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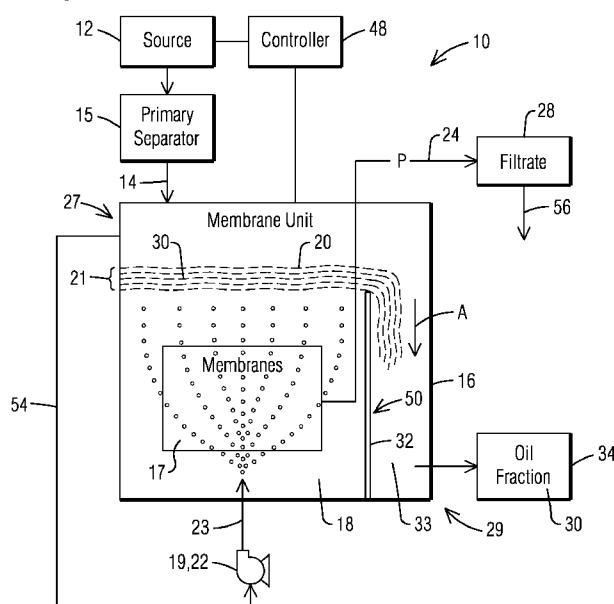
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(54) Title: PROCESSES AND SYSTEMS FOR CONCENTRATED OIL REMOVAL

FIG. 2



(57) Abstract: Processes and systems are described herein for producing a concentrated oil fraction (30) in a membrane unit (16) of a membrane filtration system (10), and periodically removing the concentrated oil fraction (30) upon or after adjusting a fluid level (20) of the fluid (18) in the membrane unit (16).

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PROCESSES AND SYSTEMS FOR CONCENTRATED OIL REMOVAL

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to and the benefit of the filing date of U.S. Provisional Application No. 62/337,624, filed May 17, 2016, the entirety of each of which is hereby incorporated by reference.

FIELD

This invention relates to treatment processes and systems, and in particular to membrane filtration processes and systems for efficiently removing oil from an aqueous feed stream containing oil.

BACKGROUND

By way of example, in the oil and gas industry, it is desirable to have solids and oils removed to varying degrees from produced water so that the water can be reused or released. Produced water generally refers to water that is produced as a byproduct in the recovery of oil and gas. The majority of the oil in produced water is free oil, which is easy to remove with known systems. However, emulsified oil may also be present in the produced water, which is more difficult to remove. Emulsified oil consists of a dispersion of oil droplets in water. These emulsions must be treated to remove the dispersed oil to meet specifications for discharge, reuse, or deep well injection. A number of techniques have been employed to remove the oil in its free or emulsified form. Filtration systems comprising a plurality of membranes through which the feed (produced) water may permeate may be employed to remove free and emulsified oil. One issue with known membrane filtration techniques is high crossflow in pressurized systems (utilized to provide turbulence to the fluid being processed to reduce membrane fouling) requires pumping, which actually further shears the oil – making oil recovery from the reject stream even more difficult. Further known membrane filtration systems produce significant volumes of fluid along with the recovered oil fractions, which is problematic in environments, e.g., offshore locations, where storage volume is

limited. Accordingly, improved solutions are desired that increase the efficiency of and implementation of oil recovery in a membrane filtration environment.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is explained in the following description in view of the drawings that show:

FIG. 1 is a schematic illustration of a system in accordance with an aspect of the present invention.

FIG. 2 is a schematic illustration of a system in accordance with an aspect of the present invention, wherein volume of fluid in the membrane unit is increased for removal of a concentrated oil fraction.

FIG. 3 is a schematic illustration of further components for a system in accordance with an aspect of the present invention.

FIG. 4 is a schematic illustration of a system in accordance with yet another aspect of the present invention.

FIG. 5 is a schematic illustration of a system in accordance with still another aspect of the present invention.

DETAILED DESCRIPTION

In accordance with an aspect of the present invention, there are provided processes and systems for producing a concentrated oil waste fraction in a membrane filtration system comprising a membrane unit. The systems and processes described herein remove oil from an aqueous oil-containing feed stream and generate a concentrated oil fraction in the membrane unit. The concentrated oil waste fraction can be periodically and easily removed from the membrane unit upon or after periodically adjusting a fluid volume within the membrane unit – in some embodiments without ceasing operation of the membrane unit. In this way, the processes and systems described herein may substantially reduce storage requirements for oil waste, reduce overall system footprint, and may allow for increased fluid processing volume and efficiency.

In accordance with one aspect, there is provided an oil removal process comprising:

- (a) directing an aqueous feed stream comprising an amount of oil therein to a membrane unit comprising one or more membranes such that the one or more membranes are submerged within a fluid comprising the feed stream;
- (b) separating an amount of oil from the feed stream via the membrane unit to produce a filtrate having a reduced amount of oil relative to the feed stream and a reject comprising an amount of oil therein which remains in the fluid;
- (c) introducing a gas into the fluid within the membrane unit;
- (d) forming a concentrated oil region at a top portion of the fluid;
- (e) periodically adjusting a volume of the fluid in the membrane unit until the volume of the fluid reaches a fluid level setpoint; and
- (f) removing at least a portion of the concentrated oil region from the fluid at the fluid level setpoint.

In accordance with another aspect of the present invention, there is provided oil removal system comprising:

- (a) a source of an aqueous feed stream comprising an amount of oil therein;
- (b) a membrane unit comprising one or more membranes submerged within a fluid comprising the feed stream;
- (c) a gas source in fluid communication with the membrane unit and configured to introduce a gas into the fluid in the membrane unit;
- (d) a controller configured to generate one or more signals effective to periodically adjust a volume of fluid in the membrane unit until the volume of the fluid reaches a fluid level setpoint; and
- (e) means for removing at least a portion of the concentrated oil region (30) from the fluid at the fluid level setpoint.

Referring to FIG. 1, there is shown an exemplary system in accordance with an aspect of the present invention. The system 10 includes at least a source 12 of an aqueous feed stream 14 (hereinafter "feed stream 14") comprising an amount of oil therein, such as a petroleum-based oil (e.g., crude oil), and a membrane unit 16. The

oil may be in the form of free oil and/or emulsified oil. In particular embodiments, the feed stream 14 comprises an aqueous stream including free and emulsified oil, each of which may be petroleum-based. When present, the emulsified oil may be in the size range of under 20 μm and the free oil may be in the size range of at least 20 μm , for example, such as from 20-1000 μm . In addition, the feed stream 14 may further comprise an amount of solids therein (e.g., bulk solids or suspended solids). In a particular embodiment, the feed stream 14 comprises produced water from an oil or gas recovery process.

In certain embodiments, as shown in FIG. 1, the feed stream 14 may first be subjected to a separation technique at a separator 15 prior to input of the feed stream 14 to the membrane unit 16. Without limitation, the separator 15 may comprise one or more of an American Petroleum Institute (API) separator, a corrugated plate interceptor (CPI) separator, a vessel packed with filtration media, a hydrocyclone, and a float cell to separate oil, bulk solids, and/or suspended solids from the feed stream 14.

The membrane unit 16 may comprise one or more porous or semipermeable membranes 17 (hereinafter "membrane 17") therein for removing an amount of oil from the feed stream 14. In an embodiment, the membrane 17 comprises a microfiltration or an ultrafiltration membrane as is known in the art. The membrane 17 may have any configuration suitable for its intended application, such as a sheet or hollow fibers. In addition, the membrane 17 may be formed of any suitable material having a desired porosity and/or permeability for its intended application. In an embodiment, the membrane 17 is formed of polymeric hollow fibers. In other embodiments, the membrane 17 may comprise a ceramic material. Further, the membrane 17 may have any suitable shape and cross sectional area such as, for example, a square, rectangular, or cylindrical shape. In one embodiment, the membrane 17 has a rectangular shape. In an aspect, the systems and processes described herein comprise a plurality of membrane units 16, which may be arranged in parallel or in series.

The feed stream 14 may be introduced on a continuous or batch basis into the membrane unit 16 at a suitable flow rate and volume, and with or without being

subjected to prior separation techniques. Typically, the feed stream 14 is introduced into the membrane unit 16 such that a fluid 18 in the membrane unit 16 is at a volume or fluid level 20 which is at least sufficient to submerge the membrane(s) 17 of the membrane unit 16. In addition, it is appreciated that the fluid 18 in the unit 16 at least comprises an amount of the feed stream 14 or a fluid derived from the feed stream (14). Typically, the one or more membranes 17 are maintained in a submerged state (by the fluid 18) in the unit 16 during operation of the one or more membranes 17. In addition, the one or more membranes 17 may be disposed in any suitable position or orientation. For example, the one or more membranes 17 may be positioned vertically within the membrane unit 16 below the fluid level 20 of the fluid 18.

In accordance with another aspect, a gas source 19, e.g., a blower 22, is provided in the system 10 for introducing a gas 23 into the fluid 18 in the membrane unit 16 to assist in scouring of the membrane(s) 17 and/or to assist in the floatation of oil toward a top of the fluid surface (e.g., fluid level 20). Without limitation, the gas source 19, e.g., blower 22, may produce fine bubbles, coarse bubbles, a jet stream of gas, a jet of gas and fluid, and combinations thereof in the fluid 18. The gas 23 may be any suitable gas such as nitrogen gas, fuel gas, or air. In addition, in certain aspects, a pump (P), e.g., a vacuum source, may be provided in communication with the membrane unit 16 to provide a suitable force to each membrane 17 in order to draw the fluid 18 through each membrane, thereby generating a treated stream (filtrate) 24 which can be delivered out of an outlet 26 of the membrane unit 16 and a reject 25 (FIG. 2) which remains in the membrane unit 16 as part of the fluid 18.

In an embodiment, the filtrate 24 may be delivered to a dedicated vessel 28 for storage. In other embodiments, at least a portion of the filtrate 24 may be directed for reuse and/or to further polishing steps as shown by arrow 56, such as total dissolved solids (TDS) removal which could employ nanofiltration or reverse osmosis, further filtration, or the like. Exemplary reuses of the filtrate 24 may include usage as irrigation water, boiler feed water, cooling tower makeup, or process water. In certain embodiments, the filtrate 24 may be reused or discharged into the ocean, such as when the system 10 is employed in an offshore environment. In an offshore environment,

nanofiltration or reverse osmosis may be used such that the treated material therefrom may be reinjected for further oil production rather than using seawater.

As the gas 19 is introduced at a suitable flow rate from the gas source 19 and fluid 18 is drawn through one or more membranes in the system 10, it is appreciated greater concentrations of oil will remain in the membrane unit 16, which due to differences in specific gravity and with the aid of the gas source 19, may travel to the surface of the fluid 18 in the membrane unit 16 and form a concentrated oil region 30 as is known in FIGS. 1-2 and 4-5.

Referring again to FIG. 1 and in accordance with an aspect of the present invention, the membrane unit 16 may be provided with a suitable removal structure (removing means) 50 for periodically removing at least a portion of the concentrated oil region 30 from the membrane unit 16. The removal structure 50 may comprise any suitable structure, such as a tap, a skimmer, or an overflow weir in communication with the fluid 18 in the membrane unit 16 and located within or at a position adjacent the unit 16 so as to remove at least a portion of the concentrated oil region 30 from the fluid 18. Referring to FIGS. 1-2 and by way of example, the removal structure 50 may comprise one or more weirs 32 positioned in the membrane unit 16 to facilitate removal of the concentrated oil region 32 from the membrane unit 16. Each weir 32 may comprise a vertical wall extending at least partially between a top end 27 and a bottom end 29 of the membrane unit 16.

In accordance with an aspect, the removal structure 50, e.g., overflow weir 32, is positioned so as to allow removal of the concentrated oil region 30 upon a suitable adjustment of the fluid level 20 to a particular fluid level (hereinafter "fluid level setpoint 21"). In an embodiment, the fluid level setpoint 21 (shown in FIGS. 2 and 4-5) may be defined as the fluid level 20 at which the concentrated oil portion 30 may be removed from the fluid 18 by the removal structure 50. In some embodiments, the concentrated oil portion 30 may be removed from the membrane unit 16 as well. Typically, the fluid level 20 is intentionally increased as will be explained below in order to reach the fluid level setpoint 21, although the present invention is not so limited. In certain

embodiments, the fluid level 20 may be decreased in order to reach the fluid level setpoint 21.

A number of methods and systems are disclosed herein for periodically adjusting (increasing or decreasing) the fluid level 20 in the membrane unit 16 to the fluid level setpoint 21 at which the oil fraction 30 may be periodically removed from the fluid 18 in the membrane unit 16; however, it is understood that the present invention is not so limited to these examples. Further, it is appreciated that the setpoint 21 may include a range of possible fluid volume values (not just a single volume or fluid level). It is further understood that the volume of and concentration of oil in the concentrated oil fraction 30 may vary significantly from application to application, and thus the range of values for fluid level setpoint 21 may also vary in order to place the fluid 18 in the membrane unit 16 in a desired position for periodic removal of the concentrated oil fraction 30.

In accordance with another aspect of the present invention, the system 10 may further include a backwash system 38 comprising a backwash fluid source 40 in fluid communication with at least the membrane unit 16 for delivering a backwash fluid 42 back through (counter to the forward flow of the feed stream 14) the membrane(s) 17 of the membrane unit 16. The backwash system 38 may serve to both clean the membrane(s) 17 for further use and/or as a tool for increasing the volume of the fluid 18 in the membrane unit 16 to the fluid level setpoint 12. The backwash fluid 42 may comprise any fluid which is flowed through the membrane(s) of the membrane unit 16 at a suitable flow rate and duration. In addition, chemical additives may be added to the backwash fluid 42 or the backwash fluid 42 may be additive-free. Thus, in an embodiment, the backwash fluid 42 comprises one or more chemical additives which serve as a cleaning agent. Exemplary cleaning agents for use herein include acids, caustic, sodium hypochlorite, and/or detergents, and the like. In another embodiment, the backwash fluid 42 may comprise the filtrate 24 from the membrane unit 16, but may also be a different clean (oil free) water source. Further, it is appreciated that the flow and frequency of the backwash fluid 42 can range depending on the extent of foulants

on the membrane(s). In certain embodiments, the backwash fluid source 40 may comprise a vessel which houses the backwash fluid 42.

In accordance with another aspect, the systems and processes described herein may include a controller 48 (FIG. 1) for adjusting or regulating any process step or operating parameters of the system or a component of the system such as, but not limited to sensors, actuating valves, pumps, and the like. The controller 48 may thus be in electrical or electronic communication with any necessary component in the system 10, for example, the gas source 19 (e.g., blower), the source 12 of feed stream 14, the membrane unit 16, the backwash system 38, valves, pumps, and/or any other desired or necessary component. Without limitation, the controller 48 may comprise a microprocessor-based device, such as a programmable logic controller (PLC) or a distributed control system, that receives or sends input and output signals to and from any components of the associated system. Communication networks may permit any sensor or signal-generating device to be located at a significant distance from the controller 48 or an associated computer system, while still providing data therebetween. Such communication mechanisms may be effected by utilizing any suitable technique including but not limited to those utilizing wireless protocols. In a particular aspect as will be set forth below, the controller 48 may be configured to regulate the fluid level 20 of the fluid 18 in the membrane unit 16 such that the fluid 18, and thus the concentrated oil region 30, may be periodically adjusted to the fluid level setpoint 21 where the concentrated oil region 30 may be periodically removed by the oil removal structure 50. In certain embodiments, sensors may be provided in the membrane unit 16 for sensing fluid level, oil concentration, or the like.

Turning now to the operation of the systems described herein, in operation, the aqueous feed stream 14 comprising an amount of oil therein is directed from the fluid source 12 to the membrane unit 16 on a continuous or batch basis. As shown in FIG. 1, this is done such that the one or more membranes 17 (hereinafter also membrane 17) of the membrane unit 16 are submerged by the fluid 18 in the membrane unit 16 (which at least comprises the feed stream 14). The membrane unit 16 draws the fluid 18 in through its membranes 17 to remove oil and solids (bulk and/or suspended solids) from

the fluid 18. In addition, the gas source 19, e.g., blower 22, introduces an amount of gas into the membrane unit 16. The gas 19 primarily assists in scouring the membranes to consistently remove oil and solids therefrom which is delivered back into fluid 18, but may, in some embodiments, also assist in allowing oil to rise to an upper portion of the fluid 18. From the operation of the membrane unit 16, a filtrate 24 is generated which may be delivered via a line to a suitable vessel 28 for storage, further treatment, use as a backwash fluid 42, disposal, or other purpose. Further, the portion of the fluid 18 that does not travel through the membranes 17 nor remains on the membranes 17 constitutes reject 25 – which remains in the fluid 18. The above process of filtering the fluid 18 through the membranes 17 is again repeated as many times as is necessary or desired.

As the process is carried out, a concentrated oil region 30 forms at an upper portion of the fluid 18 in the membrane unit 16. In some instances, the concentrated oil region 30 may be visible to the naked eye, but the invention is not so limited. In an embodiment, the fluid 18 in the concentrated oil region 30 comprises a concentration of oil that is at least greater than a sample of the fluid 18 at a midpoint of the fluid level 18. In accordance with an aspect of the present invention, at a point in time, it may be desirable to remove the concentrated oil region 30 from the fluid 18.

Because the process of generating and removing filtrate 24 from the membrane unit 16 gradually lowers the fluid level 20 in the membrane unit 16, it will likely be necessary to periodically add further liquid / feed stream 18 to the unit 16. Aspects of the present invention are aimed at optimizing this step such that the periodic readdition of fluid to the membrane unit 16 to periodically adjust the fluid level 20 therein also assists in collecting the concentrated oil fraction 30 that has formed in the fluid 18. In some embodiments, the readdition of fluid to the membrane unit 16 may also serve other functions, such as introducing more feed stream 14 to the membrane unit 16 and/or cleaning/backwashing the membranes. As set forth below, the addition of fluid to the membrane unit 16 to periodically adjust the fluid level therein 20 to the fluid level setpoint 21 and the subsequent collection of the concentrated oil fraction 30 at the fluid

level setpoint 21 may take place by a number of different possible processes – none of which are mutually exclusive.

In one aspect, the volume of the fluid 18 (fluid level 20) in the unit 16 may be periodically adjusted to the fluid level setpoint 21 via ceasing filtration of the fluid 18 through the one or more membranes 17 while the feed stream 14 is delivered into the membrane unit 16. This may be done at a suitable flow rate and duration until the fluid 18 reaches the fluid level setpoint 21. In an embodiment, to accomplish this, the controller 48 is in electrical communication with the source 12 of the feed stream 14, the primary separator 15, the membrane unit 16, the gas source 19, and/or the provided removal structure 50. The controller 48 may then be configured to generate a first signal to cease operation of the membrane unit 16. In this way, no more flow through the membrane unit 16 occurs. In addition, the controller 48 may be configured to generate one or more signals to the feed source 12 which causes an amount of the feed stream 14 to be delivered to the membrane unit 16 in order to increase the fluid level 20 in the membrane unit 16 toward/to the fluid level setpoint 21. Once the setpoint 21 has been reached, the controller 48 may generate one or more additional signals to the removal structure 50 to initiate removal of the concentrated oil fraction 30 from the fluid 18. At the same time or thereafter, the controller 48 may generate one or more signals to the membrane unit 16 in order to restart the membrane unit 16 for filtration of fluid 18 therethrough, and, if desired, to the feed stream source 12 to introduce further fluid 18 to the membrane unit 16.

In accordance with another aspect, the volume of the fluid 18 (fluid level 20) in the unit 16 may be periodically adjusted to the fluid level setpoint 21 via flowing a backwash fluid 42 in a reverse flow direction (opposite of the forward flow of feed stream 14) through the one or more membranes 17. The resulting backwash effluent, 44, which may comprise oil removed from the membranes 17, may be added back to the fluid 18 (See FIG. 3). The backwashing/cleaning step may be done at a suitable flow rate and for a time sufficient to until the fluid 18 reaches the second fluid level 21.

In an embodiment, to accomplish this, the controller 48 may be in electrical communication with the source 12 of the feed stream 14, the membrane unit 16, the

gas source 19, the backwash system 38, and/or the provided removal structure 50. In addition, the controller 48 may be configured to generate one or more first signals to cease operation of the membrane unit 16 such that the membrane unit 16 no longer draws fluid 18 therethrough in a first, e.g., forward flow, direction. In addition, the controller 48 may be configured to generate one or more second signals to direct the backwash fluid 42 in a reverse flow direction (relative to the introduction of feed stream 14) through the one or more membranes 17 in order to increase the fluid level 20 in the membrane unit 16 to the fluid level setpoint 21. Once the setpoint 21 has been reached, the controller 48 may generate one or more additional signals to the removal structure 50 to initiate removal of the concentrated oil fraction 30 from the fluid 18. At the same time or thereafter, the controller 48 may generate one or more signals to the membrane unit 16 to cease the introduction of backwash fluid 42, and one or more signals, if desired, to the source 12 and/or the membrane unit 16 to enable further filtration of the fluid 18.

In certain embodiments, one or more sensors (not shown) may be provided to assist in determining when the fluid level 20 has been adjusted to the desired setpoint 21. Further, in certain embodiments, one or more sensors may be provided which determine a concentration of oil in the fluid 18 in the unit 16. At this point, the concentrated oil fraction 30 may be collectable with or without further action.

In accordance with another aspect, introduction of the gas 19 (gas scour) from the gas source 19, e.g., blower 22, to the membrane unit 16 may be temporarily ceased so as to allow the concentrated oil fraction 30 (overflow) to be quiescent. To accomplish this, the controller 48 may generate one or more signals effective to cease flow of the gas 23 from the gas source 19 to the membrane unit 16 at any suitable time, e.g., when desiring to remove the concentrated oil fraction and/or when adding fluid 18 (via backwashing or addition of feed stream 14 as described above). In this way, the concentrated oil region 30 may form a distinct layer about the fluid 18 before or as the concentrated oil fraction 30 is being removed instead of allowing the gas 23 to continue to mix the concentrated oil region 30 with the remainder of the fluid 18.

To remove the concentrated oil fraction 30 from the fluid 18, the system 10 may employ any suitable structure, configuration, and/or methodology for adjusting an amount of fluid 18 in the unit 16 such that at the fluid level setpoint 21, the concentrated oil region 30 may be periodically collected. The removal of the concentrated oil fraction 30 may be done contemporaneously with or subsequent to the increase of the fluid level 20 to the setpoint 21. In an embodiment, one or more overflow weirs 32 are provided in the membrane unit 16 to facilitate the removal of the concentrated oil fraction 30. In this case, the fluid level 20 may be adjusted (in this case increased) in the unit 16 from the fluid level 20 in a filtration/operating mode shown in FIG. 1, for example, to a level that is within the setpoint 21 as shown in FIG. 2. At the setpoint 21, the concentrated oil region 30 may readily overflow the one or more weirs 32 as shown by arrow A, and may travel to a dedicated compartment 33 of the membrane unit 16 for removal from the fluid 18 and/or to an external vessel 34 for removal of the concentrated oil fraction 30 from the membrane unit 16. The contents of the compartment 33 and/or vessel 34 may be periodically emptied and delivered for further treatment, recycled usage, or for transportation/storage. In accordance with another aspect, since the overflowed concentrated oil fraction 30 is relatively concentrated, the reject volume from membrane filtration may be significantly reduced, thereby resulting in reduced footprint and reduced operational costs for membrane filtration operation, particularly in offshore environments such as on an offshore platform.

In certain embodiments, the removed portion (from the fluid 18 and/or membrane unit 16) of the concentrated oil fraction 30 may be directed back into the system for further processing. In the event that the removed concentrated oil fraction 30 is directed to upstream oil / water separation equipment, e.g. separator 15, this upstream equipment (designed for free oil removal) will not result in increasing an amount of emulsified oil in the system, unlike crossflow membrane systems where much of the oil rejected becomes emulsified due to the turbulence required to reduce fouling. Additionally, this upstream equipment will not need to be sized larger when the concentrated oil fraction 30 is directed back upstream for treatment since the concentrated oil fraction 30 volume is relatively small.

In accordance with yet another aspect, as shown in FIG. 4, the removal structure 50 may comprise a tap 51, and thus the membrane unit 16 may comprise a tap 51 positioned at a predetermined location on the membrane unit 16 such that when the fluid level 20 is adjusted to the setpoint 21, the tap 51 may be opened and allow the concentrated oil region 30 at the setpoint 21 to flow out the tap 51 to a dedicated vessel 52, line, or any other suitable medium. To accomplish this, in an embodiment, the controller 48 further may be in electrical communication with the tap 51 and be configured to generate one or more signals to turn the tap 51 from a closed position to an open position, and vice-versa, as needed. The tap 51 may be formed from any suitable material and sized for the particular application.

In accordance with yet another aspect, as shown in FIG. 5, a skimmer 58 may be provided within or adjacent the membrane unit 16 such that when the fluid level 20 reaches a level within the setpoint 21, the skimmer 58 may be operated and traveled across a top of the fluid 18 as needed to remove an amount of the concentrated oil fraction 30. The skimmer 58 may travel across a surface of the fluid 18 in any suitable pattern, duration, and number of paths as necessary to achieve the objective. In addition, the skimmer 58 may collect and/or direct the removed concentrated oil fraction to a suitable vessel for storage, transport, or for further treatment, e.g., back to the membrane unit 16 or the source 12. To accomplish the removal of the concentrated oil fraction 30, in an embodiment, the controller 48 may further be in electrical communication with the skimmer 58, and may further be configured to generate one or more signals to cause the skimmer 58 to start/stop removing the concentrated oil fraction 30 as desired or necessary. Any suitable skimmer 58 known in the art may be utilized for these purposes, such as a belt skimmer or the like.

Once the concentrated oil fraction 30 has been removed from the fluid 18 to a desired degree, filtration of fluid 18 through the membrane unit 16 may begin again with the gas source 19 restarted (if it was turned off). In an embodiment, to accomplish this, the controller 48 may generate one or more signals to resume filtration and/or reinitiate delivery of the gas 23 from the gas source 19. The periodic filtration of feed stream 18, periodic adjustment of fluid level 20 of the fluid 18, and the periodic removal of the oil

concentrated fraction 30 may be repeated as many times as is desired or needed for treatment of a given volume of the feed stream 14.

It is also contemplated that in any of the described systems and processes, the oil region 30 may be recovered at any desired point in time or a predetermined interval (of time), such as daily or weekly at particular time. In accordance with yet another aspect, removed solids from backwash or the like in the membrane unit 16 may settle to the bottom of the membrane unit 16 where they may ultimately be removed by any suitable process or device. In certain embodiments, an auger, rake, or other suitable component may be provided in a bottom portion of the membrane unit 16 in order to facilitate removal of the solids therefrom through a suitable outlet.

In accordance with yet another aspect, it is contemplated that the gas 23 from the gas source 19 utilized to scour the membrane(s) may be recovered, reused, and/or utilized to cover the membrane unit 16 with a protective blanket in order to prevent emission of pollutants to the environment. As shown in FIG. 1 by line 54, for example, gas may be delivered from a top portion of the membrane unit 16 back to the gas source 19 to be reintroduced back into the membrane unit 16.

In accordance with still another aspect, although the primary separation unit 15 and the membrane unit 18 are shown as distinct and separate units, it is understood that the present invention is not so limited. In certain embodiments, the membrane unit 16 may be integrated within the primary separation unit 15, such as in a distinct compartment thereof. In a particular embodiment, a membrane unit 16 as described herein may be included within a primary separator 15, such as an API separator as is known in the art.

In the systems and processes described herein, it is appreciated that one or more vessels, inlets, pathways, outlets, pumps, valves, coolers, energy sources, gas sources, sensors, or controllers (comprising a microprocessor and a memory), or the like may be included in any of the systems described herein for facilitating the introduction, output, timing, volume, selection, and direction of flows of any of the materials described therein. Moreover, the skilled artisan would understand the

volumes, flow rates, concentrations, and other parameters necessary to achieve the desired result(s) if needed to operate the described systems and processes.

While various embodiments of the present invention have been shown and described herein, it will be obvious that such embodiments are provided by way of example only. Numerous variations, changes and substitutions may be made without departing from the invention herein. Accordingly, it is intended that the invention be limited only by the spirit and scope of the appended claims.

CLAIMS

The invention claimed is:

1. An oil removal process comprising:
directing an aqueous feed stream (14) comprising an amount of oil therein to a membrane unit (16) comprising one or more membranes (17) such that the one or more membranes are submerged within a fluid (18) comprising the feed stream (14);
separating an amount of oil from the feed stream (14) via the membrane unit (16) to produce a filtrate (24) having a reduced amount of oil relative to the feed stream (14) and a reject (25) comprising an amount of oil therein which remains in the fluid (18);
introducing a gas (23) into the fluid (18) within the membrane unit (16);
forming a concentrated oil region (30) at a top portion of the fluid (18);
periodically adjusting a volume of the fluid (18) in the membrane unit (16) until the volume of the fluid (18) reaches a fluid level setpoint (21); and
removing at least a portion of the concentrated oil region (30) from the fluid (18) at the fluid level setpoint (21).
2. The process of claim 1, wherein the membrane unit (16) further comprises one or more overflow weirs (32) positioned in the membrane unit (16), and wherein the removing is done by causing the concentrated oil region (30) to flow over the one or more overflow weirs (32) at the fluid level setpoint (21).
3. The process of claim 1, wherein the removing is done by withdrawing at least a portion of the concentrated oil region (30) through a tap (51) located on the membrane unit (16) at the second fluid level setpoint (21).
4. The process of claim 1, wherein the removing is done by one or more skimmers (58) traveling across the concentrated oil region (30) at a top portion of the fluid (18).

5. The process of claim 1, wherein the increasing the volume of the fluid (18) to the fluid level setpoint (21) is done via ceasing filtration of the fluid (18) through the one or more membranes (17) while the feed stream (14) is introduced into the membrane unit (16).

6. The process of claim 1, wherein the increasing the volume of the fluid (18) is done by flowing a backwash fluid (42) in a reverse flow direction relative to introduction of the feed stream (14) through the one or more membranes (17), thereby adding a backwash effluent (44) to the fluid (18).

7. The process of claim 6, wherein the backwash fluid (42) comprises at least one of the filtrate and a cleaning solution.

8. The process of claim 1, further comprising directing the feed stream (14) to a separator (15) upstream of the membrane unit (16) for initial removal of solids and oil from the feed stream (14).

9. The process of claim 1, further comprising removing a solids portion from a bottom portion (29) of the membrane unit (16).

10. The process of claim 1, wherein the process is performed on an offshore platform.

11. The process of claim 1, further comprising recycling the introduced gas (23) via capturing the gas from a top portion (27) of the membrane unit (16) and reintroducing the gas (23) into the fluid (18).

12. The process of claim 1, wherein the gas (23) comprises a member from the group consisting of air, nitrogen, and a fuel gas.

13. The process of claim 1, wherein the removing at least a portion of the concentrated oil region (30) is done while ceasing introduction of the gas (23) to the one or more membranes (17).

14. An oil removal system (10) comprising:
a source of an aqueous feed stream (14) comprising an amount of oil therein;
a membrane unit (16) comprising one or more membranes (17) submerged within a fluid (18) comprising the feed stream (14);
a gas source (22) configured to introduce a gas (23) into the fluid (18) within the membrane unit (16);
a controller (48) configured to generate one or more signals effective to periodically adjust a volume of fluid (18) in the membrane unit (16) until a volume of the fluid (18) reaches a fluid level setpoint (21); and
means for removing (50) at least a portion of the concentrated oil region (30) from the fluid (18) at the fluid level setpoint (21).

15. The system (10) of claim 14,
wherein the controller (48) is in electrical communication with the source (12) of the feed stream (14) and the membrane unit (16), and
wherein the controller (48) is configured to generate one or more signals to cease operation of the membrane unit (16) and generate one or more signals to deliver the feed stream (14) to the membrane unit (16) in order to increase the fluid level (20) in the membrane unit (16) to the fluid level setpoint (21).

16. The system (10) of claim 14,
wherein the means for removing (50) comprises one or more overflow weirs (32) disposed in the membrane unit (16), and

wherein the controller (48) is configured to generate one or more signals effective to increase a volume of fluid (18) to the fluid level setpoint (21) such that the concentrated oil region (30) flows over the one or more overflow weirs (32).

17. The system (10) of claim 14,
wherein the means for removing (50) comprises a tap (51) located on the membrane unit (16); and

wherein the controller (48) is configured to generate one or more signals effective to increase a volume of the fluid (18) in the membrane unit (16) to the second fluid level setpoint (21) such that the concentrated oil region (30) is removable upon opening of the tap (51) at the second fluid level (20B).

18. The system (10) of claim 14,
wherein the means for removing (50) comprises a skimmer (58) configured to travel across a top portion of the fluid (18) in the membrane unit (16); and
wherein the controller (48) is configured to generate one or more signals effective to increase a volume of the fluid (18) in the membrane unit (16) to the fluid level setpoint (21) such that the concentrated oil region (30) is removable by the skimmer (58) traveling across the top portion of the fluid (18) in the membrane unit (16).

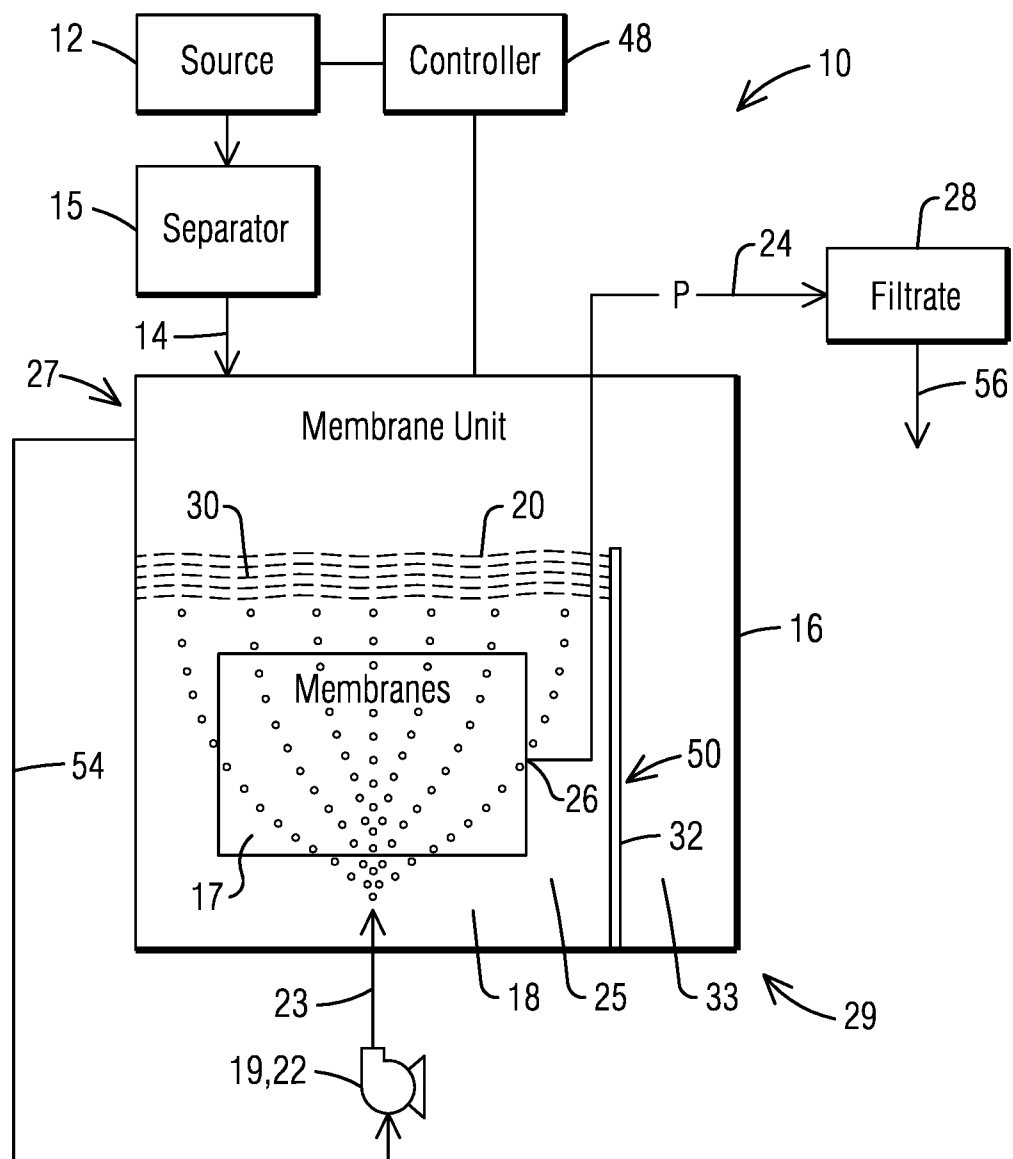
19. The system (10) claim 14, further comprising a source (40) of a backwash fluid (42) in fluid communication with the membrane unit (16), and wherein the controller (48) is configured to generate one or more signals to cease operation of the membrane unit (16) and generate one or more signals to direct the backwash fluid (42) in a reverse flow direction relative to the feed stream (14) and through the one or more membranes (17) to increase the fluid level (20) in the membrane unit (16) to the fluid level setpoint (21).

20. The system (10) of claim 19, wherein the backwash fluid (42) comprises at least one of the filtrate and a cleaning solution.

21. The system (10) of claim 14, further comprising a separator (15) disposed upstream of the membrane unit (16).

22. The system (10) of claim 14, wherein the controller (48) is configured to generate one or more signals which cease introduction of the gas (23) to the membrane unit 16 when the volume of the fluid (18) reaches the fluid level setpoint (21).

FIG. 1



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FIG. 2

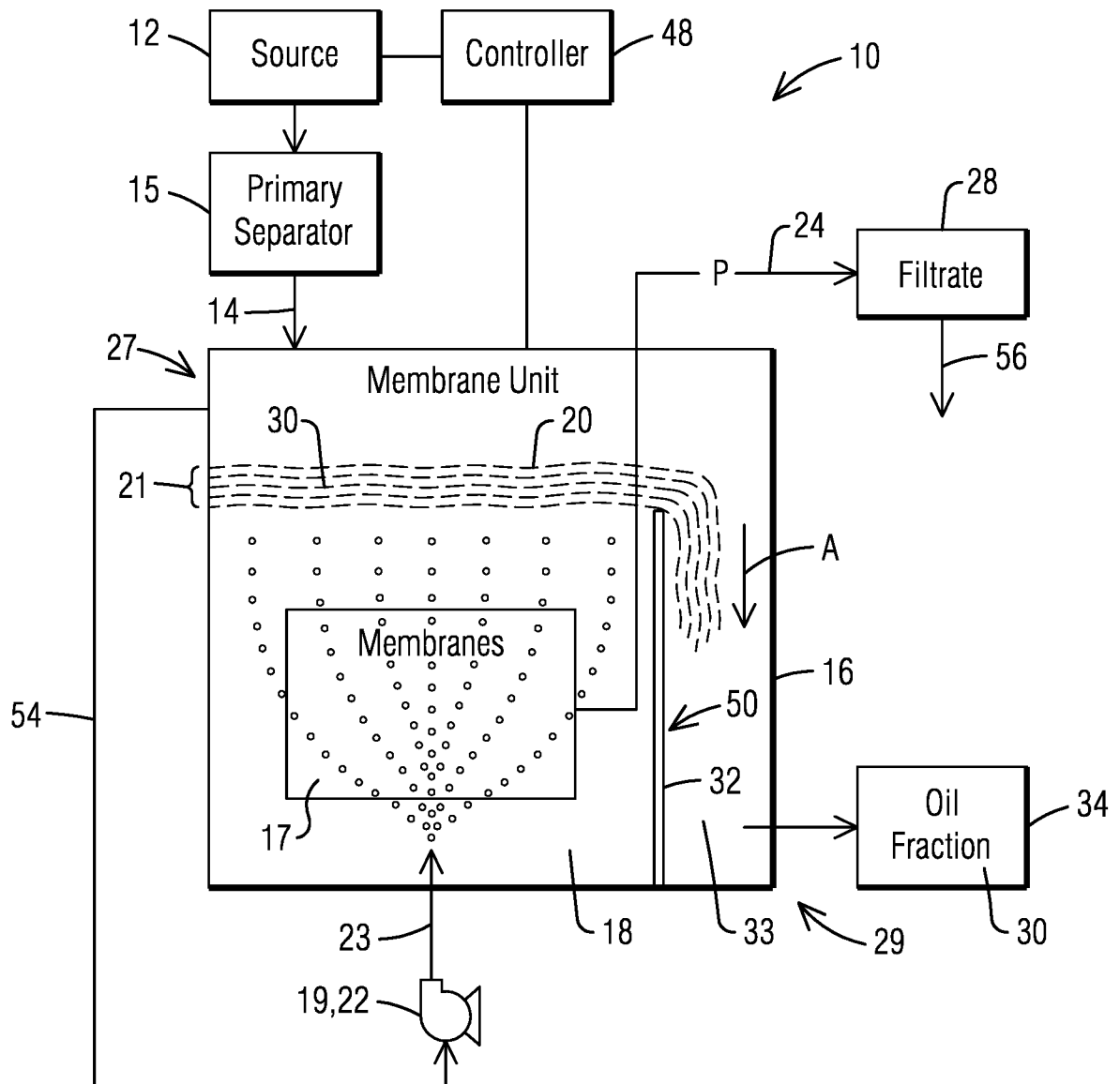


FIG. 3

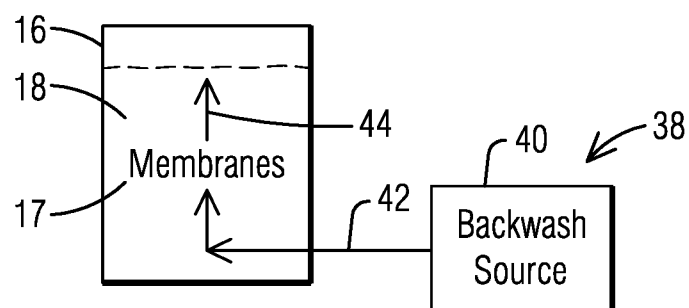


FIG. 4

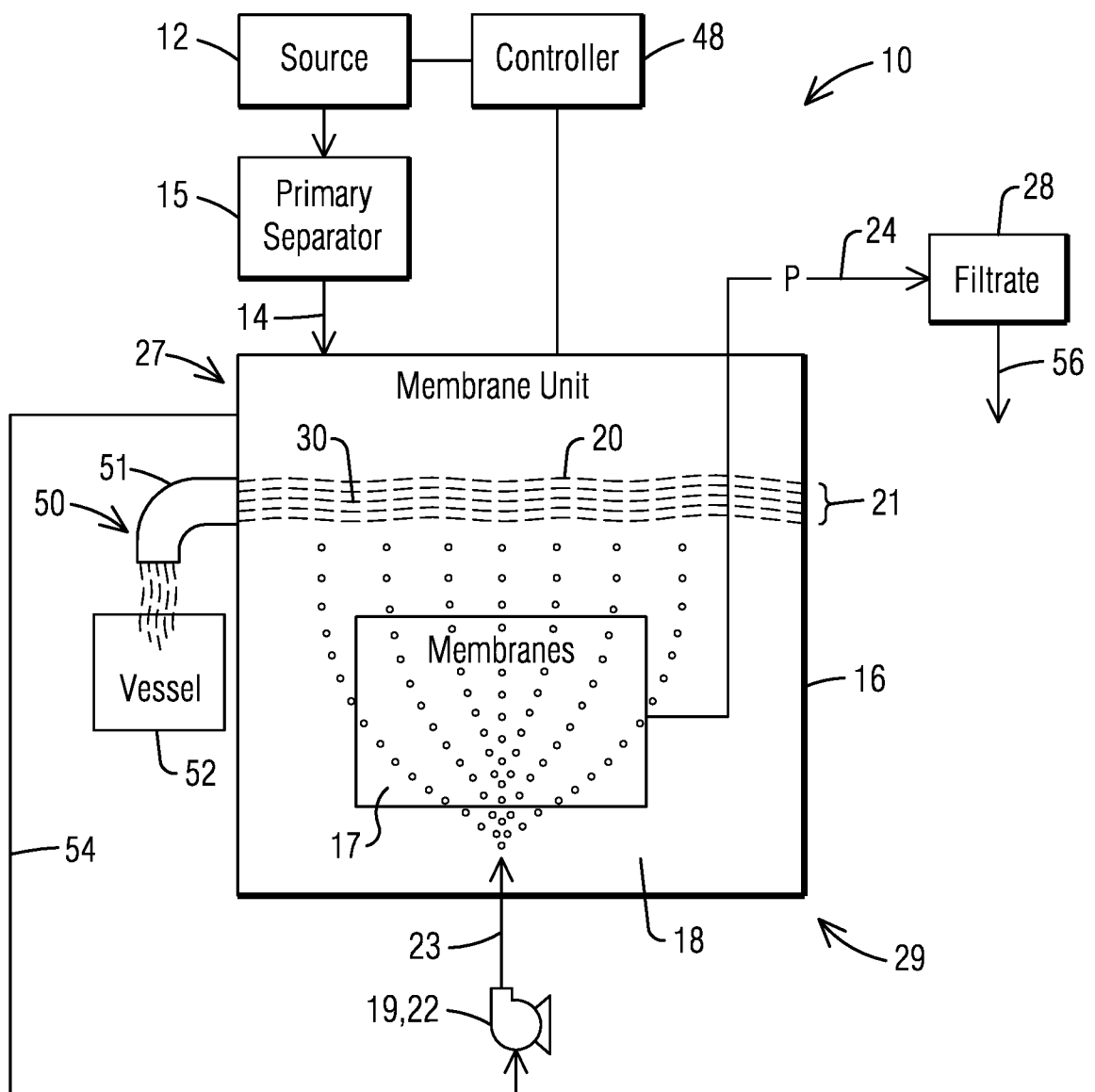
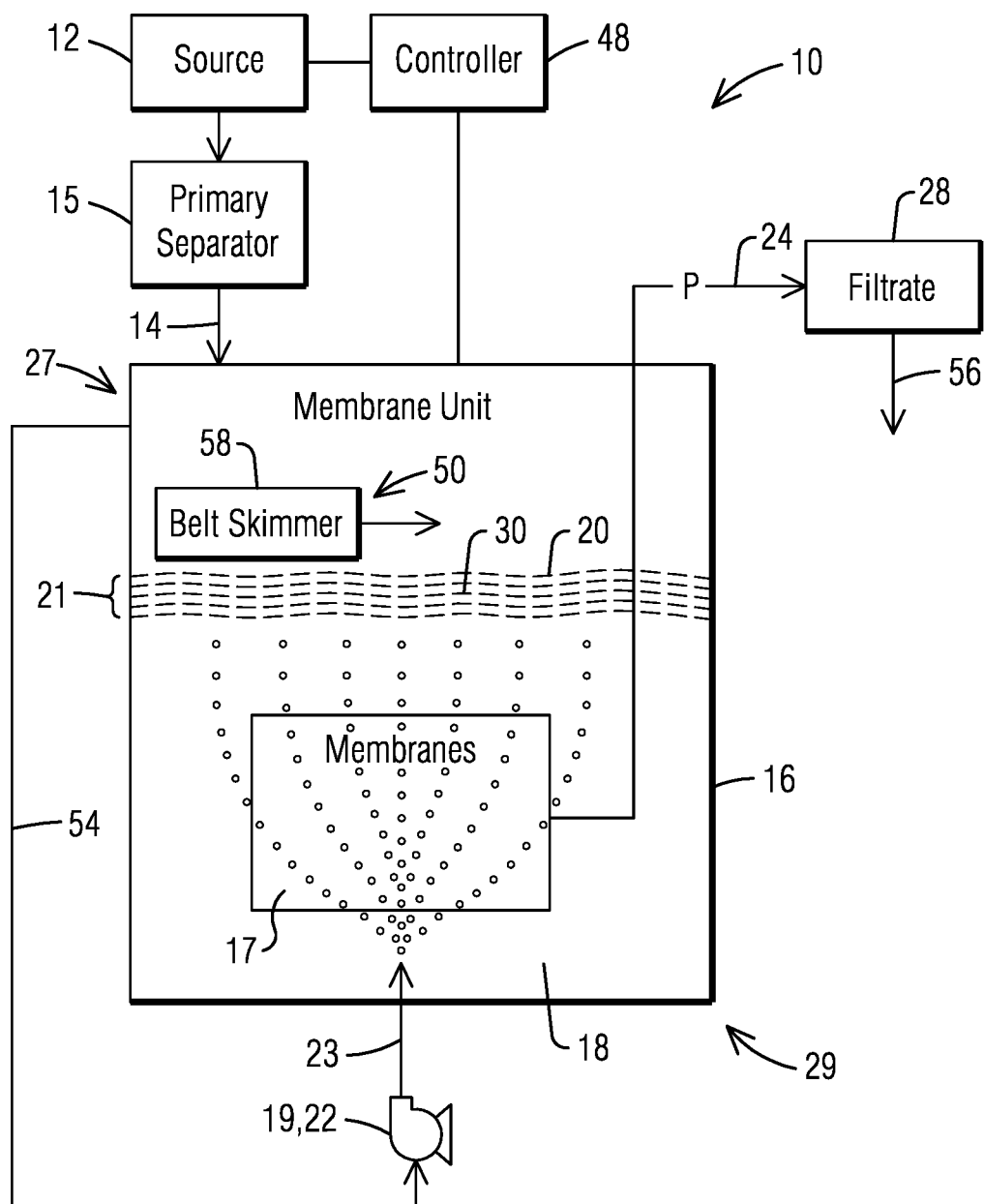


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/029743

A. CLASSIFICATION OF SUBJECT MATTER

INV. B01D61/14 B01D17/02 B01D61/16 B01D61/18 B01D61/20
C02F1/24 C02F1/44

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B01D C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/136697 A1 (SAKURAI MASAOKI [JP] ET AL) 21 May 2015 (2015-05-21) the whole document -----	1-3, 5-17, 19-22
X	US 2011/089013 A1 (SAKURAI MASAOKI [JP] ET AL) 21 April 2011 (2011-04-21) the whole document -----	1-3,5,8, 9,11-17, 21,22
X	US 2013/264254 A1 (USHIKOSHI KENICHI [JP] ET AL) 10 October 2013 (2013-10-10) the whole document ----- -/--	1,4,8,9, 12,14, 18,21



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

29 June 2017

Date of mailing of the international search report

28/07/2017

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Marti, Pedro

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/029743

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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