

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
30 January 2003 (30.01.2003)

PCT

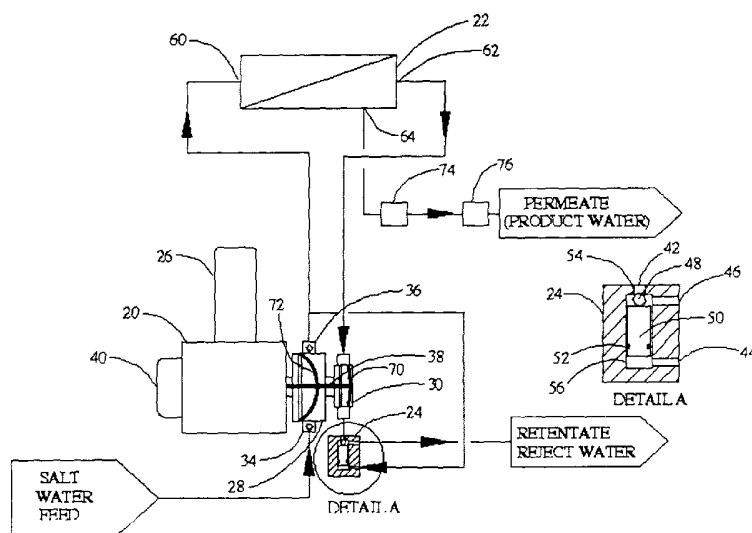
(10) International Publication Number
WO 03/008076 A1

- (51) International Patent Classification⁷: **B01D 63/00**, 61/00, 61/02, C02F 9/00, 1/44, F04B 49/00, 25/00, 3/00, 17/00, 35/00
- (74) Agent: **PEACOCK, Deborah, A.**; Peacock, Myers & Adams, P.C., P.O. Box 26927, Albuquerque, NM 87125-6927 (US).
- (21) International Application Number: PCT/US02/22618
- (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.
- (22) International Filing Date: 16 July 2002 (16.07.2002)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 60/305,912 16 July 2001 (16.07.2001) US
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- (71) Applicant (*for all designated States except US*): **MIOX CORPORATION** [US/US]; 5500 Midway Park Place, NE, Albuquerque, NM 87109 (US).
- (72) Inventors; and
- (75) Inventors/Applicants (*for US only*): **HERRINGTON, Rodney, E.** [US/US]; 8631 Glenridge Place, NW, Albuquerque, NM 87114 (US). **HAND, Frank, R.** [US/US]; 1706 Father Sky, NE, Albuquerque, NM 87112 (US).

Published:
 — with international search report
 — with amended claims

[Continued on next page]

(54) Title: DUAL HEAD PUMP DRIVEN MEMBRANE SYSTEM



(57) **Abstract:** Improvements in product water throughput from a reverse osmosis (RO) membrane achieved by thinner feed spacers in the RO element (22), enhanced recovery (ratio of permeate to feed), pressure recovery of the retentate fluid pressure opposing the feed water pressure, and fluid pulsing of the RO element feed stream. These features are preferably combined to optimize the performance and cost per unit volume of water produced. The system of the invention preferably comprises a dual head reciprocating pump (20), an RO element (22) with a housing, and a differential pressure activated ("DPA") valve (24). The DPA valve (24), in combination with offsetting fluid pressures on the two pump heads (28, 30), generate energy recovery. The frequency and amplitude of the reciprocating pump (20) create a pulse wave in the RO element (22) that improves permeate quality and throughput. A control system preferably monitors system parameters to optimize the reciprocating pump (20) speed and amplitude to tune the optimal frequency and amplitude required for maximum throughput and permeate quality from any given RO element (22) configuration.

WO 03/008076 A1



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

DUAL HEAD PUMP DRIVEN MEMBRANE SYSTEM

5

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Patent Application Serial No. 60/305,912, entitled "In-Line Reverse Osmosis Pump", filed on July 16, 2001, the specification of which is incorporated herein by reference.

GOVERNMENT RIGHTS

The U.S. Government Defense Advanced Research Projects Agency ("DARPA"), has a paid-up license in this invention and the right in limited circumstances to require the patent owner to license others on reasonable terms as provided for by the terms of Contract No. DABT63-98-C-0052 awarded by DARPA.

20

BACKGROUND OF THE INVENTIONField of the Invention (Technical Field):

The present invention relates to removing particulate and dissolved solids from water by spiral wrapped membrane elements utilizing a dual diaphragm pump system that incorporates pressure recovery, pulsing, fixed recovery (ratio of permeate to feed), and thin feed spacer spiral wrapped membrane elements. The maximum benefit of the system is achieved when reverse osmosis ("RO") is utilized as the membrane technology due to the high pressures inherent in RO membrane processes. However, the system of the present invention is also effective on microfiltration, ultrafiltration, and nanofiltration membrane systems. More particularly the present invention relates to alternative means to increase the production of potable water per unit size of membrane element and to reduce the energy cost per unit volume of water treated.

30

Background Art:

Prior art devices that engage in reverse osmosis filtration for water purification employ neither the present invention's differential pressure control nor its spring device method.

35

U.S. Patent No. 5,496,466, to Gray, discloses a portable water purification system with a double piston pump comprising a feed water piston in a feed water cylinder, a concentrate pumping section for removing concentrate from concentrate output, and a concentrate pumping section including a concentrate cylinder and piston wherein the pistons move in opposite axially directions. Gray does not teach differential pressure control or use of a spring or other mechanism for storing energy to average out the forces of the respective strokes. Further, Gray teaches use of a two-piston system only.

U.S. Patent No. 5,503,736, to Schoenmeyr, discloses a booster pump for a reverse osmosis water purification system wherein the pump has a spring return piston stroked by the pressure of feedwater and a pair of solenoid control valves (controlled by a piston position detector switch) that control the flow of feedwater into and out of the pump to move the piston between stroke and return positions. The Schoenmeyr patent, while disclosing a single piston, employs a two-headed piston with solenoid control valves and a control circuit system, unlike the differential pressure activated valve of the present invention.

Additional tangentially related prior art includes: U.S. Patent No. 5,589,066, to Gray; U.S. Patent No. 5,865,980 to Patapoff et al.; U.S. Patent No. 3,966,364, to Bachle et al.; U.S. Patent No. 5,531,887, to Miers; U.S. Patent No. 4,740,301, to Lopez; and U.S. Patent No. 3,830,372, to Manjikian.

SUMMARY OF THE INVENTION (DISCLOSURE OF THE INVENTION)

The present invention is of a pumping apparatus and method comprising: providing a dual head pump comprising a primary feed head comprising a feed diaphragm and a secondary retentate head comprising a retentate diaphragm; pumping fluid to at least one membrane surface; transferring force from the retentate diaphragm to the feed diaphragm to recovery energy; providing a fixed recovery via the two heads; and imparting a pulsing pressure wave on the membrane surface. In the preferred embodiment, pumping fluid comprises providing feed

fluid to a reverse osmosis membrane, preferably with at least one thin feed spacer element, and most preferably with at least one spiral wrapped element. Differential pressure is provided by a dual activated valve, pulsing is preferably hydraulic, and a plurality of membrane surfaces are provided, preferably wherein the spacing is reduced between the membrane surfaces to improve
5 diffusion.

Objects, advantages and novel features, and further scope of applicability of the present invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawing, and in part will become apparent to those skilled in the art upon
10 examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWING

15 The accompanying drawing, which is incorporated into and forms a part of the specification, illustrates one or more embodiments of the present invention and, together with the description, serves to explain the principles of the invention. The drawing is only for the purpose of illustrating one or more preferred embodiments of the invention and is not to be construed as
20 limiting the invention. In the drawings:

Fig. 1 is a block diagram of the overall system of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS (BEST MODES FOR CARRYING OUT THE INVENTION)

25 The present invention is of a motor driven dual headed pump that incorporates a differential pressure activated ("DPA") valve to provide a system that incorporates all of the innovations discussed previously. High Total Dissolved Solids ("TDS") feed water (e.g., seawater or brackish water) is sucked into the primary diaphragm head of a dual-headed diaphragm pump. The primary head of the pump is the larger of the two pump heads. Check valves on the inlet and
30 exit of the pump head force water to be directed in one direction only through the pump head. As feed water discharges through the primary pump head 28 (Fig. 1), the feed water enters the feed

end of the RO element housing. Water passes longitudinally through the RO element. A portion of the water passes through the membrane producing clean permeate water. The remaining water is higher TDS concentration (relative to the TDS of the feed water) that is retentate discharge from the RO element. The retentate is directed to the second, smaller diaphragm pump head. The ratio of the sizes of the pump heads explicitly define the recovery of the RO system. With the smaller pump head being, e.g., 70 percent, of the volume of the primary pump head, the recovery of the system is approximately 30 percent. In other words, 30 percent of the feed volume is forced through the membranes of the RO element, thereby producing a permeate volume that is 30 percent of the feed. Various recovery ratios may be used depending upon the configuration of the system, and the fluid being treated. This feature addresses a first benefit of the invention, namely, enhanced recovery.

Incorporating RO elements in the system with a thin feed spacer provide additional capacity to the system. By utilizing the thin spacer, the capacity of an existing RO plant is increased significantly by simply replacing existing technology RO elements with the thin feed spacer elements, and then adding the dual diaphragm pump system to provide the benefits of that system.

Diaphragm pumps produce an inherent pulse to the fluid flow stream. This is by virtue of the reciprocal motion of the pump stroke mechanism. In conventional diaphragm pumps, the stroke of the pump is controlled by an adjustable eccentric mechanism within the gear housing of the pump. This is usually controlled by a control knob or motor drive on the exterior of the pump. The frequency of the pump is controlled by the speed of the drive motor on the pump. Most diaphragm pumps manufactured today can be driven by a variable speed motor. This combination of stroke length and speed control allow variability of all key operational parameters that are important to optimizing the flow characteristics within the RO element. In addition, by monitoring torque on the pump drive motor, the stroke length and frequency are electronically optimized, or tuned, so that the optimal stroke and frequency are established for the RO element size and hydraulic system in question. The optimum conditions are achieved when the torque (or

load) on the motor is minimized at the rated flow rate of the membrane element. This feature addresses the benefits from fluid flow pulsing.

Another advantage is realized by connecting the two different sized pump diaphragms together. The feed pressure to the RO element is roughly equal to the retentate (or discharge) pressure from the RO element. Theoretically, flow through the feed spacer in the RO element is zero. Practically, there may be a pressure drop of ten percent across the element. For purposes of example, assume that there is no pressure drop across the element. This means that the same pressure is applied on the large diaphragm pump head as there is on the small diaphragm pump head. By connecting the two diaphragms with a common shaft, hydraulics in the pump heads set up so that force on the small head opposes, or offsets, the force on the large head. Therefore, the net working force on the pump is equal to the value of the recovery of the RO element. In the example discussed here, the force generated by the small pump head (70 percent) offsets the force on the large head (100 percent) so that the net force required to operate the system is 30 percent. This is defined as pressure recovery. Stated in another fashion, the energy required to operate the RO system is 30 percent of that required to operate a system that is comprised of one diaphragm. Indeed, conventional RO plants use high pressure pumps to provide the feed pressure for the RO elements, with no attempts to utilize pressure recovery. This feature alone can save 70 percent of the energy required to operate an RO plant.

20

Thin feed spacers that provide more element surface in the RO element, combined with pressure recovery, can easily produce a 100 percent improvement in kilowatt per gallon of water produced. Pulsing benefits are not impacted by these two features. Pulsing contributes additional benefits that are not degraded by the additional RO surface area or the pressure recovery features.

25

All five of the benefits discussed above are not necessarily mutually beneficial. For example, the benefits of diffusion may be offset by pulsing.

The system integrates five features, or combinations thereof, of membrane technology for water treatment. The five features comprise the use of: (1) thin feed spacer spiral wrapped elements; (2) enhanced recovery (ratio of feed to permeate); (3) diffusion effects; (4) fluid pulsing; and (5) pressure recovery. The system offers maximum benefit for reverse osmosis (RO) membranes due to the high working pressures associated with seawater desalination. Those of ordinary skill in the art of membrane technology will recognize that this system also has benefit for fluids other than water, and for membrane technology that includes microfiltration, ultrafiltration, and nanofiltration, in addition to the obvious advantages to RO technology.

The preferred embodiment is illustrated in Fig. 1. As shown therein, pump **20** comprises a diaphragm pump design with two diaphragm heads, primary or feed head **28**, and secondary or retentate head **30**. In an alternate embodiment, the pump can be a plunger type pump, a hydraulic activated diaphragm pump, a solenoid activated pump, or other configuration. One key feature of the preferred pump configuration is that the pump imparts a pulsing fluid and pressure wave on the fluid being transferred. Another primary feature of pump **20** is that pump feed diaphragm **72** and retentate diaphragm **70** are connected mechanically by shaft **38** or hydraulically in order that the fluid pressure acting on retentate head **30** transfers force to feed head **28**. The interconnectivity of feed diaphragm **72** and retentate diaphragm **70** ensures that fluid pressure on the left side (Fig. 1) of the diaphragm of retentate head **30** partially offsets fluid pressure on the right side of the diaphragm in feed head **28**. This feature provides pressure recovery and significantly reduces the total energy to operate the system versus a system that utilizes feed pressure only.

High TDS feed water (e.g., seawater) enters or is sucked into feed head **28** at feed head inlet port **34**. Lower TDS feed water (i.e., brackish water) or other waters of varying degrees of ion concentration also benefit from this system. Feed head inlet port **34** incorporates a check valve that prevents backflow of water out of feed head **28** during the pressure stroke of pump **20**. Fluid is compressed on the right side of feed diaphragm **72** and is expelled out of feed head discharge port **36**. Feed head discharge port **36** incorporates a check valve to prevent fluid

downstream of feed head **28** from returning to feed head **28** during the suction stroke of pump **20**. Fluid discharged from feed head **28** discharge port **36** is transferred to feed inlet port **60** on RO element **22**.

5 Benefits of thin feed spacer designs in RO elements are discussed below. These benefits include more membrane surface per RO element volume, concentration polarization reduction via TDS diffusion effects, and increased surface velocity and shear, all of which contribute to increased RO element throughput and product water quality. Although thin feed spacers are preferable in the system of the present invention, conventional feed spacer elements may also be
10 used. Thin feed spacer elements improve the overall efficiency and throughput of the system because there is more membrane area in the same element size housing.

Permeate, or product water, from RO element **22** is discharged through permeate water port **64**. High TDS retentate water is discharged from RO element **22** via retentate discharge
15 port **62**. Assuming no expansion of RO element **22** and hydraulic lock of the system (no air), the law of conservation of mass dictates that the volume of water entering RO element **22** inlet port **60** equals the sum of the volume of water discharged at permeate discharge port **64** and retentate discharge port **62**. Recovery in an RO element is defined as the volume of permeate (or product water) discharged from an RO element versus the feed water entering the element.
20 Therefore, the recovery of an RO element is explicitly defined by the ratio of the swept volume of pump **20** feed head **28** versus the volume of retentate head **30**. The difference in volume between the RO element feed volume and the retentate volume is the permeate, or product water, volume.

25 In order for energy recovery as well as fixed recovery (ratio of permeate to feed) to work, the discharge port retentate head **30** is closed in order for pressure to build up in the system. The ultimate pressure obtained is a function of the osmotic pressure of the feed water in RO element **22**. Closure of the discharge port of permeate pump head **30** is achieved with differential pressure activated (DPA) valve **24**. DPA valve **24** is activated by equal pressures applied across

different diameter ports in DPA valve **24**. Pressure is acted on the circular area of the back of piston **50** which is defined by the diameter of DPA valve bore **56**. The force on the back of piston **50** is defined by the pressure multiplied by the area. The force on the front of piston **50** is defined by inlet port **42** diameter **54** of DPA valve **24**. Since the pressures are unequal (feed and retentate), piston **50** is driven home with greater force on the rear of piston **50** to seal inlet port **42**. Port **42** remains sealed during the compression stroke of pump **20**. On the return stroke of pump **20**, pressure in the system is relieved and there is no net force applied to piston **50** in DPA valve **24** to seal port **42**. On the return stroke of pump **20**, fluid on the left side of diaphragm **70** is driven through port **42** of DPA valve **24** and is expelled out of retentate discharge port **46**. Fluid cannot back flow out of the inlet port of retentate head **30** since RO element **22** is a closed system and check valve **36** in feed head **28** will not allow return of fluid to feed head **28**.

The appropriate fluid pulse amplitude and frequency significantly improves permeate throughput and quality for any given unit area of membrane surface. Due to fluid dynamic considerations, the optimal fluid amplitude and frequency for any given RO element configuration is unique to that configuration. Amplitude of a diaphragm pump is defined by the stroke length of pump **20**. A shorter stroke produces less amplitude (volume of fluid per stroke). Stroke length (amplitude) is controlled on diaphragm pump **20** by virtue of manual or motor driven eccentric control knob **40**. Likewise, the frequency of the pump stroke is explicitly controlled by the rotational speed of pump motor **26**. By virtue of the appropriate controls, amplitude and frequency can be controlled either manually or electronically. By empirically determining the appropriate amplitude and frequency for a given RO element configuration, the correct amplitude and frequency can be dialed in manually to achieve optimal throughput and permeate quality. Conversely, a feedback control loop can be programmed into a computer to allow the pump to electronically optimize product throughput and quality.

The three key parameters are easily measured. First, energy into the system can be optimized by measuring the amperage load on pump motor **26**. Second, permeate, or product water, quality can be easily measured by conductivity meter **74** which measures the TDS in the

product water and verifies performance of RO elements. The third and final element is permeate flow rate. This is preferably measured by flow transmitter **76**. Likewise, since the recovery of the system is explicitly defined by the ratio of the swept volumes of feed head **28** versus retentate head **30**, then the permeate flow rate is easily determined by the frequency and amplitude of pump **20**. The frequency is electronically monitored by the speed of pump motor **26**, and the amplitude is preferably monitored by the motor position of stroke control knob **40**. Optimization control schemes use hardware and software programmable logic controllers ("PLC"). The system is preferably optimized by using a PLC to monitor the pump motor amplitude and speed, product water quality and flow rate to optimize the efficiency of the system.

10

Significant features of the system of the present invention are that the two interconnected heads of the pump simultaneously provide: (1) a fixed recovery (ratio of product water to feed water); (2) the two interconnected heads provide energy recovery by transferring force from the retentate diaphragm to the feed diaphragm; and (3) the pump imparts a pulsing pressure (and fluid) wave on the RO element.

15

Industrial Applicability:

The invention is further illustrated by the following non-limiting examples.

20

Examples

The present invention was developed under a contract funded the U.S. Department of Defense's Defense Advanced Research Projects Agency ("DARPA") to produce a small portable system that will allow individual soldiers to treat any water anywhere to drinking water quality. The research did not focus on membrane chemistry, but rather construction and hydraulic flow characteristics of spiral-wrapped RO element designs. Concurrent with design of the RO elements, a hand pump device was developed that utilizes various features including a simple differential pressure activated valve to produce pressure recovery in the pump to significantly reduce the applied force required to operate the pump.

30

Advantages of the invention, as demonstrated by the research, include as follows:

Enhanced Recovery. Recovery is defined as the amount of permeate water (clean
5 product water) divided by the volume of feed water that enters an RO element. Typically, RO
elements operating on seawater utilize a recovery of 10 percent or less. Extensive tests were
conducted on the membranes to determine the amount of water that can be driven through a
membrane and still produce acceptable quality permeate. These studies showed that a 30
percent recovery was feasible using the present invention.

10

Thin Feed Spacer. The feed spacer in a spiral wrapped RO element was constructed of a
plastic web mesh that held the faces of the membranes apart so that feed water could flow
longitudinally down the length of the element with minimal pressure loss while allowing the water
to cross the membrane. On the opposite side of the membrane leaf was the permeate carrier.
15 The permeate carrier was a porous but more structurally rigid material that withstood compression
from the membrane surface, but allowed the permeate to flow spirally to a central collection tube
where the permeate was collected. Current construction techniques limit existing feed spacer
thickness to approximately .011 inches thick. Most RO elements utilize feed spacers that are
approximately .025 inches thick. Hydraulic calculations indicated that a feed spacer that is .003
20 inches thick is adequate to allow flow through the element. The primary advantage of a thin feed
spacer is that more membrane element material can be wrapped into a smaller diameter RO
element housing, thereby significantly increasing the membrane surface in the RO element. More
membrane surface equates to more product water throughput.

25 Diffusion Effect. Concentration polarization is defined as the buildup, or accumulation, of
total dissolved solids (TDS) at the surface of the membrane. As water molecules flow through the
membrane surface, ions are rejected and are retained on the feed side of the membrane material.
This accumulation of ions represents an increase in the TDS at the surface of the membrane,
thereby increasing the osmotic pressure required to drive the water molecules through the

membrane surface. The negative result is higher operating pressures and lower production. Diffusion effects (tendency of molecules to diffuse uniformly in a solution) were improved with reduced separation between the membrane faces. Coincidentally, diffusion effects were dramatically improved when the separation between the membrane surfaces approached 0.003
5 inches. Improved diffusion resulted in reduced concentration polarization resulting in higher permeate quality and throughput. Another feature of thin feed spacers that is conducive to lower TDS is the increased fluid shear which is produced with higher fluid velocity that results from equivalent volumes of feed water traversing a thinner feed spacer thickness.

10 Hydraulic Feed Water Pulsing. Pulsing of the feed stream to an RO element has a beneficial effect for reduction of concentration polarization, and subsequent improvement in product water throughput. Tests conducted verified this effect, and show improvements, in some cases, greater than 100 percent in product water throughput versus steady flow. These same tests also demonstrated applied pressure reductions of 18 to 19 percent. In other words, in
15 steady flow tests, 800 psi is required to produced acceptable quality permeate. With pulsing, the mean operating pressure to produce the same permeate volume and quantity was 650 psi. Each RO element physical configuration had an optimal frequency and fluid amplitude to achieve maximum performance.

20 Pressure Recovery via Differential Pressure Activated ("DPA") Valve. During development of the hand held manual RO pump of the invention, a DPA valve was developed that significantly simplified the design of a hand-held RO pump and enabled a pressure recovery feature that significantly reduced the force required to operate the pump. This pump had only three metal parts, namely three stainless steel springs that acted to load check valves in the
25 pump. All other components of the pump were injection molded, thereby producing a simplified RO hand-held pump that is a low cost and therefore is disposable.

The preceding examples can be repeated with similar success by substituting the generically or specifically described reactants and/or operating conditions of this invention for those used in the preceding examples.

5 Although the invention has been described in detail with particular reference to these preferred embodiments, other embodiments can achieve the same results. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover in the appended claims all such modifications and equivalents. The entire disclosures of all references, applications, patents, and publications cited above are hereby incorporated by
10 reference.

CLAIMS

What is claimed is:

5

1. A dual head pump comprising:

a primary feed head comprising a feed diaphragm;

a secondary retentate head comprising a retentate diaphragm, said

10 retentate diaphragm operatively connected to said primary feed diaphragm wherein said two heads provide a fixed recovery;

at least one membrane surface; and

a pulsing mechanism which imparts a pulsing pressure wave on said

15 membrane surface;

wherein said two heads provide an energy recovery by transferring force from said retentate diaphragm to said feed diaphragm.

2. The pump of claim 1 wherein said membrane surface comprises a reverse

20 osmosis membrane, preferably further comprising at least one thin feed spacer element, and preferably wherein said spacer comprises at least one spiral wrapped element.

3. The pump of claim 1 further comprising a differential pressure activated valve in communication with said secondary retentate head for providing said energy recovery.

25

4. The pump of claim 1 wherein said pulsing mechanism comprises a hydraulic pulsing mechanism.

5. The pump of claim 1 wherein said at least one membrane surface comprises a

30 plurality of membrane surfaces, preferably wherein a spacing between said plurality of membrane surfaces is reduced to improve diffusion.

6. A pumping method comprising the steps of:

35

providing a dual head pump comprising:

a primary feed head comprising a feed diaphragm; and

a secondary retentate head comprising a retentate diaphragm;
pumping fluid to at least one membrane surface;
5 transferring force from the retentate diaphragm to the feed diaphragm to
recovery energy;
providing a fixed recovery via the two heads; and
imparting a pulsing pressure wave on the membrane surface.

10 7. The method of claim 6 wherein the step of pumping fluid comprises providing
feed fluid to a reverse osmosis membrane, preferably wherein the step of pumping fluid
comprises providing at least one thin feed spacer element, and preferably wherein at least one
thin feed spacer element comprises at least one spiral wrapped element.

15 8. The method of claim 6 further comprising the step of providing a differential
pressure, preferably wherein the step of providing a differential pressure comprises providing a
dual activated valve.

20 9. The method of claim 6 wherein the step of providing pulsing comprises providing
hydraulic pulsing.

25 10. The method of claim 6 wherein the step of providing at least one membrane
surface comprises providing a plurality of membrane surfaces, preferably wherein the step of
providing a plurality of membrane surfaces comprises reducing the spacing between the
membrane surfaces to improve diffusion.

AMENDED CLAIMS

[received by the International Bureau on 03 December 2002 (03.12.02)
original claims 1, 6, amended; remaining claims unchanged (2 pages)]

5

What is claimed is:

1. A dual head pump comprising:
 - 10 a primary feed head comprising a feed diaphragm;
a secondary retentate head comprising a retentate diaphragm, said retentate diaphragm operatively connected to said primary feed diaphragm wherein said two heads provide a fixed recovery;
 - 15 at least one membrane surface; and
a pulsing mechanism which imparts a pulsing pressure wave on said membrane surface;
 - wherein said two heads comprise differing radii and provide an energy recovery by transferring force from said retentate diaphragm to said feed diaphragm.
- 20 2. The pump of claim 1 wherein said membrane surface comprises a reverse osmosis membrane, preferably further comprising at least one thin feed spacer element, and preferably wherein said spacer comprises at least one spiral wrapped element.
- 25 3. The pump of claim 1 further comprising a differential pressure activated valve in communication with said secondary retentate head for providing said energy recovery.
4. The pump of claim 1 wherein said pulsing mechanism comprises a hydraulic pulsing mechanism.
- 30 5. The pump of claim 1 wherein said at least one membrane surface comprises a plurality of membrane surfaces, preferably wherein a spacing between said plurality of membrane surfaces is reduced to improve diffusion.

- 5 6. A pumping method comprising the steps of:
providing a dual head pump comprising:
a primary feed head comprising a feed diaphragm; and
a secondary retentate head comprising a retentate diaphragm
wherein the heads comprise differing radii;
- 10 pumping fluid to at least one membrane surface;
transferring force from the retentate diaphragm to the feed diaphragm to
recovery energy;
- 15 providing a fixed recovery via the two heads; and
imparting a pulsing pressure wave on the membrane surface.
7. The method of claim 6 wherein the step of pumping fluid comprises providing feed
fluid to a reverse osmosis membrane, preferably wherein the step of pumping fluid comprises
20 providing at least one thin feed spacer element, and preferably wherein at least one thin feed spacer
element comprises at least one spiral wrapped element.
8. The method of claim 6 further comprising the step of providing a differential
pressure, preferably wherein the step of providing a differential pressure comprises providing a dual
25 activated valve.
9. The method of claim 6 wherein the step of providing pulsing comprises providing
hydraulic pulsing.
- 30 10. The method of claim 6 wherein the step of providing at least one membrane surface
comprises providing a plurality of membrane surfaces, preferably wherein the step of providing a
plurality of membrane surfaces comprises reducing the spacing between the membrane surfaces to
improve diffusion.

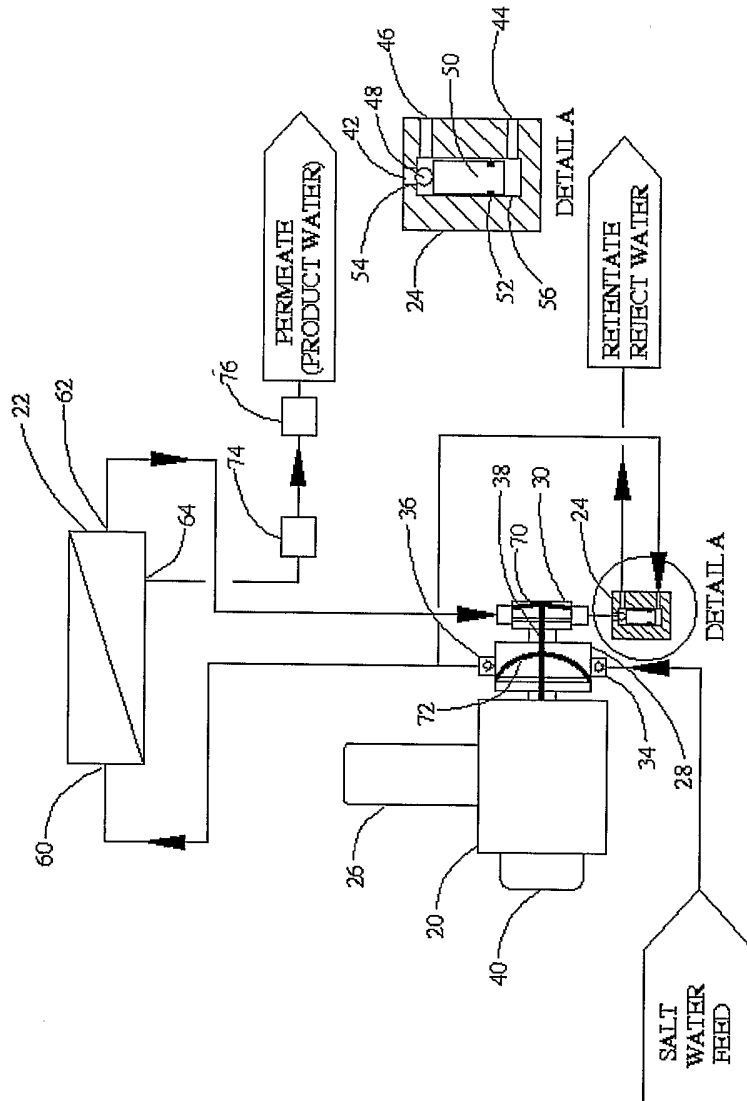


FIG. 1 DUAL DIAPHRAGM PUMP DRIVEN MEMBRANE SYSTEM

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US02/22618

A. CLASSIFICATION OF SUBJECT MATTER
 IPC(7) : B01D 63/00, 61/00, 61/02; C02F 9/00, 1/44; F04B 49/00, 25/00, 3/00, 5/00, 17/00, 35/00
 US CL : 210/650-653, 258-260, 321.76, 321.85, 91, 416.1, 416.3; 417/63, 262,403
 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)
 U.S. : 210/650-653, 258-260, 321.76, 321.85, 91, 416.1, 416.3; 417/63, 262,403

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)
 DERWENT, GOOGLE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---	US RE. 32,144 A (KEEFER) 13 May 1986 (13-5-1986), entire specification, figures	1,3,4,6,8,9
Y		1-10
X ---	US 4,187,173 A (KEEFER) 05 February 1980 (05-2-1980), entire specification and figures	1,3,4,6,8,9
Y		1-10
Y	US 6,017,200 A (CHILDS et al) 25 January 2000 (25-1-2000), Figures, col 1 line 5 - col 12 line 20	1-10
Y	US 5,496,466 A (GRAY) 05 March 1996 (05-3-1996), Figures, col 3 line 3-line 60, col 4 line 25-col 5 line 15	1-10
Y	US 4,288,326 A (KEEFER) 08 September 1981 (08-9-1981), Figure 1, col 5 line 20 - col 9 line 50	1-10
Y	US 5,503,736 A (SCHOENMEYER) 02 April 1996 (02-4-1996), entire specification	1-10
Y	US 6,203,696 B1 (PEARSON) 20 March 2001 (20-3-2001), entire specification	1-10

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:	"T"
"A" document defining the general state of the art which is not considered to be of particular relevance	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search: 11 September 2002 (11.09.2002)
 Date of mailing of the international search report: 03 OCT 2002

Name and mailing address of the ISA/US: Commissioner of Patents and Trademarks, Box PCT, Washington, D.C. 20231, Facsimile No. (703)305-3230
 Authorized officer: Krishnan S Menon (Signature), Telephone No. 703-308-0661

INTERNATIONAL SEARCH REPORT

PCT/US02/22618

C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,531,887 A (MIERS) 02 July 1996 (02-7-1996), entire specification	1-10
Y	US 4,861,487 A (FULK, Jr) 29 August 1989 (29-8-1989), col 4 line 61 - col 5 line 27	2,5,7,10