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(71) Applicant *(for all designated States except US)*: **BATTELLE ENERGY ALLIANCE, LLC** [US/US]; P.o. Box 1625, Idaho Falls, ID 83415-3899 (US).

(72) Inventors: **CARPENTER, Michael Vance**; 1150 Arklow CT., Idaho Falls, ID 83404 (US). **ROYBAL ,Lyle G**; 635 Renny Avenue, Idaho Falls IB 83401 (US). **LINDQUIST, Alan**; 26 W. Martin Luther King Blvd., Cincinnati, OH 45268 (US). **GALLARDO, Vincente**; 6527 Meis Avenue, Cincinnati, OH 45224 (US).

(74) Agent: **BARZEE, Eric, M.**; Battelle Energy Alliance, Llc., P.o. Box 1625, Idaho Falls, ID 83415-3899 (US).

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(54) **Title:** SYSTEMS AND METHODS FOR CONCENTRATING SUBSTANCES IN FLUID SAMPLES

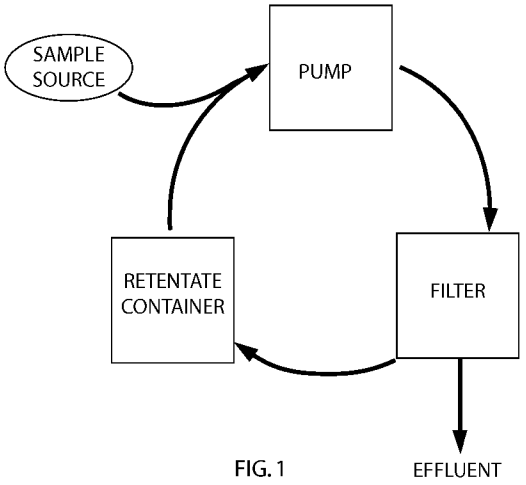

FIG. 1

(57) **Abstract:** Concentrator systems include a circulating fluid pathway passing through a pump, a filter, and a retentate container. An effluent outlet line communicates with the circulating fluid pathway through a filtering element within a body of the filter. The systems further include a control system. In some embodiments, the pump, filter, and retentate container may be secured within a portable container. Methods for concentrating a foreign substance within a fluid sample include establishing circulation of fluid through a fluid circulation path passing through a fluid pump, a filter body, and a retentate container. Fluid is caused to exit the fluid circulation path through a filtering element within the filter body, and at least one foreign substance is prevented from passing through the filtering element. A control system may be used to control at least one of a speed of the pump and a quantity of retentate within the retentate container.

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TITLE OF THE INVENTION

SYSTEMS AND METHODS FOR CONCENTRATING SUBSTANCES IN FLUID SAMPLES

RELATED APPLICATIONS

This application claims benefit of U.S. Non-provisional application No. 11/695,432, filed April 2, 2007, entitled SYSTEMS AND METHODS FOR CONCENTRATING SUBSTANCES IN FLUID SAMPLES, which is incorporated herein by reference in its entirety.

GOVERNMENT RIGHTS

The United States Government has certain rights in this invention pursuant to Contract No. DE-AC07-05ID14517 between the United States Department of Energy and Battelle Energy Alliance, LLC.

FIELD OF THE INVENTION

Embodiments of the present invention relate to systems and methods for concentrating pathogens and other foreign matter in a fluid sample.

BACKGROUND OF THE INVENTION

There are many applications in which it is desired to detect the presence and, optionally, the concentration of a foreign substance in a fluid. By way of example and not limitation, it may be desired to detect the presence and concentration of a microbial pathogen in a source of drinking water such as, for example, a lake, reservoir, river, stream, storage tank, water main, or well.

Some foreign substances may be difficult to detect using conventional methods at lower concentrations. For instance, certain microbial pathogens may be harmful to human health at concentrations that are too low to accurately, reliably, and economically detect using conventional methods. Furthermore, in some situations, the sample size used in conventional detection methods may not provide testing results that reflect the actual concentration in the source from which the sample was obtained with an acceptable level of accuracy or certainty.

For example, the concentration of a microbial pathogen in a few milliliters of water taken from a source of drinking water may not accurately represent the actual average concentration of the microbial pathogen in that source. As a result, analysis of multiple samples from a single fluid source may be required to determine the concentration of a foreign substance in the fluid source with an acceptable level of certainty.

For each of the above reasons, it has been proposed in the art to concentrate a fluid sample taken from a fluid source by a known concentration factor prior to determining the concentration of a foreign substance in the concentrated fluid sample. Once the concentration of the foreign substance in the concentrated fluid sample has been determined, the concentration in the unconcentrated fluid sample can be determined using the known concentration factor by which the fluid sample was concentrated.

As one example, it may be desired to know the concentration of a particular microbial pathogen in a source. A relatively large sample of water (e.g., about 100 liters) may be taken from the source. Some of the water may be separated or removed from the relatively large sample of water without separating or removing any significant number of the microbial pathogens of interest to provide a relatively smaller concentrated sample (e.g., about 1 liter) that includes substantially all of the microbial pathogens in the original relatively large sample of water. The identity and concentration of the microbial pathogens in the relatively smaller concentrated sample then may be determined, and the known identity and concentration of these pathogens in the concentrated sample may be used to determine the concentration in the original unconcentrated sample of water and, hence, the approximate concentration in the lake.

Such methods may result in relatively higher concentrations of the foreign substance in the concentrated sample that are more readily detectible using conventional analytical techniques than if these analytical techniques were used to attempt to detect these foreign substances at the concentrations in the unconcentrated sample, and may result in measurements that more accurately reflect the actual presence and concentration of the foreign substance in the fluid source from which the sample was obtained for analysis.

Several systems and methods for concentrating a foreign substance in a fluid sample have been presented in the art. A few examples of such systems and methods are briefly summarized below.

United States Patent No. 4,500,432 to Poole et al. discloses a method for concentrating solutes in a liquid solvent. The solvent is passed through a first trapping means such as a

chromatographic column to adsorb the solutes, and the first trapping means is flushed with a supercritical fluid such as supercritical carbon dioxide to carry out of the first trapping means at least some of the solutes. A second trapping means is then used to adsorb the solutes from the supercritical fluid. The Background of the Invention Section of United States Patent No. 4,500,432 provides a brief description of several other systems and methods for concentrating foreign substances in a fluid sample.

United States Patent No. 5,258,285 to Ægidius discloses a method for detecting the concentration of bacteria in a sample. The method involves concentrating bacteria cells on a filter, rupturing the membranes of cells on the filter, and determining the amount of adenosine triphosphate (ATP) released by the ruptured cells.

United States Patent No. 5,846,439 to Borchardt et al. discloses a method of concentrating waterborne protozoan parasites in which water is fed into a separation channel of a continuous separation channel centrifuge, and the water is centrifuged for a period of time sufficient to collect the protozoan parasites in the channel.

United States Patent No. 6,468,330 to Irving et al. discloses a mini-cyclone biocollector and concentrator that uses cyclonic forces to separate and remove large particles from an airstream to concentrate small particles for detection.

United States Patent No. 6,500,107 to Brown et al. discloses methods and apparatus for concentrating and recovering pathogens from a fluid. The method includes concentrating the pathogens contained in the fluid by continuously feeding the fluid through one or more flexible chambers and subjecting the chambers to centrifugal forces.

Despite the systems and methods known in the art for concentrating foreign substances in a fluid sample, there remains a need in the art for systems and methods that are portable, automated, that provide accurate and repeatable measurements, that provide acceptable concentration factors in acceptable amounts of time, and that minimize or reduce the risk of exposure of an operator to any foreign substance potentially carried by the fluid sample.

BRIEF SUMMARY OF THE INVENTION

In some embodiments, the present invention includes methods of concentrating one or more foreign substances in a fluid. The methods include establishing circulation of fluid flow through a filter, causing fluid to exit the fluid circulation path through a filtering element of the filter, and preventing the one or more foreign substances from passing through the filtering

element. The fluid circulation path may also pass through a retentate container and a pump, which may be used to drive fluid flow through the fluid circulation path. A control system may be used to control one or more components of the concentrator system. In some embodiments, the control system may be used to control a speed of the pump. In other embodiments, the control system may be used to control a quantity of retentate within the retentate container. In yet additional embodiments, the control system may be used to control both a speed of operation of the pump and a quantity of retentate within the retentate container.

In additional embodiments, the present invention includes systems for concentrating one or more foreign substances in a fluid. The systems include a circulating fluid pathway passing through a pump, a filter, and a retentate container. An effluent outlet line communicates with the circulating fluid pathway through a filtering element of the filter. A control system may be used to automatically control operation of one or more elements or components of the system (e.g., the pump) in response to a signal received from a sensor. For example, in some embodiments, the control system may include more than one sensor. For example, the control system may include one or more of a retentate sensor configured to sense a quantity of retentate within the retentate container, an effluent sensor configured to sense a quantity of effluent passing through the effluent outlet line, and a pressure sensor configured to sense a pressure at a location within the circulating fluid pathway. In some embodiments, the filter, retentate container, and the pump may be disposed within a housing or container for portability.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

While the specification concludes with claims particularly pointing out and distinctly claiming that which is regarded as the present invention, the advantages of this invention may be more readily ascertained from the following description of the invention when read in conjunction with the accompanying drawings in which:

FIG. 1 is a simplified process flow diagram illustrating operational principles of embodiments of sample concentrator systems of the present invention;

FIG. 2 is a process and instrumentation diagram schematically illustrating an embodiment of a sample concentrator system of the present invention;

FIG. 3 is a block diagram schematically illustrating an embodiment of a control system that may be used to control operation of the sample concentrator system shown in FIG. 2;

FIGS. 4A-4C illustrate a flow chart showing a sequence of operations that may be performed by the control system shown in FIG. 3;

FIG. 5 is a partially cut-away perspective view illustrating one particular embodiment of a portable sample concentrator system of the present invention; and

FIG. 6 is a schematic top plan view of the portable sample concentrator system shown in FIG. 5 and illustrates one example of a manner in which the various elements, components, and subsystems of the portable sample concentrator system may be located and secured within an outer housing of the portable sample concentrator system.

DETAILED DESCRIPTION OF THE INVENTION

Several of the illustrations presented herein are not meant to be actual views of any particular sample concentrator system or apparatus, but are merely idealized representations which are employed to describe the present invention. Additionally, elements common between figures may retain the same numerical designation.

FIG. 1 is a simplified process flow diagram illustrating principles that may be used to concentrate a foreign substance in a fluid sample according to embodiments of methods of the present invention. As used herein, the term "foreign substance" means and includes a substance of interest which is present in the fluid sample and is limited to any specific substance, and specifically and without limitation whether such substance may be characterized as a contaminant, a toxic substance, a substance artificially introduced into the fluid, or a naturally occurring substance. Such methods also may be carried out using embodiments of sample concentrator systems of the present invention. As shown in FIG. 1, a circular fluid path may be established using conduits such as pipes or hoses (not shown in FIG. 1) that passes through a pump, a filter, and a retentate container. As used herein, the terms "circular" and "circulating" mean and include a substantially continuous fluid path, without the exclusion of inlets thereto and outlets therefrom, and are not restricted to any particular physical path shape. The pump may be used to drive recirculating fluid flow within the circular fluid path. The fluid path may be primed with a fluid from a sample source that is potentially contaminated with a foreign substance, as also shown in FIG. 1. The sample source may comprise, for example, water from a lake, reservoir, river, stream, storage tank, water main or well. The filter may be configured to allow fluid to exit the circular fluid path as effluent, while preventing at least one foreign substance from exiting the circular fluid path. As fluid is removed from the circular fluid path

through the filter, additional fluid may be drawn from the sample source as necessary to maintain a predetermined volume of fluid in the circular fluid path and within the retentate container. As the potentially contaminated fluid recirculates within the fluid circulation path, the concentration of one or more foreign substances may increased within the circular fluid path and the retentate container as additional pathogens and other foreign matter enters the circulating fluid path from the sample source but is prevented from leaving the circulating fluid path through the filter. After a predetermined or selected concentration factor has been achieved (i.e., a predetermined or selected volume of potentially contaminated fluid has been drawn into the fluid-circulation path and processed by the filter), a volume of the potentially contaminated concentrated fluid may be removed from the retentate container for testing and analysis. For example, the volume of the potentially contaminated fluid may be tested to detect the presence of one or more foreign substances, such as pathogens (e.g., microbial pathogens), for example, within the fluid taken from the sample source, and optionally, to estimate or determine the concentration of one or more foreign substances within the fluid taken from the sample source.

FIG. 2 is a process and instrumentation diagram schematically illustrating an embodiment of a sample concentrator system 10 of the present invention. As shown in FIG. 2, the concentrator system 10 includes a pump 12, a filter 14, and a retentate container 16. As discussed in further detail below, the concentrator system 10 also includes a plurality of conduits defining a circulating fluid path passing through the pump 12, the filter 14, and the retentate container 16, as well as one or more conduits defining a sample source inlet line for drawing potentially contaminated fluid into the circulating fluid path, and one or more conduits defining an effluent outlet line for allowing fluid to exit the circulating fluid path.

The pump 12 is used to drive fluid flow of the potentially contaminated fluid through the concentrator system 10. In some embodiments, the pump 12 may comprise a peristaltic pump, in which one or more "rollers," "shoes," or "wipers" are caused to compress and wipe along the exterior surface of a flexible closed tube passing through the pump, which causes fluid to flow within the tube in the direction in which the wipers wipe along the tube. Using a peristaltic pump may prevent direct physical contact between the potentially contaminated fluid and any part of the pump, which may reduce the potential for contamination and corrosion, and prevents the accumulation of any foreign substance on parts or components of the pump, the presence of which foreign substance or substances could alter the detected concentration levels of the foreign substance within the circulating fluid path. Such peristaltic pumps are commercially

available. As one particular non-limiting example, the pump 12 may comprise a MASTERFLEX® I/P® Precision Brushless Drive Model No. 77410-10, available from Cole-Parmer Instrument Co. of Vernon Hills, Illinois, fitted with a MASTERFLEX® I/P® EASY-LOAD® Pump Head Model No. 77601-00, which is also available from Cole-Parmer Instrument Co. In additional embodiments, the concentrator system 10 may comprise any other type of pump capable of driving fluid flow through the concentrator system 10.

With continued reference to FIG. 2, fluid may flow from the pump 12 to the filter 14 through a conduit 18.

The filter 14 is used to allow fluid to exit the circulating fluid path of the concentrator system 10, while preventing one or more foreign substances, such as, for example, pathogens, from exiting the circulating fluid path of the concentrator system 10. In some embodiments, the filter 14 may comprise a plurality of longitudinally oriented hollow fibers disposed within a filter body, such as those filters disclosed in U.S. Patent No. 5,531,848 to Brinda et al., the disclosure of which is incorporated herein in its entirety by this reference. By way of example and not limitation, each of the hollow fibers may have an average diameter of between about 100 microns and about 1,000 microns, and may be formed from a material having pores or apertures having an average pore size of between about fifty nanometers (50nm) and about to microns (2μ). Such filters may have a molecular cutoff in the range from about 500 Da to about 500 kDa. More particularly in certain embodiments an ultrafiltration filter may have a molecular cutoff in the range from about 15 kDa to about 75 kDa. In other embodiments nanofilters with a molecular cutoff of less than about 500 Da may be used or microfilters with a molecular cutoff of greater than about 500 kDa may be used. The so-called filtrate or retentate moves longitudinally through the hollow fibers and through the filter body without passing through the pores in the walls of the fibers, while water and other low molecular weight components (often referred to as "permeate") pass through the pores in the walls of the fibers in a direction generally transverse to the general flow of the retentate through the fibers. In other words, the walls of the hollow fibers form or comprise the filtering element of the filter 14. Some fluid passes transversely through the walls of the hollow fibers, while other fluid and the foreign matter being concentrated passes longitudinally through the hollow fibers and the filter body, but not through the walls of the hollow fibers (the filtering element). As one particular non-limiting example, the filter 14 may comprise a HEMOCOR

HPH® filter, Model No. HPH 1400, which is available from Minntech of Minneapolis, Minnesota.

As shown in FIG. 2, an effluent outlet line 20, which communicates with the circulating fluid path through the filtering element of the filter 14, may extend from the filter 14 to a connector or fitting, to an effluent container, or to another suitable repository for the effluent. In situations in which the sample source is relatively large, such as, for example, drinking water storage tank, a drinking water distribution system, a lake, reservoir, river, a stream, a water main or stream, the effluent outlet line 20 may extend back to the sample source at a location sufficiently remote from the location at which potentially contaminated fluid is being drawn into the concentrator system 10 so as to not affect the concentration of foreign substances in the fluid being drawn into the concentrator system 10.

One or more conduits 22 may be used to allow retentate (fluid and foreign matter that has not passed through the filtering element of the filter 14) to flow from the filter 14 to the retentate container 16.

The retentate container 16 is used to accumulate a desired volume of potentially contaminated fluid or retentate in the concentrator system 10 for subsequent testing and analysis. In some embodiments, the retentate container may be easily removable from the concentrator system 10 to allow an operator to remove the retentate container 16 from the concentrator system 10 to facilitate transportation or shipment of the retentate container 16 and the potentially contaminated retentate therein to a laboratory or other location for testing and analysis. Furthermore, the retentate container 16 may be configured to minimize exposure of an operator of the concentrator system 10 to any pathogens or other harmful substances that may be present within the retentate container 16 when the operator removes the retentate container 16 from the concentrator system 10 or otherwise handles the retentate container 16.

By way of example and not limitation, the retentate container 16 may comprise a glass or plastic carboy or bottle. In some embodiments, the retentate container 16 may comprise a material that is autoclavable such as, for example, glass or polypropylene. As one particular nonlimiting example, the retentate container 16 may comprise a NALGENE® autoclavable polypropylene one liter (1 L) bottle. Such bottles are commercially available from, for example, Thermo Fisher Scientific Inc. of Waltham, Massachusetts.

With continued reference to FIG. 2, one or more conduits 24 may be used to allow retentate to flow from the retentate container 16 back to the pump 12. As shown in FIG. 2, in some embodiments, one end of a conduit 24 may be positioned in the lower interior region of the container 16 to allow fluid within the retentate container 16 to be drawn into the conduit 24 by the pump 12 even when the fluid level within the retentate container is low. A vent line 26 may also be used to provide communication between the upper interior region of the container 16 and the exterior of the container 16 to allow venting of the retentate container 16 as necessary or desired. In some embodiments, the container 16 may be fitted with a so-called "filling/venting cap," which may be used to couple the conduit 22, the conduit 24, and the conduit 26 to the retentate container 16. Such filling/venting closures also are commercially available from, for example, Thermo Fisher Scientific Inc. of Waltham, Massachusetts.

As shown in FIG. 2, in some embodiments, a coupler 28 may be provided in one or more of the conduits 22, 24, and 26 at a location proximate the retentate container 16 to allow the retentate container 16 to be quickly and easily disconnected from the concentrator system 10. By way of example and not limitation, each coupler 28 may comprise a so-called male-to-female Luer Lock type connector or other suitable connectors such as for example, straight connectors, hose connectors, barb connectors, ISO connectors, sanitary connectors, or quick disconnect connectors. Optionally, one or more of the couplers 28 may comprise a stopcock.

As shown in FIG. 2, a three-way connector 30 may be used to couple a sample inlet line 32 to the conduits 24 extending between the retentate container 16 and the pump 12. The sample inlet line 32 may be used to draw potentially contaminated fluid into the concentrator system 10 by the pump 12 from a sample source.

The fluid concentrator system 10 may comprise one or more valves that can be used to selectively control fluid flow through the system 10. For example, a valve 34A may be provided along the conduit 22 extending between the filter 14 and the retentate container 16, a valve 34B may be provided along the conduit 24 extending between the retentate container 16 and the pump 12, and a valve 34C may be provided along the vent line 26. The fluid concentrator system 10 also may comprise a valve 34D along the effluent outlet line 20 and a valve 34E along the sample inlet line 32, as also shown in FIG. 2. A check valve 36 also may be provided along the sample inlet line 32 that allow fluid flow in only one direction therethrough (i.e., in the direction extending from the fluid sample source to the pump 12) to

prevent back flow of fluid out from the fluid circulation path of the concentration system 10 through the sample inlet line 32.

The valves 34A-34E may comprise on-off shutoff type valves, or they may comprise variable flow control valves. By way of example and not limitation, the valves 34A-34E may comprise pinch valves that are configured to pinch flexible tubing of the conduit extending therethrough. In some embodiments, such pinch valves may be configured to pinch the flexible tubing of the conduit using an electrically operated solenoid or a pneumatically or hydraulically operated drive element, and may be automatically actuated by a signal received from a controller, as discussed in further detail below. In other embodiments, one or more of the valves 34A-34E may be manually operated and may comprise, for example, a simple manually actuated tubing clamp.

In some embodiments, each of the conduits 18, 22, 24, as well as the effluent outlet line 20, the vent line 26, and the sample inlet line 32 may comprise hollow flexible polymeric tubing.

In some embodiments, one or more features or functions of the sample concentrator system 10 may be substantially automatically operated or controlled using a controller, and the concentrator system 10 may include one or more sensors, meters, or gauges for monitoring one or more conditions of the concentrator system 10 and relaying signals indicative of such conditions to the controller to enable the controller to automatically adjust one or more operating parameters of the system 10 in response to the signals as necessary or desired.

By way of example and not limitation, the sample concentrator system 10 may include one or more pressure gauges for measuring the fluid pressure at selected locations within the system 10. As shown in FIG. 2, the concentrator system 10 may include a pressure gauge 42 for measuring the pressure of the fluid within the conduit 18 extending between the pump 12 and the filter 14. The pressure gauge 42 may be configured to generate a signal indicative of the pressure and to relay the signal to a controller, described in further detail below. The sample concentrator system 10 also may include one or more flow sensors for measuring the rate of fluid flow at selected locations within the system 10.

As shown in FIG. 2, the concentrator system 10 may include a flow sensor 44 for measuring the flow rate of fluid exiting the concentrator system 10 through the effluent outlet

line 20. The flow sensor 44 may be configured to generate a signal indicative of the flow rate and to relay the signal to the controller.

The sample concentrator system 10 also may include one or more sensors for measuring the volume of retentate within the retentate container 16. Such sensors may be configured to measure the volume of the retentate within the retentate container 16 without requiring direct physical contact between any part of the sensor and the retentate within the container 16. By way of example and not limitation, the concentrator system 10 may include a load cell 46 for measuring the weight of the volume of retentate within the retentate container 16, as shown in FIG. 2. The weight of the volume of retentate may be used to calculate the volume of the retentate using a known approximate value of the density of the retentate. In additional embodiments, an optical sensor, a proximity sensor, or any other type of sensor may be used to measure the volume of the retentate within the retentate container 16.

FIG. 3 is a block diagram schematically illustrating an embodiment of a control system 50 that may be used to control operation of the sample concentrator system 10 shown in FIG. 2. The control system 50 may comprise a controller 52. The controller 52 may comprise, for example, a computer (e.g., a portable computer, a desktop computer, a personal data assistant (PDA), etc.) or a programmable logic controller. The controller 52 may comprise at least one electronic signal processor 54 (i.e., a microprocessor) and at least one memory device 56 (i.e., a random access memory (RAM) device, a read only memory (ROM) device, a Flash memory device, etc.) for storing data therein in electrical communication with the electronic signal processor 54.

As shown in FIG. 3, the controller 52 may be configured to receive a signal from each of the pressure gauge 42, the flow sensor 44, and the load cell 46 previously described in relation to FIG. 2, as well as any additional gauges, sensors, or meters of the concentrator system 10. The controller 52 also may be configured to control operation of the pump 12. For example, the controller 52 may be configured to relay one or more signals to the pump 12 to cause the pump 12 to start the pump, to stop the pump, to adjust the speed of operation of the pump, and to change the direction in which the pup head rotates. The controller 52 also may be configured to selectively actuate or otherwise control one or more of the valves 34A-34E, as previously discussed with reference to FIG. 2.

With continued reference to FIG. 3, the control system 50 may further comprise at least one input device 58 for enabling an operator to input one or more commands to the control system 50 of the fluid concentrator system 10, and at least one output device 60 for outputting information to the operator. By way of example and not limitation, the input device 58 may comprise at least one of a button, a switch, a keypad, a touchpad or touchscreen, a keyboard, and a mouse or other pointing device, and the at least one output device 60 may comprise at least one of a device for emitting an visible or audible signal, a display screen or monitor, and a printer.

In this configuration, the control system 50 may be configured under control of a computer program to substantially automatically control the various elements, components, and subsystems of the sample concentrator system 10 when concentrating a fluid sample. By way of example and not limitation, the control system 50 may be configured under control of a computer program (which optionally may be recorded in memory of the at least one memory device 56 of the controller 52) to perform the sequence of operations illustrated in the flow chart shown in FIGS. 4A-4C.

Referring to FIG. 4A, upon receipt of an input signal received from an operator through the input device 58, the control system may be configured to request that the operator input the total volume of effluent to be discharged from the effluent outlet line 20 (FIG. 2) during a concentration process as shown at activity 60, which, in effect, may determine the concentration factor to be achieved during the concentration process. After the volume has been input to the control system 50 by the operator, the control system 50 may cycle power to the various components of the concentrator system 10 that require power and tare the load cell 46 or any other sensor, gauge, or meter that requires taring, as shown at activity 62. The control system 50 may be configured to ask the operator if it is desired to enter a test mode (e.g., for calibration), as shown at decision point 64. If yes, the control system 50 may enter the test mode as shown at activity 66, the details of which may be customized to particular applications and are not described in detail herein. If the decision at decision point 64 is no, the control system 50 may be configured to check hardware (e.g., one or more of the pump 12, the pressure gauge 42, the flow sensor 44, and the load cell 46) for errors, as shown at decision point 68. If one or more of the hardware components fails the hardware check, the process may abort and an error message may be conveyed to the operator via the output device 60 (FIG. 3). If all hardware passes the hardware check, the control system 50 may

initialize the hardware as shown at activity 70 and may enter a ready mode at which it waits for an input signal from the operator to initialize a concentration process or cycle, as illustrated at decision point 72.

If the control system 50 receives an input signal from the operator to initialize a concentration process or cycle, the control system 50 may prime the pump 12 (FIG. 2), as indicated at activity 74. For example, priming the pump 12 may include operating the pump 12 at a predetermined speed for a predetermined amount of time, and then determining whether the volume of retentate within the retentate container 16 (FIG. 2) is greater than a predetermined minimum value (e.g., four hundred and fifty milliliters (450 ml)), as shown at decision point 76. If the retentate volume is below the minimum value, the control system 50 may be configured to repeat the pump priming activities, as shown in FIG. 4A. If the retentate volume is above the minimum value, the control system 50 may be configured to cause the pump 12 to operate at a predetermined speed for a predetermined amount of time (e.g., three minutes) to cause fluid to flow through the fluid circulation path (i.e., from the pump 12, through the filter 14, the retentate container 16, and back to the pump 12), as shown at activity 78 in FIG. 4A.

Referring to FIG. 4B, after the pump 12 has pumped fluid through the fluid circulation path, the control system 50 may be configured to reduce the volume of retentate in the retentate container 16 to a reduced level (e.g., about two hundred and fifty milliliters (250 ml), as shown at activity 80, by closing the valve 34E (FIG. 12) and operating the pump 12 until the reduced volume level is achieved. After the reduced volume level of retentate has been achieved, the control system 50 may be configured to stop the pump 12 and to provide fluid communication to the sample source, as shown at activity 82, by opening the valve 34E. The control system 50 may be configured to then close the valve 34B and operate the pump 12 to draw potentially contaminated fluid into the fluid circulation path of the concentrator system 10 until an increased desired target volume of retentate has been obtained in the retentate container 16 (e.g., about seven hundred and fifty milliliters (750 ml)), as shown at activity 84. After the desired target volume of retentate has been obtained in the retentate container 16, the control system 50 may be configured to increase the operating speed of the pump 12 to a desired operating speed (which may be a maximum operating speed of the pump 12), as shown at activity 86, and to then enter a main process loop.

The control system 50 then may be configured to enter a main process loop in which the pump 12 is operated to pump fluid through the fluid circulation path and to selectively draw additional potentially contaminated fluid into the fluid circulation path through the sample inlet line 32 as required to maintain the volume of retentate within the retentate container 16 within selected predetermined limits as fluid exits the fluid circulation path through the effluent outlet line 20. This overall process may concentrate one or more foreign substances within the retentate.

For example, as shown in FIG. 4B, the control system 50 may be configured to determine whether the retentate volume in the retentate container 16 is below a lower threshold level (e.g., two hundred milliliters (200 ml)) using the load cell 46, as shown at decision point 88. If the volume is below the threshold level, the volume may be increased to a level within the selected predetermined limits (e.g., five hundred milliliters (500 ml)), as shown at activity 89. If the volume is above the lower threshold level, the control system 50 may be configured to determine whether the retentate volume in the retentate container 16 is below an upper threshold level (e.g., eight hundred and fifty milliliters (850 ml)) using the load cell 46, as shown at decision point 90. If the volume is above the upper threshold level, the volume may be decreased to a level within the selected predetermined limits (e.g., seven hundred milliliters (700 ml)), as shown at activity 91.

With combined reference to FIGS. 4B and FIG. 2, in the processes described above, the volume of retentate in the retentate container 16 may be increased by, for example, closing valve 34B, opening the valve 34E, and operating the pump 12 to draw additional sample fluid into the circulating fluid path. The volume of retentate in the retentate container 16 may be decreased by, for example, opening the valve 34B, closing the valve 34E, and operating the pump 12 to force additional effluent out from the circulating fluid path through the effluent outlet line 20. The valve 34A also may be closed as necessary or desired when decreasing the volume of the retentate within the retentate container 16.

As the pump 12 circulates fluid through the filter 14, a pressure differential may be generated across the filter 14. In other words, the fluid pressure in the conduit 18 may be relatively higher than the fluid pressure in the conduit 22. The volume of effluent discharged through the effluent outlet line 20 may be at least partially a function of this pressure differential, and the pressure differential may be at least partially a function of the operating speed of the pump 12. If the valve 34C on the vent line 26 (FIG. 2) is maintained in the

closed position, a back pressure may be generated within the conduit 22 upon operation of the pump 12. Providing a back pressure within the conduit 22 (and within the retentate container 16) of about thirteen thousand eight hundred Pascals (13,800 Pa) (about two pounds per square inch (2 PSI)) or more may help to stabilize the fluid level of the retentate in the retentate container 16 and may help to force effluent out the effluent outlet line 20 through the filter 14. This back pressure may be a function of the pressure within the conduit 18, the flow characteristics of the filter 14, and the state of the various valves 34A-34E. As a result, it can be determined (e.g., using empirical studies) what the pressure in the conduit 22 will be for a given pressure within the conduit 18 and state of the valves 34A-34E. In other words, the pressure differential between the conduit 18 and the conduit 22 can be deduced using the known pressure within either the conduit 18 or the conduit 22, and the state of the valves 34A-34E for any particular embodiment of a concentrator system 10.

In some embodiments, it may be desirable to maintain the pressure differential between the conduit 18 and the conduit 22 within a predetermined range of pressures. For example valve 34A may be an adjustable valve used to create a pressure differential. By way of example and not limitation, it may be desirable to maintain this pressure differential between about thirty five thousand Pascals (35,000 Pa) (about five pounds per square inch (5 PSI)) and about one hundred and seventy two thousand Pascals (172,000 Pa) (about twenty five pounds per square inch (25 PSI)). Therefore, in some embodiments, the control system 50 may be configured to monitor the pressure within the conduit 18 using the pressure gauge 42, and to automatically adjust the operating speed of the pump 12 so as to maintain this pressure differential within the predetermined range of pressures.

With continued reference to FIG. 4B, in some embodiments, the control system 50 may be configured to allow an operator to pause operation of the concentrator system 10 (e.g., the pump 12) at any time during the main process loop by, for example, providing an input signal using the input device 58 (FIG. 3). Therefore, in some embodiments, if the volume of retentate within the retentate container 16 is below the upper threshold level, the control system 50 may be configured to determine whether an input signal has been received indicating that the operator wishes to pause operation of the concentrator system 10, as shown at decision point 92. If such a signal has been received, the control system 50 may be configured to pause or wait until the operator provides an additional input signal indicating that it is desired to resume operation, as shown at activity 93. If no such signal has been

received, the control system 50 may be configured to determine whether the total volume of effluent that has been discharged from the effluent outlet line 20 is greater than or equal to that entered by the operator during activity 60 (FIG. 4A) as the desired target volume, as shown at decision point 94. If the desired final volume has not been achieved, the control system 50 may be configured to repeat the main process loop, as shown in FIG. 4B. If the desired target volume has been achieved, the control system 50 may be configured to close the valve 34E to prevent additional sample fluid from being drawn into the concentrator system 10, and to optionally reduce the volume of retentate within the retentate container 16 to a desired target sample volume (e.g., about one hundred milliliters (100 ml)), as shown at activity 95.

Referring to FIG. 4C, the control system 50 may be configured to then pause operation of the concentrator system 10 (e.g., the pump 12) to allow the operator to remove the final sample volume from the concentrator system 10 for testing and analysis, as shown at activity 96. In some methods, the entire retentate container 16 may be removed from the concentrator system for transportation or shipment to a remote location for testing and analysis. The pause operation may used to allow the operator to change the supply side source such as a carboy. For example, a 50 liter carboy weighs approximately 50 kg, using multiple supply side containers may be advantageous when the source is not a large body such as a kitchen or bath sink, lake, pond, or stream.

Optionally, after the final sample volume from the concentrator system 10, the control system 50 may be configured to enable an operator to perform one or more rinsing or washing operations. For example, it may be desired to flush the system 10 with an eluent. As shown at activity 96, fluid communication may be established between the sample inlet line 32 and an eluent. The control system 50 may be configured to then operate the pump 12 at a predetermined speed for a predetermined amount of time to draw the eluent into the concentrator system 10 through the sample inlet line 32, as shown at activity 98.

As shown at activity 100, the volume of eluent being discharged from the concentrator system 10 trough the effluent outlet line 20 may be reduced by closing the valve 34D, after which the control system 50 may be configured to operate the pump 12 at a predetermined speed for a predetermined amount of time to recirculate the eluent through the fluid circulation path, as shown at activity 102.

The control system 50 may be configured to then pause operation of the concentrator system 10 to enable an operator to configure the system 10 for an optional backwash process by establishing fluid communication between the effluent outlet line 20 and a backwash eluent, as shown at activity 104. The control system 50 may be configured to perform a backwash sequence, as shown at activity 106. By way of example and not limitation, the backwash sequence may comprise, for example, closing the valves 34A and 34E and operating the pump 12 at a predetermined speed 12 for a predetermined amount of time to draw the backwash eluent into the concentrator system 10 through the effluent outlet line 20 and the filter 14. Backwashing the filter 14 in this manner may help to dislodge and otherwise free matter that has accumulated in the hollow fibers of the filter 14, and to allow such matter to be discharged from the concentrator system 10 through the sample inlet line 32 or through the retentate container 16.

Optionally, embodiments of concentrator systems 10 of the present invention may be configured as a portable system that can be transported or shipped to a location of a potentially contaminated fluid sample source, such as, for example, a lake, reservoir, river, stream, or well.

FIG. 5 is a partially cut-away side perspective view of one particular portable embodiment of the concentrator system 10 that is represented schematically in FIG. 2. As shown in FIG. 5, the portable concentrator system 10 includes a portable outer housing or container 110, which may comprise one or more handles and one or more wheels to facilitate transportation of the concentrator system 10. As shown in FIG. 2, the pump 12, the filter 14, and the retatentate container 16 each may be secured within the container 110. For example, one or more of the pump 12, the filter 14, and the retatentate container 16 may be structurally fastened or otherwise secured to an internal frame member 112 positioned within the container, and the internal frame member 112 optionally may be fastened or otherwise secured to the interior of the container 110. Each of the other various elements and components of the concentrator system 10 shown in FIG. 2 also may be secured within the container 110.

The portable concentrator system 10 shown in FIG. 5 may include a power distributor 114, which may be used to distribute power to the various components of the concentrator system 10 requiring independent power for operation (e.g., the pump 12). The portable concentrator system 10 may operate on power supplied by at least one of an external power supply grid and an internal power source (e.g., a battery, fuel cell, generator, etc.) For example, the portable concentrator system 10 may comprise an internal battery 116 that may be used to power the various components of the concentrator system 10.

As shown in FIG. 5, the portable concentrator system 10 also may include various electronic components 118, which optionally may be mounted to the internal frame member 112. The electronic components 118 may comprise, for example, the controller 52 of the control system 50 (FIG. 3), an electronic meter for the load cell 46 (FIG. 2), electronic components associated with flow meters or pressure gauges, relay boxes, fuse boxes, etc.

In some embodiments, the portable concentrator system 10 may comprise one or more data ports 124 for transmitting electrical signals between the electronic components within the container 110 and electronic devices outside the container 110. By way of example and not limitation, the controller 52 of the control system 50 shown in FIG. 3 may comprise a portable computer device located outside the container 110, and electrical communication may be established between the portable computer device and the other components of the control system 50 shown in FIG. 3 (which may be disposed within the container 110) through one or more data ports 124. Such data ports 124 may be mounted through the wall of the container, as shown in FIG. 5, to enable electrical communication between the electronic components within the container 110 and electronic devices outside the container 110 without requiring that a lid or cover of the container 110 be removed or opened.

Furthermore, the container 110 may comprise one or more windows (not shown) to enable an operator to visually inspect the various components of the concentrator system 10 within the container 110 without requiring that a lid or cover of the container 110 be removed or opened.

FIG. 6 is a schematic top plan view of the portable concentrator system 10 shown in FIG. 5 and illustrates the physical layout of the various operational elements, components, and subsystems of the portable concentrator system 10 within the container 110. Many other physical layouts are contemplated and embodiments of concentrator systems of the present invention may have physical layouts other than that shown in FIGS. 5 and 6.

As shown in FIGS. 5 and 6, a coupler 126 also may be mounted through the container 110 for coupling an external conduit (not shown) to the sample inlet line 32 (FIG. 2), and an additional coupler 126 also may be mounted through the container 110 for coupling another external conduit (not shown) to the effluent outlet line 20 (FIG. 2). By way of example and not limitation, the couplers 126 may comprise, for example, straight connectors, hose connectors, barb connectors, ISO connectors, sanitary connectors, quick disconnect connectors, or Luer Lock type connectors. In this manner, the entire concentrator system 10 may be operated

without requiring that the container 110 be opened during a concentration process until it is necessary or desired to remove the final concentrated volume of retentate within the retentate container 16 for testing and analysis.

Embodiments of sample concentrator systems of the present invention may provide various benefits and improvements over previously known concentrator systems. For example, embodiments of sample concentrator systems of the present invention may be automated, portable, easily configurable in the field, and may minimize or reduce the risk of exposure of an operator to potentially harmful pathogens or other foreign substances being concentrated by the concentrator systems.

While the invention may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the following appended claims.

CLAIMS

What is claimed is:

1. A method of concentrating a foreign substance in a fluid sample comprising:
establishing circulation of fluid through a fluid circulation path;
drawing fluid into the fluid circulation path from a sample source;
causing fluid to exit the fluid circulation path through a filtering element;
preventing at least one foreign substance from passing through the filtering element;
concentrating the at least one foreign substance in fluid within a container in the fluid circulation path; and
using an electronic control system to substantially automatically control at least one of a speed of a pump circulating fluid through the fluid path and a quantity of retentate within the container.

2. The method of claim 1, further comprising using a sensor to sense at least one of a quantity of retentate within the container and a quantity of effluent exiting the fluid circulation path through the filtering element.

3. The method of claim 2, wherein using a sensor to sense at least one of a quantity of retentate within the container and a quantity of effluent exiting the fluid circulation path through the filtering element comprises sensing a rate of flow of effluent exiting the fluid circulation path using a flow sensor.

4. The method of claim 2, wherein using a sensor to sense at least one of a quantity of retentate within the container and a quantity of effluent exiting the fluid circulation path through the filtering element comprises using a load cell to determine a weight of retentate within the container.

5. The method of claim 2, further comprising:
generating a signal indicative of at least one of the quantity of retentate within the container and the quantity of effluent exiting the fluid circulation path through the filter; and
transmitting the signal from the sensor to the electronic control system.

6. The method of claim 5, further comprising using the electronic control system to substantially automatically control a quantity of fluid drawn into the fluid circulation path from the sample source at least partially in response to the signal transmitted from the sensor to the electronic control system.

7. The method of claim 1, further comprising:

measuring the fluid pressure of fluid entering a filter body housing the filtering element using a pressure gauge;

generating a signal with the pressure gauge indicative of the measured fluid pressure;

transmitting the signal from the pressure gauge to the electronic control system; and

substantially automatically controlling the speed of the pump in response to a varying characteristic of the signal.

8. The method of claim 1, wherein causing effluent to exit the fluid circulation path through a filtering element comprises:

causing effluent to pass through pores in at least one wall of each of a plurality of hollow fibers extending through a filter body housing the filtering element; and

selecting an average size of the pores in the at least one wall of each of the plurality of hollow fibers to prevent the at least one foreign substance from passing through the pores.

9. The method of claim 1, wherein preventing at least one foreign substance from passing through the filtering element comprises preventing at least one microbial pathogen from passing through the filtering element.

10. A system for concentrating at least one foreign substance in a fluid comprising:

a filter having at least one filtering element disposed within a filter body;

a retentate container;

a pump configured to drive fluid flow through a circulating fluid pathway passing through the filter body and the retentate container;

a sample inlet line in fluid communication with the circulating fluid pathway;

an effluent outlet line in fluid communication with the circulating fluid pathway through the filtering element of the filter;

at least one valve configured to control fluid flow through the circulating fluid pathway;

at least one sensor for sensing a characteristic relating to fluid in the circulating fluid pathway; and

a control system configured to substantially automatically control at least one of the pump and the at least one valve in response to a signal received from the at least one sensor.

11. The system of claim 10, wherein the at least one sensor comprises a retentate sensor configured to detect a quantity of retentate within the retentate container.

12. The system of claim 11, wherein the retentate sensor comprises a load cell configured to detect a weight of the retentate within the retentate container.

13. The system of claim 12, wherein the control system is configured to substantially automatically maintain the quantity of the retentate between a predetermined minimum quantity and a predetermined maximum quantity.

14. The system of claim 10, wherein the at least one sensor comprises a flow meter configured to measure a quantity of effluent passing through the effluent outlet line.

15. The system of claim 14, wherein the control system is configured to substantially automatically stop the pump after a predetermined quantity of effluent has passed through the effluent outlet line.

16. The system of claim 10, wherein the at least one sensor comprises a pressure gauge configured to measure a fluid pressure within the circulating fluid pathway.

17. The system of claim 16, wherein the control system is configured to substantially automatically adjust a speed of the pump to maintain the fluid pressure between a predetermined maximum pressure and a predetermined minimum pressure.

18. The system of claim 10, wherein the at least one filtering element disposed within the filter body comprises a plurality of hollow fibers extending through the filter body.

19. The system of claim 18, wherein each hollow fiber comprises a longitudinally extending central lumen surrounded by a porous wall, the porous wall comprising a plurality of pores having an average pore size selected to prevent the at least one foreign substance from passing through the plurality of pores.

20. The system of claim 19, wherein the porous walls of the hollow fibers of the plurality of hollow fibers have an average pore size of between about fifty nanometers (50 nm) and about two microns (2 μm).

21. The system of claim 10, wherein at least the filter, the pump, and the retentate container are each secured within a container.

22. The system of claim 21, further comprising at least one handle attached to the container.

23. The system of claim 22, further comprising at least one wheel rotatably mounted to an exterior surface of the container.

24. The system of claim 21, further comprising at least one fluid coupler mounted to a wall of the container, the fluid coupler configured to provide fluid communication between a conduit on the interior of the container comprising at least one of the sample inlet line and the effluent outlet line and a conduit on the exterior of the container through the wall of the container.

25. The system of claim 21, further comprising at least one electrical coupler mounted to a wall of the container, the electrical coupler configured to provide electrical communication between at least one electronic device on the interior of the container and at least one electronic device on the exterior of the container through the wall of the container.

26. The system of claim 21, further comprising at least one of a battery, a fuel cell, and a generator operably coupled to supply power at least to the pump.

27. The system of claim 10, wherein the control system comprises:

a controller;
at least one input device; and
at least one output device.

28. The system of claim 27, wherein the controller comprises at least one of a computer and a programmable logic controller.

29. A system for concentrating at least one foreign substance in a fluid comprising:
a filter having at least one filtering element disposed within a filter body;
a retentate container;
a pump configured to drive fluid flow through a circulating fluid pathway passing through the filter body and the retentate container;
a sample inlet line in fluid communication with the circulating fluid pathway;
an effluent outlet line in fluid communication with the circulating fluid pathway through the filtering element of the filter;
a container having the filter, the retentate container, and the pump disposed therein; and
a control system comprising:
a controller;
at least one input device;
at least one output device;
at least one retentate sensor configured to sense a quantity of retentate within the retentate container and transmit a signal to the controller indicative of the quantity of retentate within the retentate container; and
at least one effluent sensor configured to sense a quantity of effluent passing through the effluent outlet line and transmit a signal to the controller indicative of the quantity of effluent passing through the effluent outlet line.

30. The system of claim 29, wherein the controller of the control system is configured under control of a computer program to automatically adjust a speed of the pump in response to a signal received from at least one of the retentate sensor and the effluent sensor.

31. The system of claim 29, further comprising at least one pressure sensor configured to sense a pressure in the circulating fluid pathway and to transmit a signal to the controller indicative of the pressure in the circulating fluid pathway.

32. The system of claim 29, wherein the retentate sensor comprises a load cell configured to detect a weight of the retentate within the retentate container.

33. The system of claim 29, wherein the at least one filtering element disposed within the filter body comprises a plurality of hollow fibers extending through the filter body.

34. The system of claim 33, wherein each hollow fiber comprises a longitudinally extending central lumen surrounded by a porous wall, the porous wall comprising a plurality of pores having an average pore size selected to prevent the at least one foreign substance from passing through the plurality of pores.

35. The system of claim 29, further comprising at least one of a handle and a wheel mounted to an exterior surface of the container.

36. The system of claim 29, further comprising at least one fluid coupler mounted to a wall of the container, the fluid coupler configured to provide fluid communication between a conduit comprising at least one of the sample inlet line and the effluent outlet line on the interior of the container and a conduit on the exterior of the container through the wall of the container.

37. The system of claim 36, further comprising at least one electrical coupler mounted to a wall of the container, the electrical coupler configured to provide electrical communication between at least one electronic device on the interior of the container and at least one electronic device on the exterior of the container through the wall of the container.

38. The system of claim 29, further comprising at least one of a battery, a fuel cell, and a generator operably coupled to supply power at least to the pump.

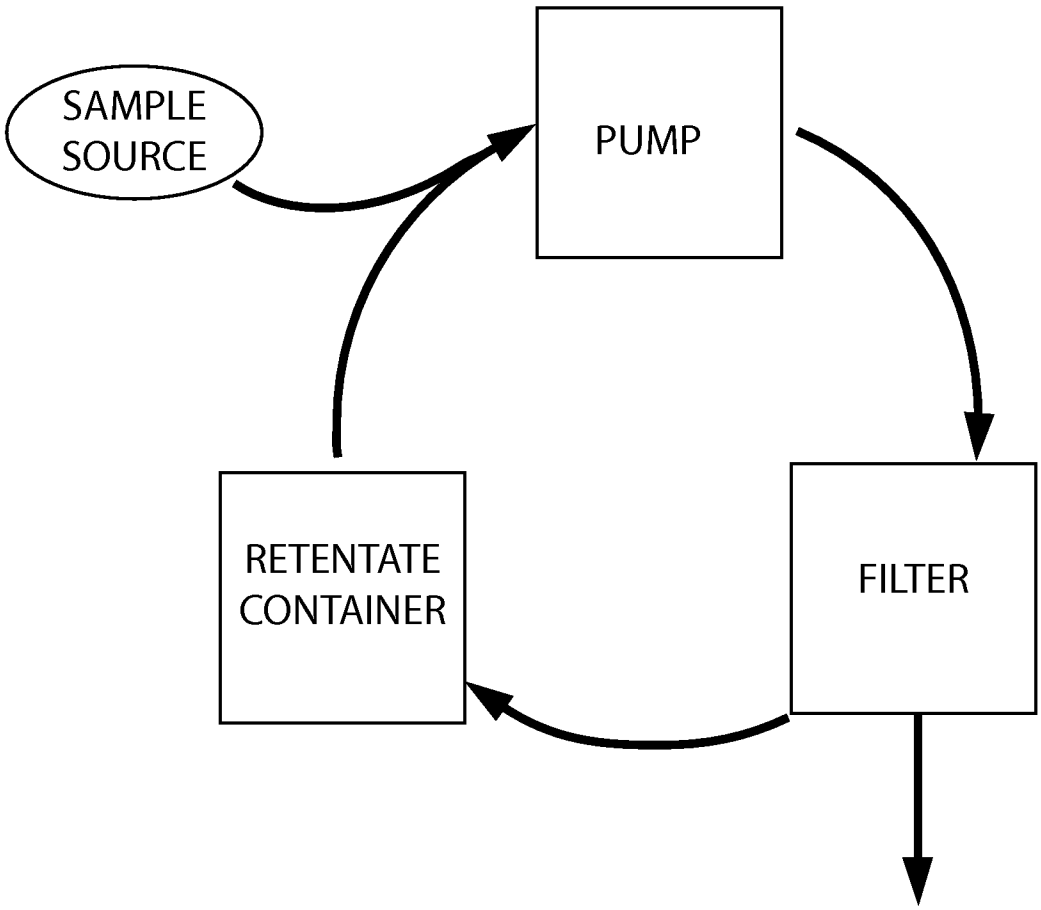

FIG. 1

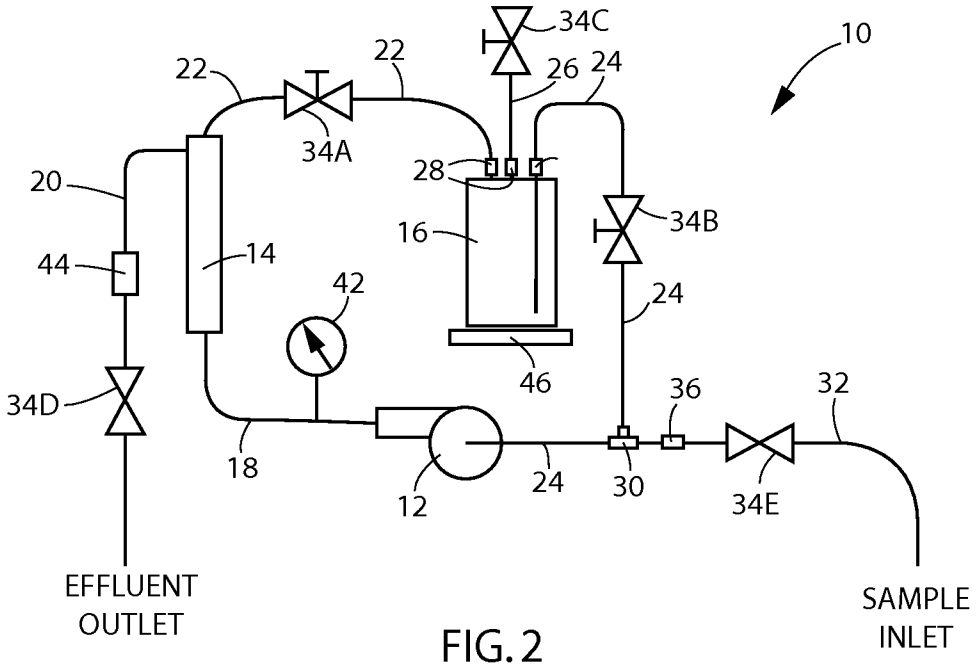
10
34C
22
22
26
24
34A
28
20
16
34B
44
14
42
24
46
34D
36
32
18
12
24
30
34E
EFFLUENT OUTLET
SAMPLE INLET

FIG. 2

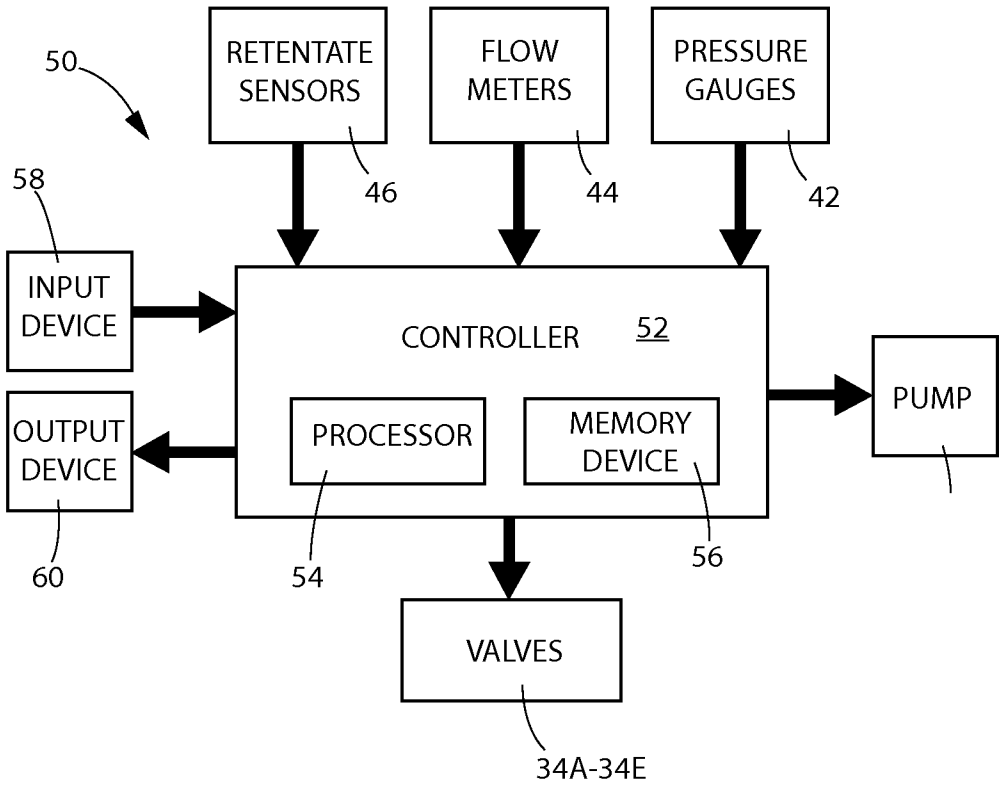
50
RETENTATE SENSORS
FLOW METERS
PRESSURE GAUGES
46
44
42
58
INPUT DEVICE
CONTROLLER 52
PUMP
OUTPUT DEVICE
PROCESSOR
MEMORY DEVICE
60
54
56
VALVES
34A-34E

FIG. 3

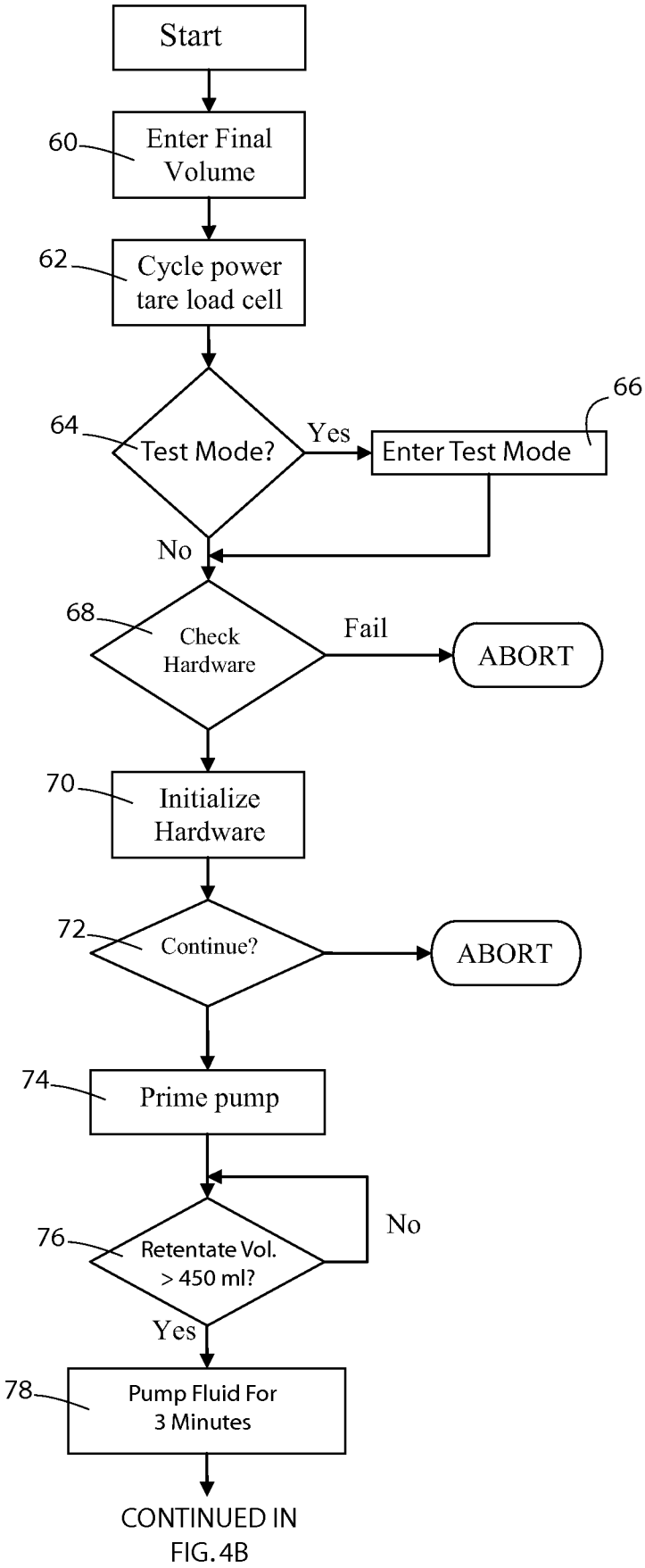
Start
60
Enter Final Volume
62
Cycle power tare load cell
64
Test Mode?
Yes
66
Enter Test Mode
No
68
Check Hardware
Fail
ABORT
70
Initialize Hardware
72
Continue?
ABORT
74
Prime pump
76
Retentate Vol. > 450 ml?
No
Yes
78
Pump Fluid For 3 Minutes
CONTINUED IN FIG. 4B

FIG. 4A

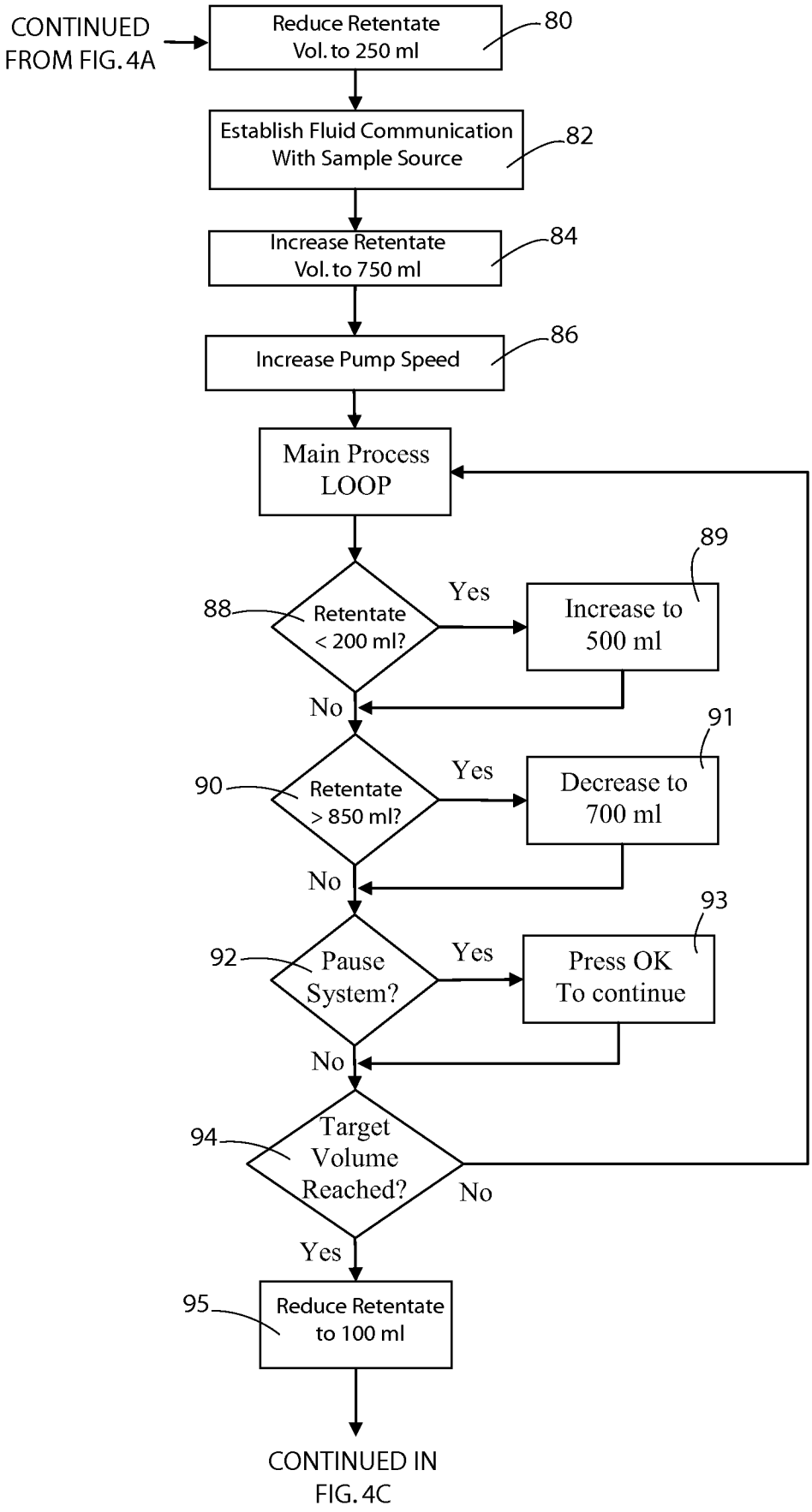
CONTINUED FROM FIG. 4A
Reduce Retentate Vol. to 250 ml
80
Establish Fluid Communication With Sample Source
82
Increase Retentate Vol. to 750 ml
84
Increase Pump Speed
86
Main Process LOOP
88
Retentate < 200 ml?
Yes
89
Increase to 500 ml
No
90
Retentate > 850 ml?
Yes
91
Decrease to 700 ml
No
92
Pause System?
Yes
93
Press OK To continue
No
94
Target Volume Reached?
No
Yes
95
Reduce Retentate to 100 ml
CONTINUED IN FIG. 4C

FIG. 4B

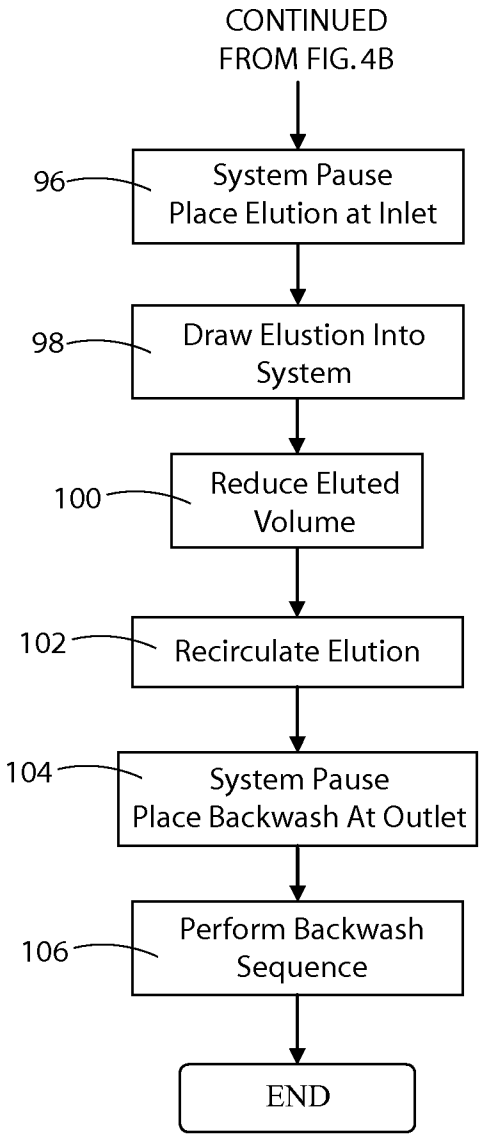
CONTINUED
FROM FIG. 4B
96
System Pause
Place Elution at Inlet
98
Draw Elustion Into
System
100
Reduce Eluted
Volume
102
Recirculate Elution
104
System Pause
Place Backwash At Outlet
106
Perform Backwash
Sequence
END

FIG. 4C

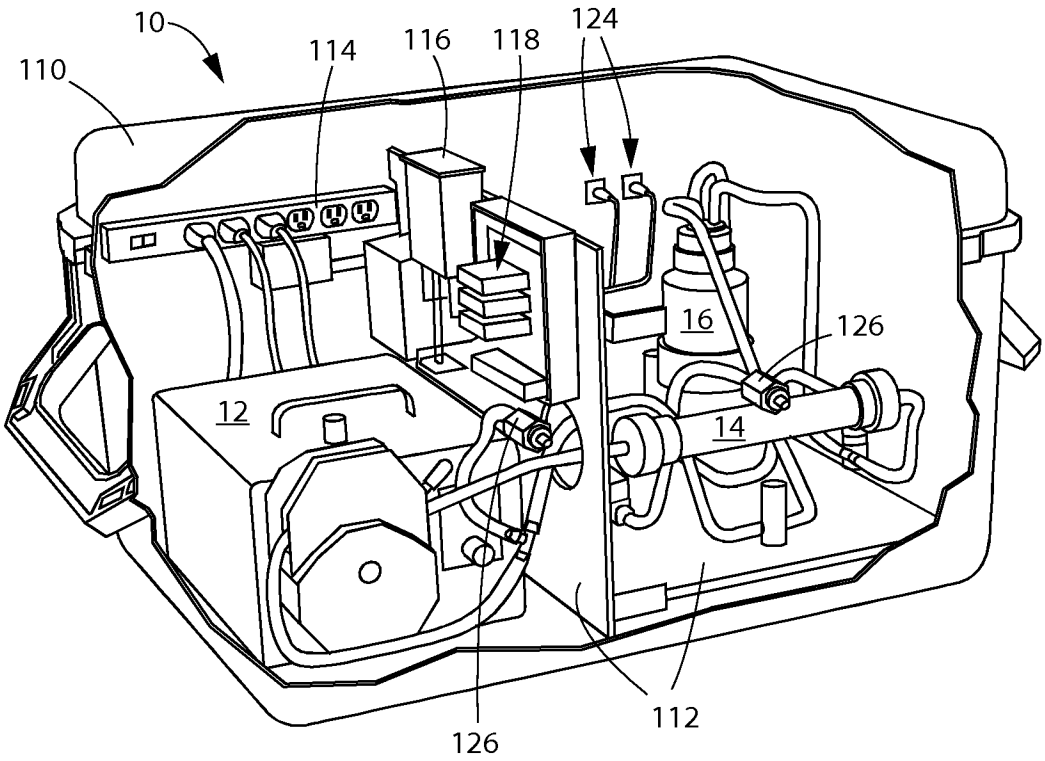
10
110
114
116
118
124
16
126
12
14
126
112

FIG. 5

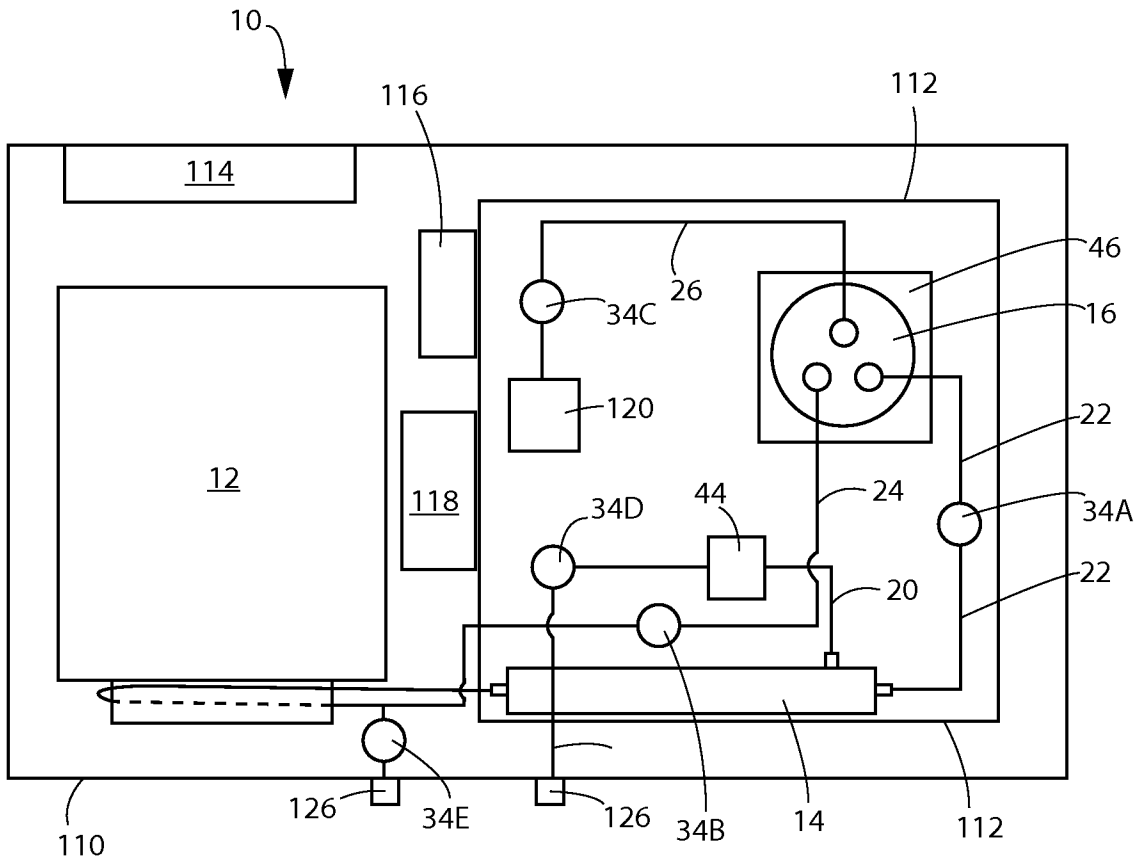
10
116
112
114
46
26
34C
16
120
22
12
118
44
24
34D
34A
20
22
126
34E
126
34B
14
112
110

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 07/86268

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - C01F 7/00, B01D 61/14 (2008.04)
USPC - 210/739, 210/767
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)
USPC - 210/739, 210/767
IPC(8) - C01F 7/00, B01D 61/14 (2008.04)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 210/739, 210/767
IPC(8) - C01F 7/00, B01D 61/14 (2008.04) (text search)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST (USPT,PGPB,EPAB,JPAB); Yahoo, Google Scholar
Search terms used: effluent outflow electronic control flow pump pressure sensor sample liquid flow path concentrate filtrate retentate matter substance valve

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	US 5,947,689 A (Schick) 07 September 1999 (07.09.1999), col 2, ln 53-59; col 2, ln 53-59; col 13, ln 17-23; col 13, ln 18-22; col 13, ln 51-53; col 4, ln 29-32; col 13, ln 32-40; col 13, ln 51-53; col 14, ln 15-18	1-18, 29-33, 35-38 ---------- 19-28, 34
Y	US 5,656,372 A (Gentile et al.) 12 August 1997 (12.08.1997), col 1, ln 58-61; col 2, ln 46-50	19, 20, 34
Y	US 5,242,595 A (Morgart et al.) 07 September 1993 (07.09.1993), col 1, ln 16-25	20
Y	US 6,207,051 B1 (Anderson et al.) 27 March 2001 (27.03.2001), col 5, ln 40-59; col 5, ln 61-64; col 2, ln 36-38; col 6, ln 9-18	21-28

☐ Further documents are listed in the continuation of Box C. ☐

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06 October 2008 (06.10.2008)	31 OCT 2008
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