

(12) STANDARD PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. **AU 2005231684 B2**

(54) Title
Tankage system incorporating adsorption clarification and parallel plate separation

(51) International Patent Classification(s)
B01D 21/02 (2006.01) **B01D 36/04** (2006.01)
B01D 21/00 (2006.01) **B03D 1/24** (2006.01)
B01D 24/46 (2006.01)

(21) Application No: **2005231684** (22) Date of Filing: **2005.03.22**

(87) WIPO No: **WO05/097287**

(30) Priority Data

(31) Number	(32) Date	(33) Country
60/556,141	2004.03.24	US

(43) Publication Date: **2005.10.20**

(44) Accepted Journal Date: **2010.10.21**

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(56) Related Art
JP 06-063321 A
JP 07-080210 A
US 6461,511
US 1,820,974
US 4,547,286
US 5,120,435

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
20 October 2005 (20.10.2005)

PCT

(10) International Publication Number
WO 2005/097287 A1

(51) International Patent Classification⁷: **B01D 21/02**,
24/46, 36/04

(21) International Application Number:
PCT/US2005/009472

(22) International Filing Date: 22 March 2005 (22.03.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/556,141 24 March 2004 (24.03.2004) US

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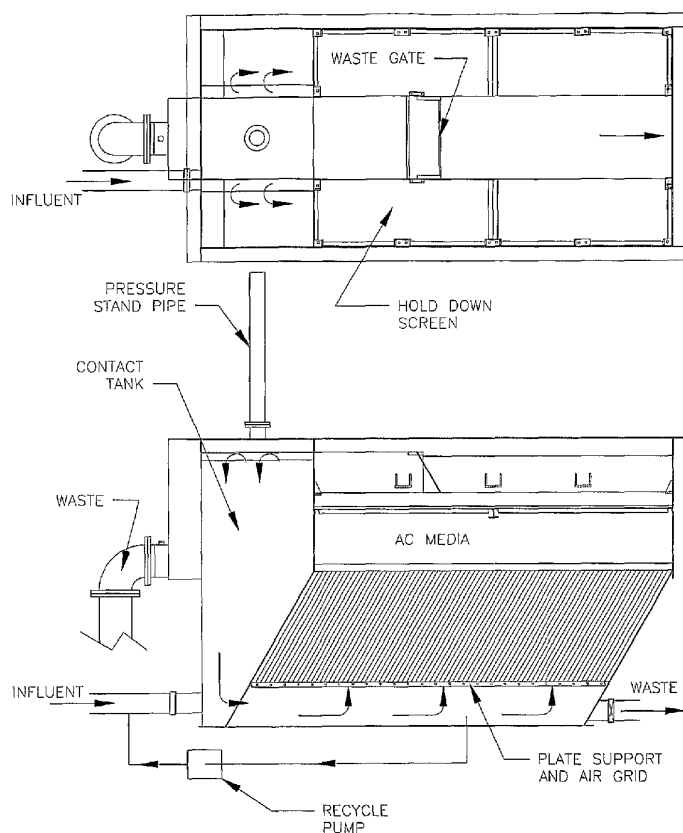
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(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN,
CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI,
GB, GD, GE, GH, GM, HR, HU,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

[Continued on next page]

(54) Title: TANKAGE SYSTEM INCORPORATING ADSORPTION CLARIFICATION AND PARALLEL PLATE SEPARATION



(57) Abstract: A water treatment process and equipment for implementation of the process are provided. The equipment incorporates a high rate clarifier with series operated inclined parallel plate settlers, followed by adsorption clarification with buoyant media.

WO 2005/097287 A1



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, MC, 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).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Published:

— *with international search report*

2005231684 16 Sep 2010

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TANKAGE SYSTEM INCORPORATING ADSORPTION CLARIFICATION AND PARALLEL PLATE SEPARATION

Field of the Invention

A water treatment process and equipment for implementation of the process are
5 provided. The equipment incorporates a high rate clarifier with series operated inclined
parallel plate settlers, followed by adsorption clarification with buoyant media.

Summary of the Invention

Any discussion of the prior art throughout the specification should in no way be
considered as an admission that such prior art is widely known or forms part of common.
10 general knowledge in the field.

While adsorption clarification and parallel plate separation are commonly used in
stand alone filtration systems, an integrated system including both an adsorption clarifier
and an inclined parallel plate separator in combination in a single tankage system is
desirable.

15 Accordingly, in a first aspect an apparatus for filtering a liquid containing solids,
the apparatus comprising an inclined parallel plate separator; and an adsorption clarifier,
wherein the inclined parallel plate separator and the adsorption clarifier are in a stacked
configuration, wherein the adsorption clarifier is situated above the inclined parallel
plate separator, and wherein the apparatus is configured to provide a liquid flow path
20 such that the liquid containing solids first enters the inclined parallel plate separator,
then the liquid, from which a portion of the solids has been removed, enters the
adsorption clarifier, and said apparatus further comprises an air diffusion grid located in
the liquid flow path between the inclined plate separator and the adsorption clarifier.

In a second aspect, an apparatus for filtering a liquid containing solids is
25 provided, the apparatus comprising an inclined parallel plate separator; and an
adsorption clarifier, wherein the inclined parallel plate separator and the adsorption
clarifier are in a side-by-side configuration, and wherein the apparatus is configured to
provide a liquid flow path such that the liquid containing solids first enters the inclined
parallel plate separator, then the liquid, from which a portion of the solids has been
30 removed, enters the adsorption clarifier, and said apparatus further comprises an air
diffusion grid located in the liquid flow path between the inclined plate separator and the
adsorption clarifier.

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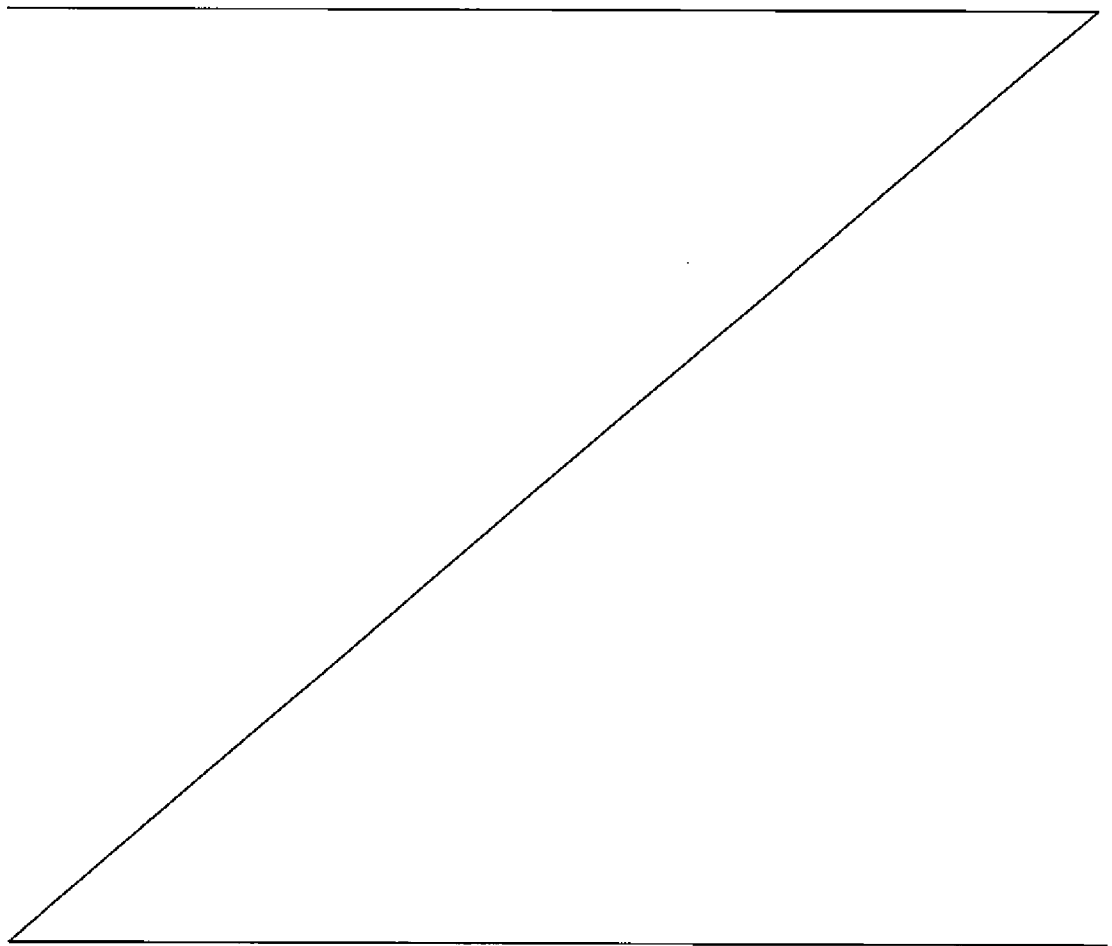
In an embodiment of the second aspect, the apparatus further comprises a contact tank, wherein the contact tank is upstream of an entry into a chamber containing the inclined parallel plate separator.

5 In an embodiment of the second aspect, the apparatus further comprises a filter situated downstream of the adsorption clarifier.

In an embodiment of the second aspect, the apparatus further comprises a filter situated downstream of the inclined parallel plate separator.

In an embodiment of the second aspect, the apparatus further comprises a porous hollow fiber membrane filter.

10



In a third aspect, a method for cleaning an apparatus for filtering a liquid containing solids is provided, the apparatus comprising an inclined parallel plate separator and an adsorption clarifier, wherein the inclined parallel plate separator and the adsorption clarifier are in a side-by-side configuration, the method comprising the steps of introducing a liquid containing solids into the inclined parallel plate separator, whereby a portion of the solids are removed, yielding a separated liquid; introducing the separated liquid into an adsorption clarifier; stopping flow of the liquid containing solids into the inclined parallel plate separator; air scouring the adsorption clarifier; air scouring the inclined parallel plate separator; and opening a waste gate to flush a waste liquid containing solids from the apparatus.

In an embodiment of the third aspect, the method further comprises the step of flushing a liquid through the adsorption clarifier after air scouring the adsorption clarifier.

In an embodiment of the third aspect, the method further comprises the step of flushing a liquid through the inclined parallel plate separator after air scouring the inclined parallel plate separator.

Brief Description of the Drawings

Figure 1 depicts an apparatus of a preferred embodiment, employing an adsorption clarifier and inclined parallel plate separator in a stacked configuration.

Figure 2 depicts an apparatus of a preferred embodiment, employing an adsorption clarifier and inclined parallel plate separator, as well as a lower air grid, lower waste connection, and contact tank.

Figure 3 depicts an apparatus of a preferred embodiment, employing an adsorption clarifier and inclined parallel plate separator, as well as an upper air grid, lower waste connection, and contact tank.

Figure 4 depicts an apparatus of a preferred embodiment, employing an adsorption clarifier and inclined parallel plate separator, as well as a lower air grid and lower waste connection, but no contact tank.

Figure 5 depicts an apparatus of a preferred embodiment, employing an adsorption clarifier and inclined parallel plate separator, as well as an apparatus employing a lower air grid, but no contact tank or lower waste connection.

Figure 6 depicts an apparatus of a preferred embodiment, employing an adsorption clarifier and inclined parallel plate separator in a side-by-side configuration with each other and a membrane filter.

Figure 7 depicts a membrane filter wherein a jet is employed to inject air into a membrane module.

Figure 8 depicts a membrane filter wherein a jet with an integrated air line is employed to inject a mixture of air and sludge into a membrane module.

Figure 9 depicts a membrane filter wherein a jet with an integrated air line is employed to inject a mixture of air and mixed liquor into a membrane module.

Figure 10 depicts a continuous microfiltration system.

Detailed Description of the Preferred Embodiment

5 The following description and examples illustrate a preferred embodiment of the present invention in detail. Those of skill in the art will recognize that there are numerous variations and modifications of this invention that are encompassed by its scope. Accordingly, the description of a preferred embodiment should not be deemed to limit the scope of the present invention.

Water for Treatment

10 The liquid that is filtered can include water, such as raw water, chemically dosed water, or water that has been subjected to other pretreatments. Water having an influent turbidity of 25 NTU or lower up to 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, or 300 NTU or higher can generally be treated according to the preferred embodiments. A variety of raw water types can be treated, including those containing turbidity, color, iron, manganese, dissolved organic carbon,
15 microorganisms, arsenic, phosphate, silica, radionuclides, lead and other heavy metals, copper, selenium, and antimony, as well as water having taste and/or odor. While the apparatus of preferred embodiments is generally preferred for treatment of water, in certain embodiments it can also be employed to treat other liquids containing solids.

 In certain embodiments, it can be preferred to subject the water to be treated to a
20 pretreatment, such as chemical coagulation or precipitation to achieve some degree of solids removal. The water can be treated with alum, ferric sulfate, ferric chloride, sodium aluminate, and/or cationic polymers. In many situations wherein metal salts are used, it is desirable to use a non-ionic or anionic polymer, preferably in a small amount, for improving solids capture in the adsorption media. In some situations, for example, when a media filter is employed downstream
25 of the adsorption clarifier, a cationic polymer can be employed to enhance overall treatment. Low molecular weight cationic polymers can also be used to augment or replace metal salt coagulants in the charge neutralization destabilization of colloidal particles during pretreatment.

 Phosphorous can also be removed according to methods of the preferred embodiments. Other elements, such as arsenic, uranium, or radium, can be removed by appropriate chemical
30 pretreatment, such as coprecipitation with an aluminum or ferric salt.

 Optionally, sorbent materials such as powdered activated carbon, ion exchange resins, hydrous manganese oxide, magnetic ion exchange resin (such as resins marketed under the MIEX® trademark, available from Orica Advanced Water Technologies Pty. Ltd., of Ascot Vale, Victoria, Australia) can be employed to remove certain contaminants. Optionally, an inert, finely
35 divided material with a specific gravity greater than water, such as bentonite, silica sand, or

garnet sand, can be added to the raw water or to the coagulated water to improve the settling characteristics of the solids.

The raw water can also be treated with an oxidant to form insoluble metal oxides, such as ferric hydroxide or manganese oxide, to convert elements present as oxyanions, such as arsenic, to preferred valence states for removal by adsorption or co-precipitation, to achieve partial destruction of dissolved organic compounds such as those contributing to taste and odor, or to improve flocculation and overall particle removal across the system. Suitable oxidant chemicals include potassium permanganate and chlorine, which can be dosed as dissolved chlorine gas, as electrolytically generated chlorine produced on site, or as sodium or calcium hypochlorite solutions.

Various alkaline or acidic chemicals can also be added to adjust pH to a preferred set point.

Adsorption Clarifier

One of the components of the systems of preferred embodiments is an adsorption clarifier. Adsorption clarifiers are generally constructed as tanks containing buoyant media for removal of turbidity and color from pre-coagulated water. Pre-engineered steel tanks are generally preferred; however, tanks of concrete or other material can also be employed. Suitable tanks, vessels, or other containment structures can be employed, as will be appreciated by one skilled in the art. The buoyant media is typically restrained in the tank with a retention screen, generally constructed of aluminum or stainless steel. A buoyant media is preferably employed in the clarifier. The specific gravity of such media can be less than 1.0, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, or 0.1. In a particularly preferred configuration, buoyant media comprising a layer of about 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, or 60 inches in thickness is restrained in the tank. Preferably, the tank contains from about 15 or 20 inches to about 40 or 45 inches of buoyant media, most preferably from about 24 to about 36 inches of buoyant media. In certain embodiments, however, the buoyant media can comprise a layer more than about 60, 65, 70, 80, 90, or 100 inches in thickness. Suitable buoyant media include those consisting of flattened, disk-shaped beads of polyethylene with a slightly roughened surface, or other commercially available buoyant media. Depending upon various factors, such as the nature of the liquid to be treated and the configuration of the apparatus, buoyant media having other shapes can be preferred, such as spherical, rod-shaped, irregularly shaped, or any suitable shape. While polyethylene is preferred, other materials can also be employed, such as other polymers, ceramics, glass, metallic materials, minerals, or synthetic materials. The media can be subjected to surface treatment, for example, physical or chemical roughening, coating, or other suitable treatments.

In certain embodiments, it can be preferred to employ a neutrally buoyant media or a media with a specific gravity greater than 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, or 2 or more. In these embodiments, the parallel plate separator can be placed above the adsorption clarifier or even placed beside the adsorption clarifier.

5 In operation, pretreated water, having passed through the inclined plate settler, enters the bottom of the adsorption clarifier and flows upward through the media bed where solids are removed. Contact flocculation and clarification occur as the coagulated particles move through the bed of adsorption media and are retained. The process is enhanced by repeated contact with previously trapped solids. Hydraulic loading rates during operation are generally from about 1, 2,
10 3, or 4 gpm/ft² to about 16, 17, 18, 19, 20, 25, 30, 35, 40, 45, or 50 or more gpm/ft², preferably from about 5, 6, 7, 8, 9, or 10 gpm/ft² to about 11, 12, 13, 14, or 15 gpm/ft². However, in certain embodiments higher or lower loading rates can be employed. The upper limit of influent turbidity for a stand-alone adsorption clarifier is typically about 75 NTU, and the color limit is typically about 25 color units. However, higher turbidity levels and color limits can be tolerated,
15 particularly when they are of short duration. Turbidity as high as 100, 125, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400, 425, 450, 475, or 500 NTU or higher can typically be tolerated for periods up to several hours or more.

The adsorption clarifier is typically flushed with raw water or some other liquid and incorporates an air scour system to remove captured solids. The direction of the water flow
20 during the flush cycle is preferably in the upward direction. However, downward, sideward, or a flush in other directions can also be employed. The air scour expands and scrubs the media to remove adhered solids. While manual control of the flush and/or air scour systems can be employed, it is generally preferred to employ automatic controls to monitor the unit and provide control during a flush cycle. Depending on flow rates and media type, suspended solids
25 reductions of from about 40%, 45%, 50%, 55%, 60%, 65% or less to about 95% or more are achievable in an adsorption clarifier. Typically, the adsorption clarifier removes from about 70% or 75% to about 80%, 85%, or 90% of influent solids.

Parallel Plate Separator

One of the components of the systems of preferred embodiments is a parallel plate
30 separator. Parallel plate separators provide a large settling area for suspended solids in considerably less space than conventional clarifiers do. Systems typically range in capacity from 5, 10, or 15 gpm to several million gallons per day, using multiple units. Hydraulic loading rates, based on the superficial area of the settler, are typically from about 0.05, 0.1, 0.2, 0.3, 0.4, 0.5,
0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.4, 1.6, 1.8, 2, 2.25, 2.5, 2.75, 3, 3.25, 3.5, 3.75, 4, 4.25, 4.5, 4.75, or 5
35 gallons per minute per square foot (gpm/ft²) or less to as high as about 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30, 35, 40, 45, 50 gpm/ft² or more.

Performance of parallel plate separators is generally equal to or better than conventional clarification apparatus, providing distinct advantages. Advantages of parallel plate separators include utilization of minimal floor space, and low maintenance, installation, and capital costs. Parallel plate separators can include lamella plate settlers incorporating arrays of parallel flat plates, generally all aligned in a single orientation, with a perpendicular distance between plates of from about 0.1, 0.2, 0.3, 0.4, 0.5 inches or less to about 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 inches or more. Other types of parallel plate separators include tube settlers, in which thin sheets are arranged in one or more orientations, providing flow paths which can include one or more direction changes. The thin sheets can be flat, corrugated, or incorporate various other surface configurations. Other clarification devices employ sheets of material that are used to provide additional surface area for solids to settle on, to modify the flow path of the liquid to be clarified, or both.

In a preferred embodiment, the parallel plate separator consists of an epoxy coated carbon steel vessel (or a vessel of another suitable material), fiber reinforced plastics (FRP) parallel plates, inlet, outlet, and sludge nozzles, sludge collection hopper, influent feed and distribution zone, effluent launder, and access manhole in the sludge hopper. The plates are typically inclined at an angle to enhance rapid settling. Generally, the angle of inclination is from about 15, 20, 25, 30, 35, 40, or 45 degrees or less to about 75, 80, or 85 degrees or more, preferably from about 50 or 55 degrees to about 65 or 70 degrees, and most preferably about 60 degrees. The plates can all be inclined to the same angle, or different plates can be inclined at different angles. Likewise, a plate can be curved, so as to provide varying angles of inclination at various points on its surface.

The plates are typically spaced from about ½ inch apart to about six inches apart, preferably about two inches apart. Typical hydraulic loading rates vary from a 0.05, 0.1, 0.15, 0.2, or 0.25 or less gpm/ft² effective area for light hydroxide type precipitates to a 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, or 0.9 or higher gpm/ft² effective area for surface water clarification. Higher or lower loading rates can be preferred in certain embodiments. Effective area is defined as the surface area of the inclined plates available for settling.

The system can be configured such that settled solids are collected at the bottom of the tank, having settled out on the plates and having moved down the plates under the influence of gravity. Alternatively, the settler can be designed so that sludge is collected towards the top of the plates by allowing for a crossflow movement of sludge across the plates to a sludge collector system located at one side of the tank. With either type of sludge collector, provision can be made to collect a portion of the sludge and recycle it to a point close to the introduction of coagulant to the raw water, or some other point in the system. This recirculation of pre-formed floc generally improves the formation and growth of settleable floc.

Flash mixing and flocculation basins can be employed in conjunction with the parallel plate separator, especially if the system employs coagulants and/or flocculants. Variable speed flocculator drives are typically employed on the flocculation basins. Chemical pretreatment systems, sludge pumping systems, tank covers, and special coatings are also available. Separate rapid mix and flocculation tanks can be provided if specific detention times for specific applications are desirable. Rapid mix conditions can also be provided by use of static mixers. Long detention times for the rapid mix and flocculation can result in significant savings in chemical consumption and sludge generation rates and disposal cost. The system shown in Figure 1 uses the hopper shaped volume immediately upstream of the plate settler system as a flocculation volume. If this volume is not sufficient for adequate pretreatment, then separate flocculation and rapid mix volumes can be provided upstream.

Integrated System

Figure 1 depicts a device of a preferred embodiment. The device combines two technologies for clarification of water: Inclined parallel plate (inclined parallel plate separator) separation and adsorption clarification (adsorption clarifier). Both methods are capable of producing high quality treated water. When turbidity or solids content of the water is increased, however, both have drawbacks that negatively impact their water treatment efficiency. Inclined parallel plate separator separation generally requires additional projected plate area per flow rate provided for by more plates, a reduced angle of incline, or a greater plate depth in order to produce effluent with low suspended solids and/or turbidity. Adsorption clarifier units generally require more flushing and a possible reduction in flow rate when feed water solids are increased.

By combining the two processes into a single series operated system, a feed water with high solids levels can be treated with enhanced efficiency. In devices of preferred embodiments, the portion of the device directed to inclined parallel plate separator separation reduces the influent solids level such that a low to normal concentration of solids is directed to the adsorption clarifier unit. Normal solids concentrations are typically defined as from about 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 or 30 NTU, however in certain embodiments higher or lower solids concentrations can be considered as normal, for example, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, or 19 NTU, or 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, or 100 or higher NTU. As discussed above, the adsorption clarifier is capable of handling up to 300 NTU or more for short periods of a few hours or less.

In certain embodiments, a sludge recycle system is incorporated into the system to return solids from the settling plate area to the influent water stream. There, additional solids contacting is provided, which promotes a more readily settled solid for the inclined parallel plate separator separation.

The arrangement of the inclined parallel plate separator and adsorption clarifier in a stacked configuration is depicted in Figure 1. In the drawing, a contact tank providing about 1, 1.5, or 2 minutes or less to 2.5, 3, 3.5, or 4 minutes or more of coagulation/flocculation time is situated before the entry to the chamber containing the inclined parallel plate separator and adsorption clarifier. The contact tank can be expanded or eliminated, depending on site-specific conditions. Figures 2 through 5 depict various configurations of apparatus of preferred embodiments, including a configuration including a lower air grid, lower waste connection, and contact tank (Figure 2), a configuration including an upper air grid, lower waste connection, and contact tank (Figure 3), a configuration including a lower air grid and lower waste connection, but no contact tank (Figure 4), and a configuration including a lower air grid, but no contact tank or lower waste connection (Figure 5).

Other configurations can also be employed, depending upon the particular application and other system requirements. For example, arrangement of the inclined parallel plate separator and adsorption clarifier in a side-by-side configuration is particularly preferred. Such a side-by-side configuration, including an incline plate separator, an interstage pump, an adsorption clarifier, a water collection manifold, and a membrane filter is illustrated in Figure 6. In the system depicted in Figure 6, water flows up through the incline plate settler, up through the adsorption clarifier, and down through the membrane filter.

A filter section can also follow the adsorption clarifier in a packaged treatment unit. The filter can include a media filter containing a bed of sand, anthracite, granular activated carbon, manganese greensand, any of the previously listed media coated with manganese hydroxide, any combination of these particular media, or any other suitable granular or other filtration media. The filter can function primarily as an adsorption or ion exchange contactor, in which case the media can include granular activated carbon, granular ferric hydroxide, activated alumina, ion exchange resin, or any other suitable sorption media.

The filter can also include a membrane filter. The membrane filter can include a submerged membrane, in which the membrane elements are immersed in a tank during filtration and the filtrate flow is driven by the pressure differential between the tank liquid and the filtrate side of the membrane. This pressure differential can arise solely due to gravity, or can be augmented by the suction provided by a filtrate pump, by a positive pressure provided on the tank, or by any combination of these. The membrane filter can also include a pressurized membrane system, wherein membrane modules are enclosed in housings, each housing containing one or more membrane modules. Pressurized membrane filters are generally operated with the pressure provided by a feed pump, but the driving force can also be provided by gravity, by pump suction, or by any combination of these methods.

Any suitable membrane filter system can be employed with the parallel plate separator and adsorption clarifier systems of preferred embodiments, but particularly preferred systems utilize either a Continuous MicroFiltration System (CMF-S), or a Membrane BioReactor (MBR) filtration system.

5 Such membrane filtration systems are designed to draw filtrate from a reservoir of liquid substrate by the use of microporous hollow fibers immersed within the substrate. The fibers can be oriented in any suitable orientation; however, a vertical orientation is particularly preferred for ease and efficiency of manufacture, operation, and maintenance. Figures 7, 8, and 9 illustrate preferred designs for representative filtration systems. The figures show a "cloverleaf" filtration
10 unit comprising four sub-modules. Typically, a plurality of such filtration units, most commonly in a linear "rack," is immersed in the substrate reservoir. The illustrated filtration units include a filtrate sub-manifold (not shown) and an air/liquid substrate sub-manifold, which receive the upper and lower ends, respectively, of the four sub-modules.

Each sub-manifold includes four circular fittings or receiving areas, each of which
15 receives an end of one of the sub-modules. Each sub-module is structurally defined by a top cylindrical pot (not shown) and a bottom cylindrical pot. In preferred embodiments, a cage (not shown) connects the top and bottom pots and secures the fibers. Alternatively, one or more rings, ties, or other structures can also be employed to secure the fibers, or the fibers are unsecured. Instead of a cage configuration, rods can be employed to connect the top and bottom pots, or
20 other arrangements can be employed. The pots secure the ends of the hollow fibers in the MBR module and can be formed of a resinous, polymeric, or other suitable material. The ends of the cage or other supporting member, if employed, are preferably fixed to the outer surfaces of the pots. Each pot and associated end of the cage is together received within one of the circular fittings of each sub-manifold. The sub-manifolds and pots of the sub-modules are coupled
25 together with the aid of circular clips, O-ring seals, or the like.

Each sub-module preferably includes fibers arranged vertically between its top and bottom pot. The fibers preferably have a length somewhat longer than the distance between the pots, such that the fibers can move laterally. Depending upon the application, the length of the fibers can be adjusted to provide various degrees of slack. When reduced movement of the fibers
30 is desired, a cage can be employed to closely surround the fibers of the sub-module so that, in operation, the outer fibers touch the cage, and lateral movement of the fibers is restricted by the cage. The lumens of the lower ends of the fibers are typically sealed within the bottom pot, while the upper ends of the fibers are not sealed, permitting removal of filtrate from the lumens of the membranes upon application of a transmembrane pressure.

35 During filtration, a liquid substrate is introduced into the region of the hollow fibers, between the top and bottom pots. A pump (not shown) can be utilized to apply suction to the

filtrate manifold, creating a pressure differential across the walls of the fibers, causing filtrate to pass from the substrate into the lumens of the fibers. The filtrate flows upward through the fiber lumens into the filtrate sub-manifold, through the filtrate withdrawal tube, and upward into the filtrate manifold to be collected outside of a reservoir. For applications wherein aeration of the substrate is desired, the bottom pot can include a plurality of holes, slots, or passages extending from its lower face to its upper face, so that a mixture of air bubbles and liquid substrate in the air/liquid substrate sub-manifold can flow upward through the bottom pot to be discharged between the lower ends of the fibers. Alternatively, air can be injected into the region surrounding the membranes by means of tubes, perforated sheets, or the like separate from the bottom pot.

In one embodiment, the system includes an air manifold near the bases of the filtration units, as depicted in Figure 10. The air manifold can include a horizontal air conduit just above the air sub-manifolds. The horizontal air conduit can employ bottom connections to central upper surfaces of the air sub-manifolds, the bottom connections supplying air to the air sub-manifolds. Each air sub-manifold ducts the air to the lower faces of the four bottom pots of the filtration unit, the air then flowing upward through holes or passages in the bottom pots. One or more vertical air droppers can be employed between the filtration units to deploy air from above the tank down to the horizontal air manifold.

The filtrate sub-manifold can be connected to a vertically oriented filtrate withdrawal tube that in turn connects to a filtrate manifold (not shown) that receives filtrate from all of the filtration units (such as the illustrated cloverleaf unit) of a rack. The filtrate withdrawal tube is in fluid communication with the upper faces of the top pots of the sub-modules, so that filtrate can be removed through the withdrawal tube. In addition, the system can include an air line that injects air into the open skirt under the air/liquid substrate sub-manifold. The air line can inject air through the top of the air/liquid substrate sub-manifold and into the open skirt, or alternatively the air line can be integrated with the line providing liquid substrate for jet mixing. While such embodiments are particularly preferred, other arrangements can also be employed, as will be appreciated by one skilled in the art.

It is desirable to provide for additional chemical feeds to the system between each separation stage. This allows a different chemical environment to be created in each separation stage, thereby improving or optimizing the performance of each stage. Furthermore, removal conditions for different contaminants can be optimized at each stage. For example, if iron, manganese, and aluminum are to be removed in the system, the raw water can be aerated to form ferric hydroxide floc. The pH in the clarifier can be adjusted to about pH 6.5 to minimize aluminum solubility and thereby achieve maximum aluminum removal through the plate settler and adsorption clarified stages. An oxidant chemical can be added to oxidize manganese oxide,

and the pH in the filter system can be adjusted to above pH 8.0. A polymer can be added to the adsorption clarifier effluent to maximize manganese capture in the filter section, which preferably employs a manganese oxide coated media. Other pH can be preferred if different contaminants are present.

- 5 Chemicals can also be added to improve the separation performance of each stage, or to optimize the overall performance of the system. For example, unreacted polymer carryover from adsorption clarifiers or other types of clarifiers is known to produce rapid head loss development in media filter systems and rapid fouling of membrane filter systems. A chemical can be added to the adsorption clarifier effluent to react with or destroy some or all of this polymer carryover.
- 10 The chemical can be either a charged species with charge opposite to the polymer, an oxidant, a finely divided solid or colloid, or other suitable chemical.

Backwash

- In certain preferred embodiments, a backwash is conducted to clean the filtration media. It is generally preferred to combine air and water simultaneously for the duration of the
- 15 backwash. The combined air and water wash provide a vigorous scouring action to clean the media, during which all of the filter media is lifted to the bed surface by an air/lift pumping action. The highly agitated backwash water promotes intense collisions of the media grains to effectively detach and dislodge adhered solids from the bottom of the bed to the top, where they are removed. The combined cleaning action of air and water is effective at sub-fluidization rates,
- 20 reducing the volume of backwash water required and the volume of backwash waste produced. Specially designed wash trough baffles can optionally be employed to eliminate media loss. The superior cleaning performance of the backwash methods of preferred embodiments minimizes chemical and biological fouling of the filter media, eliminating the necessity of expensive chemical cleaning or media replacement.

- 25 Advantages of the backwash method can include increased scouring energy, superior cleaning performance, longer filter runs, significantly lower backwash water usage rates, lower operating costs, flexibility in media selection such as the ability to use larger media, elimination of a need for additional chemical cleaning systems, and reduced pumping and piping costs.

- In a preferred backwash process, a drain down step is followed by an air scour step.
- 30 After the air scour step, a step is conducted wherein air scour is provided in combination with low-rate water. Air scour is then terminated, and low-rate water is provided for a period of time, after which the rate increases to the high-rate water rate. The preferred duration for the drain down step is typically from about 0.25, 0.5, 1, 1.5, 2, 2.5, 3, or 3.5 minutes or less to about 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, or 10 minutes or more, preferably about 4 minutes. The preferred
- 35 duration of the air scour only is from about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.25, 1.5, 1.75, 2, 2.25, 2.5, or 2.75 minutes or less to about 3.25, 2.5, 3.75, 4, 4.25, 4.5, 4.75, 5, 5.5, 6, 6.5, 7, 8,

9, or 10 minutes, preferably about 3 minutes. The preferred duration of the air scour and low-rate water step is about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.25, 1.5, or 1.75 minutes or less to about 2.25, 2.5, 2.75, 3, 3.25, 3.5, 3.75, 4, 4.5, 5, 5.5, 6, 7, 8, 9, or 10 minutes or more, preferably about 2 minutes or less. The water rate is preferably ramped up over from about 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, or 6.5 minutes or less to about 7.5, 8, 8.5, 9, 9.5, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 minutes or more, preferably over about 7 minutes, to the high-rate water rate. Total backwash time is preferably from about 5 or 10 minutes or less to about 25, 30, 35, 40, 45, 50, 55, or 60 minutes or more, preferably about 11, 12, 13, 14, 15, 16, or 17 minutes to about 19, 20, 21, 22, 23, or 24 minutes, and most preferably about 18 minutes.

In another preferred backwash method, air scour and low rate water are provided for from about 0.25, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4.5, 5, 5.5, 6, 6.5, 7, or 7.5 minutes or less to about 8.5, 9, 9.5, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 minutes or more, preferably about 8 minutes. Then, air scouring is terminated and the water rate is ramped up to the high-rate water rate over from about 0.25, 0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, or 4.5 minutes or less to about 5.5, 6, or 6.5, 7.5, 8, 8.5, 9, 9.5, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 minutes or more, preferably over about 5 minutes, to the high-rate water rate. The total backwash time for this method is preferably from about seven minutes to about twenty minutes, most preferably about thirteen minutes.

While it is generally preferred to employ simultaneous air scour and water for at least a portion of the backwash cycle, other backwash methods may also be employed which utilize various combinations of air scour and/or water steps, conducted simultaneously or separately, at different rates, and for different durations, as suitable for the particular filtration media and system configuration employed.

Cleaning the Clarifier

Cleaning of the clarifier system is preferably accomplished according to either of the following two methods.

Method 1

Method 1 utilizes an air scouring step and a liquid flush to clean the clarifier system, followed removal of dislodged solids. When the headloss through the clarifier reaches a preset point, or time duration has been exceeded, the clarifier is taken off line to remove accumulated solids. Influent flow is stopped and an air scour is initiated. The air scour can be conducted intermittently or continuously. If conducted intermittently, it is generally preferred that air scour be conducted in cycles of from about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 minutes to about 2.25, 2.5, 2.75, 3, 3.25, 3.5, 3.75, 4, 4.25, 4.5, 4.75, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 11, 12, 13, 14, or 15 minutes of air on followed by from about 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, or 2 minutes to

about 2.25, 2.5, 2.75, 3, 3.25, 3.5, 3.75, 4, 4.25, 4.5, 4.75, 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5, 10, 11, 12, 13, 14, or 15 minutes of air off (or air at a lower flow rate, for example, 90%, 85%, 80%, 75%, 70%, 65%, 60%, 55%, 50%, 45%, 40%, 35%, 30%, 25%, 20%, 15%, 10%, 5% or less of the higher, or air on, flow rate). Aeration can be provided wherein the air is in the form of bubbles of uniform sizes, or a combination of different bubble sizes can be employed, for example, coarse bubbles and/or fine bubbles. Regular or irregular cycles (in which the air on and air off times vary) can be employed, as can sinusoidal, triangular, or other types of cycles, wherein the rate of air is not varied in a discontinuous fashion, but rather in a gradual fashion, at a preferred rate or varying rate. Different cycle parameters can be combined and varied, as suitable.

The flow rate of air provided to the clarifier during air scour can vary depending upon system design, but generally from about 0.01 or less to about 30, 40, 50, 60, 70, 80, 90, 100 or more standard cubic feet per minute per square foot (scfm/ft²) is employed, preferably from about 0.05, 0.1, 0.5, 1, 2, 3, 4, or 5 scfm/ft² to about 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, or 20 scfm/ft². While air is generally preferred for use in the air scour process, any suitable gas or mixture of gases can be employed. Generally, air scour is initiated after a headloss of from about two feet to about four feet, or after operation of the device for from about 4, 5, 6, 7, 8, or 9 hours to about 10, 11, 12, 13, or 14 hours. However, in certain embodiments, it can be preferred to initiate air scour at a headloss higher than four feet or lower than two feet, or after a longer or shorter duration of operation. The amount of solids in the water to be treated can impact the desired air scour frequency. Generally, the more solids present, the greater the air scour frequency preferred for optimal filtration efficiency.

The support system for the inclined parallel plate separator typically incorporates an air diffusion grid. Air, or another suitable gas, passes through the inclined parallel plate separator and upward through the adsorption clarifier media. The air dislodges solids accumulated on the inclined parallel plate separator and expands the adsorption clarifier media to allow removal of captured solids. The adsorption clarifier media can expand into the inclined parallel plate separator section to provide additional scouring of the plates.

Air only agitation occurs for a period of time (typically from about 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30, 45, 50, or 55 seconds to about 5.5, 6, 6.5, 7, 8.5, 9, 9.5, or 10 or more minutes, preferably from about one minute to about 1.25, 1.5, 1.75, 2, 2.25, 3, 3.25, 3.5, 3.75, 4, 4.25, 4.5, 4.75, or 5 minutes) prior to a raw water flush or flush of other suitable liquid upward through the unit. The waste gate is then opened to allow the solids to be flushed to waste through the waste trough and piping. Air scouring and water flushing typically continue for about less than about 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30, 45, 50, or 55 seconds to about 11, 12, 13, 14, 15, 20, 25, 30, 35, 40, 45, 50, 55, or 60 or more minutes, preferably from about 1 minute

to about 1.25, 1.5, 1.75, 2, 2.25, 3, 3.25, 3.5, 3.75, 4, 4.25, 4.5, 4.75, 5, 5.5, 6, 6.5, 7, 8.5, 9, 9.5, or 10 minutes. Air is then discontinued and a water only flush continues for about less than about 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30, 45, 50, or 55 seconds to about 5.5, 6, 6.5, 7, 8.5, 9, 9.5, 10, 11, 12, 13, 14, 15, 20, 25, or 30 or more minutes, preferably from about 1 minute to about 1.25, 1.5, 1.75, 2, 2.25, 3, 3.25, 3.5, 3.75, 4, 4.25, 4.5, 4.75, or 5 minutes. At the end of the cycle, the waste gate is closed and the treated flow is sent to effluent. In addition to the air scouring and water flushing methods discussed above, chemical cleaning can also be employed.

Method 2

Method 2 utilizes an air scouring step to clean the clarifier system, followed removal of dislodged solids. When the headloss through the clarifier reaches a preset point, or time duration has been exceeded, the clarifier is taken off line to remove accumulated solids. Influent flow is stopped and an air scour is initiated. The air scour can be conducted intermittently or continuously, as described above in regard to Method 1. The support system can be configured as described above in regard to Method 1.

Air only agitation occurs for a period of time (typically from about 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30, 45, 50, or 55 seconds to about 5.5, 6, 6.5, 7, 8.5, 9, 9.5, or 10 or more minutes, preferably from about one minute to about 1.25, 1.5, 1.75, 2, 2.25, 3, 3.25, 3.5, 3.75, 4, 4.25, 4.5, 4.75, or 5 minutes), after which the waste pipe at the bottom of the clarifier is opened and the solids in the clarifier are flushed to waste from the bottom of the tank. Air scour is then discontinued prior to media being lost to waste. Once the draining down is complete, the tank is refilled.

In certain preferred embodiments, a disinfection module can be incorporated in the system downstream of the filter and this can incorporate ultraviolet radiation or a chemical disinfectant such as chlorine. Both ultraviolet and chemical disinfection can be used in some cases. Incorporation of a disinfection module is particularly useful in municipal drinking water treatment applications because it allows the system to be credited with very high efficiency in inactivation of pathogens.

Systems and methods relating to the preferred embodiments are disclosed in copending U.S. Provisional Application No. 60/556,141, filed March 24, 2004. All references cited herein are incorporated herein by reference in their entirety, and are hereby made a part of this specification. To the extent publications and patents or patent applications incorporated by reference contradict the disclosure contained in the specification, the specification is intended to supersede and/or take precedence over any such contradictory material.

The term "comprising" as used herein is synonymous with "including," "containing," or "characterized by," and is inclusive or open-ended and does not exclude additional, unrecited elements or method steps.

All numbers expressing quantities of ingredients, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and attached claims are approximations that may vary depending upon the desired
5 properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should be construed in light of the number of significant digits and ordinary rounding approaches.

The above description discloses several methods and materials of the present invention.
10 This invention is susceptible to modifications in the methods and materials, as well as alterations in the fabrication methods and equipment. Such modifications will become apparent to those skilled in the art from a consideration of this disclosure or practice of the invention disclosed herein. Consequently, it is not intended that this invention be limited to the specific embodiments disclosed herein, but that it cover all modifications and alternatives coming within
15 the true scope and spirit of the invention as embodied in the attached claims.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:-

1. An apparatus for filtering a liquid containing solids, the apparatus comprising:
an inclined parallel plate separator; and
an adsorption clarifier, wherein the inclined parallel plate separator and the
5 adsorption clarifier are in a stacked configuration, wherein the adsorption clarifier is
situated above the inclined parallel plate separator, and wherein the apparatus is
configured to provide a liquid flow path such that the liquid containing solids first enters
the inclined parallel plate separator, then the liquid, from which a portion of the solids
has been removed, enters the adsorption clarifier, and
10 said apparatus further comprises an air diffusion grid located in the liquid flow
path between the inclined plate separator and the adsorption clarifier.
2. An apparatus for filtering a liquid containing solids, the apparatus comprising:
an inclined parallel plate separator; and
an adsorption clarifier, wherein the inclined parallel plate separator and the
15 adsorption clarifier are in a side-by-side configuration, and wherein the apparatus is
configured to provide a liquid flow path such that the liquid containing solids first enters
the inclined parallel plate separator, then the liquid, from which a portion of the solids
has been removed, enters the adsorption clarifier, and
said apparatus further comprises an air diffusion grid located in the liquid flow
20 path between the inclined plate separator and the adsorption clarifier.
3. The apparatus of claim 2, further comprising:
a contact tank, wherein the contact tank is upstream of an entry into a chamber
containing the inclined parallel plate separator.
4. The apparatus of claim 2 or claim 3, further comprising:
25 a filter situated downstream of the adsorption clarifier.
5. The apparatus of claim 2 or claim 3, further comprising:
a filter situated downstream of the inclined parallel plate separator.
6. The apparatus of any one of claims 2 to 5, further comprising:
a porous hollow fiber membrane filter.

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7. An apparatus for filtering a liquid containing solids substantially as herein described with reference to any one of the embodiments of the invention illustrated in the accompanying drawings and/or examples.

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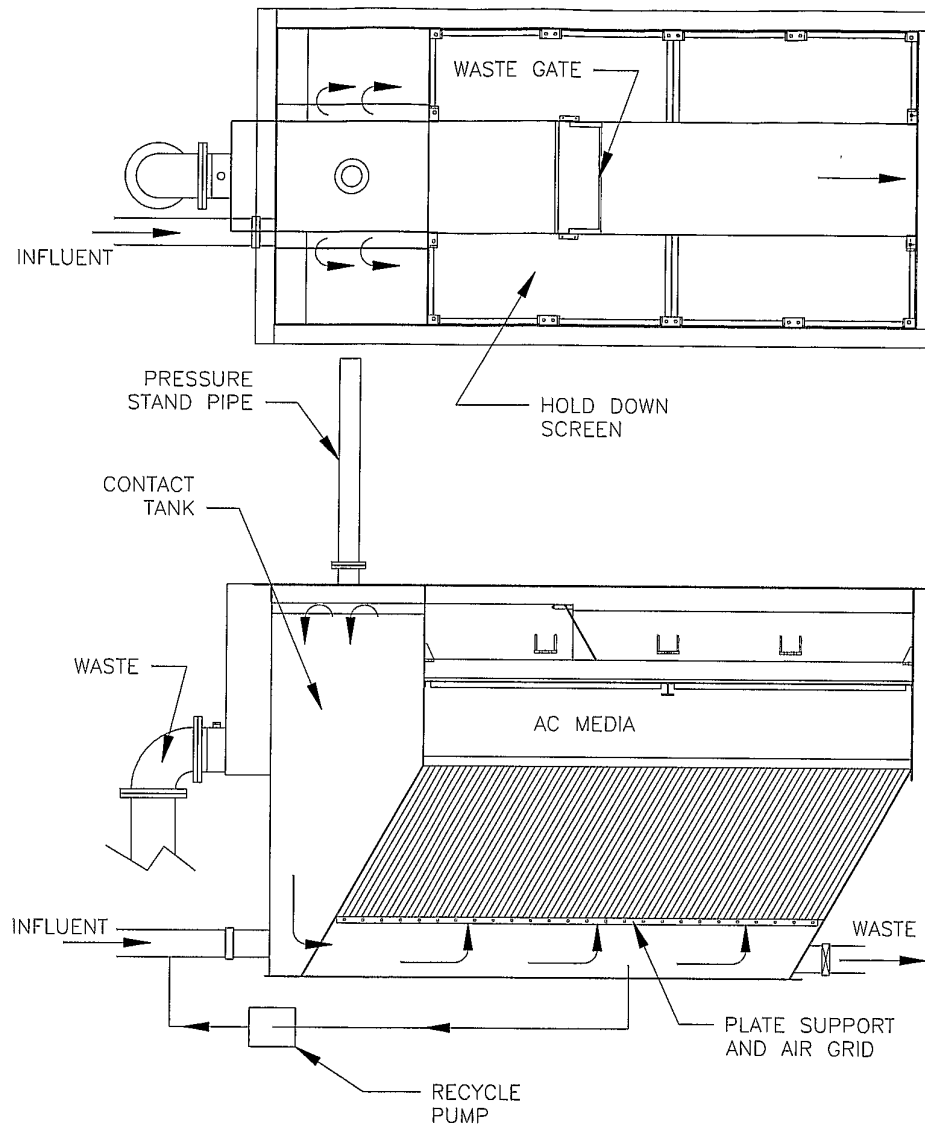
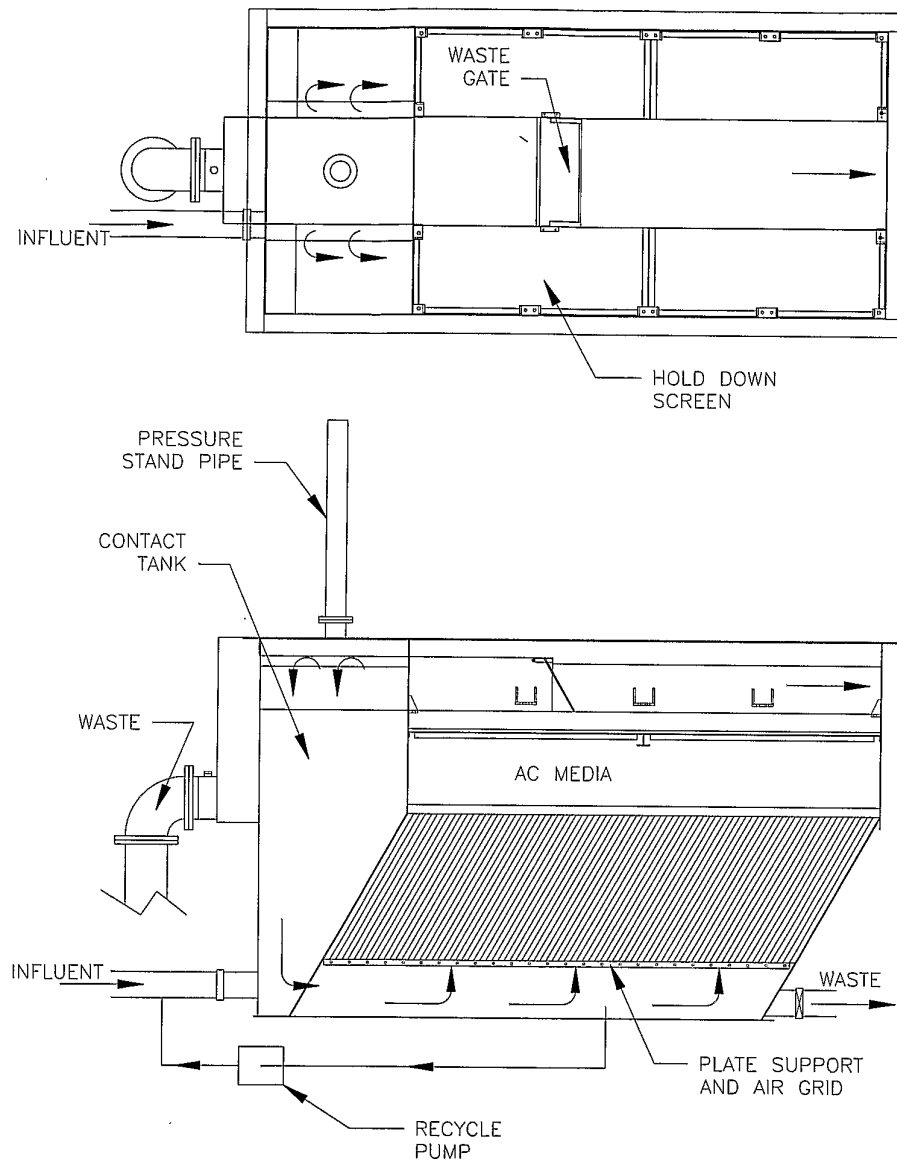


Figure 1

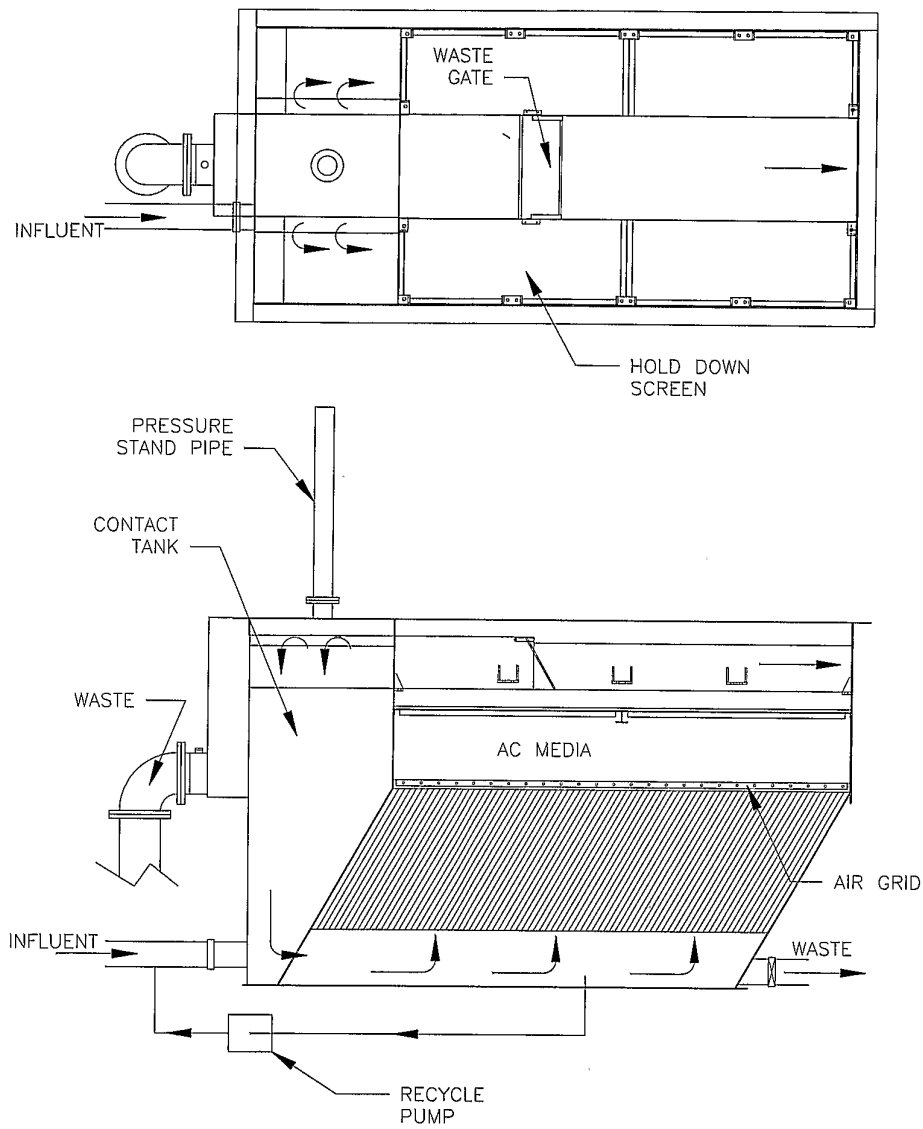
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CONTACT TANK, LOWER AIR GRID, LOWER WASTE CONNECTION

Figure 2

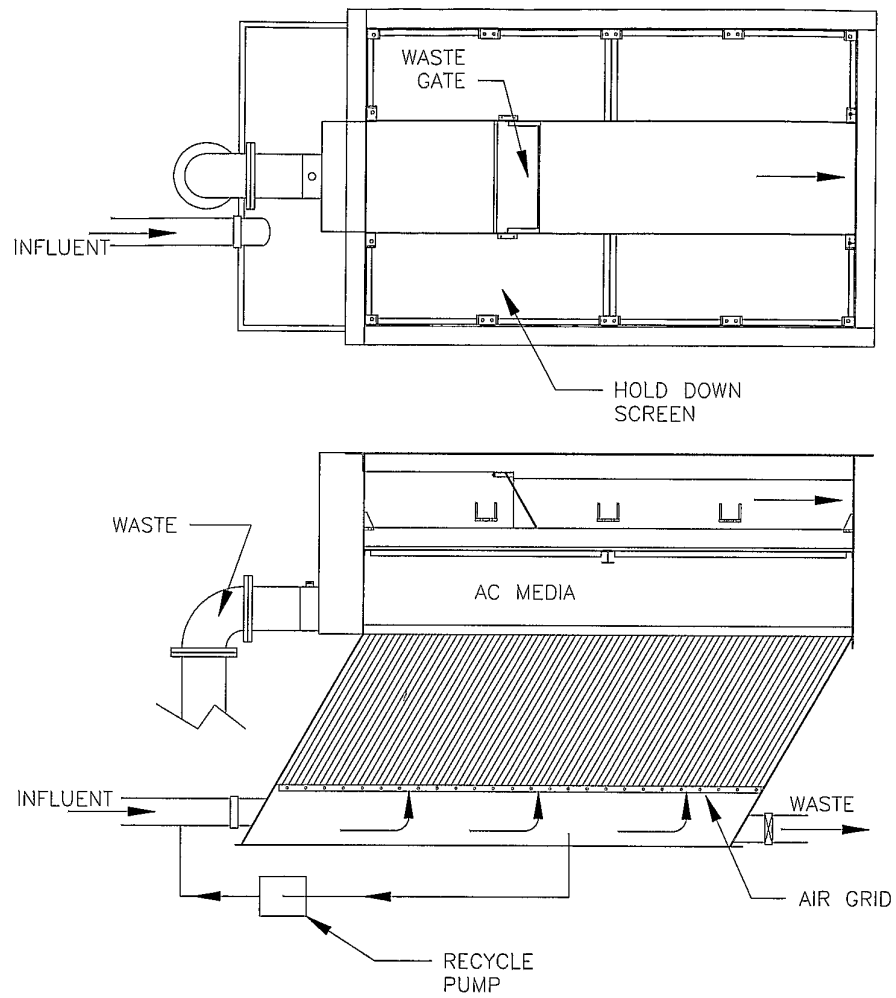
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CONTACT TANK, UPPER AIR GRID, LOWER WASTE CONNECTION

Figure 3

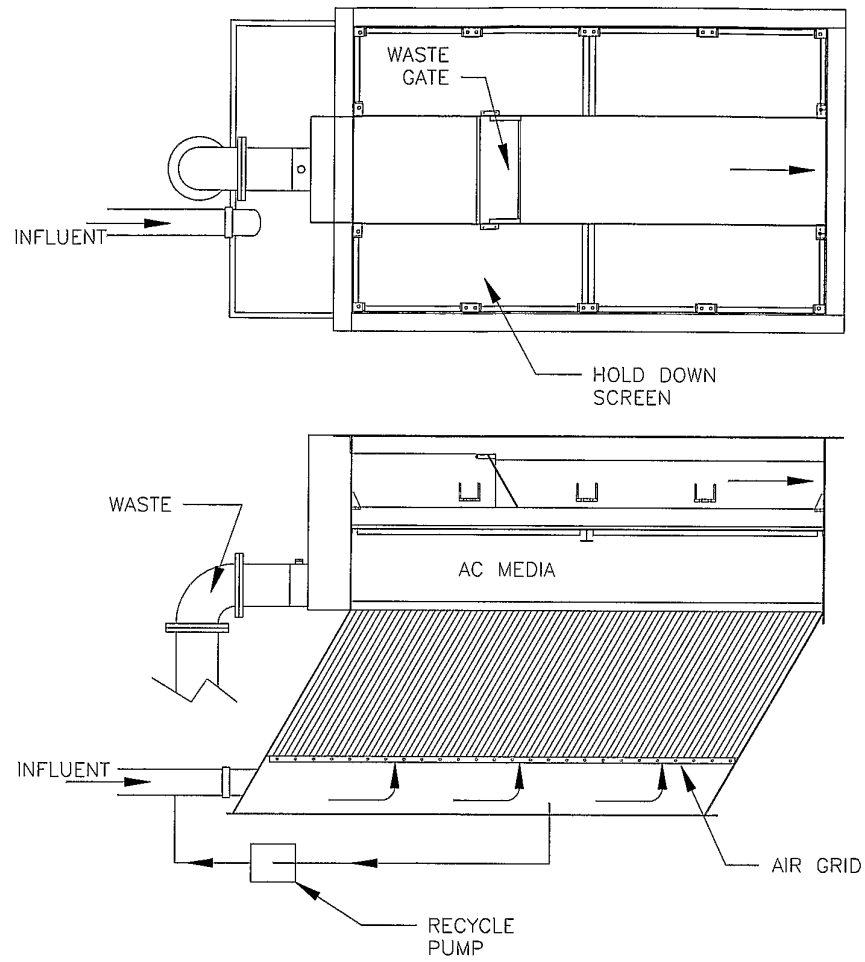
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NO CONTACT TANK, LOWER AIR GRID, LOWER WASTE CONNECTION

Figure 4

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NO CONTACT TANK, LOWER AIR GRID, NO LOWER WASTE CONNECTION

Figure 5

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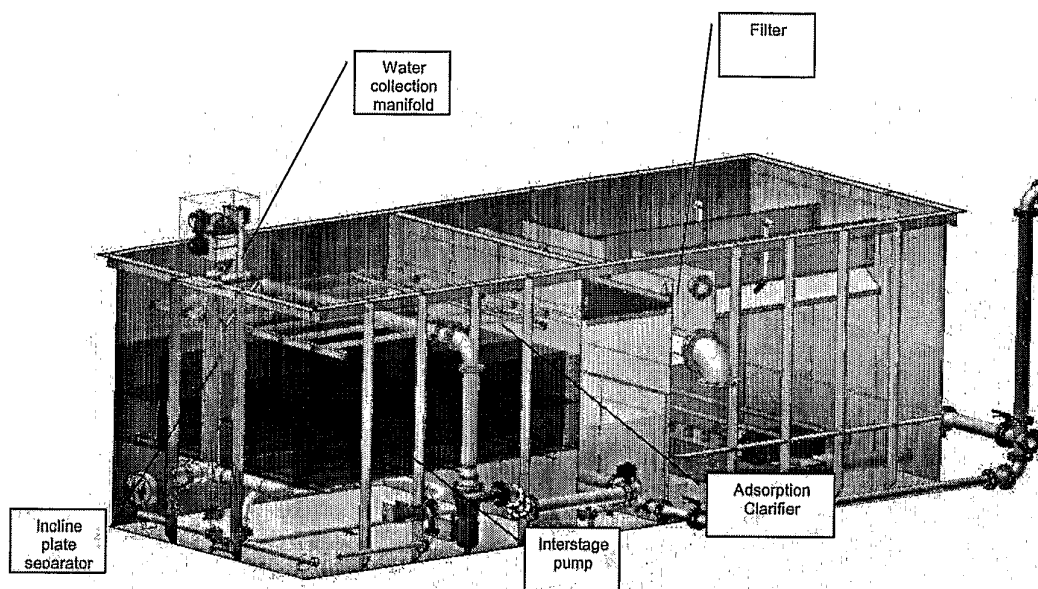


Figure 6

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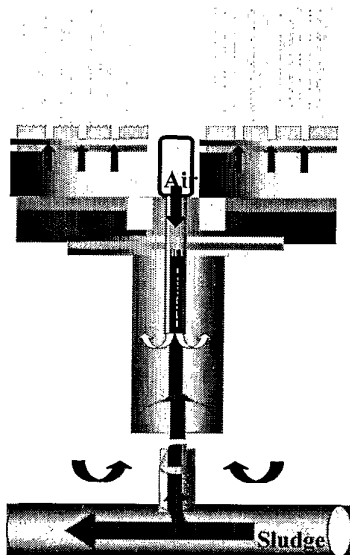


Figure 7
Jet

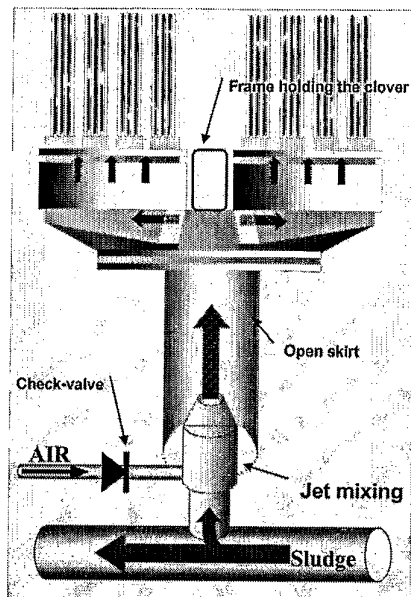


Figure 8
Jet With Integrated Air Line

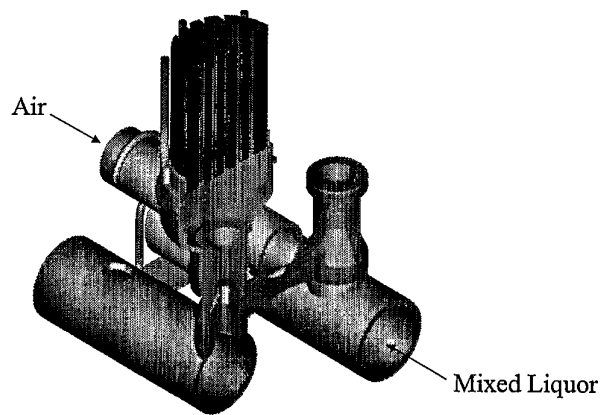


Figure 9
Jet With Integrated Air Line

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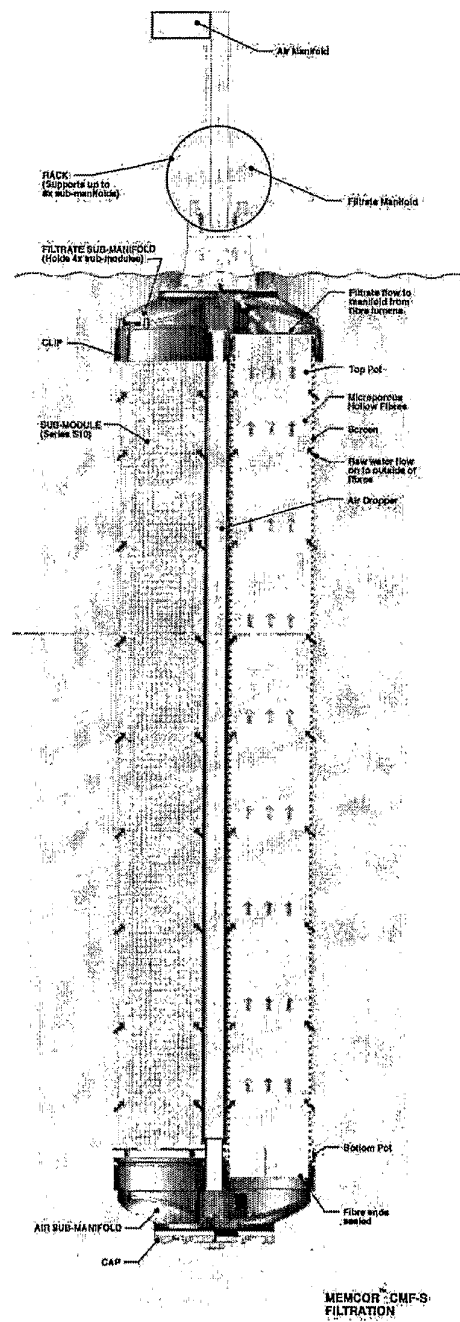


Figure 10