be installed. In one embodiment, the magnetic seed material or particles will be collected along an inner magnetized surface 4C closest to the flocculation chamber 2 and moved by a mechanical scrapers 3A disposed on ends of arm 12 driven by motor 3. An outlet pipe 6 is communicatively connected to the tank to receive clarified water. Clarified water overflows out pipe 6 while scrapers 3A urge magnetically collected seeded floc along surface 4C and are returned to tank 5 where the floc are ultimately collected on drum (magnetic collector) 9 of a magnetic seed cleaning system disposed in the tank. A typical magnetic seed cleaning system is described in more detail in a co-pending application entitled "A Device and Methods for Shearing Magnetic Floc in a Water Treatment System" filed on September 27, 2007, Application Serial Number

11/862,732, the disclosure of which is expressly included herein by reference. Briefly, a motor 7 drives two magnetic drum devices 9 and 11. The first magnetic drum 9 collects magnetic floc and directs the magnetic floc to a shear device or tank 10 that includes a shear mixer 8 that shears the magnetic particles away from the non-magnetic material of the floc producing a slurry of magnetic seeds and sludge. These materials are separated magnetically on drum 11 with the magnetic seed material being back into the flocculation chamber 2 for reuse and the non-magnetic pollutants, or sludge, being discharged for disposal through line 11A. The location of the first magnetic drum 9 can be advantageously placed in front of the opening 4A so that it removes magnetic particles before they reach the final magnetic collector 4. This dual duty for the first magnetic drum or collector 9 reduces the solids loading on the final magnetic collector 4. The first magnetic collector 9 that removes the magnetic floc for seed separation and cleaning is typically shown as a magnetic drum but can be in other configurations.
In one embodiment, the final magnetic collector 4 includes a cleaner 14 to continuously clean the final collector 4 as shown in Figures 2 - 5. Cleaner 14 may be of various designs depending on the type of final collector 4 utilized. For example, scrapers 3A shown in Figure 1 comprise one example of a cleaner.

In one embodiment, the magnetic collector may take the form of a bed of magnets 40A in a spaced array disposed over a screen 43 forming the bottom of an annular trough that that encircles the perimeter of tank 5. See Figures 4 and 8. The magnets 40A may each be encased in a porous shell or cage such that they are held apart in the bed. Water with magnetically-seeded floc flows upward through bed 40, as illustrated in Figure 8, and the floc are magnetically captured by the magnets 40A in the bed. An exit screen 42 prevents magnetic material that

may become dislodged and entrained with the cleaned water from flowing out with the cleaned water. Final magnetic collector 4 may be constructed so as to be buoyant and free to rotate like a carousel propelled by the circular action of water in the flocculation chamber 2. Portions of the final magnetic collector 4 then move past a stationary cleaning device 14. In this embodiment, cleaning device 14 may take the form of a high pressure counter-current water spray system that continuously back flushes the magnetic floc from the magnetized bed 40. In another embodiment, illustrated in Figure 5, final magnetic collector 4 is stationary and anchored to the tank. A similar back flushing but moving cleaning device 14 is driven around the perimeter of tank 5 cleaning portions of final magnetic collector 4.

As noted above, cleaning device 14 may include a high pressure water spray system that directs cleaning water in a counter flow fashion through magnetized bed 40. Those ordinarily skilled in the art will appreciate that there are various ways to operatively connect and utilize backflushing cleaning devices in water treatment systems such as disclosed herein. Magnetic particles cleaned or flushed from the final magnetic collector bed 40 fall back into the flocculation zone 2 while clarified water is discharged through exit screens 42. See Figure 8.

In this way, the magnetic floc are continuously returned to tank 5 and from whence they are ultimately collected by a first moving collector 9 of a seed cleaner, sheared in a shear device 8, and scraped back into the tank from a second moving collector 11. Sludge produced by the shear device 8 is ejected through line 11A. See Figures 2 and 3.

In another embodiment, the magnetic bed 40 may be buoyant and does not have to be retained in its present position by a screen or other support element as

illustrated in Figure 9. As in the foregoing embodiment, retaining screen 42 is employed to prevent stray magnetic materials from leaving tank 5.

The weight of final magnetic collector 4 may be supported by the natural buoyancy of the final magnetic collector by configuring the collector such that it is of sufficient buoyancy to generally float in the water while being horizontally constrained to the wall of tank 5. This approach eliminates costly support structures to hold up the final magnetic collector 4. In cases where it is not convenient to design final magnetic collector 4 as a generally buoyant structure, the collector may be entirely supported on tank 5 or another superstructure.

If first magnetic collector 9 is used to reduce the load on the final magnetic collector 4 as discussed above, then an elongated magnetic belt collector 18 that extends down into the flocculation chamber 2 may be used as the first collector. Details of this elongated magnetic belt are shown in Figures 6 and 7. Permanent magnets 240 are affixed to a conveyor belt 250 stretched between two rollers 230. Belt 250 includes a reinforced backing and a pliant surface bonded thereto in a common fashion of conveyor belt design. Magnets 240 are embedded in the belt and the belt is encased in a water-proof jacket. The magnetic conveyor belt is driven by a shaft 200 attached to two drive gears 210. The conveyor belt is affixed with flexible gearing on each edge that engage the drive gears 210. .

Referring in particular to Figure 6, flocculation takes place in the center and bottom of tank 5. The final magnetic collector 4 is located proximate to the tank perimeter. Magnetic belt collector 18 comprises a vertical magnetized conveyor belt 250, driven through drive 17 from the same or a different power source (not shown) as final magnetic collector 4. As the endless belt 250 is driven, magnetic floc are collected on the belt. As seen in Figure 6, an upper portion of the endless

magnetic belt 250 extends above the surface of the water being treated. Once the magnetic floc collected on the belt 250 reaches an upper area, above the surface of the water being treated, the magnetic floc is scraped or removed from the belt and directed into the shear device 8. Here the shear device 8 separates the magnetic floc into magnetic seed and sludge. The sludge is directed away from the system and this is represented at 18A. The clean magnetic seed is directed back into the tank 5 and is represented at 18B. The manner of removing collected magnetic floc from a collector and cleaning the same is similar to that disclosed in my co-pending application entitled "A Device and Methods for Shearing Magnetic Floc in a Water Treatment System" filed on September 27, 2007, and designated by Serial No. _____, the disclosure of which is expressly incorporated herein by reference. Reference is also made to the magnetic seeding and subsequent separation techniques disclosed in application Ser. No. 11/503,951 (the '951 application) and U.S. Patent No. 7,255,793. The disclosures of the '951 application and U.S. Patent No. 7,255,793 are expressly incorporated herein by reference.

A baffle 18C is disposed adjacent magnetic belt 250 to mechanically isolate the magnetic belt from the turbulence of the mixing in the flocculation zone 2 and to tend to prevent premature magnetic floc from attaching to the magnetic belt.

Clarified water produced by the system of Figure 6 is directed out outlet 6. Note that a final magnetic collector 4 is disposed between the conveyer belt 250 and the outlet 6. This final magnetic collector 4 will tend to collect magnetic floc and small magnetic particles from the water prior to the particles being discharged out the outlet 6. Magnetic particles collected by the collector 4 are scraped

therefrom and permitted to fall back into the tank 5 where eventually the magnetic particles or magnetic floc will be collected by the magnetic belt 250.

HORIZONTAL SHEAR DEVICE

A first magnetic drum collector is used to collect the composite magnetic particles, or magnetic floc, comprising the pollutants to be removed, the flocculant, and the magnetic seeds. The first magnetic drum collector or a second magnetic drum collector can be used clean the pollutant and flocculant from the magnetic seed material so the seeds can be reused. For example, a first magnetic drum rotating about a horizontal axis is submerged into the floc tank where the first magnetic drum collects the composite magnetic floc. Typically, the magnetic floc is scraped off the magnetic drum into a vertical shear tank where fine pollutant particles are detached from the magnetic seed by a vigorous mixing action. The clean magnetic seed is then collected on a second magnetic drum collector and scraped back into the floc tank.

Mounting the shear tank in a vertical position causes a surging in the tank, especially if the tank is square, when the magnetic floc is scraped into the tank. This surging action causes an uneven amount of magnetic seed to be deposited on the second magnetic drum collector. There are also some layout problems caused by use of a vertical shear tank; notably, if a relatively wide first magnetic drum collector is used for removing magnetic floc from the floc tank, it will not match up well to a much narrower vertical shear tank. A better configuration is to mount the shear tank in a horizontal position, parallel to the first magnetic drum collector, and to make the shear tank of similar width to the first and second

magnetic drum collectors. Doing so also avoids the surging found in a vertically mounted shear tank.

Figure 10 shows one embodiment of a horizontal shear tank 22 juxtaposed to a rotating magnetic drum 20 which removes composite magnetic particles from the flocculation chamber for cleaning the pollutant particles and flocculant from the magnetic seed particles. The composite particles are scraped from the surface of drum 20 by a scraper 21 and flow down its upper surface into the horizontal shear tank 22. Inside this tank is a high-shear powerful mixer 23 that causes separation of the magnetic seed magnetite, for example from the pollutant particles. The sheared slurry flows out of the tank 22 through a slot onto a trough 24 and back onto the magnetic drum 20. The magnetic particles are attracted to the surface of the drum 20, while a scraper 26 pressing against the magnetic drum 20 causes the water that contains the pollutants to overflow into a discharge pipe 25 for disposal. See Fig. 11 for an enlarged view. The pressed magnetic seed is then scraped 27 off the magnetic drum so the magnetic seed can be returned to the floc chamber to be reused.

The present invention discloses water treatment system for treating water that includes seeded floc. The water treatment system comprises a horizontally disposed collector for collecting the seeded floc. A horizontally-extending shear tank is provided for receiving the seeded floc from the collector and shearing the seeded floc to produce a sheared slurry of seeds and sludge. The horizontally-extending shear tank includes a horizontally-extending tank, a horizontally disposed shearing device mounted in the horizontally extending tank, and an outlet formed in the horizontally extending tank for discharging the sheared slurry of seeds and sludge.

The invention also discloses a method of treating water that contains seeded floc. The method comprises collecting the seeded floc on a collector and removing the seeded floc from the collector. Further comprised in the method are the steps of directing the seeded floc into a horizontally-extending shear tank and shearing the seeded floc in the horizontally-extending shear tank to produce a sheared slurry of seeds and sludge. The method also includes the step of discharging the sheared slurry of seeds and sludge from the horizontally-extending shear tank.

Turning now to a detailed description of the alternate embodiments, a horizontally-extending shear tank 22 may comprise the horizontal shear device as illustrated in Figure 12. It is appreciated that horizontally-extending shear tank 22 is a generally elongated tank adapted to be disposed adjacent or at least partially within a treatment tank in a water treatment system. Horizontally-extending shear tank 22 is oriented such that a longitudinal axis of the tank is generally parallel with the surface of the water in the treatment tank. Thus disposing horizontally-extending shear tank 22 facilitates interfacing the tank with floc collection and seed extraction and recovery devices as will be described in more detail here below.

Turning now to a description of the structure of horizontally-extending shear tank 22, it is appreciated that in one embodiment the tank is a generally cylindrical hollow body. Disposed in an upper portion of tank side wall 22A is an inlet slot 22B extending longitudinally along a substantial portion of the tank side wall. An outlet slot 22C is spaced away from the inlet slot and similarly extends along a substantial portion of the tank wall. In one embodiment, inlet slot 22B is positioned at a level that is above the level of outlet slot 22C. Slots 22B and 22C

enable access to the interior 22D of horizontally-extending shear tank 22 to permit the flow of materials into and out of the tank. Further, positioning inlet 22B at a level above outlet 22C tends to prevent backflow of material through the inlet. Other forms of backflow prevention devices may include one way valves and various kinds of baffles.

Rotatably mounted within horizontally-extending shear tank 22 is a mixer 23. Mixer 23 comprises an elongated shaft 23A and a plurality of blades 23B extending from the shaft and spaced apart along the shaft. Elongated shaft 23A may extend partially through an end wall 22E of horizontally-extending shear tank 22 to facilitate connection to a rotary drive source (not shown) for rotating the shaft about a central and longitudinal axis thereof relative to the tank. Each blade 23B extends from the shaft generally towards tank sidewall 22A, permitting a relatively small clearance, as compared to the inside diameter of the tank, between the blade and the side wall. It is appreciated that rotation of elongated shaft causes blades 23B to move within horizontally-extending shear tank 22.

In one embodiment, horizontally-extending shear tank 22 may be employed with a rotating magnetic drum 20 as illustrated in Figures 10 and 11 and discussed here before. As illustrated in Figure 10, horizontally-extending shear tank 22 is disposed alongside a rotating magnetic drum 20 The drum 20 is partially submerged below the water line in a treatment tank containing flocculated water formed using magnetic seeds and a binder or flocculant. A swath 29 of floc 28A containing magnetic seeds 28B may be collected on an outer surface of rotating magnetic drum 20 as it rotates in the water. A swath is understood to be flow of material that is relatively wide and somewhat thin. Swath 29 of floc is scraped from drum 20 by floc scraper 21 and is directed along an upper surface of

the scraper into horizontally-extending shear tank 22. Contact of swath 29 of floc with the plurality of blades 23B, moving due to rotation of elongated shaft 23A, shears the floc and produces sheared slurry of seeds 28B and sludge 28A. The sheared slurry flows out of horizontally-extending shear tank 22 and forms a swath 28 of seeds and sludge on first trough 24 as illustrated in Figure 10. Swath 28 of seeds and sludge is deposited on the same rotating magnetic drum 20, received in a receiving area formed by scraper 26. Seeds 28B are magnetically attracted to drum 20, scraper 26 further compressing seeds 28B and sludge 28A such that most of the sludge overflows and is discharged via discharge pipe 25 and such that relatively dry seed remain on drum 20. A seed scraper 27 scrapes seed 28B off drum 20, and the seed are deposited into the treatment tank for re-use.

In another embodiment, horizontally-extending shear tank 22 may be used with a first and second rotating magnetic drums 20A, 20C as illustrated in Figures 13 and 14. Horizontally-extending shear tank 22 is positioned between first rotating magnetic drum 20A and second rotating magnetic drum 20C. First magnetic drum 20A includes a first rotating magnetic surface 20B and is disposed near the surface of the water in a treatment tank such that the first surface 20B moves through the water. First magnetic drum 20A thus forms a collector for collecting floc 28A having magnetic seeds 28B. A first scraper 26A is disposed against the first magnetic surface 20B to scrape a swath 29 of floc 28A from the first rotating magnetic surface 20B. Swath 29 of floc 28A is directed along the upper surface of the scraper 26A and into inlet 22B of the horizontally-extending shear tank 22. Contact of the swath 29 of floc 28A with blades 23B causes shearing of the floc and the forming of a slurry of seeds 28B and sludge 28C. The

slurry of seeds 28B and sludge 28C flows through outlet 22C of the horizontally-extending shear tank 22, on trough 24 forming a swath 28 of seeds 28B and sludge 28C that is directed to a seed extractor or cleaner comprising a second rotating magnetic drum 20C.

The second rotating magnetic drum 20C has a second rotating magnetic surface 20B that is isolated from the water. Rotating magnetic surface 20D forms a part of a seed extraction device to extract magnetic seeds 28B from sludge 28C and return the seeds to the treatment tank for re-use. Swath 28 of seeds and sludge is deposited against rotating magnetic surface 20D where the seeds are magnetically attracted to the surface and the sludge, being non-magnetic, falls away and is collected by sludge collection surface 20E. Seeds 28B are magnetically attracted to rotating magnetic surface 20E. Scraper 26B scrapes seeds 28B off rotating magnetic surface 20D and into the treatment tank for re-use.

It is appreciated that horizontally-extending shear tank 22 is configured such that the length thereof, and in particular, the length of slot 22B disposed in wall 22A facilitates the efficacious movement of swath 29 of floc 28A from a collection surface such as rotating magnetic surface 20B into horizontally-extending shear tank 22. Horizontal disposition of the tank 22 and the disposition of blades 23B spaced apart along elongated shaft 23A provide for effective and efficient shearing of flocs 28A to produce the sheared slurry of seeds 28B and sludge 28C. Further, the length and position of slot 22C facilitates the discharge of a swath 28 of seeds and sludge from tank 22, and the direction thereof to a seed extraction device such as the device including rotating magnetic surface 20D as described above.

MAGNETIC DRUM DESIGN

The goal is to use only one magnetic collector to remove magnetic floc from the floc tank and return cleaned magnetic seed into the floc tank. Magnetic floc collected on the magnetic collector are scraped off by a first removal device, or scraper, and transferred into a shearing device. The shearing device shears the magnetic floc to free the magnetic seed from the floc, producing a slurry of magnetic seeds, flocculant, and pollutants., the flocculant and pollutants forming a sludge Magnetic seed is separated from the sludge so the magnetic seed can go back into the floc tank for re-use, while the separated sludge is disposed. It was observed that a blade, or retainer, pressing against the magnetic drum will squeeze or compress the magnetic seed together, urging any remaining sludge away from the seed and leaving the seed substantially dry. The sludge will then overflow over the blade, or retainer, to be discharged, while the compressed and substantially dry magnetic seed will be removed by another scraper and returned to the floc tank for re-use. This approach employs the same magnetic collector to remove magnetic floc from the water and to separate the magnetic seed from the sludge after shearing. One magnetic drum is eliminated, which reduces cost, space requirements, and mechanical complexity of the system.

Figure 11 shows an enlarged detail of Fig. 10, illustrating the manner in which magnetic seed is separated from non-magnetic pollutants. Sheared sludge, referred to sometimes as a sheared slurry of magnetic seeds a sludge, exits through a slot in the horizontal shear tank 22 which contains a shear mixer 23 and flows down a trough 24 back onto the surface of the same rotating magnetic drum 20 that first removed the dirty sludge from the flocculation tank. The magnetic

material adheres to the drum and is collected in a wedge-shaped collection area formed by a retainer or trough 26 extending along the surface of the drum 20. The lower end of trough 26 is spaced close to the surface of drum 20, so that it squeezes out water that contains the non-magnetic pollutants while the separated magnetic seed material is attracted to and retained on the surface of the drum 20. The retainer 26 prevents the non-magnetic slurry from going back on the drum and into the flocculation chamber. Rather the slurry overflows the retainer 26 into a sludge collector comprising a discharge pipe 25 for disposal. The magnetic seeds that adhered to the magnetic drum 20 are scraped off its surface by a scraper 27, and drop back into the flocculation chamber for reuse.

SCRAPER DESIGN

Fig. 15a shows a removal device or scraper 51 that includes a ferromagnetic material disposed such that the scraper is attracted to a magnetic drum 52 to remove collected magnetic floc from the drum. A magnetic attraction, or force, acts between drum 52 and scraper 51, and maintains a constant pressure between the drum and the scraper 51 over the entire length of the scraper, thus providing good scraping efficiency. This also provides a self adjusting feature to allow compensation for wear. The magnetic attraction, or force is independent of wear of the drum 52 or the scraper 51. Thus as either the drum 52 or the scraper 51 wears, the scraper is kept in contact with the drum with essentially the same force. Moreover, the magnetic force has an intensity that is generally constant over the area of contact or approach between the scraper 51 and the drum 52. This facilitates maintaining uniform contact over the area of contact or approach. This uniform contact is also therefore obtainable even in

cases where the scraper 51 or drum 52 wears in a pattern that produces irregularities in the contact area. This design enhances the consistent and continuous cleaning of permanent magnet collectors.

It should be noted, that scraper 51 also functions to convey removed magnetic floc from the magnetic drum 52. That is, since scraper 51 is magnetically held adjacent to or in contact with the magnetic drum 52, magnetic floc scraped from the drum 52 tends to move down the upper surface of scraper 51. Thus, scraper 51 not only removes the magnetic floc from magnetic drum 52, but also directs or channels the removed magnetic floc away from the magnetic drum. As discussed elsewhere herein, the removed magnetic floc is typically directed to a shear device where the magnetic floc is sheared producing magnetic seed and sludge.

Figs. 15b and 15c show a removal device or scraper 55 that can be easily removed and which does not impede the flow of water between disks of a rotary magnetic collector that is disposed in a tank of water to collect magnetic floc. A plurality of scrapers 55 is preferably disposed between adjacent disks 53, so as to engage and scrape magnetic flocs from the opposed faces of the adjacent disks. Each scraper 55 has a hook end 55A by which it is suspended from a center shaft 54 holding the disks of the magnetic collector. An opening 55B formed by hook end 55A facilitates easy installation and removal of the scraper from above the magnetic collector for convenience. Preferably, the magnets are maintained stationary on disk (not shown) sandwiched between two plastic, or other non-magnetic material-based, rotating disks. Typically, magnets are omitted from a lower sector of the disks, forming a magnet-free sector 53A on each disk. This facilitates magnetic floc detaching at sector 53A of the disk surface where the

scrapers 55 are be located. The scrapers 55 extend radially beyond the magnetic collection disks so that they can engage a stop or retaining bar 56 that prevents each scraper from moving out of the magnet-free sector 53A at the bottom of the magnetic collection disks. Alternatively, magnets may be embedded in a uniformly distributed array in a disk which rotates and from which magnetically-collected material is scraped. Scrapers 55 are hung from the center shaft 54 of the disk collector and mounted in a near vertical position so it does not impede the flow of water through the magnetic disk collector. In one embodiment, the general direction of flow is generally parallel to scrapers 55. Each space between disks includes one scraper, which can be arranged to scrape the opposed surfaces of adjacent disks.

MAGNETIC SEPARATION AS A BATCH PROCESS

Magnetic separation systems have typically involved continuous flow applications. In the case of the magnetic batch system shown in Figures 16-22, all treatment functions are carried out in the same tank, using a single variable speed motor and a mixing and shearing assembly.

With reference to Figure 16, a batch treatment system is shown therein and comprises a tank 42 that includes a bottom, sidewall structure, and a top. A variable speed motor 41 drives a central shaft that has secured thereto a mixing blade 430 and a shearing blade 44. An inlet 40A permits water to be treated to enter the tank 42. An outlet 40B is disposed about a lower portion of the tank 42 for discharging treated water. As seen in Figure 8, the bottom of the tank 42 slopes inwardly and downwardly to a central area where there is provided a valve

47 for discharging sludge from the tank 42. Valve 47 is actuated by an operator or actuator 48.

As noted above, the batch treatment system shown in Figure 16 employs magnetic seeding and magnetic separation. To accomplish magnetic separation, the batch treatment system is provided a plurality of magnets 46. In the case of the embodiment illustrated herein, the magnets 46 are permanent magnets, but it is understood that other types of magnets could be used, such as electromagnets. To move the magnets 46 between the operative position shown in Figure 16 and the inoperative position shown in Figure 17, there is provided a series of air cylinders 45. Each cylinder is operative to move a magnet from a position relatively close to the bottom of the tank 42 to a position away from the bottom of the tank.

To treat water with the batch treatment system shown in Figure 16, the tank 42 is charged with contaminated water by directing the water into inlet 40A. Magnetic seed, such as magnetite, is either present from a prior process or is added. Once the tank 42 is filled, a flocculant is added and functions to attach pollutant particles to the magnetic seed. In one embodiment, mixer 41 is operated at a relatively slow speed to ensure good mixing while avoiding shearing of the magnetic floc that are being formed in the tank. During this flocculation phase of the batch treatment process, the magnets 46 are inoperative, as shown in Figure 17. The gentle mixing by the mixing blade 430 causes suspended solids, and particulate matter in general, to agglomerate around the magnetic seed to form the floc indicated by the numeral 60.

After sufficient flocculation has occurred, the floc 60 are settled to the bottom of tank 42. Settlement can be achieved in various ways. In one

embodiment, the motor 41 is turned off and the magnetic floc 60 is allowed to settle by gravity to the bottom of the tank 42. In another embodiment, the motor 41 is operated at a relatively slow speed, thereby providing gentle mixing, and the magnets 46 are positioned closely adjacent the bottom of the tank 42 and the magnetic attraction caused by the magnets 46 causes the magnetic floc 60 to settle to the bottom of the tank. In this embodiment, the magnetic field applied by the magnets 46 attract the magnetic floc to the lower collection surface of the tank 42.

Figure 18 shows the magnetic floc settled in the lower portion of the tank 42. At this point, a valve associated with outlet 40B can be actuated and the clarified water in the tank 42 can be discharged through the outlet 40B. This is illustrated in Figure 19. While the water is being discharged out outlet 40B, the magnets 46 are disposed in their operative position and function to retain the magnetic floc about the lower portion of the tank while clarified water is being decanted through line 40B.

Once the clarified water has been decanted from the tank 42, the magnets 46 are moved to their inoperative position shown in Figure 20, and the motor 41 is driven at a relatively high speed. During this phase of the process, the shearing blade 44 disposed about the lower portion of the central shaft, engages and shears the magnetic floc in the lower portion of the tank. This shearing action, shears the magnetic seed from the particulate matter surrounding the same. Effectively, this shearing action separates the magnetic seed from sludge.

Once the shearing phase of the batch process is completed, the magnets 46 are moved back to their operative position, a position relatively close to the bottom of the tank 42. This is illustrated in Figure 21. Now the separated sludge

can be discharged out outlet of 49. In this phase of the process, the motor 41 may be driven at a relatively slow speed and valve 47 is open to permit the sludge to be discharged out the sludge outlet 49. It may not be essential to drive the shear blade 44 while discharging the sludge out outlet 49. However, some gentle agitation of the sludge in the lower portion of the tank 42 may facilitate the discharge of sludge through outlet 49. While the sludge is being discharged out outlet 49, the magnets 46 retain the separated magnetic seed in the tank 42 and generally in close proximity to the bottom surface thereof.

Once the sludge has been discharged, the magnetic seed remains in the bottom of the tank 42. This is illustrated in Figure 22. Now the batch process can be repeated by closing valve 47 and introducing a new batch of water to be treated through inlet 40A. Again, a flocculant is added, and from time-to-time, additional magnetic seed, such as magnetite, may be added in order to provide for efficient and effective flocculation.

RETROFITTING AN EXISTING WATER TREATMENT SYSTEM

Aging municipal wastewater treatment plants have difficulty meeting flow requirements and removing necessary pollutants to meet discharge limits. Often the problem is either inefficient clarification or undersized biological treatment. Until now, a common solution to these problems was to shut down the plant and build a new plant elsewhere because there is usually not enough space to correct these problems. Finding a suitable new site is difficult and costly. Distribution systems would have to be rerouted to a new site at great cost.

Disclosed herein is a method for addressing both of these problems by adding one or more high-rate clarifiers and converting existing gravity clarifiers to

biological treatment systems. This conversion can be made with any high rate clarification technology such as a magnetic treatment system, possibly combined with vortex separation as disclosed in U.S. patent application Ser. No. 11/503,951 and entitled "Water Treatment Using Magnetic and Other Field Separation Technologies." According to the present invention, biological treatment such as Integrated Fixed-film Activated Sludge (IFAS) treatment, with or without recycled activated sludge, is added. Having no returned activated sludge will reduce the solid loading on the high rate clarifiers. This approach may provide significant savings in cost and space.

Thus, high rate clarification technology is employed to convert gravity clarifiers to a biological treatment process. In one embodiment, the high rate clarification technology is based on magnetic seeding and separation technologies.

Even though biological treatment is usually not a part of drinking water treatment per se, the concept of increasing treatment capacity without increasing the footprint size by installing a high rate clarifier within a gravity clarifier also applies. In the case of drinking water treatment, clarification is the primary treatment method. The clarifiers used are traditional clarifiers that rely upon gravity settling to clarify the water. The Surface Overflow Rate for this type of clarifier is about 0.5 gallons per minute per square foot of surface area. Therefore, to clean 10,000 gallons per minute, the size of the clarifier would have to be about 20,000 square feet. Accordingly the present high rate clarifiers can be mounted inside the old gravity clarifiers. A high rate clarifier may have a Surface Overflow Rate of 50 which is approximately 100 times smaller than a conventional clarifier. Accordingly, a large number of high rate clarifiers could be contained

inside a conventional clarifier and therefore greatly increase the treatment capacity without increasing the footprint of the treatment process.

The generation of malodorous gases from municipal wastewater treatment facilities is a common operational problem. These odors are usually caused by the presence of hydrogen sulfide or other sulfur-containing chemicals, e.g. mercaptans. Removal of odor-causing chemicals from wastewater can be accomplished in a variety of ways. One way is to treat the gas coming from the wastewater with such technologies as wet scrubbing, activated carbon, biological filters. etc. Alternatively, and as preferred according to the present invention, the water is treated directly. This can be accomplished by introduction of reagent chemicals such as iron salts, hydrogen peroxide, etc. or by biological treatment with microorganisms that use sulfur as a metabolic food source.

Effective water phase treatment requires good contact to be made between the odor-causing chemicals and a chemical reagent or with microorganisms. Effective separation is then needed to remove the resulting reaction product. According to one embodiment, a magnetic seed material, such as magnetite, is coated with biofilm and used to biologically treat the odor causing chemicals, and then a magnetic separation technology is used to control the discharge of treated wastes.

Municipal wastewater treatment systems in this country are aging, and are often under capacity and not capable of meeting water quality discharge limits. This application discloses the use of high rate clarification, preferably using magnetic separation technology, to address the limitations of existing municipal wastewater systems.

Existing municipal wastewater treatment systems typically contain primary clarification, biological treatment, secondary clarification, and sometimes sand filtration. The primary and secondary clarifiers rely on gravity alone to perform separation, and are extremely inefficient compared to the new generation of high rate clarifiers disclosed herein. The surface overflow rate (SOR) of conventional clarifiers is usually below one gpm/ft^2 and often as low as 0.1 gpm/ft^2. Assuming an average SOR of 0.5 gpm/ft^2, the total surface area for the primary and secondary clarifiers for a flow rate of 10,000 gpm will be 40,000 square feet. Under these conditions, each circular structure would be 160 feet in diameter. A typical magnetic separator as disclosed herein would have a footprint of about 144 square feet or about 140 times smaller than a conventional clarifier.

According to one aspect of the present invention, existing clarifiers can be converted into biological treatment tanks. Clarifiers are often similar in size and shape to biological treatment tanks and are designed with sludge removing equipment. Basically, clarifiers are only lacking aeration equipment. Then the converted clarifiers would be replaced with more efficient high rate clarification systems, such as those employing magnetic separation systems. This approach will increase the capacity of the plant, both hydraulically and biologically, to better clean a greater volume of water. Additional high rate clarifiers can be added to treat wet weather flows. These additional high rate clarifiers when not in use becomes spares to increase plant reliability.

Figure 23 shows schematically the components of a traditional municipal wastewater treatment system with clarification and biological treatment. Figure 24 shows a modified water treatment system where conventional gravity clarifiers have been converted to biological reactors and where a number of high rate

clarifiers have been added. "High rate clarifiers" are defined as clarifiers that have a surface overflow rate greater than five gallons per minute per square foot of surface area.

In the conventional system 70 of Fig. 23, wastewater influent entering first flows through a primary clarifier 72 to separate out large solids by gravity. Flow then proceeds to a biological treatment tank 73. In many cases the biological treatment tank 73 is utilized for aerobic treatment. However, biological treatment can also entail anaerobic and/or anoxic treatment as used, for example, in nitrification and denitrification. The biologically treated wastewater then flows to a secondary clarifier 74 to remove most of the suspended solids, followed by sand filtration 75 for final removal of most turbidity, and is then discharged. During wet weather conditions, when flow exceeds the capacity of the treatment facility, untreated water is bypassed through pipe 77. During wet weather conditions, when flow exceeds the capacity of the treatment facility, untreated water can be bypassed at several possible stages through pipe 77 as indicated by the broken lines in Figure 23.

Figure 24 illustrates a retrofitted wastewater treatment plant or system 70A in which certain components of the prior system 70 have been modified and new components have been added. The prior existing gravity clarifiers 72, 74 shown in Figure 23 have been converted to biological reactors 76A, 76B and a number of HRC units have been added. Converting the gravity clarifiers 72, 74 of prior plant 70 to biological treatment systems will typically involve the addition of aeration equipment if an aerobic system is desired. In some cases, it is appreciated that the biological reactors 73, 76A and 76B in retrofitted plant 70A could be operated as anaerobic or anoxic reactors. In one embodiment, the biological system would

be a Moving Bed Biological Reactor (MBBR). In this case, a plastic media is added for the growth of fixed biofilms. The particulars of the conversion will vary depending upon the type of biological treatment desired. It is contemplated that a wide range of biological treatments is performed in the biological reactors. For example, various mixes of aerobic, anaerobic, and anoxic treatments can be employed to accomplish BOD removal, nitrification-denitrification, phosphorus removal, etc. Retrofitted plant 70A includes a primary HRC unit 71A, possibly employing vortex separators with magnetic seeding according to the teachings of U.S. patent application Ser. No. 11/503,951to serve as a primary clarifier for the retrofitted system. An auxiliary HRC 71B is incorporated to provide for high flow conditions. Converted biological reactors 72, 74 along with the original biological reactor 73 are configured to operate in parallel as illustrated in Figure 24. Secondary High Rate Clarification units 71C may be located inside the biological reactors 73, 76A and 76B to conserve space, or downstream from the biological reactors of retrofitted system 70A.

In operation of retrofitted system 70A of Figure 24, raw sewage or wastewater influent enters the primary HRC 71A for removing large suspended solids. If phosphate removal is needed, iron or aluminum reagents can be added at this point to precipitate phosphate as a metal salt, which will be removed with the primary sludge. Following clarification in the primary HRC 71A, flow passes to the biological treatment tanks 73, 76A and 76B disposed in parallel relationship. From the biological reactors 73, 76A and 76B, the wastewater being treated is directed to secondary HRCs 71C where the mixed liquor suspended solids (MLSS) are removed. In one embodiment, one of the HRCs 71C is located inside each respective biological treatment tank 73, 76A and 76B to save on footprint as

noted here before, and to simplify the return of sludge to the system. Alternatively, the HRCs 71C can be placed downstream from the biological reactors 73, 76A and 76B of retrofitted system 70A.

In HRCs 71C, iron or aluminum reagents can be added to polish out residual amounts of phosphate not removed in the primary clarification and biological treatment stages. Clarified water then flows from the HRC units 71C to the existing sand filter 75. An additional sand filter 78 may be necessary to handle the increased flow through the system. The clean effluent is significantly increased and with better water quality.

In the event of a wet weather event, a spare HRC 71B is available to treat excess flows that can be routed through pipeline 79A for additional biological treatment, or routed through pipeline 79B for additional sand filtration, or routed through pipeline 79C for direct discharge through pipeline 79D. During normal operation, spare HRC 71B provides backup reliability to the primary HRC 71A.

As seen in Figure 24, the retrofitted water treatment system includes a series of biological reactors 73, 76A and 76B. These biological reactors are disposed in parallel relationship. When these three biological reactors 73, 76A and 76B are utilized in parallel, it is appreciated that the capacity of the wastewater treatment system is substantially increased compared to the preexisting water treatment system 70 shown in Figure 23 that operates in series.

In disclosing and describing the methods and systems for treating water, magnetic seeding and magnetic separation have been disclosed as a means of clarifying and removing solids from the water. Generally, magnetic seeding and separation entails mixing magnetic seed, such as magnetite, with the water being treated. Through flocculation, adsorption, absorption and other physical or

chemical means, contaminants such as suspended solids, scalants, heavy metals, etc. attach to the magnetic seed to form magnetic particles or magnetic floc. In the case of flocculation, a coagulant and a flocculant may be mixed with the water. Typically, the process of magnetic separation entails utilizing a magnetic collector such as a rotary magnetic drum or a series of rotary magnetic disks or any device that creates a magnetic field strong enough to remove ferromagnetic particles from water. Such collectors are at least partially submerged in the water being treated and are normally driven such that portions of the collectors move through the water. In the process, magnetic particles or magnetic floc are collected by the magnetic collector. These magnetic particles or magnetic floc are removed from the magnetic collector and directed to a shear chamber. In the shear chamber, the magnetic particles or magnetic floc are sheared, separating the magnetic seed and effectively producing magnetic seed and sludge. The same magnetic collector, or a second magnetic collector, can be utilized to collect the separated magnetic seed. After the magnetic seed has been collected by the magnetic collector, the seed is removed from the magnetic collector and returned to the same treatment tank or chamber, or otherwise recycled. The separated sludge is collected and directed from the system or process.

MAGNETIC SEPARATION AND SEEDING TO IMPROVE BALLASTED CLARIFICATION OF WATER

A ballasted clarification system uses a seed material that is heavier than water to weigh down less dense pollutant particles, so that they settle out of the water stream to be treated. A flocculant such as an organic flocculating polymer is used to attach the pollutant particles to the ballast material.

Figure 25 illustrates a ballasted flocculation process for clarifying water. Water 61 enters into a series of flocculation chambers 64, 65, and 66 the contents of which are agitated by mixers 62 to bring pollutants into contact with ballast material (non-magnetic) in the presence of a flocculating polymer. The combined particles flow into a settling chamber 69A where the particles settle by gravity and the clarified water exits through separator plates or lamella 69B and out an outlet 69C. In a typical ballast system, the settled particles are moved to a pump inlet with a scraper 67 and then pumped with a high shear pump 68 to a hydrocyclone 69 that centrifugally separates the pollutants from the ballast material. Pollutants are discharged 63A from the system and the ballast material 63 is returned to the flocculation chamber 65. The pump applies enough shearing action to break the floc, detaching the ballast from the pollutant particles, so they can be effectively separated in the hydrocyclone.

Figure 26 illustrates a ballasted flocculation system and process where the ballast or seed comprises magnetic material such as magnetite. In this process, water flows via an inlet into a mixing chamber 81A where treatment chemicals, specifically coagulants, flocculants, and/or phosphate removing chemicals are added through injection lines 82, 83. Effective mixing is provided by a stirring device 84 in zone 81A. The water being treated then flows into another mixing or flocculation chamber 85 or zone where the fine particles and particulate matter attach to magnetic seed, such as magnetite, which is a form of iron oxide. Chamber 81B can be referred to as a flocculation chamber or zone because in this zone the magnetic seed attaches to particulate matter and the particulate matter agglomerates around the magnetic seed to form magnetic floc. In the flocculation zone 81B is located a magnetic cleaning system 86 which collects a

fraction or a portion of the "dirty" magnetite particles or magnetic floc which, in one example, are composed of particles made up of magnetite bound by the flocculant to the particulate matter to be removed from the water. In one embodiment, the magnetic cleaning system 86 includes a rotating magnetic drum that is at least slightly submerged in the water in the flocculation zone. The drum is scraped to remove the collected magnetic floc, and the magnetic floc is directed to a shear tank that forms a part of the magnetic cleaning system 86. The shear tank includes a shear mixer that produces a sheared slurry comprised of the magnetic seed, which in the case of one embodiment is magnetite, and sludge. The cleaned magnetic seed or magnetite 86Ais then returned to the flocculation zone 81B while the sludge is discharged from the system through line 86B.

The magnetic floc from chamber 81B then flows into a downstream settling chamber or zone 81C that is located beneath a gravity separation device 69B such as lamella or separator plates. Also disposed in the settling tank adjacent the outlet thereof is a magnetic separator 88. Large magnetic floc, which are separated by the gravity separation device 69B, settle downwardly on an inclined bottom 89 of the settling chamber or zone 81C. The slope of bottom 89 is steep enough to allow the magnetic floc to slide down the incline and back into the flocculation zone 81B. Clarified water flows out of the settling tank 81C and if necessary can flow past the magnetic separator 88 to remove any remaining magnetic floc. The clean or clarified effluent is then discharged from the settling tank 81C.

Magnetic separator 88 is preferably composed of permanent magnets that are continuously cleaned. For example, magnets may be disposed in one or more disks rotated about a horizontal axis, with scrapers in contact with the disk

surfaces to remove the collected magnetic particles or magnetic floc. The magnetic floc are scraped off the magnetic separator 88 and flow or fall into the settling zone 81C and then back down the inclined bottom 89 and then into the flocculation zone 81A where the magnetic floc can recombine with other magnetic floc and eventually removed by the magnetic cleaning system 86. That is, eventually all of the magnetic floc come into contact with the magnetic separator associated with the magnetic cleaning system 86, where the magnetic ballast or seed, such as magnetite, is removed from the magnetic floc and recycled while the sludge is directed from the system via line 86B.

As noted above, the settled magnetic floc that slides down inclined bottom 89 enters the flocculation zone 81B. Because of the mixing or agitating action of the mixer 84 in zone 81B, the previously settled magnetic floc is generally mixed in flocculation zone 25, and because of the mixing action remains in a generally homogeneous suspension in the vicinity of the magnetic cleaning system 86. Thus, even the previously settled magnetic floc will eventually move into contact with the magnetic collector associated with the magnetic cleaning system 86.

In some cases it may be desirable to collect settled magnetic floc in the settling zone or tank 81C itself. Therefore, it is contemplated that a magnetic collector may be designed to extend adjacent the bottom 89 of the settling tank 81C. This will permit the settled magnetic floc to actually be collected while in the settling zone or tank 81C. By utilizing a magnetic collector in the settling tank, this eliminates the cost of a pump and will result in less shearing of the floc. Another alternative design includes the possibility of providing a low shear pump, such as a diaphragm pump or a progressive cavity pump that removes the settled magnetic floc from the settling tank 89 and directs the magnetic floc to a shearing

device that will separate the magnetic ballast from the sludge and permit the magnetic ballast to be recycled.

In Figure 26, the mixer 84 in flocculation zone 81B is schematically illustrated as being offset in the flocculation zone. It is appreciated that more than one mixer 84 can be provided in flocculation zone 81B or that the mixer shown therein can be generally centrally located so as to maintain magnetic floc in suspension generally uniformly throughout the flocculation zone in order that the magnetic floc can come into contact with the magnetic separation system 86.

In disclosing and describing the methods and systems for treating water, magnetic seeding and magnetic separation have been disclosed as a part of the magnetic cleaning system 86 and as a means of clarifying and removing solids from the water. Generally, magnetic seeding and separation entails mixing magnetic seed, such as magnetite, with the water being treated. Through flocculation, adsorption, absorption and other physical or chemical means, contaminants such as suspended solids, scalants, heavy metals, etc. attach to the magnetic seed to form magnetic particles or magnetic floc. In the case of flocculation, a coagulant and a flocculant may be mixed with the water. Typically, the process of magnetic separation entails utilizing a magnetic collector such as a rotary magnetic drum or a series of rotary magnetic disks. Such collectors are at least partially submerged in the water being treated and are driven. In the process, magnetic particles or magnetic floc are collected by the magnetic collector. These magnetic particles or magnetic floc are removed from the magnetic collector and directed to a shear chamber. In the shear chamber, the magnetic particles or magnetic floc are sheared, separating the magnetic seed and effectively producing magnetic seed and sludge. The same magnetic

collector, or a second magnetic collector, can be utilized to collect the separated magnetic seed. After the magnetic seed has been collected by the magnetic collector, the seed is removed from the magnetic collector and returned to the same treatment tank or chamber, or otherwise recycled. The separated sludge is collected and directed from the system or process.

Thus, according to the invention, magnetite is used both as a conventional ballast, that is, separation is accomplished by gravity acting on the massive composite particles to settle them out of the water stream, and as a magnetic component of the composite particles, so that magnetic separation can additionally be performed.

There are three major advantages of this approach over traditional ballast clarification. The first advantage is that the waste discharged from the system is more concentrated because of the magnetite cleaning system and therefore there is less volume. The second advantage is that magnetic seed or ballast from the final separation chamber flows back into the flocculation chamber without the use of a pump or scraper device. The third advantage is the SOR (surface overflow rate) in the final collector can be higher because of the final magnetic collector 33. That is, because magnetic collection is more effective than gravity collection, the throughput of the system can be increased.

A MULTISTAGE SORPTION PROCESS FOR TREATING WATER UTILIZING MAGNETIC SEED

A known commercial use of magnetic treatment technologies is the "Sirofloc" technology used in Australia to clean drinking water. This process uses the absorption capacity of magnetite to remove color and other

pollutants from water. The spent magnetic seed material (magnetite) settles out by gravity in a clarifier and then is pumped to a magnetite regeneration step that cleans the magnetite so it can be reused.

In Sly et al., US patent 5,443,729 issued August 22, 1995, a method was described using magnetite as a bed material in a fluidized bed bioreactor to remove manganese from water. Manganese is the only pollutant identified as suitable for this type of treatment, and pedomicrobium manganicum is the only microorganism disclosed. There is no mention of use of the magnetic properties of magnetite to prevent solids from leaving the bioreactor.

In an Australian patent 534 238, to Weiss it was shown that microorganisms attach strongly to magnetite without diminishing their capacity to function microbiologically. Mac Rae and Evans, in Factors Influencing the Adsorption of Bacteria to Magnetite in Water and Wastewater, Water Res. 17: 271-277 (1983), and Removal of Bacteria from Water by Adsorption to Magnetite, Water Res. 18: 1377-1380 (1984) show that magnetite rapidly adsorbed 95-99% of a variety of microbial cells from aqueous suspensions.

This application discloses use of the magnetic properties of magnetite in a system for magnetically capturing these particles and returning them to the bioreactor to increase the Solid Residence Time (SRT) of the microorganisms, that is, the magnetic properties of magnetite are exploited in separation of the pollutants from the water stream to be treated.

Magnetite is a suitable bed material for biofilm growth to biologically treat dissolved organics. More specifically, there are a large number of other biofilms that can be attached to magnetite. The bacteria that make up these

biofilms can be selected to target specific pollutants. The specific targeted pollutants include but are not limited to organics found in municipal wastewater treatment plants, sulfates found in acid mine drainage and cooling water, organics found in ground water contamination, oil and grease from industrial processes, and chlorinated solvents.

It is reasonable to believe that a wide range of biofilms can be attached to magnetite for treating a wide range of dissolved pollutants. The Sly patent states that "magnetite particles used in the Sirofloc water purification process have the necessary density and surface characteristics for a suitable support particle."

In summary, the Sly patent shows the significant advantage of a fluidized bed bioreactor to treat water because of its low pressure drop and the high surface area of the bed material. It also shows the suitability of magnetite as a bed material for the growth of a biofilm to treat manganese. As noted, however, the Sly patent only discloses use of one microorganism, pedomicrobium manganicum, to remove one pollutant, manganese.

The present process relates to use of Polymer Coated Magnetite (PCM), which has the ability to absorb dissolved organic or inorganic pollutants from water. Research performed at Oklahoma State University by Dr. Allen Apblett under EPA Grant Number: R827015-01-0 shows methods for imparting magnetic properties to activated carbon and coating magnetite with polymers such as polydimethylsiloxame (PDMS) for the absorption of dissolved hydrocarbons from water. Hydrocarbon removal efficiency was shown to exceed 99.9+ %. This proof of concept demonstrated that magnetic extractants in combination with magnetic filtration are capable of removing

hydrocarbons from water and in breaking oil in water emulsions. Specialized fine magnetic absorbents have improved mass transfer kinetics of absorption, reduced pressure drop through the treatment system, and are easy to remove from water with a magnetic separator.

According to one aspect of the present invention, the two magnetite based treatment technologies are used to provide an effective approach to treating organics. Biological treatment is effective, inexpensive, and produces less sludge than chemical treatment systems. Combining biological treatment and magnetic separation is an added advantage because the solid residence time (SRT) can be significantly increased. However, bacteria are slow acting and therefore require large process tankage. Absorption of pollutants is much faster than biological treatment and therefore reduces the size of tankage. Magnetite can be modified to enhance its absorption properties. This can be done by combining it with activated carbon or coating the magnetite with special polymers that have an affinity for organics. This PCM can contain small particles which improves absorption kinetics and capacity. Combining these two technologies together makes a very effective treatment system. The magnetite absorption media quickly removes the organics from the waste stream and concentrates these wastes. This reduces tankage size and does not add treatment chemicals that increase sludge quantities. These concentrated wastes then can be cleaned off the PCM either biologically, chemically, or by heat so that the PCM can be reused.

The addition of a flocculating polymer is an appropriate step in most magnetic seeding processes. The flocculating polymer is used to attach magnetic particles to non-magnetic particles so the combined particles can be

removed from the water with a magnetic device. However, the use of PCM to absorb dissolved hydrocarbons may be affected by the addition of a flocculating polymer. At a minimum, the flocculating polymer in some cases may cause the particles to come together and reduce their surface area. The flocculating polymer will be absorbed onto the surface of the PCM and reduce its capacity to absorb other dissolved pollutants. This can affect the absorption properties of activated carbon and polymers. Use of too high a concentration of flocculating polymer can have an adverse effect on biological activity. Since using flocculating polymers to clarify water may interfere with the absorption properties of the PCM or with the biological action of bacteria, a two-step process can be used.

The first stage of treatment is the absorption of organics, e.g. hydrocarbons, on the PCM. The PCM is kept in the first stage treatment tank with a magnetic separator. A PCM cleaning system that uses, for example, biological treatment to digest organics, thermal treatment to volatilize the organics, ozone to oxidize organics, adjustment of pH to repel the organics (as performed in the Sirofloc process), or solvents to extract the organics, is provided to regenerate the PCM, so it can be reused to absorb dissolved pollutants. In one embodiment, other solid pollutants in the waste stream that are not magnetic or absorbed onto the PCM will pass through the absorption phase of treatment into a secondary clarification phase. This secondary clarification phase uses a flocculating polymer to attach the non-magnetic particles to a magnetic seed material. This clarification stage also has a cleaning system to clean the magnetite seed material.

Accordingly, the present application is directed to the use of a multistage treatment process that uses a sorption stage and a clarification stage for the removal of dissolved pollutants and solids from water. Each stage uses some form of magnetic seeding/separation technology and magnetic seed cleaning.

With particular reference to Figure 27, a multistage process is disclosed therein. Water to be treated containing solids, dissolved inorganic or organic pollutants flow through an inlet 90 into a reactor or tank 91. Disposed in tank 91 is an agitator or mixer 92. Injected into the tank 91 is magnetic seed. The magnetic seed may be in various forms and can include PCM, magnetic seed coated with biofilm or activated carbon. The magnetic seed, whether coated or uncoated, is referred to as magnetic particles. The mixer 92 is driven so as to maintain the magnetic particles in suspension and generally uniform throughout the tank 91.

Located in the tank 91 are two magnetic devices. One is a cleaning system 15 and the other is a magnetic collector 93 that keeps the magnetic particles contained within the treatment tank 91. Cleaning system 95 acts to collect the magnetic particles such as PCM or other coated magnetic seed on a magnetic collector, and separates the pollutants or contaminants adsorbed onto the magnetite particle from the coated magnetic seed. In the case of magnetite coated with a biofilm, for example, a magnetic cleaning system may not be required. The separated contaminants are discharged through line 95B and the cleaned magnetic seed or coated magnetic seed is returned through line 95A to the tank 91 to be reused. The second magnetic device 93

located in tank 91 is a final magnetic collector that prevents magnetic seed or coated magnetic seed from exiting tank 91.

In one embodiment, the magnetic collector 93 includes a rotary disk magnetic collector with a series of scrapers that scrape collected magnetic seed or coated magnetic seed from the collector and direct the magnetic seed or coated magnetic seed back into the tank 91 where the magnetic seed or coated magnetic seed can be reused.

In a second phase or stage, the water is clarified by removing suspended solids from the water. In this stage, a second tank or vessel 91 is used. Here magnetic seed and a flocculant polymer are mixed with the water in tank 91. The polymer can be added through line 97. By mixing the magnetic seed such as magnetite and the flocculant, suspended solids tend to agglomerate around magnetic seed and form magnetic floc. The mixer 92 maintains the magnetic floc in suspension, and during the process the magnetic floc grows as more suspended solids agglomerate.

To remove the magnetic floc, and hence the suspended solids, from the tank 91, there is provided two magnetic collection or separation devices. The first is a magnetic cleaning system 96. The magnetic cleaning system 96 typically includes one or more magnetic collectors and a shear chamber. In the example shown, one magnetic collector is in the form of a rotary magnetic collector and collects magnetic floc thereon. The magnetic floc collected is scraped from the magnetic collector and falls into a shear chamber where the magnetic floc is sheared, resulting in a sheared slurry comprising magnetic seed and sludge. A second magnetic collector disposed to the left of the shear tank, as shown in Figure 27, collects the separated magnetic seed and

returns the magnetic seed to tank 91. The separated sludge is collected and directed out sludge line 96B.

The second magnetic collection system associated with tank 91 is a final magnetic collector 93 disposed adjacent outlet 98. Magnetic collection system 93 typically includes a rotary magnetic collector for collecting any magnetic floc that is contained in water being directed from tank 91 through outlet 98.

Therefore, it is appreciated that the present process is a multistage, or phase, process. In one phase, contaminants in solution are sorbed by a magnetic material such as magnetite that may be coated with a polymer, activated carbon, biofilm, etc. In another phase, suspended solids are removed by a magnetic clarification process. In Figure 27, the magnetic sorption process precedes the clarification process. It should be appreciated that the staging can be reversed, with magnetic clarification being performed prior to magnetic sorption.

HIGH RATE CLARIFICATION OF COOLING WATER USING MAGNETITE SEEDING AND SEPARATION

According to one aspect of the present invention, sulfide precipitation is employed to remove heavy metal contaminants from Ultra High Lime with Aluminum (UHLA) sludges. Before the scalants are precipitated by the UHLA process, a sulfide precipitant is added to react with all divalent heavy metals in the coolant. This precipitates metals such as copper, zinc, iron, and nickel originating as heated surface corrosion products, trace metals that are not precipitated in the high lime softening of makeup water, and contaminants including trace metals

found in water treatment chemicals. Sulfide precipitation of heavy metals is not generally sensitive to pH and therefore practically all of the divalent heavy metals can be removed. The precipitated heavy metal sulfides are removed from the cooling water before the scalants, and corrosion products are removed by UHLA. Therefore these sludges are relatively free of heavy metal contamination and are suitable for reuse.

More specifically, alum sludge, a waste product from water treatment, is a good source of aluminum to precipitate chlorine as calcium chloroaluminate. However, it contains trace amounts of heavy metals and other contaminants found in water. The potential use of this byproduct has significant cost and environmental benefits. The coolant is mixed with this sludge at a high pH (greater than 10) to dissolve the aluminum. Adding a sulfide to this waste stream according to this aspect of the invention will precipitate divalent heavy metals but not the aluminum. Therefore, the total suspended contaminants and heavy metals are first removed from the alum sludge, while the aluminum stays in solution and goes on to the UHLA process, where scalants and corrosives such as chlorine are removed. That is, in order to use waste sources of aluminum and to remove the dissolved heavy metals in the coolant, the process of the invention also includes a high alkaline precipitation of heavy metals with sulfides to keep the aluminum in solution and available for the UHLA process. Because aluminum is soluble at high and low pH, acid precipitation of the heavy metals with sulfide is an alternative that may be cost effective. However, in this mode, a sulfide precipitant that does not emit large amounts of toxic gases in an acid environment must be used, such as those taught in U.S. patents nos. 5,451,327 and 5,762,807.

The UHL process sludges exhibit a design Surface Overflow Rate (SOR) of 1-1.3 gallons per minute per square foot of clarifier surface area. When aluminum is used, as in the UHLA process, the SOR is even lower or about 0.8 gpm/square foot. Therefore, large gravity clarifiers are required to settle UHLA sludge from cooling water. This is a significant barrier to adoption of the UHLA technology.

According to another aspect of the present invention, high rate clarification, preferably magnetic separation, is performed to remove UHLA sludges efficiently, making the UHLA process practical. Optimally, three clarifiers are employed: one to separate solids from the ultra high lime process used to treat blow down, one for treating makeup water using the high lime softening process, and one for the removal of heavy metal sulfides and cleanup of waste aluminum sludge precipitated in the chlorine removal step.

In summary, the process of the invention treats cooling water in three treatment steps, each employing high rate clarification, preferably magnetic seeding and separation technology. The three steps are sulfide precipitation to remove heavy metals, ultra-high lime precipitation with or without aluminum, and high lime softening.

Another advantage of using magnetic seeding in the cleaning of cooling water is in connection with the removal of silica, a significant problem in evaporative cooling water systems. Midkiff US patent 6,416,672 describes a method for removing silica by depositing the silica on particles of a nucleation site material. By providing a large surface area of fine material, silica will scale on this surface area and reduce the scaling on heat transfer surfaces. However, Midkiff points out a potential problem: if the nucleation site material is too small, there will be excessive pressure losses and the nucleation site material will be difficult to

remove from the cooling water. Magnetite is mentioned as a suitable nucleation site material but the magnetic properties of magnetite are not mentioned.

Therefore, the present process entails a scale removal system comprising a treatment reactor containing magnetite, a magnetite cleaning system, and a magnetic separator comprising permanent magnets. A magnetic clarifier removes suspended particles from the water flowing from the reactor, If a flocculating polymer used to bind the magnetite to particles to be removed presents a problem, e.g. fouling of heat transfer surfaces in the condenser, filtering may be employed.

The process employs magnetite particles to provide nucleation sites for scale removal. Using fine magnetite will provide a very large surface area for the deposit of silica and the magnetite can be easily removed in a magnetic separator. That is, the ferromagnetic properties of the magnetite allow it and the particles to which it is bound to be easily removed from water with no pressure drop. It is anticipated that the magnetite cleaning process will abrade the silica off the magnetite so it can be reused; chemical cleaning is another option.

Figure 28 depicts in schematic form a process for treating cooling water with lime, sulfides, aluminum sludge, and high rate clarification for removing precipitates that are formed at several different treatment process steps. Figure 29, discussed below, shows schematically a system for removing dissolved chemicals that might otherwise form scale. The Figure 28 system can be used in conjunction with the system of Figure 29 where appropriate.

Thus, in Fig. 28, cooling water flows from an evaporative cooling tower 101 through a condenser 102 for cooling. The cooling water stream is recycled 103 back to the cooling tower and some portion of the flow 104 is diverted (blown

down) to a heavy metal and suspended solids removal system 108. This is a high rate clarification system, preferably one employing magnetic seeding and separation technology. As mentioned above, according to one aspect of the present invention, this treatment system comprises addition of sulfides 105 for heavy metal precipitation, addition of waste aluminum sludge 106, preferably recovered from potable water treatment, for removal of sulfates and chlorides, and pH control 107 to maintain the pH at a level suitable to keep the aluminum in solution. Precipitated heavy metals and total dissolved solids from the aluminum source settle out and are discharged through a pipe 109 for disposal. The cooling water stream then flows through a pipe 110 to another high rate treatment system 111 that performs UHLA softening to remove scaling and corrosive compounds containing principally of calcium, magnesium, silica, sulfate, and chloride. This is accomplished by the addition of large amounts of lime 112. The compounds precipitated in this stage and removed at 113 have higher commercial value since heavy metals and other contaminants have been removed in the prior treatment stage. Additional purification steps can be taken to increase the purity and value of these compounds. Water then flows 114 to a high lime softening stage 116 that further treats the cooling water and new makeup water 115 with the addition of a source of inorganic carbon 117, preferably soda ash to remove some of the calcium scalants. The pollutants in the make up water and scale producing chemicals are removed at 119. The recycled cooling water then flows 118 back into the cooling system.

Figure 29 shows a two-stage treatment system to remove dissolved chemicals that might otherwise form scale. Briefly, magnetite is employed as a sacrificial surface on which the scale forms, so that scale does not form on the

heat transfer surfaces. Water flows 121 into a chamber or reactor 122 that contains magnetite, and is continually stirred with a mixer 123. Magnetite that has collected scale from the water is removed from the reactor by magnetic attraction and is then cleaned by a cleaning system 124 that removes scale from the magnetite by chemical treatment, or by mechanical means to abrade the scale off the magnetite. The cleaned magnetite is then returned to the stirred reactor 122 for reuse. Scale is disposed of through pipe 125. A magnetic collector 135 prevents the magnetite from exiting the stirred reactor 122. The first stirred reactor 122 removes scale from the cooling water. However, it does not remove suspended solids. This is accomplished when water flows 127 to a similarly-configured unit operated as a magnetic clarifier 128. The contents of the clarifier are continuously mixed by mixer 129, and a magnetite cleaning system 130 is also provided. This system returns cleaned magnetite for reuse 131 and disposes waste solids 132. Water then flows back to the cooling system 133. A magnetic collector 134 prevents the magnetite from leaving the magnetic clarifier 128.

Thus, the magnetic seed or magnetite used in chamber or reactor 122 functions to sorb scalant contaminants. When the magnetic seed or magnetite sorbs the contaminants, magnetic particles are formed. The mixing action in the chamber 122 maintains the magnetic particles in suspension, generally uniformly throughout the reactor 122. The magnetic cleaning system 124 collects the magnetic particles and cleans the magnetic seed from the magnetic particles after which the magnetic seed is reintroduced to reactor 122. In the other reactor 128, the method or process deals with removing suspended solids through a flocculation process involving magnetic seed such as magnetite. Here, a

flocculant is added and mixed with the magnetic seed in the water in reactor 128. This forms magnetic floc, which is eventually removed from the reactor 128 via the cleaning system 130.

USE OF A MAGNETIC SEPARATOR TO BIOLOGICALLY TREAT WATER

The present invention relates to removing dissolved pollutants from water using Magnetic Bed Media (MBM). It is applicable to industrial wastewater, municipal wastewater, potable water, combined sewer overflow, storm water, process water, cooling water and any other waters that contain dissolved organic or inorganic contaminants that can be treated biologically. The invention involves a Magnetic Separation Bio-Reactor (MSBR), which combines magnetic separation with activated sludge treatment in a process that has significant advantages over the membrane bio-reactor (MBR) technology discussed here before. The mechanical membrane in the MBR system is replaced with a "magnetic separator" for magnetic separation of the biologically-reduced pollutants from the water stream.

More specifically, the present invention provides a method for using ferromagnetic solids as a magnetic bed media (MBM) for growing biofilms that are designed to remove dissolved pollutants from water and to employ a magnetic separator to retain the biofilms in the bioreactor. Our investigation shows that magnetite is a suitable MBM to serve as a granular substrate for biofilm growth, such that the biofilm actively reduces dissolved organics. It is reasonable to believe that a wide range of biofilms can be attached to magnetite for treating a wide range of dissolved pollutants. More specifically, there is a large number of other biofilms that can be attached to magnetite in addition to *pedomicrobium*

manganicum that was disclosed by Sly. The bacteria that make up these biofilms can be selected to target specific pollutants. The specific targeted pollutants include, but are not limited to, organics found in municipal wastewater treatment plants, sulfates found in acid mine drainage and cooling water, organics found in ground water contamination, oil and grease from industrial processes, and chlorinated solvents.

The invention also relates to use of a flocculating polymer to attach the MBM to solid organic pollutants that have undergone biological treatment by the biofilm growing on the MBM, and to other pollutant solids. The attachment of the solid pollutants to the MBM allows physical separation of the pollutants from the water stream with a magnetic separator and thereby avoids significant limitations on the use of membranes or other mechanical filters. US Patent No. 6,726,832, hereinafter Collins, teaches use of organic flocculating polymers to enhance the performance of MBRs in the biological treatment of waste, specifically to reduce fouling of mechanical membranes. That is, the flocculated particles are large enough that they cannot enter into the fine pores of the membrane and therefore avoid fouling. Collins asserts that flocculating polymers if not used in excess will not inhibit biological activity. This relates to the present invention because the flocculating polymer attaches magnetic particles to non-magnetic particles so they can be separated from the water stream and retained in the bioreactor by a "magnetic separator." The Collins patent does not refer to a magnetic separator as proposed according to this invention and does not make any suggestion that use of flocculating polymers would be beneficial to the operation of a magnetic separator in a MSBR according to the present invention.

Thus, while Collins shows that the use of flocculating polymers reduces fouling of mechanical membranes as found in MBRs, according to the present invention the mechanical membrane is replaced with a magnetic separator and combined with the use of MBM.

The magnetic separator used according to this invention to separate the biological sludge from the water stream is preferably made up of rotating disks that contain permanent magnets. Water containing composite magnetic particles, formed by the use of flocculating polymers that attach solid pollutants to MBM, flows between the rotating disks of the magnetic separator and is collected by the permanent magnets. The disks rotate and are continually cleaned with a scraper that scrapes off the MBM with attached solid pollutants and returns them to the treatment vessel. Any magnetic separator using either permanent magnets or electromagnets designed to separate composite magnetic particles from water can be used. The dose of flocculating polymer can be controlled by monitoring biological activity as measured by TOC (total organic carbon), COD (chemical oxygen demand), or BOD (biological oxygen demand) of the effluent.

The scope of the present invention includes but is not limited to building upon the findings of Sly, who showed that magnetite can be used as a suitable bed material for the growth of biofilms that can biologically treat waste. Similarly, the present invention includes but is not limited to building on Collins, who showed that flocculating polymers do not inhibit biological activity. Based on these teachings. it appears that biological treatment taking place on the MBM can be employed to reduce dissolved pollutants in the water, and that a flocculant can then be used to bind the MBM and other solid pollutants, so that the separation of the particles from the water stream can be effected by a magnetic separator which

retains the magnetic particles in the bioreactor for reuse and to limit the amount of sludge. Thus, the present invention provides a MSBR system to effectively treat wastewater containing biologically degradable pollutants.

Known membrane bio-reactor (MBR) systems have significant advantages arising from their ability to separate solids from the water stream using a mechanical barrier, thus keeping the solids in the bio-reactor for extended periods of time. However, the MBR technology is subject to many operational disadvantages and high cost. The magnetic separator bio-reactor (MSBR) of the invention has all the advantages of MBR technology and none of its disadvantages. The advantages include:

No membrane fouling: Since the MSBR does not have a mechanical membrane, it cannot foul. Even in applications highly susceptible to fouling, the magnetic bed media (MBM) that is employed in the MSBR has never exhibited a fouling problem, because it is not necessary to achieve complete cleaning. In any event, any fouling that does occur will not affect the magnetic properties of the MBM.

No pressure drop: Forcing liquid through small (micron-sized) pores in a mechanical membrane of a MBR system results in significant pressure loss. The magnetic separator of the MSBR has large openings of about one inch that do not cause any significant pressure loss. Water flows through the MSBR by gravity so no pump is needed.

No membrane replacement: There are no mechanical membranes to wear out in the MSBR. The magnetic separator is composed of permanent

magnets that have an indefinite life. The magnets are encapsulated in plastic and do not come into contact with the wastewater.

Lower capital cost: The cost of a MBR capable of treating 100,000 gallons per day is calculated to be $500,000 ["Membrane Bioreactors in the Changing World Water Market", Susan Hank BCC Research, January 2006.]. The manufacturing cost of a MSBR is estimated to be much less.

No membrane scaling: Membranes are prone to scaling from calcium, magnesium, and silica chemicals. Magnetite, a commonly used MBM, is not known to scale but if it did, it would continue to perform its magnetic function until it could be disposed of at low cost. It is believed that the MBM will be descaled from abrasion that occurs in the cleaning process. Chemical cleaning of the MBM is also an option.

No membrane damage: Cleaning chemicals, water quality, or physical abrasion from suspended solids can cause damage to MBRs. Replacement cost of damaged membranes will be very high. After two years of operation of a closely-related magnetic clarifier, there has been no noticeable wear to the magnetic collection surfaces. Additionally, replacement costs would be low.

No membrane leakage: Membranes in a MBR have connection points where leakage can occur. This is not possible with a MSBR.

No membrane cleaning: Membranes have to be periodically cleaned with harsh acids and chlorine chemicals. This can cause hazardous exposure to employees and discharges of hazardous chemicals to the

environment. Although chemical cleaning of the MBM cannot be definitely excluded, it is anticipated that the MSBR will not require chemical cleaning, and that cleaning of magnetic surfaces mechanically in a continuous mode will be sufficient.

Less energy use: Forcing water through fine pores in a membrane requires significant pumping power. A prototypical MSBR system capable of treating 100 gpm has only three small drive motors that draw less than 5 amps total.

Greater waste concentration: The waste concentration in the MBR is limited by membrane fouling concerns. This is evidenced by the sludge wastage of 1.5-2.0% of the influent flow claimed for the "Zenon" technology ["Membrane Bioreactors: Wastewater Treatment Applications to Achieve High Quality Effluent", Henry Mallia, Steven Till, 2001 Conference Papers, Water Industry Operators Association, Australia]. The sludge wastage in a closely-related MSBR beta system was approximately 0.5%. Removing waste from a MSBR magnetically produces a more concentrated waste than can be achieved when waste is removed from a MBR. Greater waste concentration means less waste to dewater.

Lower operating cost: Operating costs for a MSBR are lower because of lower energy usage, no replacement membranes required, higher concentrated waste, and no membrane cleaning chemicals. The only extra cost for a MSBR is the MBM which is consumed in the treatment process.

Better suited for anaerobic treatment: In anaerobic treatment, fine organic particles are formed which readily foul membranes. Also, air cannot be used to scrub the membrane clean because of the necessity to maintain anaerobic conditions. Therefore using membranes in the denitrification stage of biological treatment becomes a bigger problem because of fouling issues.

Continuous operation: Flow through the MBR has to be interrupted during membrane cleaning and membrane breaks. This is not a problem with the MSBR because cleaning is continuous and there are no mechanical membranes to break.

More flexible and robust technology: MBRs can be damaged by unexpected chemicals or contaminants in the wastewater. For example, oxidizers like chlorine can damage membranes or organics can coat and foul the membranes. The MSBR has no delicate membranes to be damaged.

Fewer aeration limitations: Submerged mechanical membranes require coarse air bubbles to scour the membranes clean. This limits the amount of aeration available for the biological treatment process which is more efficient with fine air bubbles.

Turning now to specific embodiments of the invention, a two-step biological process is provided. For example, as generally known in the art, effective removal of typical nutrient pollutants, e.g., ammonia, can be accomplished by successive nitrification and denitrification steps, employing aerobic and anaerobic bacteria respectively. The MSBR system according to the present invention is expected to

be useful with substantially any desired biological treatment method. In one embodiment, a fixed-film media is used to enhance biological treatment. Iron is added to remove phosphates in one embodiment. One embodiment comprises using metal precipitants to remove heavy metals.

With further reference to the drawings (see Figures 30 and 31), in a layout for a MSBR treatment system for municipal and industrial wastewater treatment applications, ammonia is reduced to nitrates via an aerobic nitrification process in a first reactor vessel or chamber 142. Contained in first reactor vessel 142 are a fixed-film media 148 and a first MBM 149. Aerobic biofilm attaches to the surfaces of fixed-film media 148 and first MBM 149 to perform the reduction of ammonia to nitrates. This approach is similar to the known Mixed Bed BioReactor (MBBR) practiced by Anox Kaldnes and has similar benefits. Both first MBM 148 and fixed-film media 149 may be provided in one embodiment to ensure adequate biofilm growth while permitting magnetic separation to be performed. Fixed-film media 149 promotes the biofilm formed thereon staying attached to the media by providing a protected surface on which biofilm can grow thick and be protected from toxic shock. Typically, fixed-film media 148 is made of plastic that is nearly neutrally buoyant so it floats freely in water. Further, fixed-film media 148 has a porous surface for the attachment of biofilm, and the fixed-film media is nontoxic and noncorrosive. In one embodiment, the surface of fixed-film media 148 is textured so biofilm can attach readily, and so as to provide protected recesses in which the biofilm can grow to a thick layer that is not scoured off by abrasion with particles in the water. A common configuration for fixed-film media 148 that of a collection of small plastic cylinders.

By comparison, first MBM 149 provides a large surface area for the growth of biofilm and provides a way to increase the solids retention time (SRT) of the bacteria. However, the biofilm growing on MBM 149 is liable to loss due to abrasion. First reactor vessel 142 contains a first magnetic separator 145 that prevents particles of MBM 149 from being discharged from the vessel. The only particles passing through first magnetic separator 145 are non-magnetic biofilm particles that break away from MBM 149 or from fixed-film media 148.

The nitrates are then reduced to nitrogen gas via an anaerobic denitrification process in a second reactor vessel or chamber 152. Second reactor vessel 152 contains a second MBM 159 for affixing an anaerobic biofilm. A fixed-film media may optionally be included in second reactor vessel 152, depending on the effects of toxic shock on the bacteria. A second flocculating polymer 156 is added for attaching suspended solids including biomass to MBM 159 and forming a biofilm, thereby forming magnetic floc. Second reactor vessel 152 has a second magnetic separator 155 to keep magnetic particles from being discharged with the clean water 153. A cleaning device 150 is also included to separates the biomass and other solids, which comprise a sludge 150A, from the magnetic floc. Sludge 150A is discharged for disposal or further treatment.

More specifically, water to be treated 141A typically contains dissolved inorganic or organic pollutants. Water 141A flows into the first chamber or reactor vessel 142 where a first mixer 143 solids in suspension. The solids are made up of flocculating polymer 147 (if used), organic waste solids, and first MBM 149 (preferably magnetite). Mixer 143 keeps the solids in suspension, such that a "stirred" or "fluidized bed" reactor is effectively provided. High flow rate of the water and/or aeration is used in one embodiment to keep the solids in suspension.

First magnetic separator 145 prevents magnetic particles from leaving the first reactor vessel 142. First magnetic separator 145 comprises one or more magnetic disk(s), to which particles comprising MBM 149 are attracted to prevent the MBM from being discharged with the water after treatment in vessel 142. Scrapers 144 contact the surfaces of the disk(s) and scrape MBM 149 from the disks so that the MBM is returned to the first reactor vessel 142 for re-use. As noted here before, fixed film media 148 protects the biofilm formed thereon from abrasion so that it can build up in thickness, and MBM 149 provides a large surface area for the formation of a thin aerobic biofilm layer. The biofilm layer on MBM 149 is kept thin because of abrasion between particles of the MBM, and the thin film is therefore more vulnerable to toxic shock and death. Therefore, when containing fixed film media 148 the MSBR will act like an MBBR reactor.

In one embodiment, air 146 is added for aeration to first reaction vessel 142 to establish aerobic (with oxygen) conditions conducive to nitrification of ammonia to nitrates. Chemicals may be added at 146, e.g., to remove phosphorus. A first flocculating polymer may optionally be added at 147 if needed, depending on SRT results. If it is desirable to increase the SRT, then the flocculating polymer should be used.

Water, free of particles of MBM 149 removed by first magnetic separator 145 but containing biosolids, flows through a conduit 141B into a second chamber or reactor vessel 152 that is continuously stirred with a mixer 159. Conditions in this vessel are anaerobic (without oxygen) to promote the denitrification of nitrates to nitrogen gas. Second reactor vessel 152 contains two magnetic devices.

Second reactor vessel 152 includes a magnetic device forming a cleaning system 150, details of which are shown in Figure 31. Cleaning system 150

includes a first magnetic drum 150A submerged below waterline 160 so the drum will magnetically attract particles formed with second MBM 159 These particles have pollutants bound thereto by a second flocculant 156. First magnetic drum 150A rotates bringing pollutant-laden second MBM 159 to a first cleaner scraper 150B which scrapes the second MBM into a shear tank 150C, the movement of the second MBM indicated by arrow 150D. Inside shear tank 150C is a high-shear mixer 150E that shears pollutant-laden second MBM 159 to separate the MBM from the pollutants. A resulting sheared slurry then flows onto a second magnetic drum 150F. Cleaned second MBM 159 adheres to second magnetic drum150F and is scraped by second cleaner scraper 150G to cause the cleaned MBM to flow back into second reactor vessel (the flow indicated by 151) for re-use. The non-magnetic pollutants that do not adhere to second magnetic drum 150F are discharged at 150H for disposal as a sludge.

Second reactor vessel 152 also includes a magnetic device forming a second magnetic separator 155. Second magnetic separator 155 prevents MBM 159 from exiting the second reactor or treatment vessel 152 with the cleaned water. Scrapers 154 scrape collected MBM 159 back to the vessel 152.

Chemicals 158, e.g., iron to precipitate phosphorus, metal precipitants 157 to precipitate heavy metals, and flocculating polymers or flocculant 156 to attach second MBM 159 to non-magnetic pollutants are added to the second treatment vessel 152. Clean water is then discharged through a pipe 153.

Thus, according one aspect of the invention, different MBM is present in each vessel. The biofilm growing on first MBM 149 in first vessel 146. metabolizes dissolved waste only in an aerobic environment. MBM 149 is kept in this vessel because the biofilm cannot exist in anaerobic conditions. However,

some nonmagnetic biofilm will break off and enter second vessel 152. By comparison, the biofilm on second MBM 159 in second vessel 152 can only exist and metabolize dissolved waste in anaerobic conditions. Therefore in summary, each vessel has its own MBM; only second vessel 152 needs a MBM cleaning system 150, to collect and remove waste solids from the MSBR system.

It is appreciated that after aerobic nitrification in first vessel 142, the water is transferred to second vessel 152 where the nitrates are biologically converted to nitrogen gas which is liberated. The biological conversion of nitrates is facilitated by biofilm grown on MBM 159. However, in addition to nitrification, removal of solids is accomplished in second vessel 152 by use of a flocculating polymer to bind suspended solids to MBM 159. The solids are sheared from MBM 159 to form a sludge which is ejected as described here before. To some extent, there are competing processes being undertaken in second vessel 152. Namely, maintaining a biofilm on MBM 159 particles to perform denitrification of the water and at the same time removing the biofilm associated with the magnetic floc in second vessel 152.

In an alternate embodiment, second vessel 152 may be utilized primariy for biological denitrification. The water denitrified in second vessel 152 would be cleaned of MBM 159 as described here before and then directed to a downstream reactor for clarification. Clarification downstream would be performed by adding a polymer flocculant along with magnetic bed media, such as magnetite, forming magnetic flocs where the suspended solids are bound with the magnetic bed media, and performing magnetic separation of the magnetic bed media from the sludge.

The present invention may, of course, be carried out in other specific ways than those herein set forth without departing from the scope and the characteristics of the invention. The present embodiments are therefore to be construed in all aspects as illustrative and not restrictive and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

CLAIMS

1. A method of treating water utilizing magnetic seeding and magnetic separation, the method comprising: mixing magnetic seed and a flocculant with the water to be treated to form magnetic floc; collecting the magnetic floc on a magnetic collector that extends a substantial distance around an upper perimeter portion of a tank having the magnetic floc and water being treated therein; and removing the magnetic floc from the magnetic collector.
2. The method of claim 1 wherein the magnetic collector includes a magnetized trough that is at least partially submerged in the water being treated in the tank and the method includes directing the magnetic floc and water into and through the magnetized trough and collecting magnetic floc on a wall forming a part of the magnetized trough.
3. A water treatment system for treating water including seeded floc, comprising:
    a. a horizontally disposed collector for collecting the seeded floc;
    b. a horizontally extending shear tank for receiving the seeded floc from the collector and shearing the seeded floc to produce a sheared slurry of seeds and sludge; and
    c. the horizontally extending shear tank including:
        i. a horizontally-extending tank;
        ii. a horizontally disposed shearing device mounted in the horizontally extending tank; and

iii. an outlet formed in the horizontally extending tank for discharging the sheared slurry of seeds and sludge.

4. The water treatment system of claim 2 wherein the seeded floc include magnetic seeds and wherein the horizontally disposed collector is a horizontally disposed magnetic collector.

5. A water treatment system comprising:

   a. a moving magnetic collector for collecting magnetic floc;

   b. a shear device for receiving the magnetic floc and producing a sheared slurry of magnetic seeds and sludge;

   c. a removal device for removing the magnetic floc from the moving magnetic collector such that the magnetic floc can be transferred to the shear device;

   d. the magnetic collector and shear device being configured such that the magnetic collector collects the magnetic seeds from the sheared slurry ; and

   e. wherein the same moving magnetic collector collects the magnetic floc and collects the magnetic seeds that have been sheared from the magnetic floc.

6. The water treatment system of claim 5 including a retainer disposed adjacent the magnetic collector and cooperating with the magnetic collector to form a collection area for receiving the sheared slurry, wherein the retainer is adapted to cooperate with the moving magnetic drum to compress the sheared slurry and separate the sludge from the magnetic seeds

7. A method of removing solids from water comprising:

a. mixing magnetic seed, a flocculant and water in a tank to form magnetic floc;

b. settling the magnetic floc in a lower portion of the tank;

c. decanting purified water from the tank;

d. shearing magnetic floc in the lower portion of the tank, producing magnetic seed and sludge; and

e. magnetically retaining magnetic seed in lower portion of the tank while discharging the sludge from the tank.

8. The method of claim 7 including disposing one or more magnets adjacent the lower portion of the tank such that the one or more magnets are operative to retain the magnetic seed in the lower portion of the tank while sludge is being discharged.

9. A water treatment system for treating water including magnetic floc, comprising:

a. a moving magnetic collector for collecting the magnetic floc from the water;

b. a removal device for removing the magnetic floc from the moving magnetic collector;

c. the removal device being magnetically held adjacent the moving magnetic collector; and

d. a conveying structure to convey the magnetic floc away from the moving magnetic collector.

10. The water treatment system of claim 9 wherein the removal device includes a magnetic portion for magnetically holding the removal device adjacent the moving magnetic collector.

11. A method of retrofitting an existing water treatment system having one or more biological reactors and one or more gravity clarifiers, comprising: converting the one or more gravity clarifiers of the existing water treatment system to one or more biological reactors; and adding a high rate clarifier to the existing water treatment system.

12. The method of claim 13 wherein the high rate clarifier includes a magnetic separator for removing magnetic floc from water contained in the high rate clarifier.

13. A ballasted flocculation process for treating water, comprising:

a. mixing a magnetic ballast, flocculant and the water to form magnetic floc;

b. agitating the magnetic floc in a flocculation zone;

c. collecting some of the magnetic floc on a first magnetic collector;

d. shearing the collected magnetic floc to produce a sheared slurry including magnetic ballast and sludge;

e. recycling the magnetic ballast;

f. directing the water and some of the magnetic floc to a settling zone located downstream from the flocculation zone;

g. settling by gravity some of the magnetic floc in the settling zone;

h. returning at least a portion of the settled magnetic floc to a point upstream from the settling tank; and

i. magnetically collecting the returned magnetic floc at a point upstream from the settling zone.

14. The process of claim 13 wherein the settling zone includes a bottom having an inclined surface, and the method includes utilizing the inclined surface of the bottom to move the settled magnetic floc towards the flocculation zone.

15. A process for removing dissolved contaminants and suspended solids from water utilizing magnetic seed and magnetic separation comprising:

    a. in a first tank, removing suspended solids by mixing water with magnetic seed and a flocculant to produce magnetic floc;

    b. collecting magnetic floc on a magnetic collector

    c. in a second tank, removing dissolved contaminants by mixing magnetic seed with water, wherein the magnetic seed is coated with a polymer, activated carbon or biofilm, to form a magnetic particle.

    d. removing dissolved contaminants from the water by sorbing the dissolved contaminants on the magnetic particle

    e. collecting the magnetic particle on a magnetic collector

16. The process of claim 15 wherein the magnetic seed in the second tank is coated with polydimethylsiloxane.

17. A method of treating cooling water and removing scalants therefrom, comprising:

    a. directing the cooling water into a chamber;

    b. mixing magnetic seed with the water and causing the scalants to attach to the magnetic seed to form magnetic particles;

    c. collecting the magnetic particles on a magnetic collector so as to remove the scalants from the cooling water; and

    d. removing the magnetic particles from the magnetic collector.

18. The method of claim 17 including:

a. chemically precipitating the scalants from the cooling water;

b. mixing a flocculant with the magnetic seed;

c. flocculating the precipitated solids, magnetic seed and flocculant to form magnetic floc comprising the magnetic seed and scalants;

d. collecting the magnetic floc on the magnetic collector; and

e. removing the magnetic floc from the magnetic collector.

19. A biological nitrification-denitrification and clarification process that utilizes magnetic seeding and magnetic separation to treat water containing ammonia, comprising:

a. directing the water into a vessel;

b. mixing the water with a first magnetic bed media in the vessel;

c. maintaining conditions in the vessel that result in a biofilm forming on the first magnetic bed media;

d. utilizing the biofilm formed on the first magnetic bed media to nitrify the water;

e. separating the first magnetic bed media from the nitrified water and transferring the nitrified water from the vessel;

f. mixing a second magnetic bed media with the nitrified water and forming magnetic floc where the magnetic floc comprise magnetic bed media, suspended solids, and a biofilm;

g. utilizing the biofilm to denitrify the nitrified water;

h. utilizing the second magnetic bed media to clarify the nitrified water; and

i. collecting the magnetic floc with a magnetic collector.

20. The process of claim 19 including performing denitrification and clarification in a single vessel.

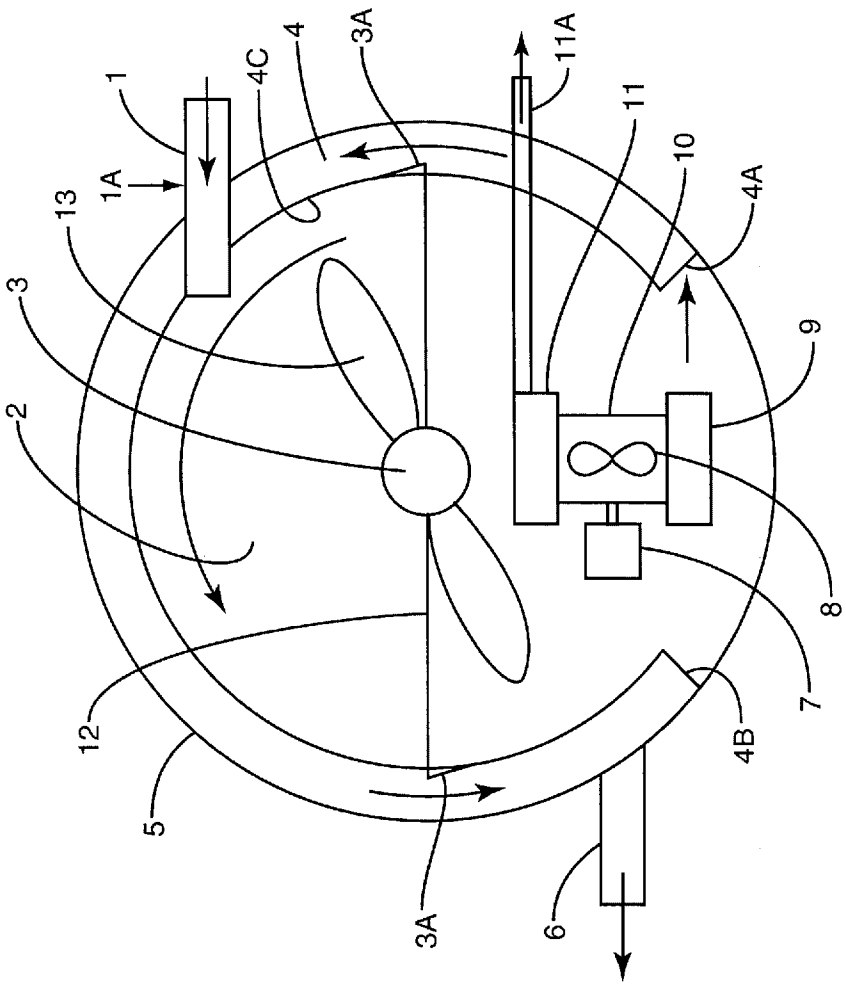


FIG. 1

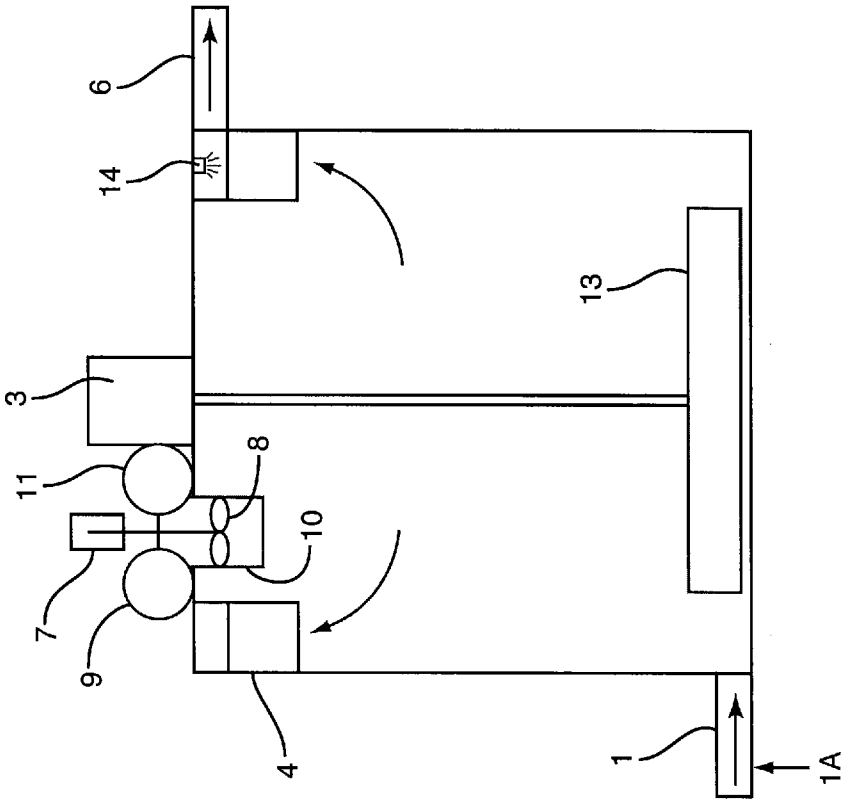


FIG. 3

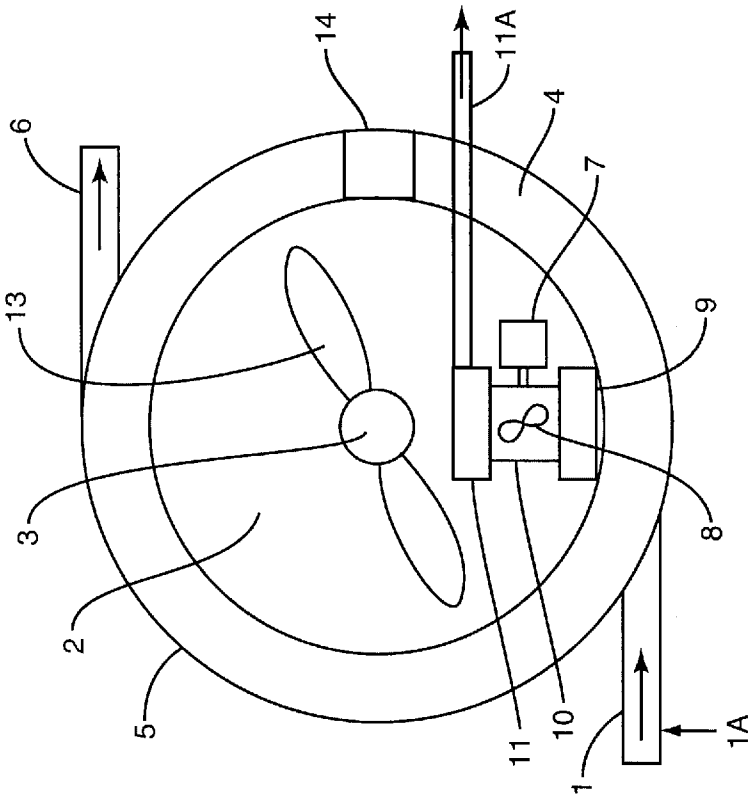


FIG. 2

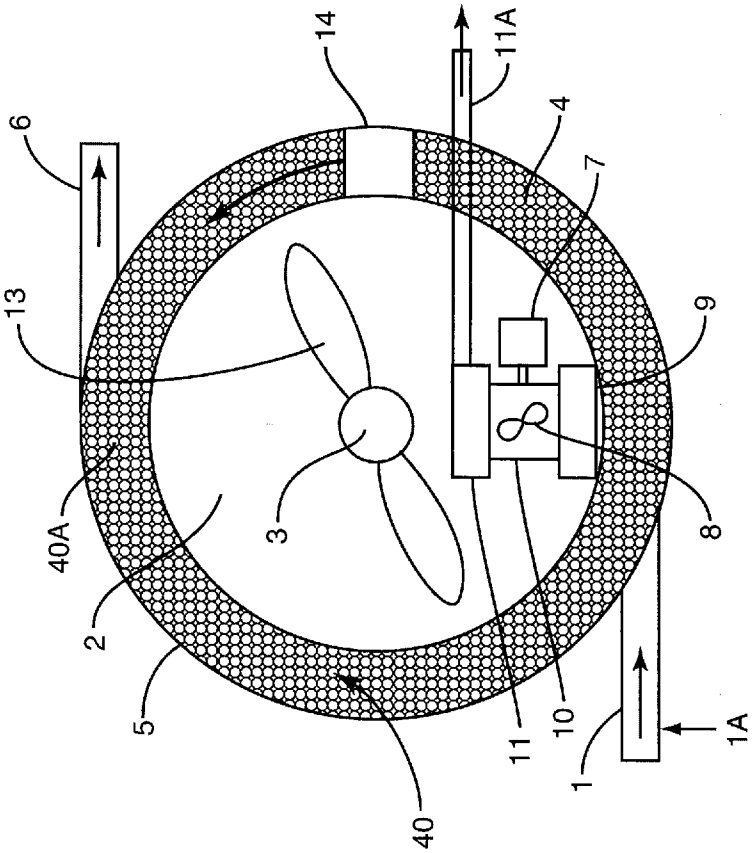

14
11A
6
4
7
13
9
3
40A
8
2
5
11
10
1
1A
40

FIG. 5

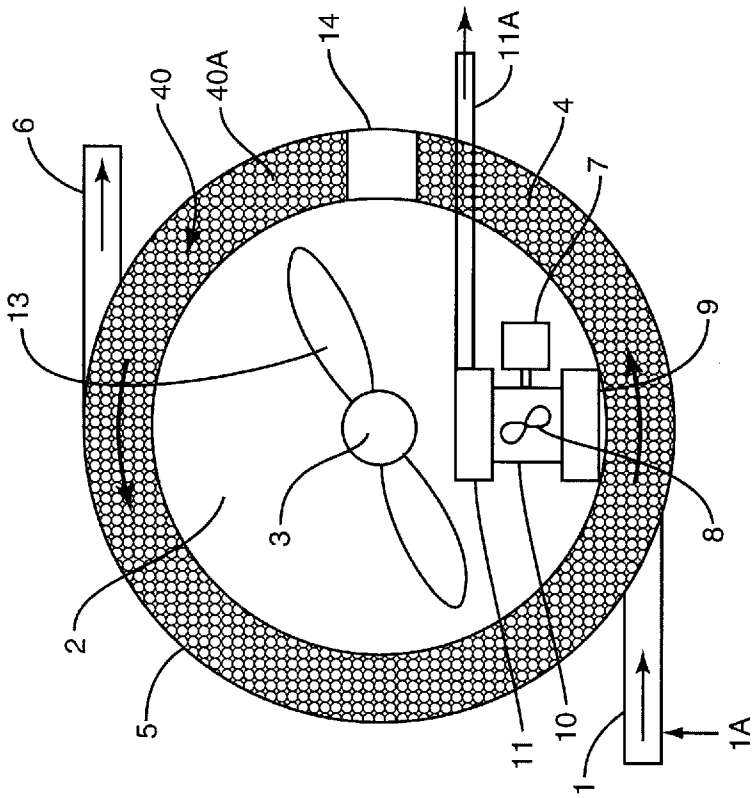

14
11A
6
40
40A
4
7
13
9
3
8
2
5
11
10
1
1A

FIG. 4

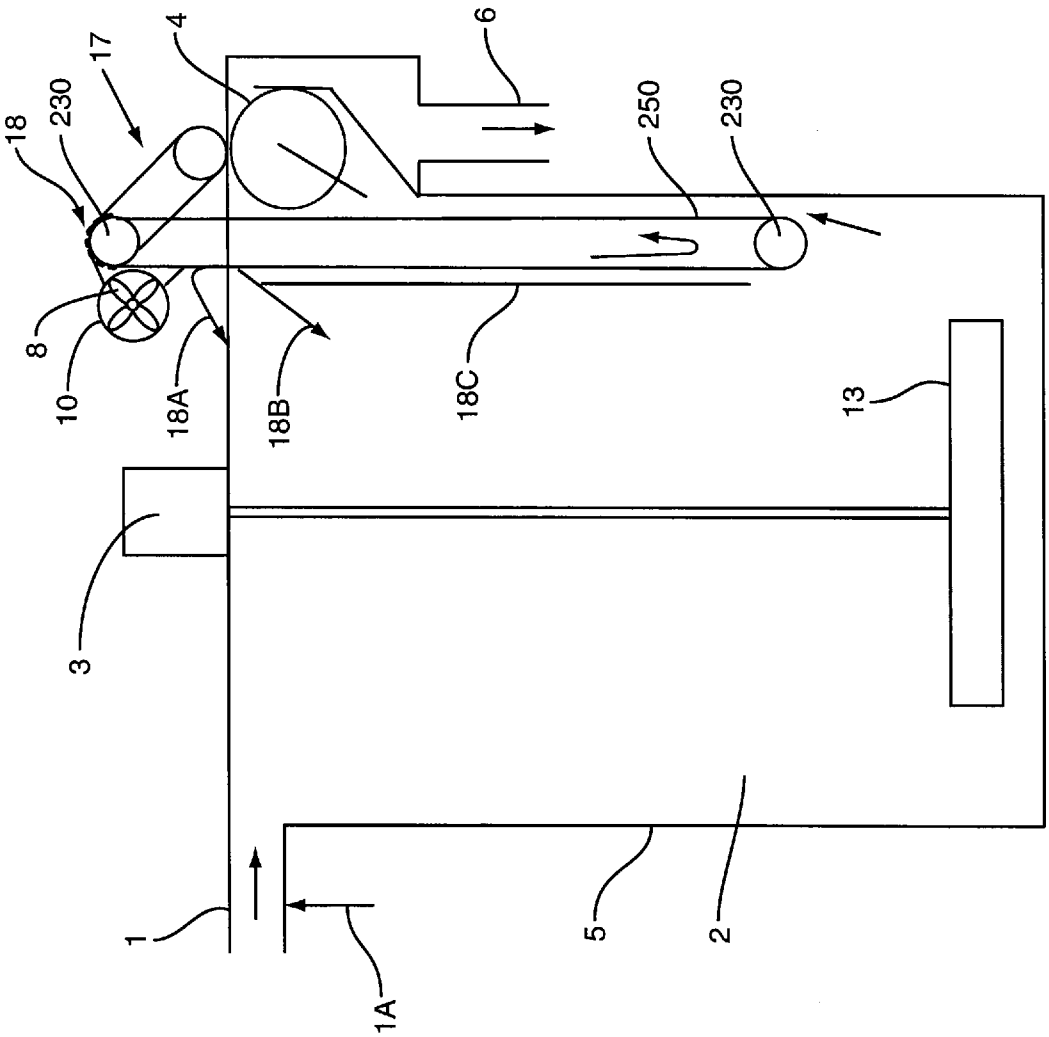


FIG. 6

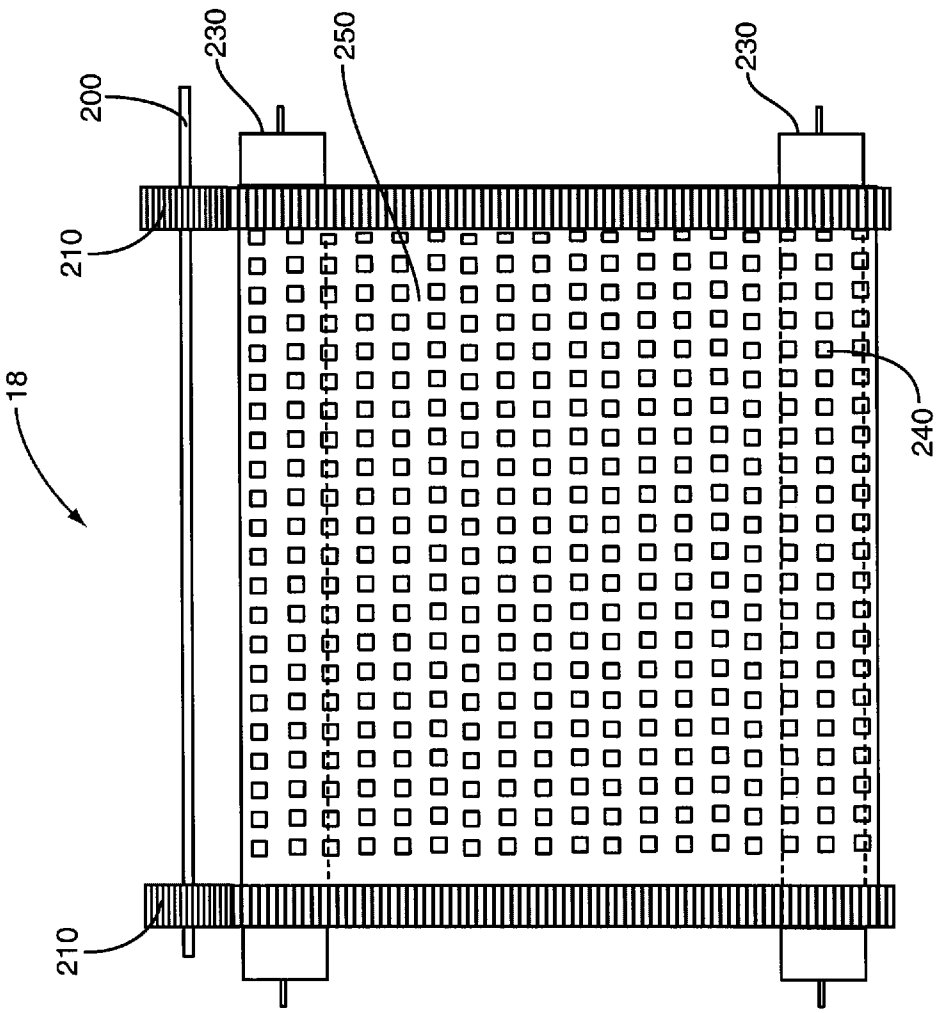


FIG. 7

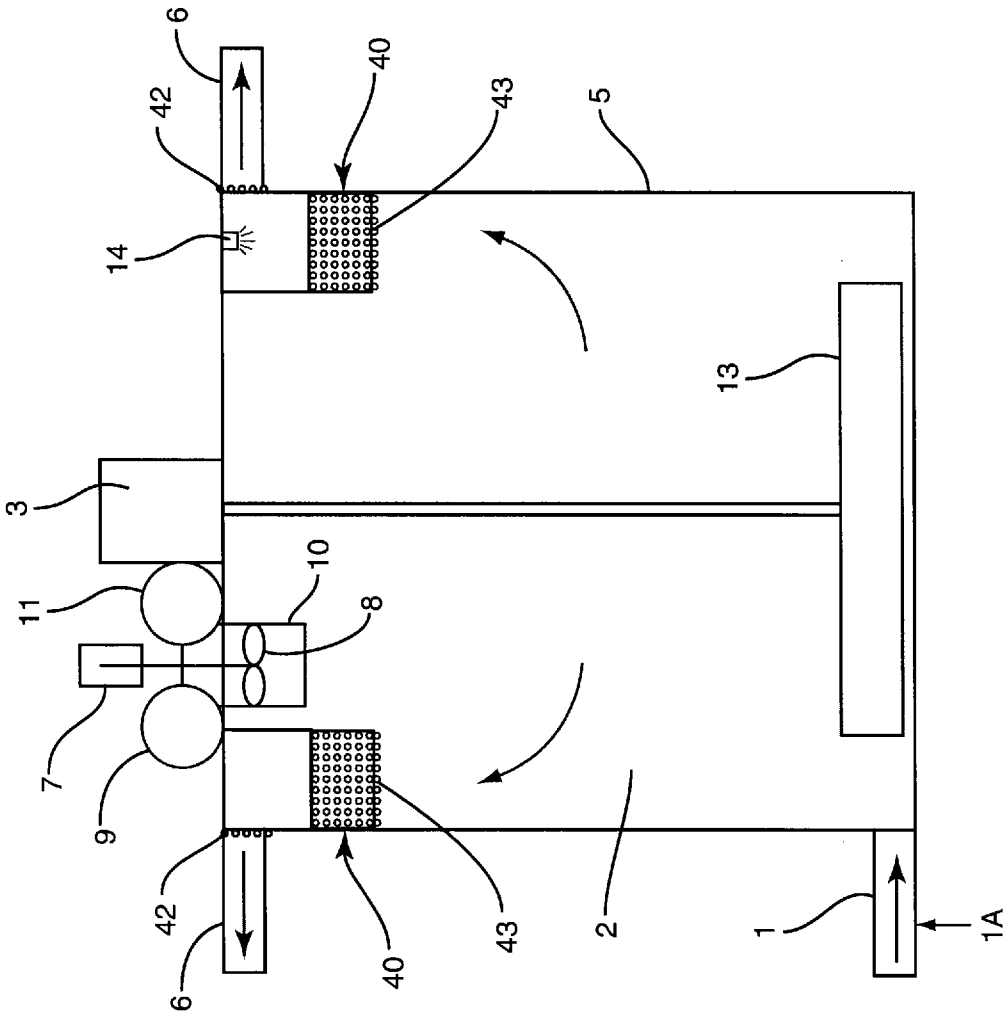


FIG. 8

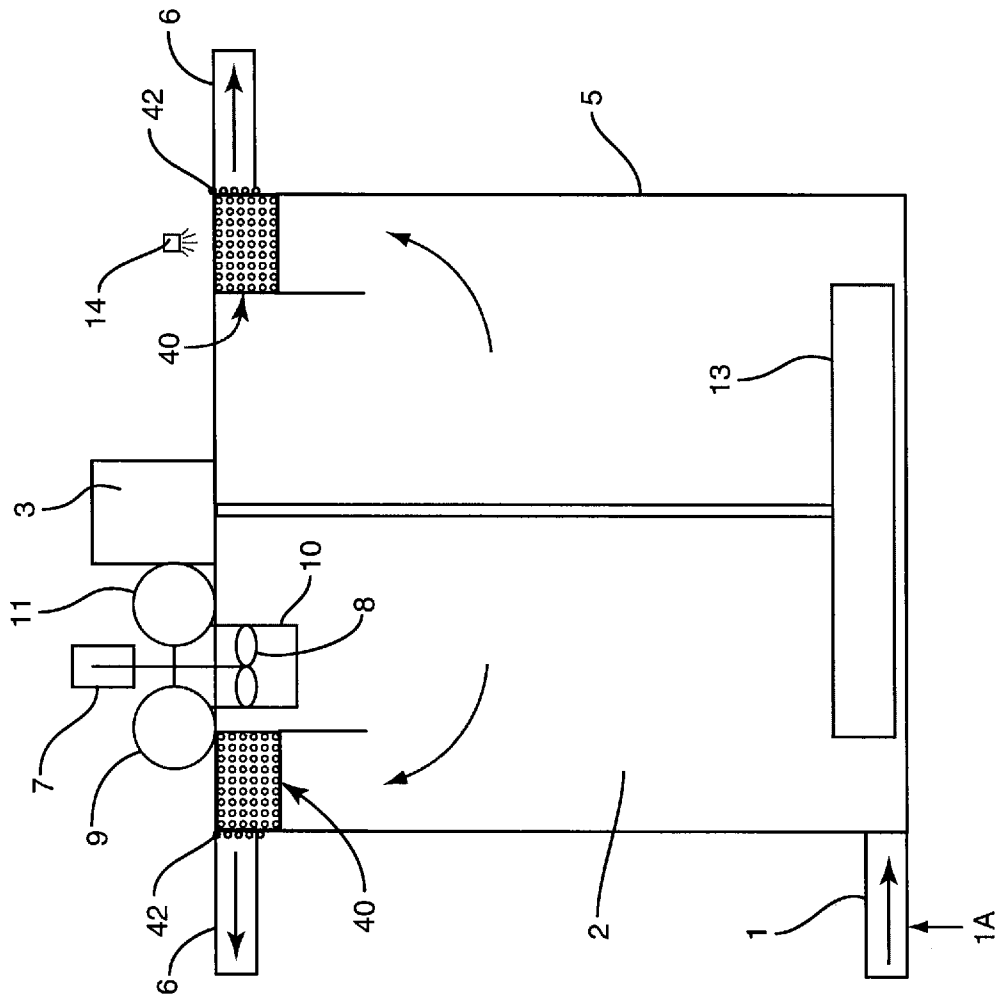


FIG. 9

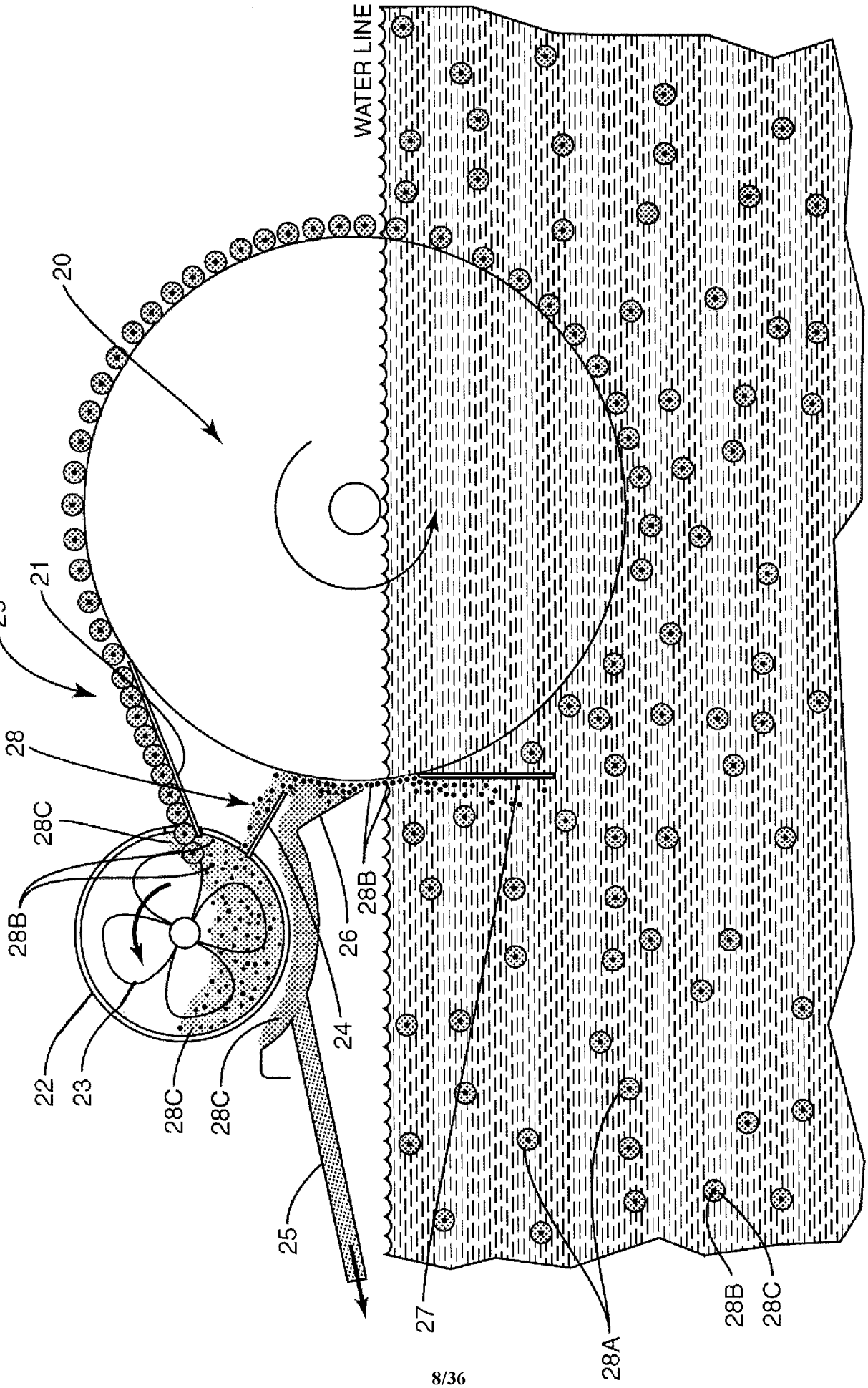

WATER LINE
20
21
29
28
28C
28B
22
23
28C
28C
24
26
28B
25
27
28A
28B
28C

FIG. 10

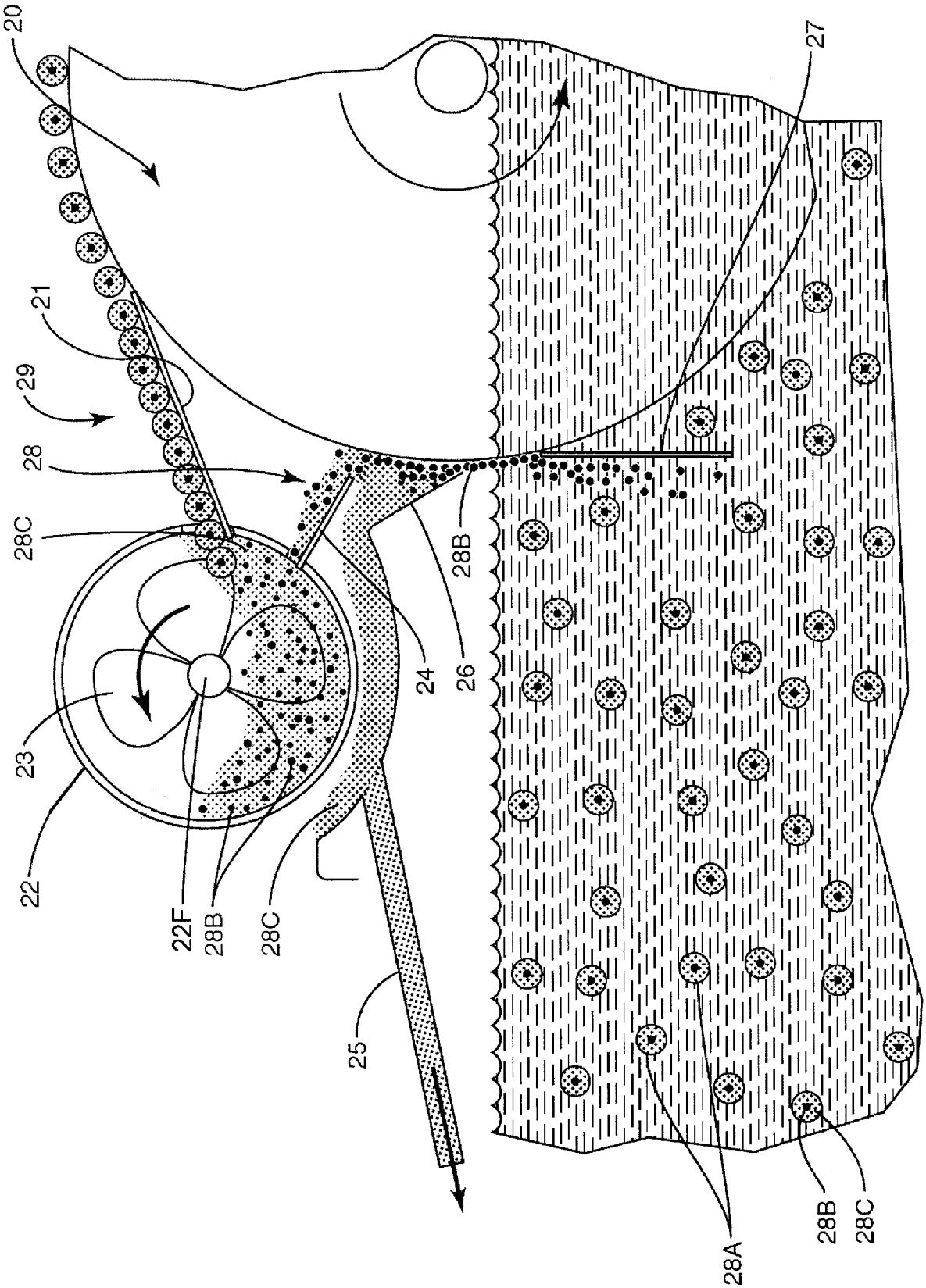


FIG. 11

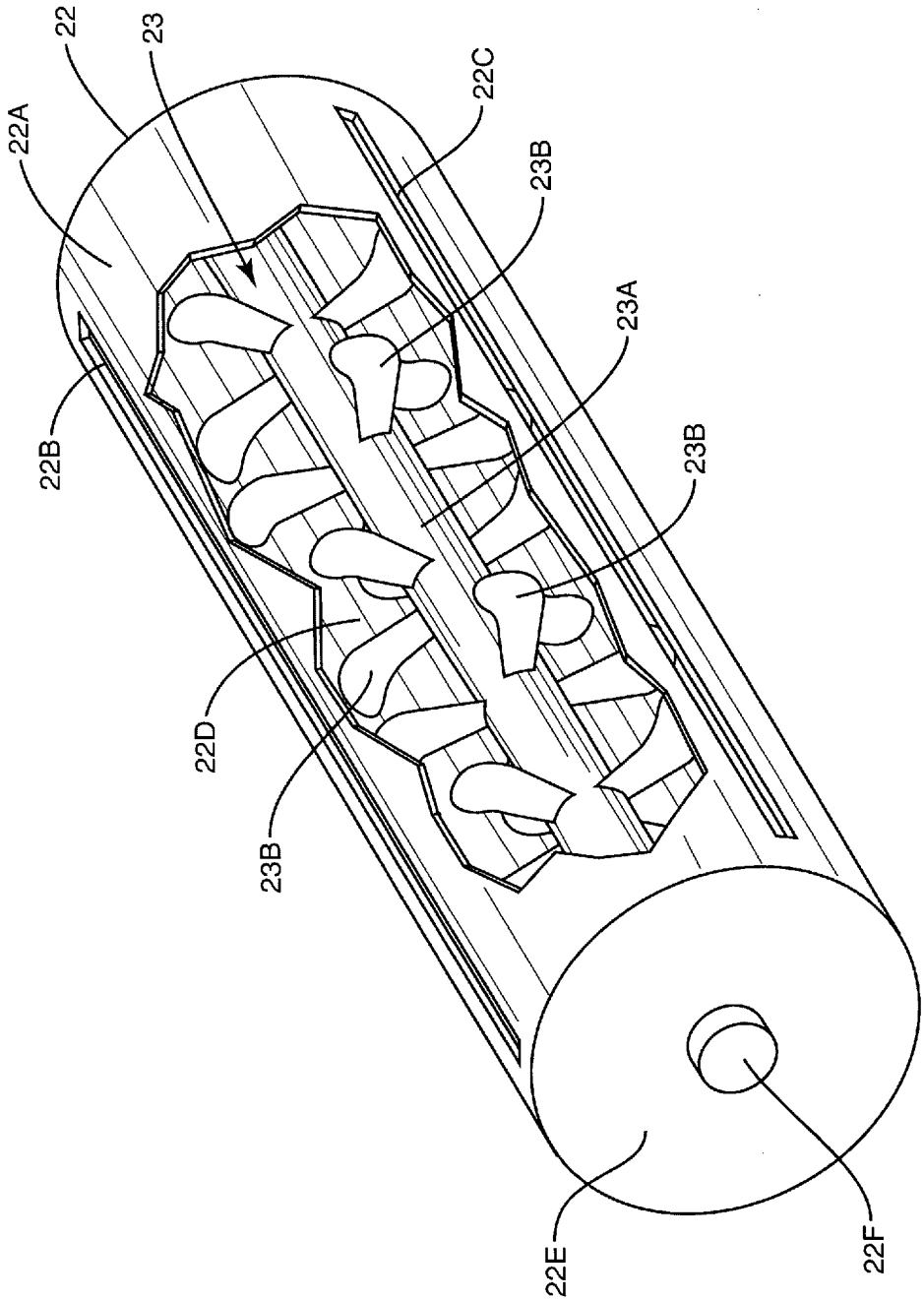


FIG. 12

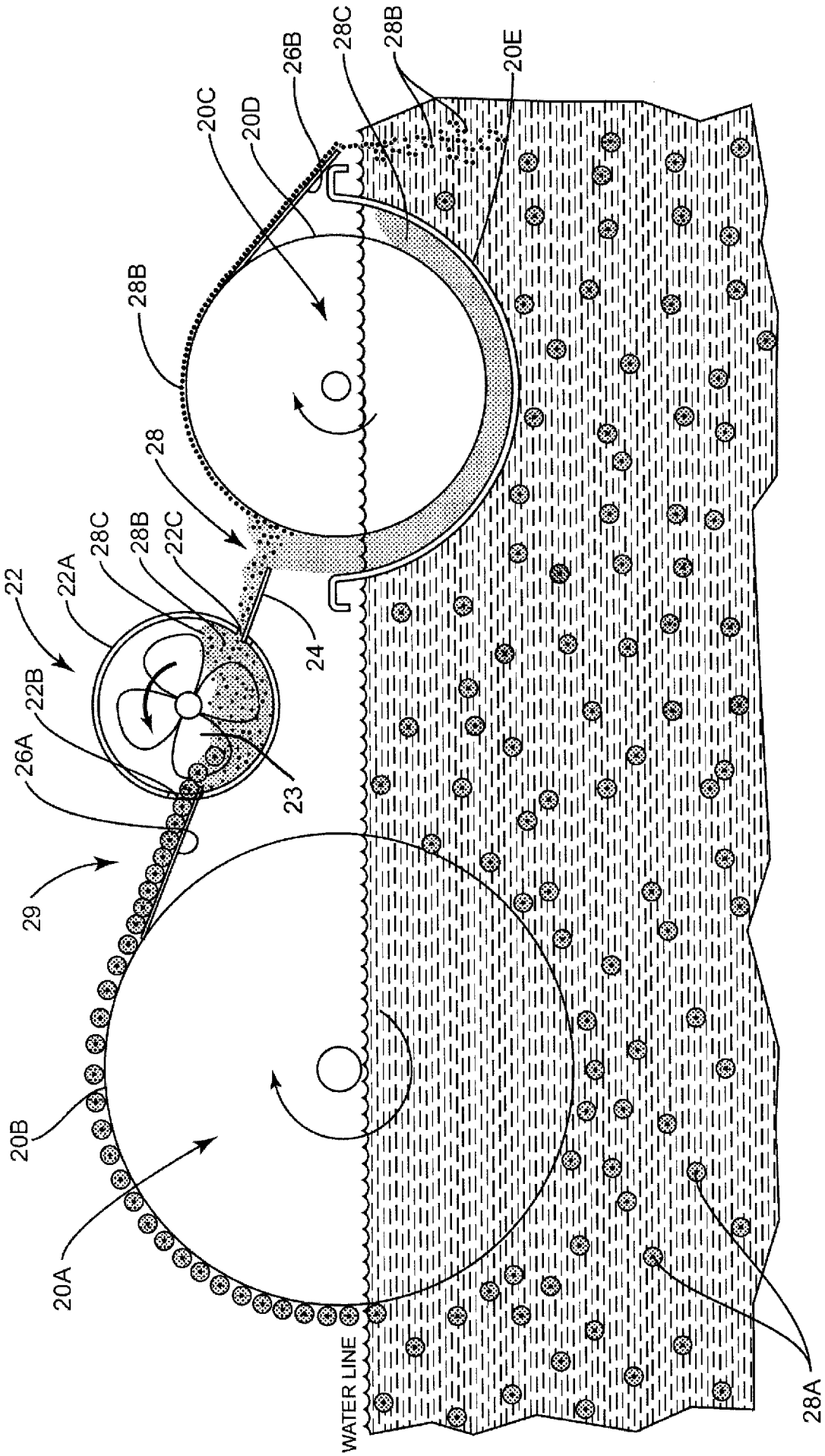

20A
20B
20C
20D
20E
22
22A
22B
22C
23
24
26A
26B
28
28A
28B
28C
29
WATER LINE

FIG. 13

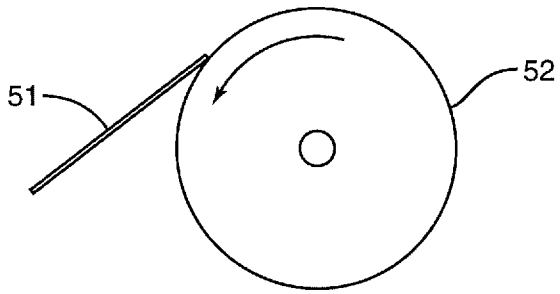


FIG. 15a

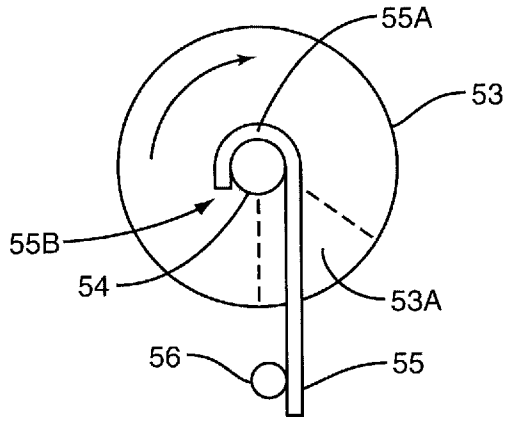


FIG. 15b

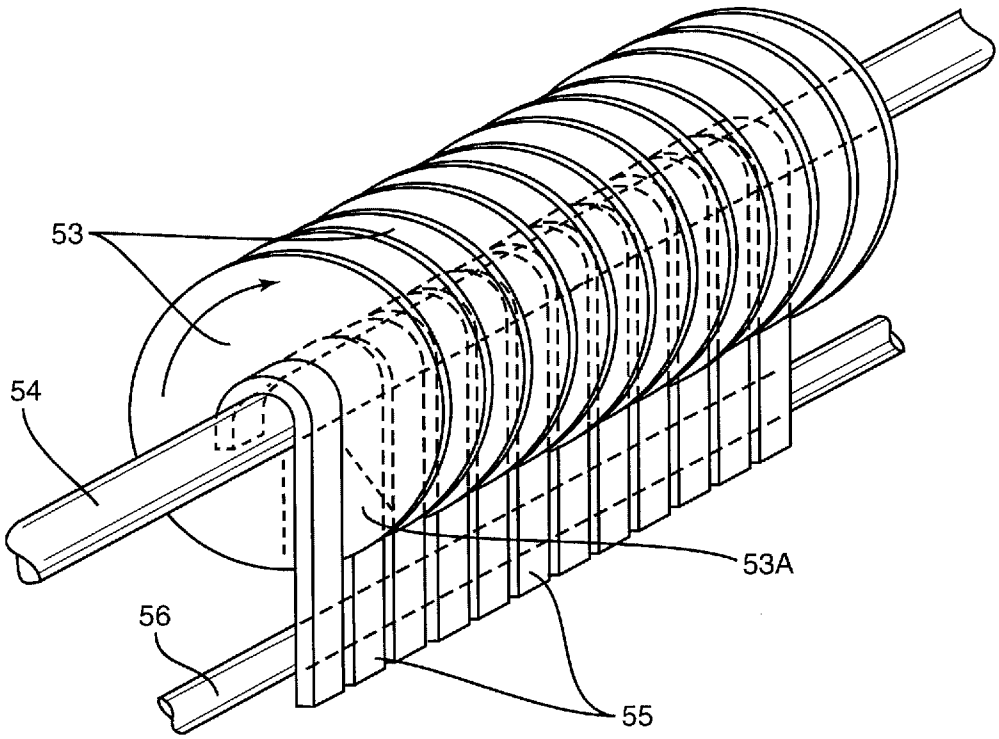


FIG. 15c

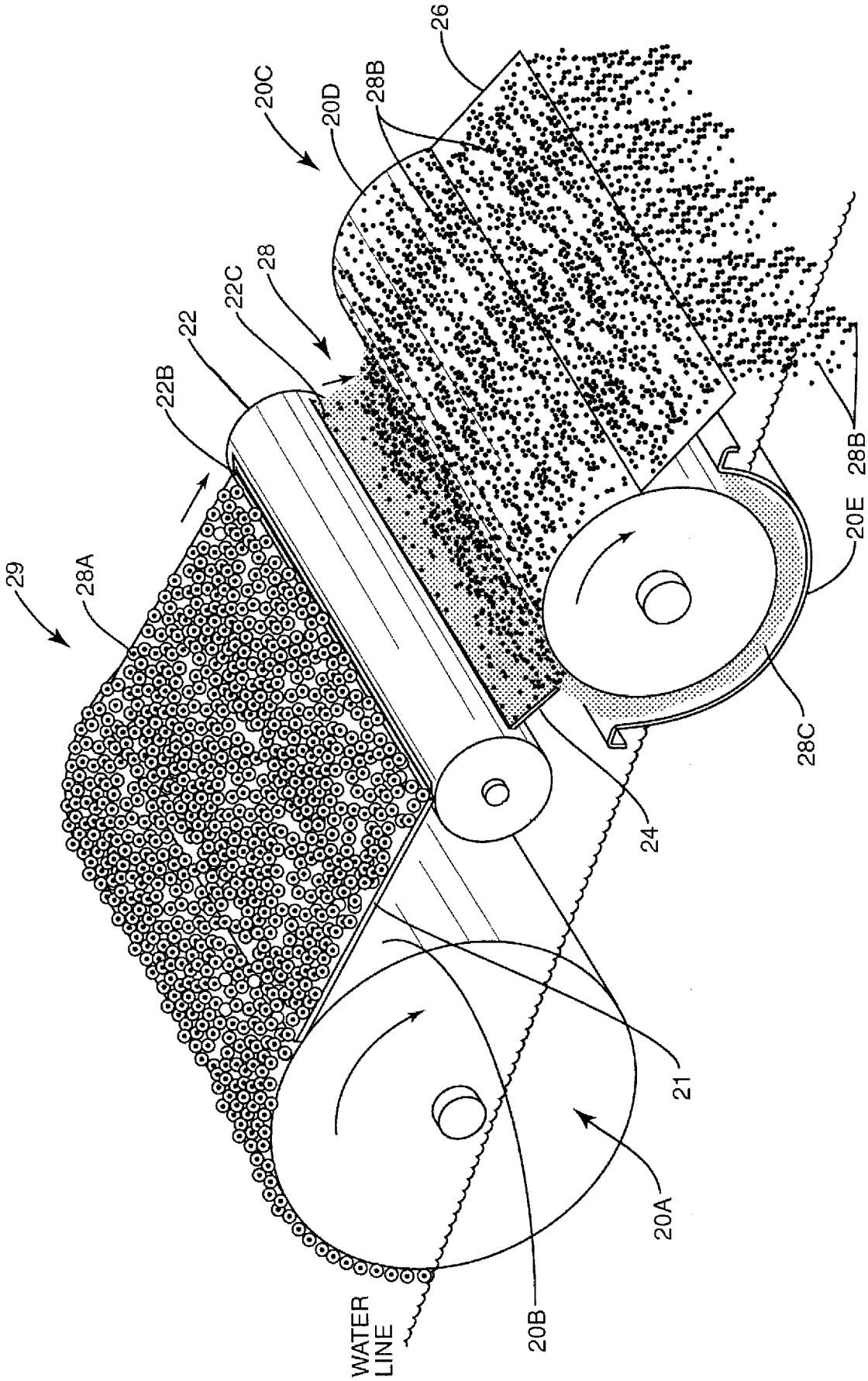

29
28A
22B
22
22C
28
20C
20D
28B
26
28B
20E
28C
24
21
20A
20B
WATER LINE

FIG. 14

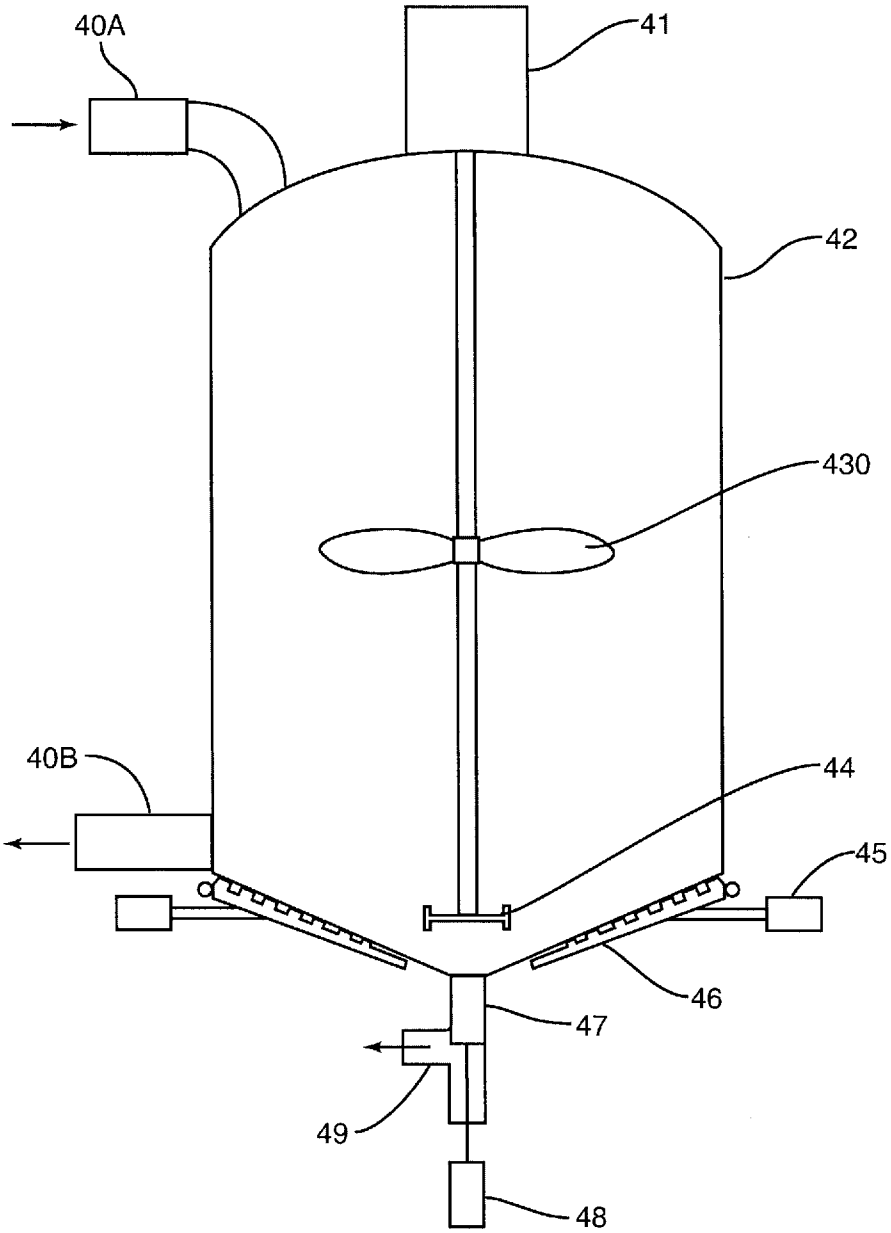


FIG. 16

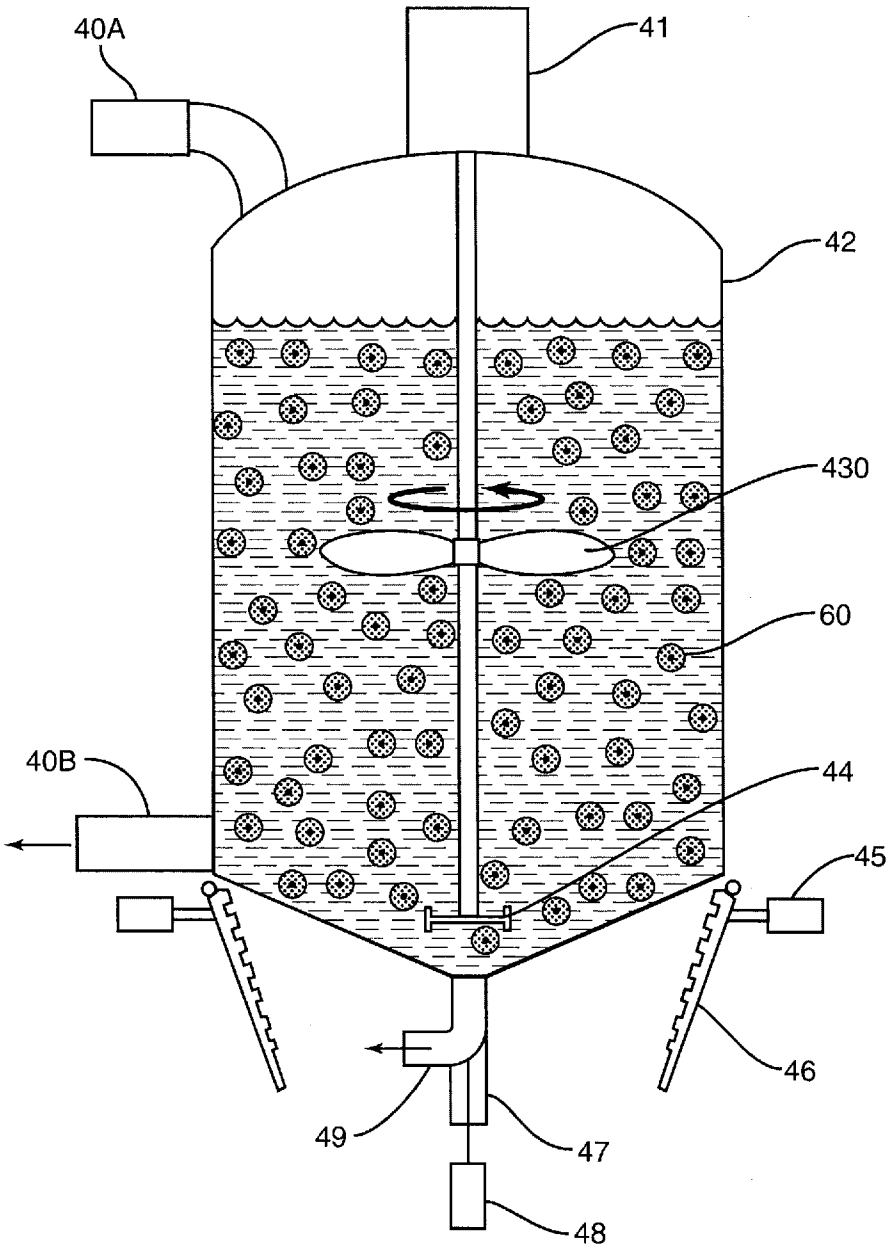


FIG. 17

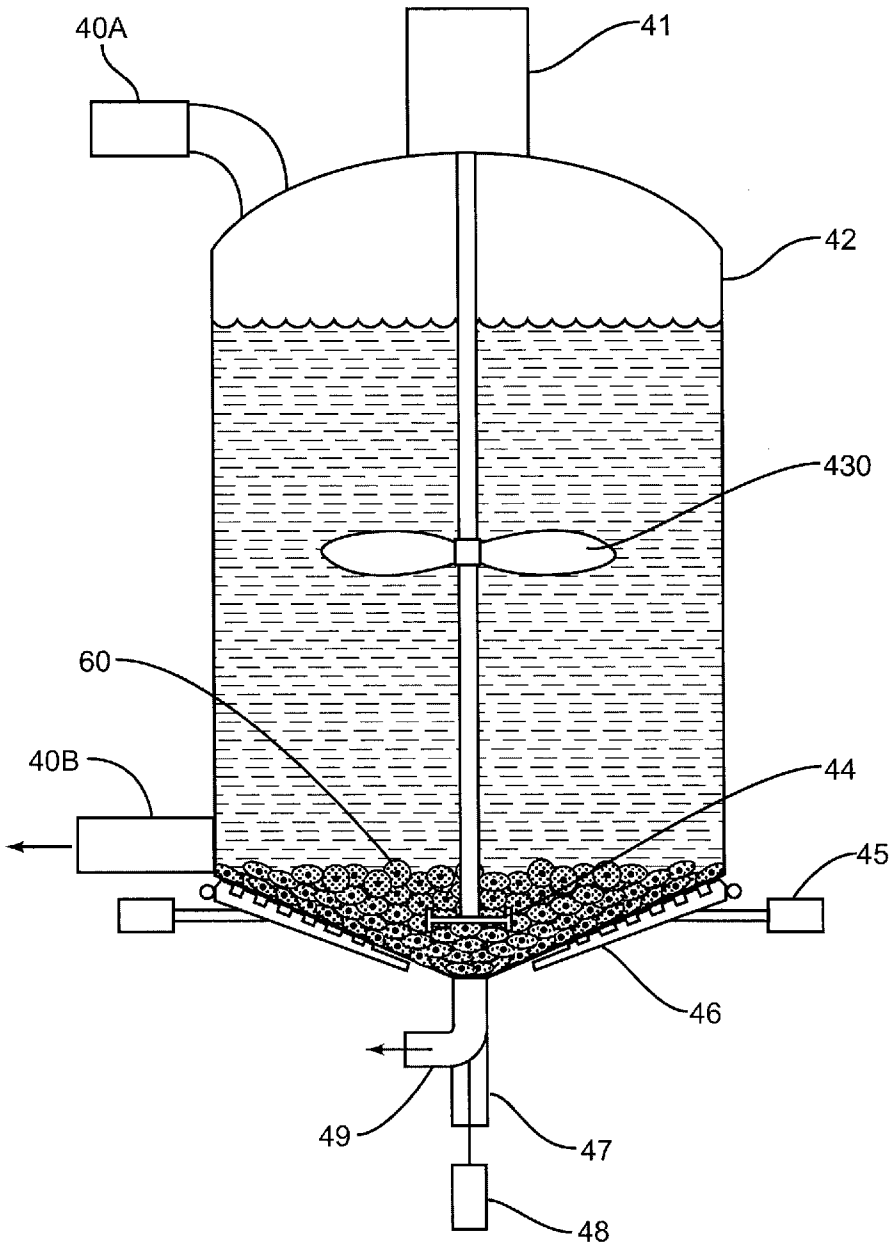


FIG. 18

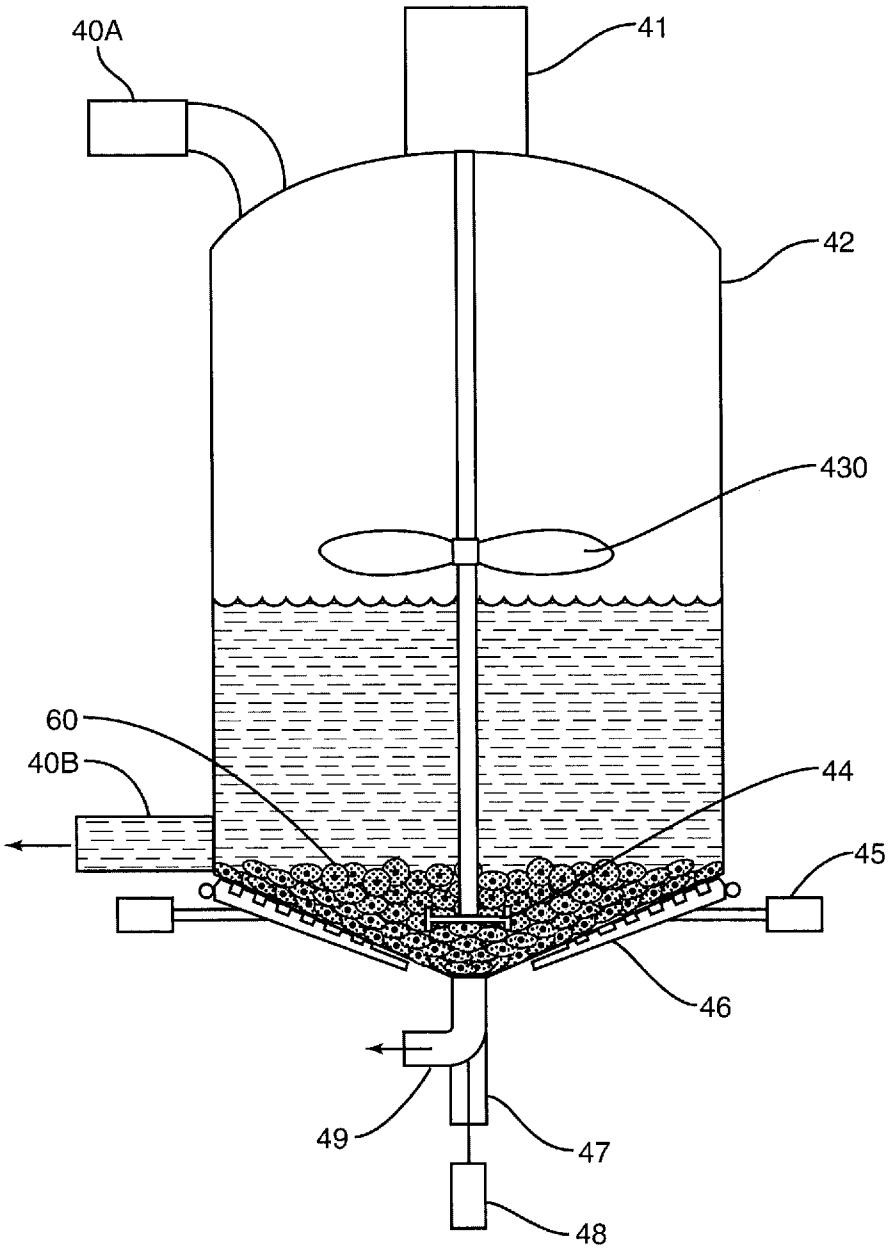


FIG. 19

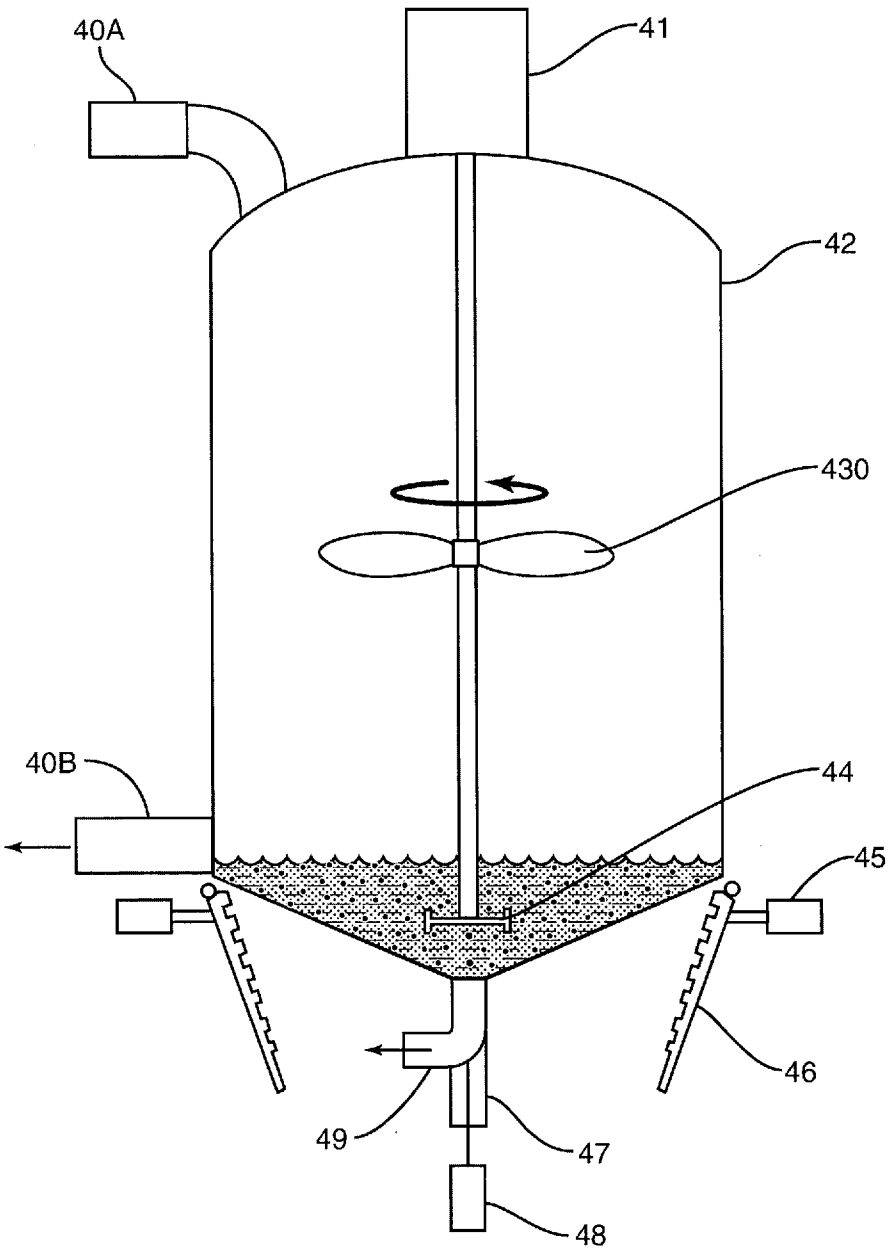


FIG. 20

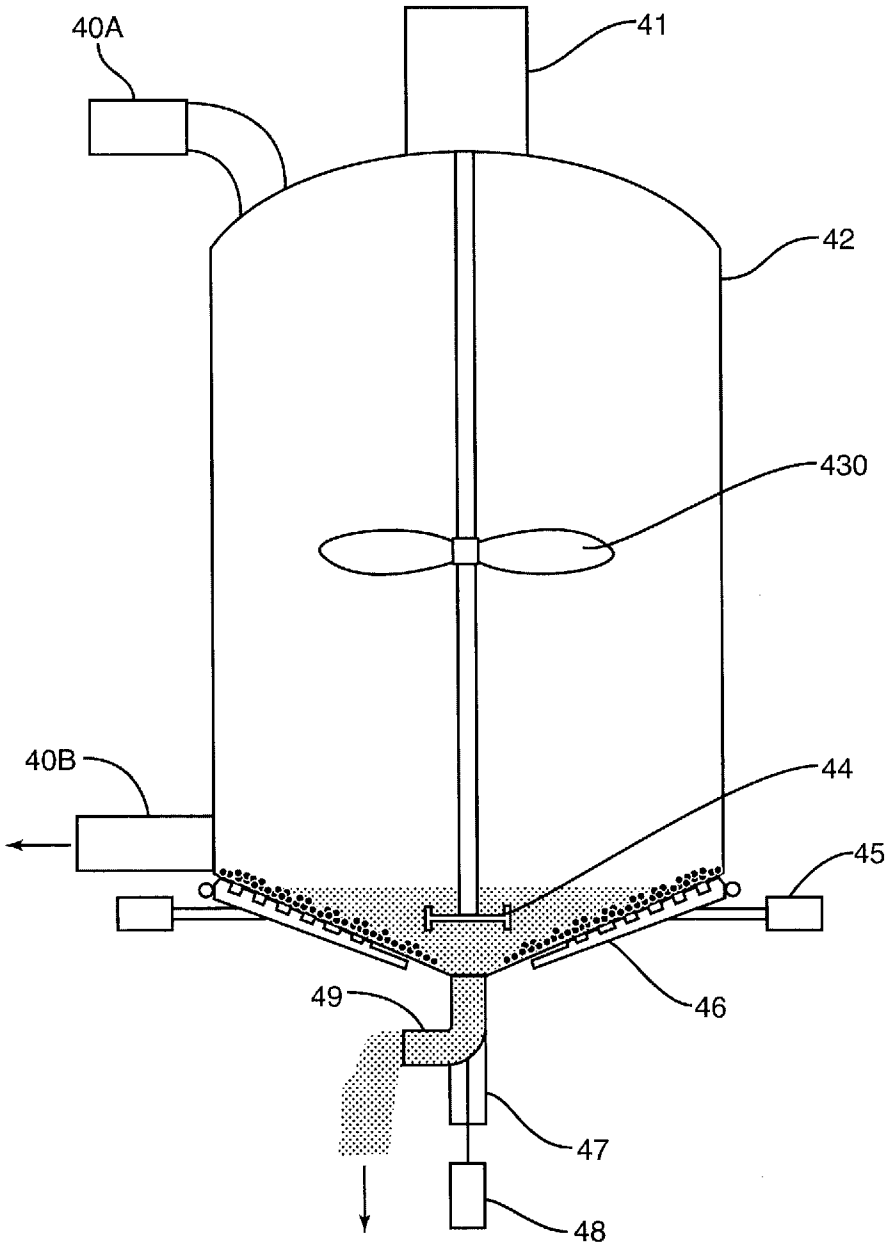


FIG. 21

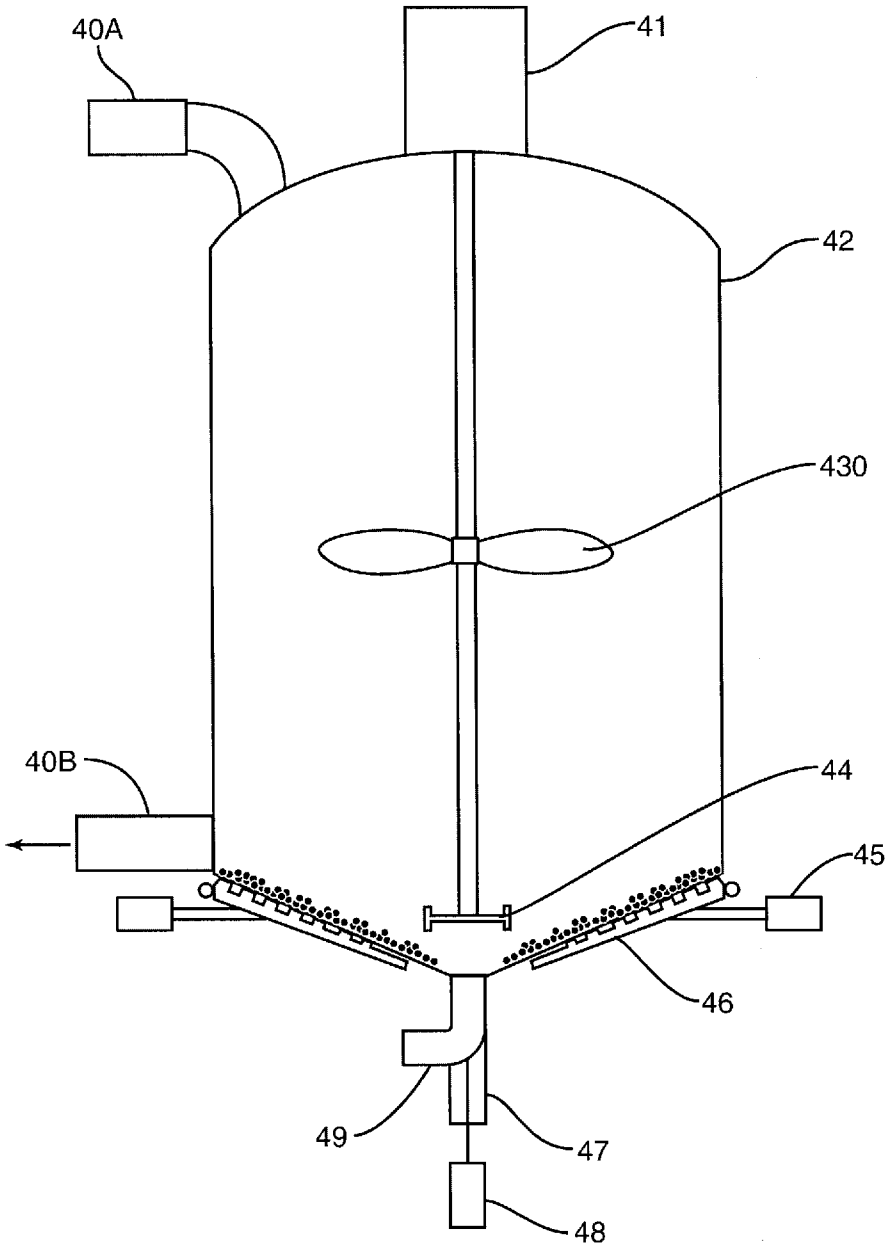


FIG. 22

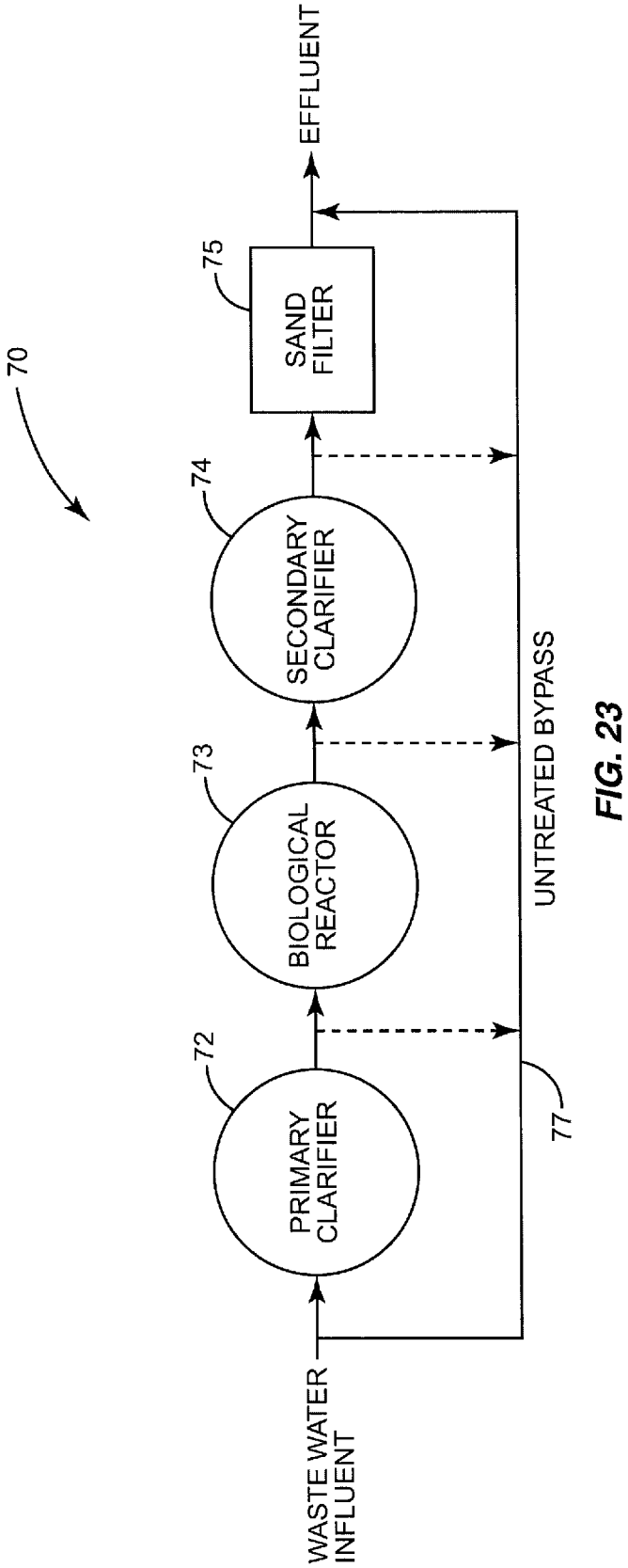

70
WASTE WATER INFLUENT
72
PRIMARY CLARIFIER
73
BIOLOGICAL REACTOR
74
SECONDARY CLARIFIER
75
SAND FILTER
EFFLUENT
UNTREATED BYPASS
77

FIG. 23

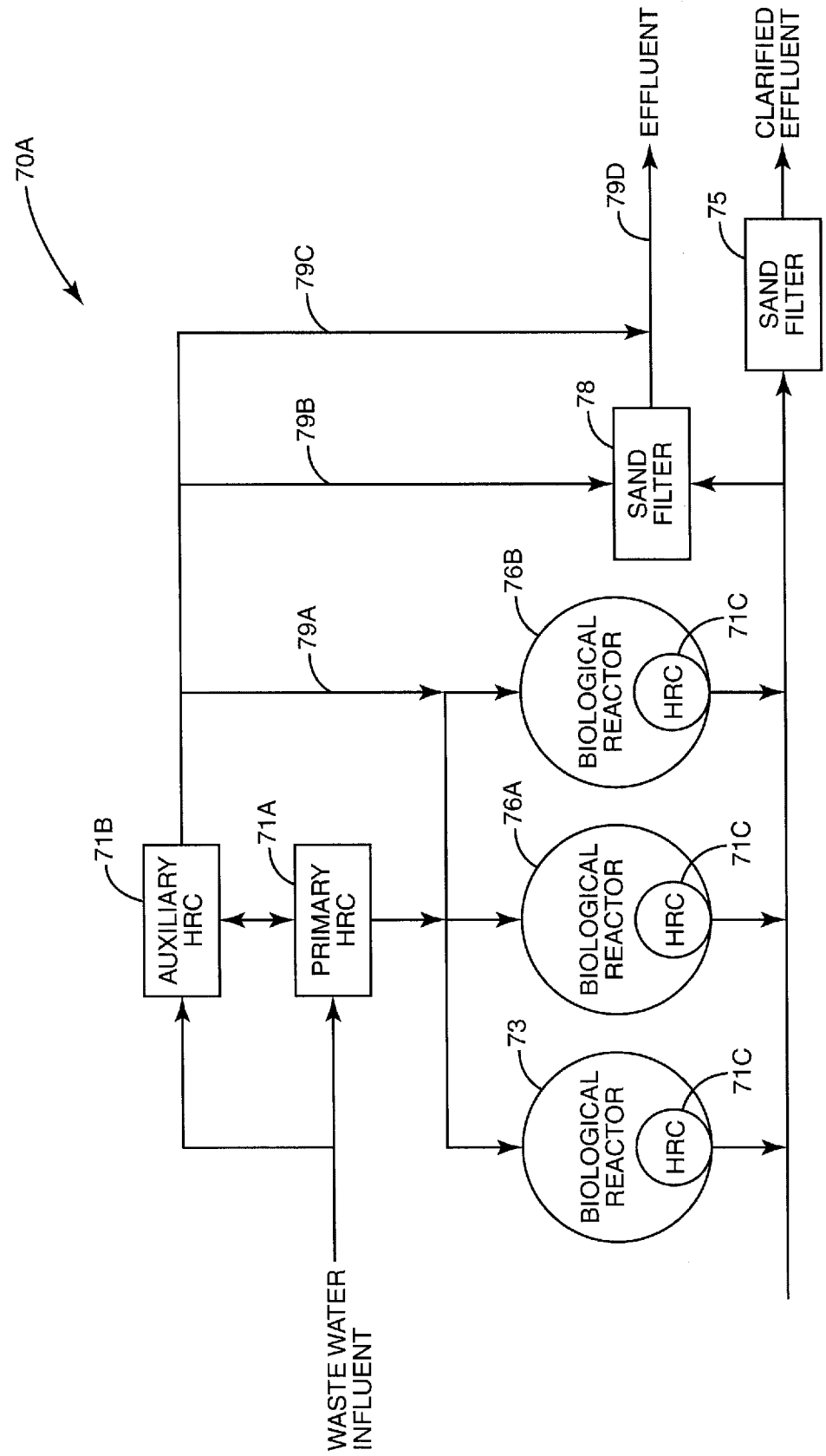

70A
WASTE WATER INFLUENT
AUXILIARY HRC
71B
PRIMARY HRC
71A
BIOLOGICAL REACTOR
HRC
71C
73
76A
76B
79A
79B
79C
SAND FILTER
78
79D
EFFLUENT
75
SAND FILTER
CLARIFIED EFFLUENT

FIG. 24

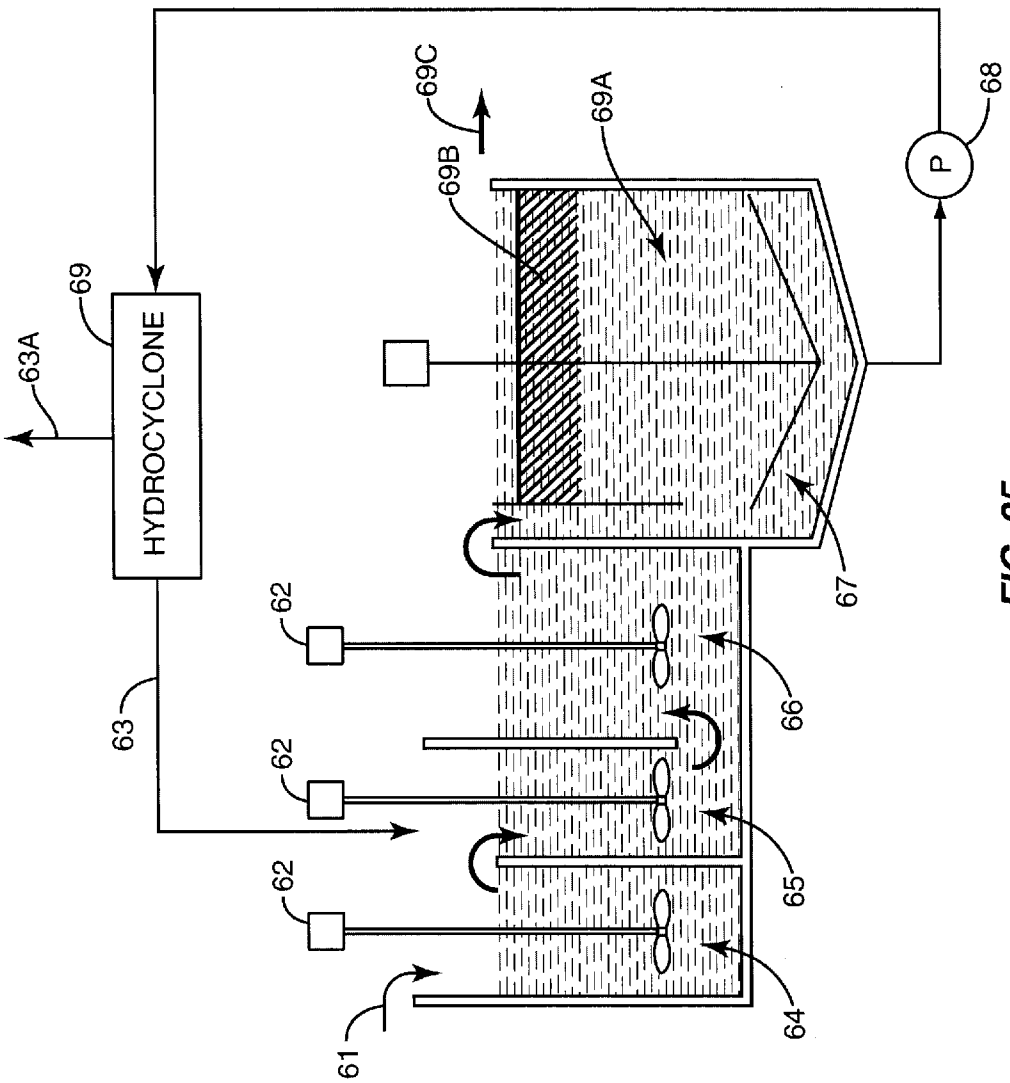


FIG. 25

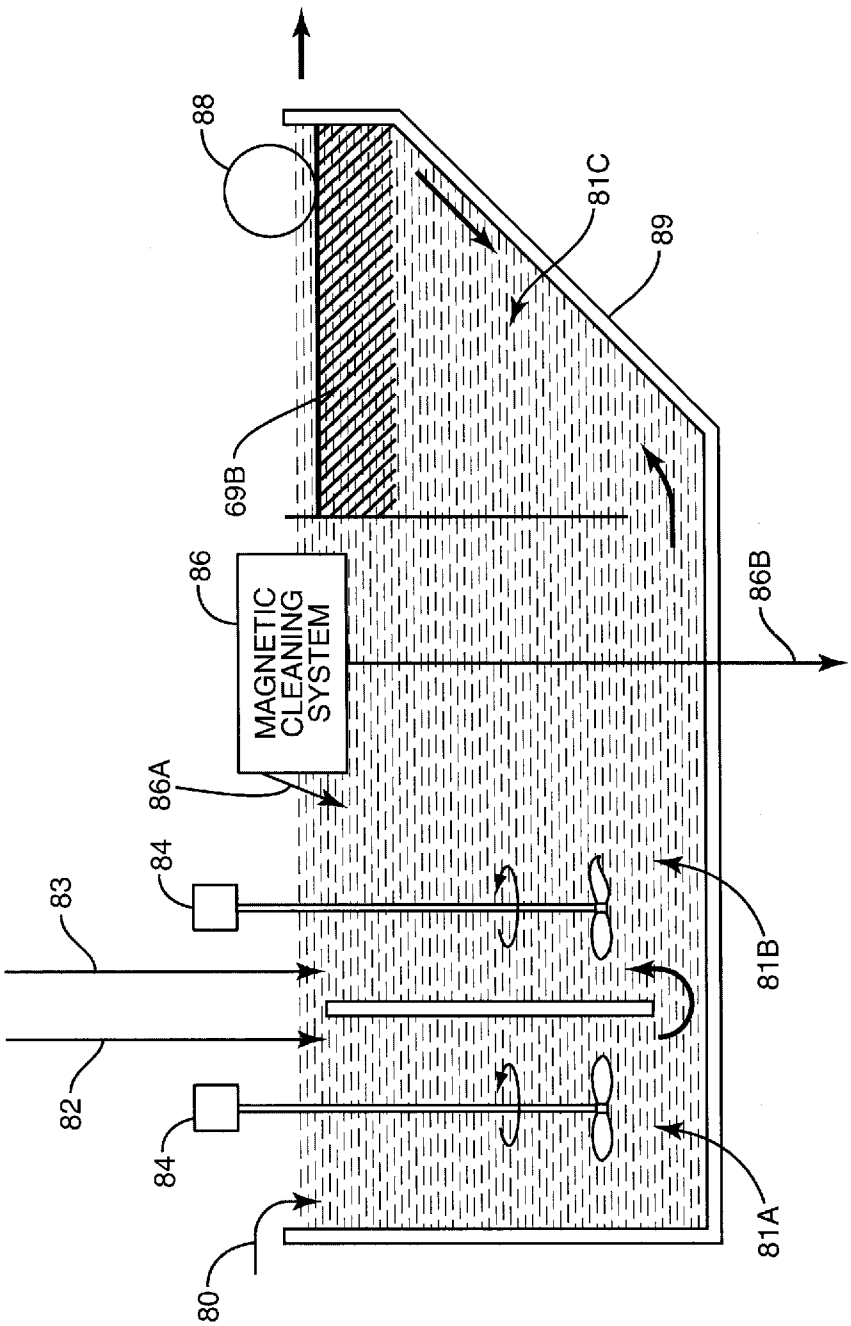

88
81C
89
69B
86
MAGNETIC CLEANING SYSTEM
86B
86A
84
83
81B
82
84
81A
80

FIG. 26

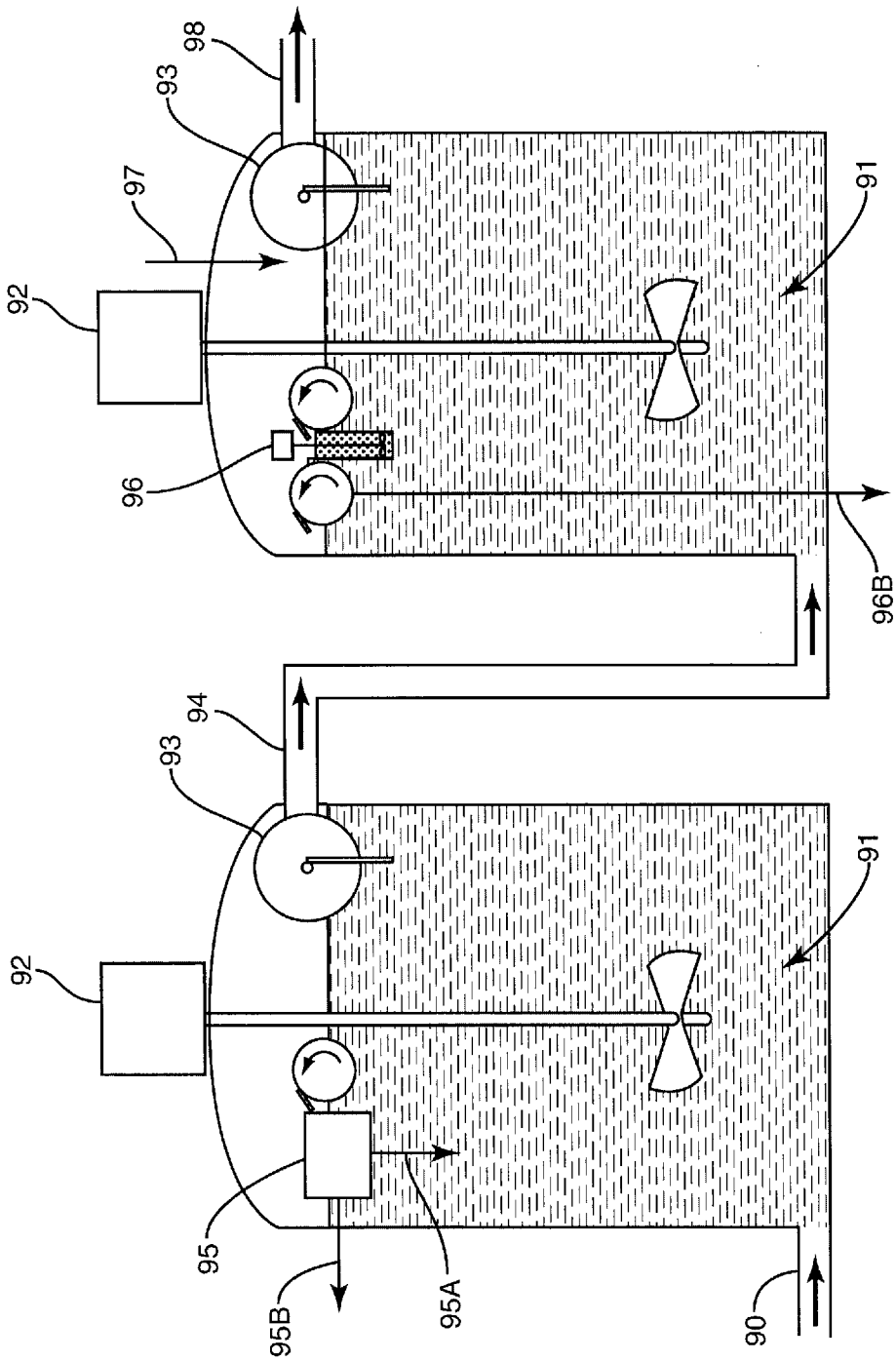


FIG. 27

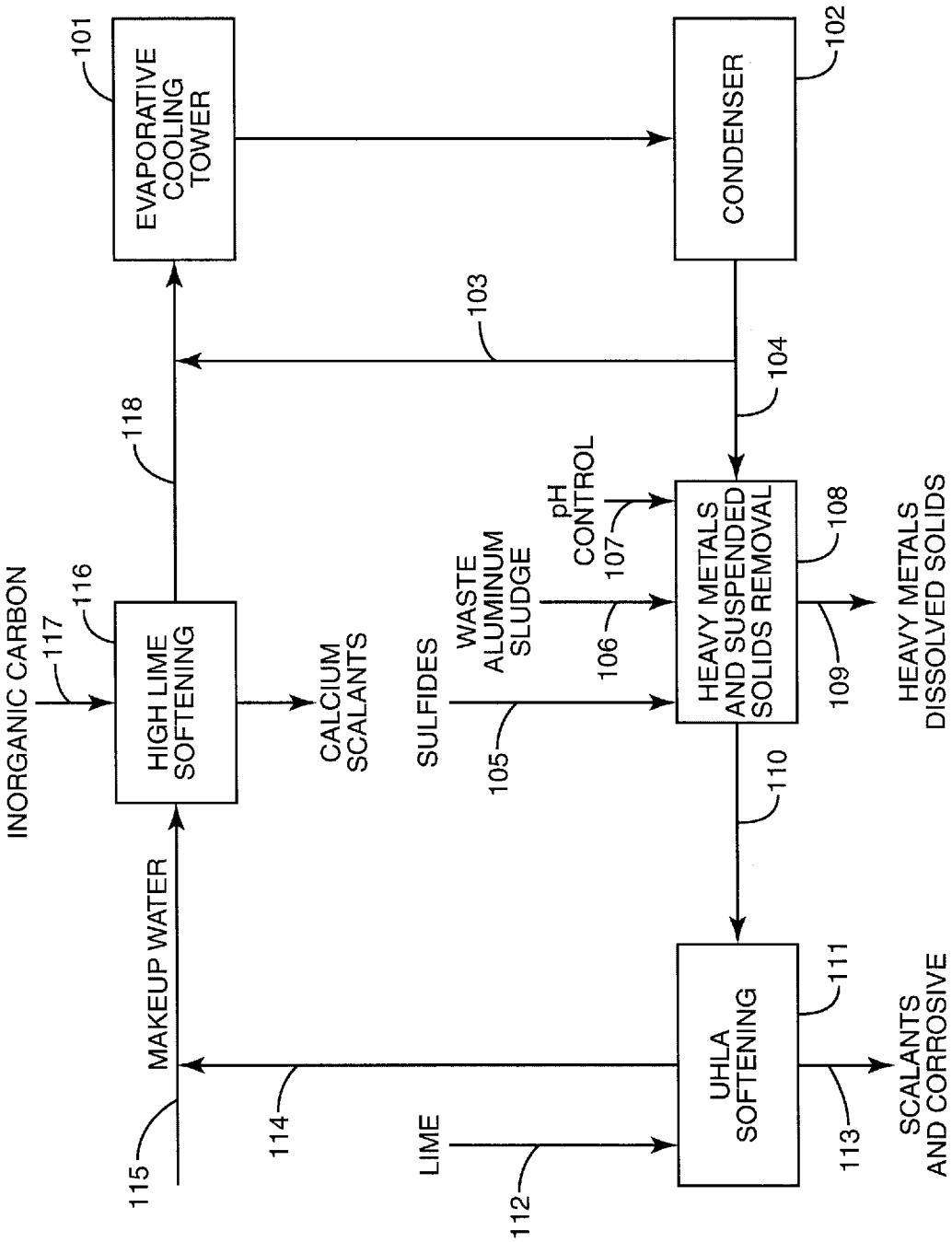

EVAPORATIVE COOLING TOWER
101
CONDENSER
102
103
104
118
INORGANIC CARBON
117
116
HIGH LIME SOFTENING
CALCIUM SCALANTS
SULFIDES
WASTE ALUMINUM SLUDGE
105
pH CONTROL
107
106
HEAVY METALS AND SUSPENDED SOLIDS REMOVAL
108
109
HEAVY METALS DISSOLVED SOLIDS
110
MAKEUP WATER
115
114
LIME
112
UHLA SOFTENING
111
113
SCALANTS AND CORROSIVE COMPOUNDS

FIG. 28

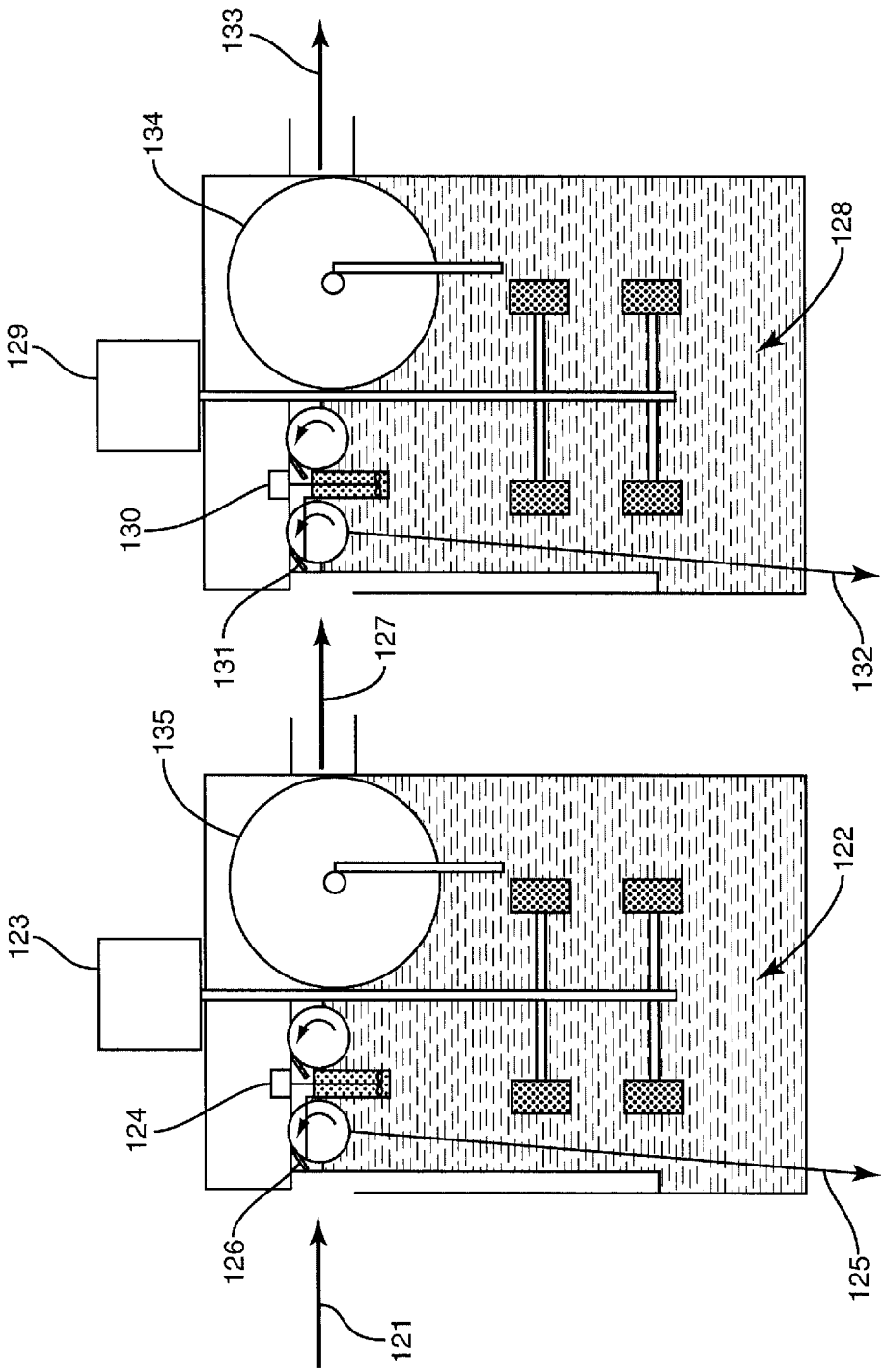


FIG. 29

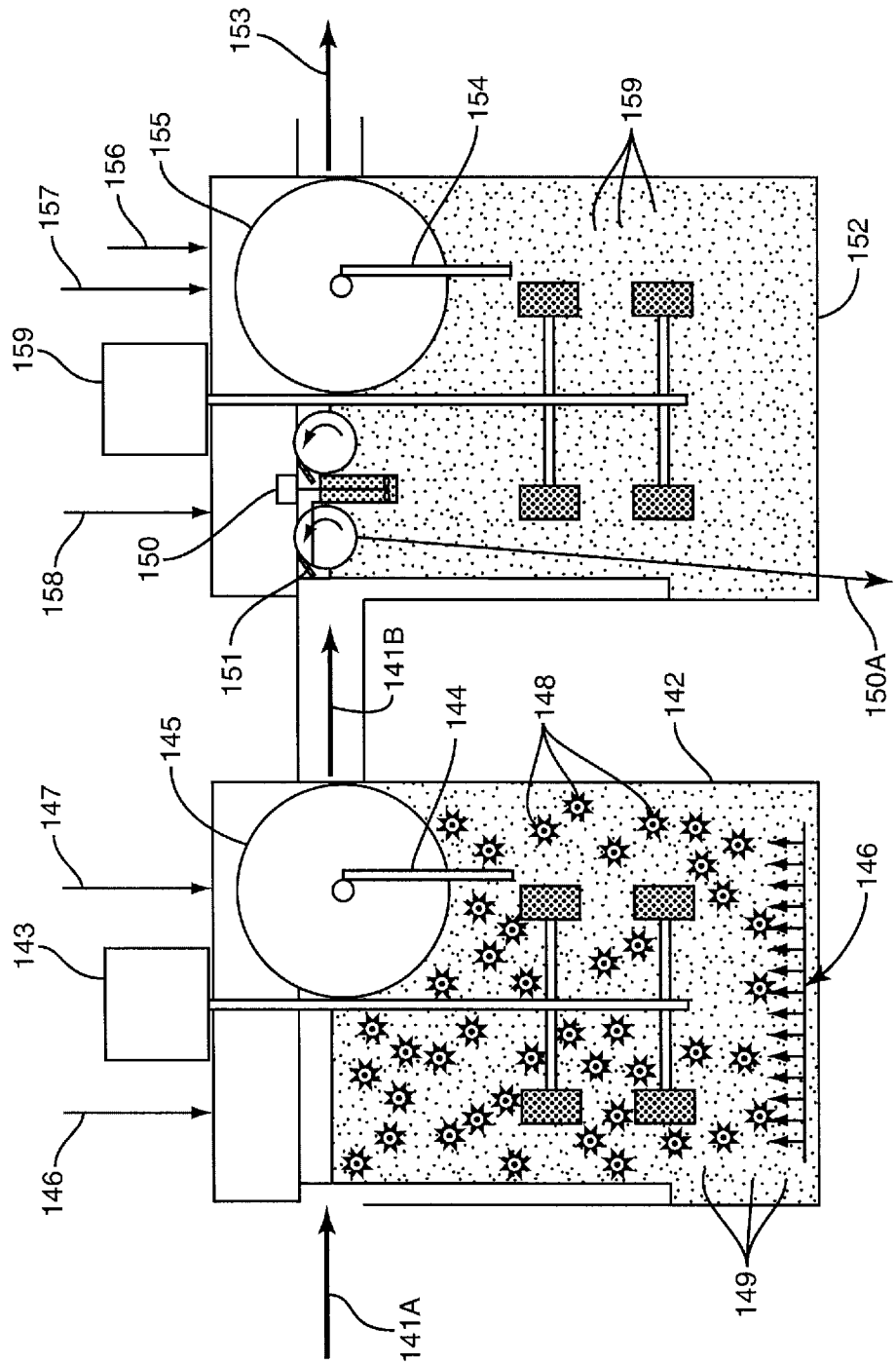

153
154
159
155
156
157
152
159
158
150
151
150A
141B
144
148
142
145
147
146
143
146
149
141A

FIG. 30

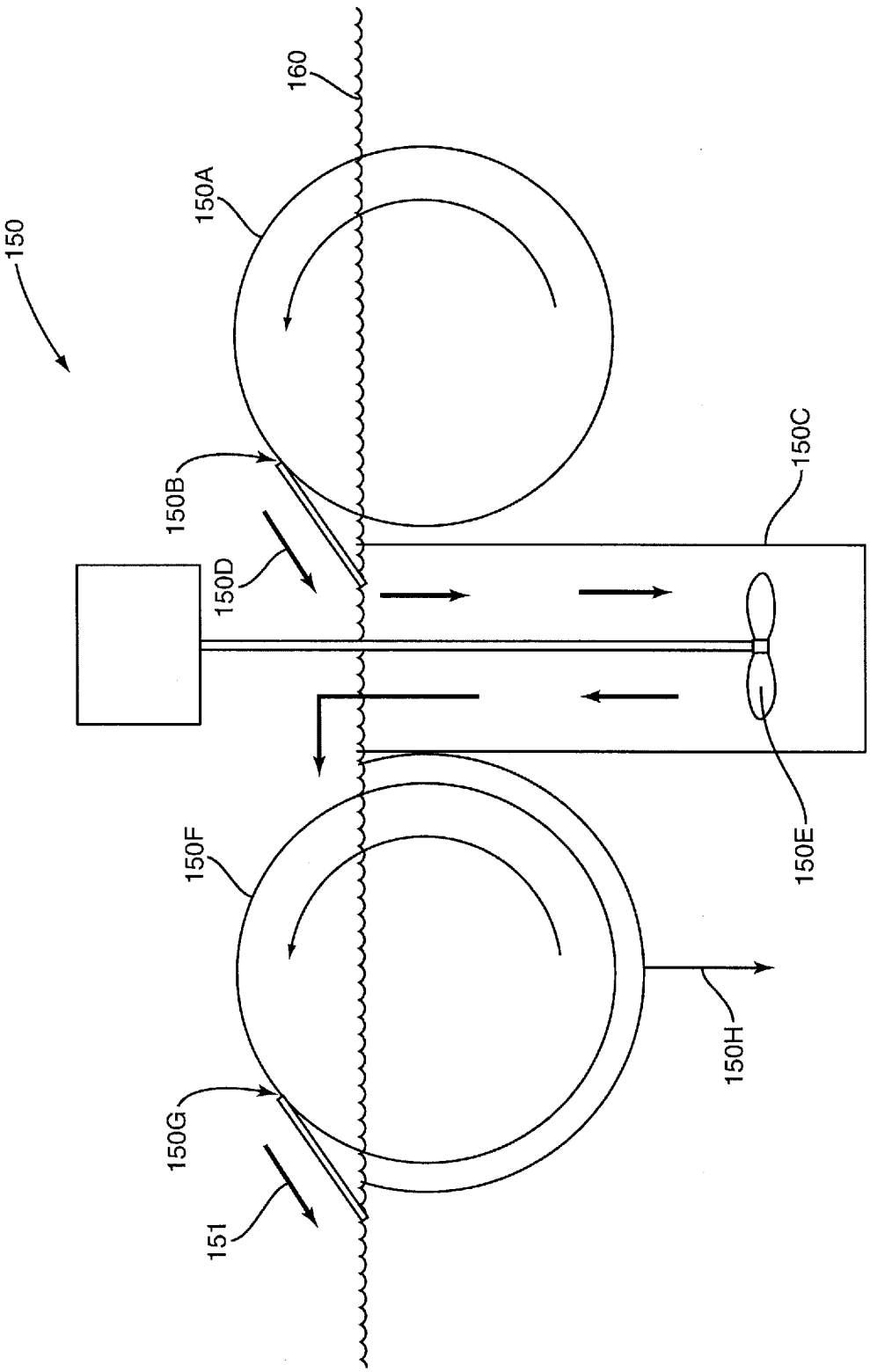


FIG. 31