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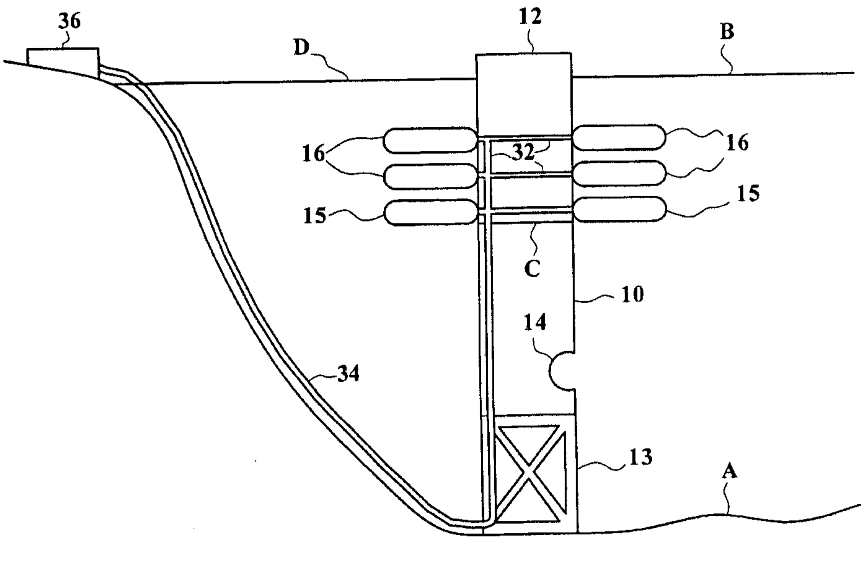

(57) Abstract

An apparatus and method of removing salt from seawater to produce potable freshwater. A large metal cylinder (12), with open top and bottom ends, is anchored to the sea floor offshore. Several pressure hulls (15, 16) are attached to the side of the cylinder. The interior of each pressure hull is maintained at about one atmosphere, but the hulls are submerged at a depth at which the ambient water pressure is several atmospheres. Within each pressure hull there are several reverse osmosis devices ("RODs") (20). Check valves (30) allow seawater to pass from outside the hulls into the RODs. Due to the pressure differential, freshwater passes through the membranes (22) of the RODs by reverse osmosis, and is pumped out of the pressure hulls to a storage facility (36) onshore.

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SEAWATER PRESSURE-DRIVEN DESALINIZATION APPARATUS AND METHOD WITH GRAVITY-DRIVEN BRINE RETURN

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a reverse osmosis method of removing the salt from water in the ocean or inland bodies of salt water, using the pressure of the seawater itself, and the force of gravity.

2. DESCRIPTION OF THE PRIOR ART

Due to the shortage of freshwater in the southwestern United States and other arid parts of the world, there have been numerous inventions for desalinating sea water, by reverse osmosis, distillation, and other means. However, desalinization remains an expensive process. The concentrated brine produced as a by-product of desalinization can itself contribute to pollution of the environment in onshore facilities. The production of electricity or other forms of energy consumed in desalinization can also contribute to pollution of the air, water and land.

U.S. Patent No. 4,335,576, issued on June 22, 1982, to Harold H. Hopfe, discloses a device for producing freshwater from seawater which floats on the surface of the sea. It derives the energy for desalinization from the motion of the waves on the surface of the water. Movement of the water on the surface causes reaction plates to move, and the movement is ultimately transmitted to pistons that move in cylinders to exert pressure on seawater to force reverse osmosis.

U.S. Patent No. 4,452,969, issued on June 5, 1984, to Fernand Lopez, discloses a reverse osmosis apparatus for producing freshwater from seawater, which is designed to be temporarily submerged, as on a fishing line. U.S. Patent No. 4,770,775, issued on September 13, 1988, to Fernand Lopez, discloses another apparatus for the production of freshwater from seawater, which is also designed to be temporarily submerged, and has a chamber that expands as freshwater is produced. Both of these apparatuses use the pressure of the seawater itself to force reverse osmosis.

U.S. Patent No. 5,167,786, issued on December 1, 1992, to William J. Eberle, discloses a wave power collection apparatus, which is anchored in the sea floor, and in one embodiment desalinates seawater by reverse osmosis. The movement of floats is used in that embodiment to turn a generator which produces electricity to power pumps that force seawater through a membrane in a reverse osmosis unit.

U.S. Patent No. 5,229,005, issued on July 20, 1993, to Yu-Si Fok and Sushil K. Gupta, discloses a process for the desalinization of seawater, by lowering reverse osmosis devices into the ocean by means of lines attached to pulleys, and raising them again by the same means to remove the freshwater produced. The pressure of the seawater itself is used to force reverse osmosis of the seawater across a membrane to produce freshwater.

U.S. Patent No. 5,366,635, issued on November 22, 1994, to Larry O. Watkins, discloses a desalinization apparatus and means in which a separator is placed on the sea floor, and the pressure at the sea floor is used to force seawater through a membrane to form freshwater by reverse osmosis, which is then pumped out.

British Patent No. 2,068,774, published on August 19, 1981, to Jose Luis Ramo Mesple, discloses an apparatus for desalinating water by reverse osmosis in cells located deep underground, utilizing the pressure resulting from the water being deep underground.

The present invention is distinguishable from the prior art cited, in that only it takes advantage of the fact that the concentrated brine produced as a by-product of reverse osmosis desalinization is heavier than seawater to reduce the energy consumed in desalinization. None of the above inventions and patents, taken either singly or in combination, will be seen to describe the present invention as claimed.

SUMMARY OF THE INVENTION

The present invention is an apparatus and method of removing salt from seawater to produce potable freshwater. A large metal cylinder, with open top and bottom ends, is anchored to the floor of the ocean (or inland sea) offshore. Several pressure hulls are attached to the side of the cylinder. The interior of each pressure hull is maintained at about one atmosphere of pressure, but the hulls are submerged at a depth at which the ambient water pressure is several atmospheres. Within each pressure hull there are several reverse osmosis devices ("RODs"), each containing a membrane that will allow water molecules, but not sodium and chlorine ions, to pass through. Check valves allow sea water to pass from outside the hulls into the RODs. Due to the pressure differential, water molecules pass through the membranes by reverse osmosis, while salt is left behind, and freshwater is pumped out of the pressure hulls to a storage facility on shore (or where ever else it is needed). Initially, the seawater remaining on the other side of the membrane, which has a greatly increased concentration of salt due to water passing through the membrane, is pumped into the cylinder. (The water with an increased concentration of salt is hereinafter referred to as "brine".) After an initial surge, the level of the brine in the cylinder will eventually reach equilibrium, at a height below the height of the seawater outside the cylinder, due to the greater weight of the brine compared to unconcentrated seawater. After equilibrium is reached, the pumps for the brine can be turned off, as gravity will cause it to flow down from the pressure hulls to the surface of the brine in the cylinder. This will reduce the energy needed to desalinate seawater. (It will still be necessary to pump out the freshwater.)

Accordingly, it is a principal object of the invention to provide a means for reducing the energy required to desalinate seawater. Conventional desalinization plants, located on or near the seashore, require four pumping processes: first, pumping the seawater to the plant; second, pumping to raise the pressure high enough for the RODs to operate; third, pumping the brine back out to sea; and fourth, pumping the freshwater to a reservoir or a treatment facility for further purification, and ultimately to the consumer. The present invention eliminates all but the fourth pumping process. While prior inventions of offshore desalinization apparatus, as in U.S. Patent No. 5,366,635 to Watkins, will also eliminate the first and second processes, only the instant invention will also eliminate the third process of pumping out the brine, without requiring that energy be expended in raising the RODs, as in U.S. Patent No. 4,452,969 to Lopez and U.S. Patent No. 5,229,005 to Fok et al.

It is second object of the invention to provide a means for reducing the need for using expensive real estate on or near the oceanfront for desalinization facilities. As no oceanfront or near-oceanfront property is used exclusively for the process, most real estate costs associated with desalinization plants can be avoided. Some offshore site leasing may be required, but this cost should be much lower than for offshore sites involved in petroleum or mineral extraction.

It is a third object of the invention to provide a means for making the expansion of desalinization facilities easier and less expensive. As no dry land is used, and each platform must have a clear navigation zone around it (as most jurisdictions require by law), sufficient space for attaching additional pressure hulls to the cylinder will be available and facility expansion considerably eased. The expansion of a facility is limited only by the number of pressure hulls that can be fitted onto the cylinder at appropriate depths, rather than allowances made by a zoning commission with many other constituents to satisfy, as may the case with a land-based desalinization facility.

It is a fourth object of the invention is to provide a means for reducing the cost of desalinizing seawater by centralizing maintenance facilities, as the pressure hulls can be removed and taken to a central facility for maintenance, rather than the on-site maintenance required by conventional shore-based desalinization plants.

It is a fifth object of the invention to reduce pollution of the shoreline from the release of concentrated brine by desalinization plants. Conventional onshore desalinization facilities pump their brine out to sea through a bottom-laid pipeline, which releases the brine on or near the ocean floor. Releasing the brine near the ocean floor increases the area affected by the brine's toxicity. Existing methods to reduce the toxic effects add to the cost of desalinization through greater plant infrastructural requirements or reduced process efficiency. The present invention allows an offshore desalinization facility to release its brine into mid-water, where mixing with the ocean current is more efficient, with fewer effects upon bottom-dwelling flora and fauna. Because the facility can be located offshore, ocean currents and tidal action will thoroughly mix the brine back into the surrounding seawater, and the overall impact of increased salinity from the brine release could be infinitesimal as little as two or three kilometers down-current.

It is an object of the invention to provide improved elements and arrangements thereof in an apparatus for the purposes described which is inexpensive, dependable and fully effective in accomplishing its intended purposes.

These and other objects of the present invention will become readily apparent upon further review of the following specification and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic environmental front elevational view of the first preferred embodiment of the invention.

Fig. 2 is a schematic environmental front elevational view of the second preferred embodiment of the invention.

Fig. 3 is a schematic environmental front elevational view of the third preferred embodiment of the invention.

Fig. 4 is a schematic cross-sectional view of one of the pressure hulls of the first type that may be used in any of the preferred embodiments of the invention.

Fig. 5 is a schematic cross-sectional view of one of the pressure hulls of the second type that may be used in any of the preferred embodiments of the invention.

Similar reference characters denote corresponding features consistently throughout the attached drawings.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is an apparatus and method of removing salt from seawater to produce potable fresh water. It may be used in either the oceans or in inland bodies of salt water.

Fig. 1 is a schematic environmental front elevational view of the first preferred embodiment of the invention. A large metal cylinder **10**, with an open top end **12** and an bottom opening **14**, rests on platform **13** which is anchored to the floor **A** of the ocean **B** (or inland sea) offshore. (Alternatively, a tube or channel of a different shape and/or with a plurality of top openings and/or a plurality of bottom openings may be used. Also, the apparatus can be supported by flotation devices, or by cables attached to ships, rather than resting on the sea floor.) Bottom pressure hulls **15** are removably attached to the side of the cylinder, just above the equilibrium level **C** of brine in the cylinder. When greater production capacity is needed, upper pressure hulls **16** are added.

Fig. 2 is a schematic environmental front elevational view of the second preferred embodiment of the invention, which is the same as the first preferred embodiment, except that the bottom of the cylinder rests directly on the sea floor.

Fig. 3 is a schematic environmental front elevational view of the third preferred embodiment of the invention, which is the same as the second preferred embodiment, except that brine pipe **35** projects over a cliff **E** in the sea floor. This embodiment may be used in areas such as the Red Sea where the submarine topography makes it possible. Sending the brine over a submarine cliff will make possible more efficient mixing of the brine with the sea water.

Fig. 4 is a schematic cross-sectional view of one of the pressure hulls of the first type that may be used in any of the preferred embodiments of the invention. The fresh water enclosure **18** in the interior of each pressure hull is maintained at a pressure below that of the ambient seawater, preferably at one atmosphere of pressure, but the hulls are preferably submerged at a depth at which the ambient water pressure is several atmospheres. Within each pressure hull there are several reverse osmosis devices **20** ("RODs"), each having a selectively permeable membrane **22** surrounding a brine enclosure **24**. The membrane allows water molecules, but not sodium and chlorine ions, to pass through. (Other substances may also be filtered out of the seawater, depending on the characteristics of the membrane.) The pressure hulls have an external skin **26** which is impermeable to water. Seawater conduits **28**, having check valves **30,** pass through the external skin and the membranes, to allow seawater to pass from outside the hulls into the RODs. The check valves enhance the efficiency of the process, by preventing brine from returning directly to the surrounding seawater by the same route. The space between the external skin and the other contents of the pressure hulls forms the fresh water enclosure **18**. Due to the pressure difference, water molecules pass through the membranes by reverse osmosis, and desalinated water is pumped out of the pressure hulls through the freshwater conduit **32** and (referring back to Fig. 1) pipeline **34** to an onshore storage facility **36** (or where ever else it is needed). The freshwater conduit should be external to the cylinder, as concentrated brine is highly corrosive. Freshwater pumps (not shown in the drawings) may be located in the storage facility, the pipeline, the cylinder, and/or elsewhere. The pumping out of the freshwater maintains the pressure difference across the membrane, so that reverse osmosis can continue. The desalinated water may undergo further purification at a local water treatment plant.

Fig. 5 is a schematic cross-sectional view of one of the pressure hulls of the second type that may be used in any of the preferred embodiments of the invention. It differs from the first type in having a dry interior **42**, which is kept dry by an air vent **44** to the atmosphere above the surface **D** through which any moisture evaporates. The RODs are enclosed by water proof surfaces **46**. Freshwater is drained from the RODs by freshwater pipes **48** which are connected to the fresh water conduit **32**.

Initially, the seawater remaining on the other side of the membranes ("brine"), which has a greatly increased concentration of salt due to water passing through the membranes, is pumped into the cylinder by the brine pumps **38** through the brine conduits **40** (see Fig. 4). At least one of the brine pumps is preferably located in each pressure hull, as shown, but other locations are possible. The pumping out of the brine maintains a pressure difference across the seawater conduits, causing seawater to continue to flow into the reverse osmosis devices. After an initial surge, the level of the brine **C** in the cylinder will eventually reach equilibrium at an elevation below the sea level **D** outside the cylinder (see Fig. 1), due to the greater weight of the brine compared to unconcentrated seawater. After equilibrium is reached the pumps for the brine can be turned off, as gravity will cause it to flow down from the hulls to the surface of the brine in the cylinder. This will reduce the energy needed to desalinate seawater. (It will still be necessary to pump out the freshwater.) The lower pressure hulls **15** should be attached to the cylinder first, as the pressure difference will be greatest just above the brine level **C**. (While the pressure difference would be greater at lower depths, gravity will not cause brine to flow out of the pressure hulls if they are below the brine's surface.) When greater capacity is needed, the upper hulls **16** should be added, desalinization will not be as efficient in them, as the pressure difference will be lower.

The earth's gravity will cause the brine in the tube to flow out of the bottom opening until the weight of the brine in the tube equals the weight of an equivalent column of water in the sea outside the tube. As brine continually flows into the tube when the invention is in operation, the weight of the brine in the tube will continue to be heavier than that an equivalent column of seawater outside, and brine will continue to flow out. If there were no currents in the sea, the salinity of the sea in the immediate area around the tube could eventually rise to almost the degree of salinity in the tube (though not to complete equality, due to diffusion of salt through the seawater). This would cause the level of brine in the tube to rise to almost the level of the sea outside the tube, and it would be necessary to reactivate the brine pumps for desalinization to continue. (This might actually happen in inland bodies of salt water, which lack drainage to the oceans, if desalinization were carried out on a massive scale over a long period of time.) Thus, the present invention derives its energy savings, not out of nothing, as would a perpetual motion machine, but from the force of the earth's gravity, from ocean currents and interlayer mixing that are driven by electromagnetic radiation produced by nuclear reactions in the sun, and from diffusion made possible by random movements of molecules and ions in the seawater that are also driven by heat from the sun.

It is to be understood that the present invention is not limited to the embodiments described above, but encompasses any and all embodiments within the scope of the following claims. Although the method of the invention is primarily intended as a means for desalinating seawater, it can also be used to remove a purified solvent from any solution, where a solution with a higher concentration of solute is denser than a solution with a lower concentration of solute. An apparatus similar to the preferred embodiment, but smaller in size, may be useful in chemistry laboratories and chemical processing plants.

MATHEMATICAL APPENDIX

In the following discussion, let:

P_d = Process depth

P_e = Process efficiency (1.0 = 100% efficiency)

d_f = Density of fresh water (999.97 kilograms per cubic meter at four degrees Celcius)

d_s = Density of sea water (1,025 kilograms per cubic meter at four degrees Celcius)

d_b = Density of brine (variable dependant upon process efficiency)

h_s = Height of a seawater column (in meters)

h_b = Height of a brine column (in meters)

For brine to flow out of the cylinder by the force of gravity, the pressure of the brine column must exceed the pressure of the seawater at the same depth as the cylinder's bottom opening:

(1) $d_b h_b > d_s h_s$

The brine density may be calculated from the process efficiency and the densities of freshwater and seawater as follows:

(2) $d_b = d_f + [(d_s - d_f)/(1 - P_e)]$

Alternatively, the brine's density will equal the density of the freshwater plus the concentration of Total Dissolved Solids ("TDS") in the remaining fluid. The concentration of TDS in seawater is given by:

(3) $TDS_{seawater} = (d_s - d_f)$

Dividing equation (3) by 1 - P_e gives the concentration factor. E.g., an 80% efficient process (P_e = 0.80) will concentrate the TDS of 100 cubic meters of seawater into 20 cubic meters of brine and produce 80 cubic meters of freshwater:

(4) 1.00 - 0.80 = 0.20

with the TDS concentration of the brine being five times that of seawater, as dividing by 0.20 is equivalent to multiplying by five. Thus, the TDS load in the brine is given by:

(5) $[(d_s - d_f)/(1 - P_e)]$

Adding the TDS load for the brine to the density of freshwater gives the total density of the brine:

(6) $d_b = d_f + [(d_s - d_f)/(1 - P_e)]$

which is identical to equation (2).

The process depth may be determined by the desired operating pressure for the desalinization process. If a pressure of four atmospheres (4.05 bars or 58.8 pounds per square inch) is desired, then the process must operate at a depth of forty meters below mean low tide. For every increase or decrease of one atmosphere (1.013 bars or 14.7 pounds per square inch) in the process operating pressure the process depth must change by approximately ten meters.

For any process depth and any process efficiency, the range of allowable depths for the bottom opening of the cylinder is given by the following inequality:

(7) $h_b > P_d(d_s/d_b)/(1 - d_s/d_b)$

This inequality is derived as follows: We seek the depth at which the pressure of the brine column exceeds that of the seawater column, i.e., when the following inequality is satisfied:

(8) $d_b h_b > d_s h_s$

We know that the height of the seawater column is the same or greater than the height of the brine column plus the process depth:

(9) $h_s > h_b + P_d$

An inequality is preferred to an equation to allow a safety factor for brine density fluctuations. Substituting inequality (9) into inequality (8), we get:

(10) $d_b h_b > d_s(h_b + P_d)$

Isolating the height of the brine column, we get:

$h_b > d_s(h_b + P_d)/d_b = h_b(d_s/d_b) + P_d(d_s/d_b)$

Subtracting $h_b(d_s/d_b)$ from both sides of the inequality gives:

$h_b(1 - d_s/d_b) > P_d(d_s/d_b)$

Dividing both sides of the inequality by $(1 - d_s/d_b)$ gives:

(11) $h_b > P_d(d_s/d_b)/(1 - d_s/d_b)$

which is the same as inequality (7).

E.g., for a process which is 80% efficient, operating at a depth of 40 meters, we first use equation (2) to determine the brine's density:

$$d_b = d_f + [(d_s - d_f)/(1 - P_e)]$$
$$= 999.97 + (1{,}025.00 - 999.97)/(1 - 0.80)$$
$$= 999.97 + (25.03/0.20)$$
$$= 999.97 + 125.15$$
$$= 1{,}125.12 \text{ kg/m}^3$$

Substituting the value of 1,125.12 kg/m^3 into inequality (7) gives:

$$h_b > P_d(d_s/d_b)/(1 - d_s/d_b)$$
$$> 40(1{,}025.00/1{,}125.12)/(1 - 1{,}025.00/1{,}125.12)$$
$$> 409.51 \text{ meters}$$

Thus, the depth of the bottom opening in the cylinder must be at least 409.51 + 40.00 = 449.51 meters below the surface of the surrounding seawater (at mean low tide). Adding a ten percent safety factor (about 40.1 meters) increases this difference to approximately 490 meters. We can check this result by comparing the difference between the pressures of the seawater column at 490 meters and the brine column at

450 meters (with the 10% safety factor) with the difference between the pressures of the seawater column at 450 meters and the brine column at 410 meters (without the 10% safety factor):

With the safety factor:

$d_b h_b - d_s h_s = (1{,}125\text{kg/m}^3)(450\text{m}) - (1{,}025.00\text{kg/m}^3)(490\text{m})$

$= (506{,}304.0 - 502{,}250.0)\ \text{kg/m}^2$

$= 4{,}054.0\ \text{kg/m}^2$

Without the safety factor:

$d_b h_b - d_s h_s = (1{,}125\text{kg/m}^3)(410\text{m}) - (1{,}025.00\text{kg/m}^3)(450\text{m})$

$= (461{,}299.2 - 461{,}250.0)\ \text{kg/m}^2$

$= 49.2\ \text{kg/m}^2$

The fact that the difference is positive in both cases ensures an outward flow of brine. These depths and pressures are well within the state of the art in off-shore platform construction and operation. The desalinated water will need to be pumped out of the pressure hulls with sufficient pressure to overcome the difference in hydraulic head, its own viscosity, and the friction in the pipeline through which it is carried to shore. This is a proven engineering task that is well with our current capabilities.

CLAIMS

I claim:

1. An apparatus for desalinating seawater, comprising:

at least one membrane through which water molecules can flow, but through which sodium and chlorine ions cannot flow;

at least one fresh water enclosure, within which water that has been desalinated by passing through at least one membrane, can be collected and separated from salt water;

at least one brine enclosure, within which water that has not passed through at least one membrane, and has an increased concentration of salt, can be collected and separated from water with a lower concentration of salt;

a channel having at least one top opening and at least one bottom opening; and

at least one brine conduit between at least one brine enclosure and the channel.

2. The apparatus for desalinating seawater according to claim 1, wherein:

at least one membrane and at least one freshwater enclosure are positioned far enough below the surface of a body of salt water, that there is a sufficient pressure difference across the membrane for water to be desalinated by reverse osmosis and to collect in the freshwater enclosure;

the top openings of the channel are positioned above the surface of a body of water;

the bottom openings of the channel are positioned below the surface of the body of water and below at least one brine enclosure and at least one brine conduit; and

at least one brine enclosure and at least one brine conduit are positioned above a level at which water having an increased concentration of salt will reach equilibrium in the channel.

3. The apparatus for desalinating seawater according to claim 2, further comprising:

at least one freshwater pump for removing desalinated water from at least one freshwater enclosure; and

at least one brine pump for removing water having an increased concentration of salt from at least one brine enclosure, until the level of water having an increased concentration of salt has reached equilibrium in the channel.

4. The apparatus for desalinating seawater according to claim 3, further comprising:

at least one pressure hull, retained on the channel, and containing at least one membrane, at least one brine enclosure, and at least one freshwater enclosure;

at least one seawater conduit, through which water exterior to the pressure hull can flow into at least one brine enclosure; and

at least one check valve in at least one seawater conduit, that prevents water from flowing from the brine enclosure back through the seawater conduit.

5. The apparatus for desalinating seawater according to claim 4, wherein there are a plurality of pressure hulls.

6. The apparatus for desalinating seawater according to claim 5, wherein the channel has only one top opening and only one bottom opening, and the channel is impermeable to water except at the top opening and the bottom opening.

7. The apparatus for desalinating seawater according to claim 6, wherein each pressure hull has an external skin that is impermeable to water.

8. The apparatus for desalinating seawater according to claim 7, wherein each pressure hull has

a plurality of reverse osmosis devices, with each of the reverse osmosis devices comprising one of the brine enclosures surrounded by one of the membranes, with a seawater conduit for each reverse osmosis device passing through the external skin of the pressure hull and the membrane.

9. The apparatus for desalinating seawater according to claim 8, wherein each pressure hull has one of the brine pumps, and internal brine conduits through which water can flow from the brine enclosures to the brine pump.

10. The apparatus for desalinating seawater according to claim 9, wherein each pressure hull has only one fresh water enclosure, which is formed by the external skin, and occupies space between the external skin and the reverse osmosis devices, the internal brine conduits, and the brine pump, with a freshwater conduit passing through the external skin through which desalinated water can be pumped out.

11. The apparatus for desalinating seawater according to claim 10, wherein the freshwater pump maintains water pressure within the pressure hulls lower than water pressure outside the pressure hulls.

12. The apparatus for desalinating seawater according to claim 11, wherein the water pressure within the pressure hulls is equivalent to pressure at the surface of the sea.

13. The apparatus for desalinating seawater according to claim 9, wherein each reverse osmosis device is surrounded by a water proof surface connected by a freshwater pipe to a freshwater conduit passing through the external skin through which desalinated water can be pumped out.

14. The apparatus for desalinating seawater according to claim 13, wherein each pressure hull has an interior between the external skin and the water proof surfaces of the reverse osmosis devices, with the interior connected to an air vent.

15. The apparatus for desalinating seawater according to claim 9, wherein the pressure hulls are removably retained on the channel, whereby they can be temporarily removed for maintenance.

16. The apparatus for desalinating seawater according to claim 15, wherein the channel is cylindrical.

17. The apparatus for desalinating seawater according to claim 16, wherein the desalinated water is pumped out to a water treatment facility for further purification.

18. The apparatus for desalinating seawater according claim 1, wherein the apparatus is positioned in a current so as to minimize environmental effects of discharge of brine.

19. The apparatus for desalinating seawater according to claim 1, wherein the channel has a bottom end resting on the floor of the sea.

20. The apparatus for desalinating seawater according to claim 1, wherein the apparatus is supported by means of flotation.

21. The apparatus for desalinating seawater according to claim 1, wherein the apparatus is supported on an offshore platform.

22. The apparatus for desalinating seawater according to claim 1, wherein the apparatus is adjacent to a sudden drop in elevation of a sea floor, and includes a means for conveying brine over the sudden drop in elevation.

23. A method for desalinating seawater, comprising the steps of:

allowing sea water to flow through a check valve into a brine enclosure which is separated from a freshwater enclosure by a membrane through which water molecules, but not sodium and chlorine ions, can flow;

reverse osmosis of the seawater, by maintaining a pressure differential across the membrane, by pumping out desalinated water from the freshwater enclosure;

causing seawater to continue to flow into the brine enclosure, by maintaining a pressure differential across the check valve, by pumping out water having an increased concentration of salt from the brine enclosure into a channel with an open top above the surface of the sea, and an open bottom below the surface of the sea and below the brine enclosure; and

allowing the surface level of the water having an increasing concentration of salt to reach equilibrium in the channel below the surface of the sea and below the brine enclosure, and then discontinuing the pumping of water out of the brine enclosure, and allowing water to flow out of the brine enclosure into the channel by the force of gravity.

24. A method for separating a lighter solvent from a heavier solution, comprising the steps of:

allowing a solution to flow through a check valve into a first enclosure which is separated from a second enclosure by a membrane through which a solvent, but not a solute, can flow;

reverse osmosis of the solution, by maintaining a pressure differential across the membrane, by pumping out purified solvent from the second enclosure;

causing the solution to continue to flow into the first enclosure, by maintaining a pressure differential across the check valve, by pumping out the solution having an increased concentration of solute from the first enclosure into a channel with an open top above a surface of the solution, and an open bottom below the surface of the solution and below the first enclosure; and

allowing the surface level of the solution having an increased concentration of solute to reach equilibrium in the channel below the surface of the solution and below the first enclosure, and then discontinuing the pumping of the solution out of the first enclosure, and allowing the solution to flow out of the first enclosure into the channel by the force of gravity.

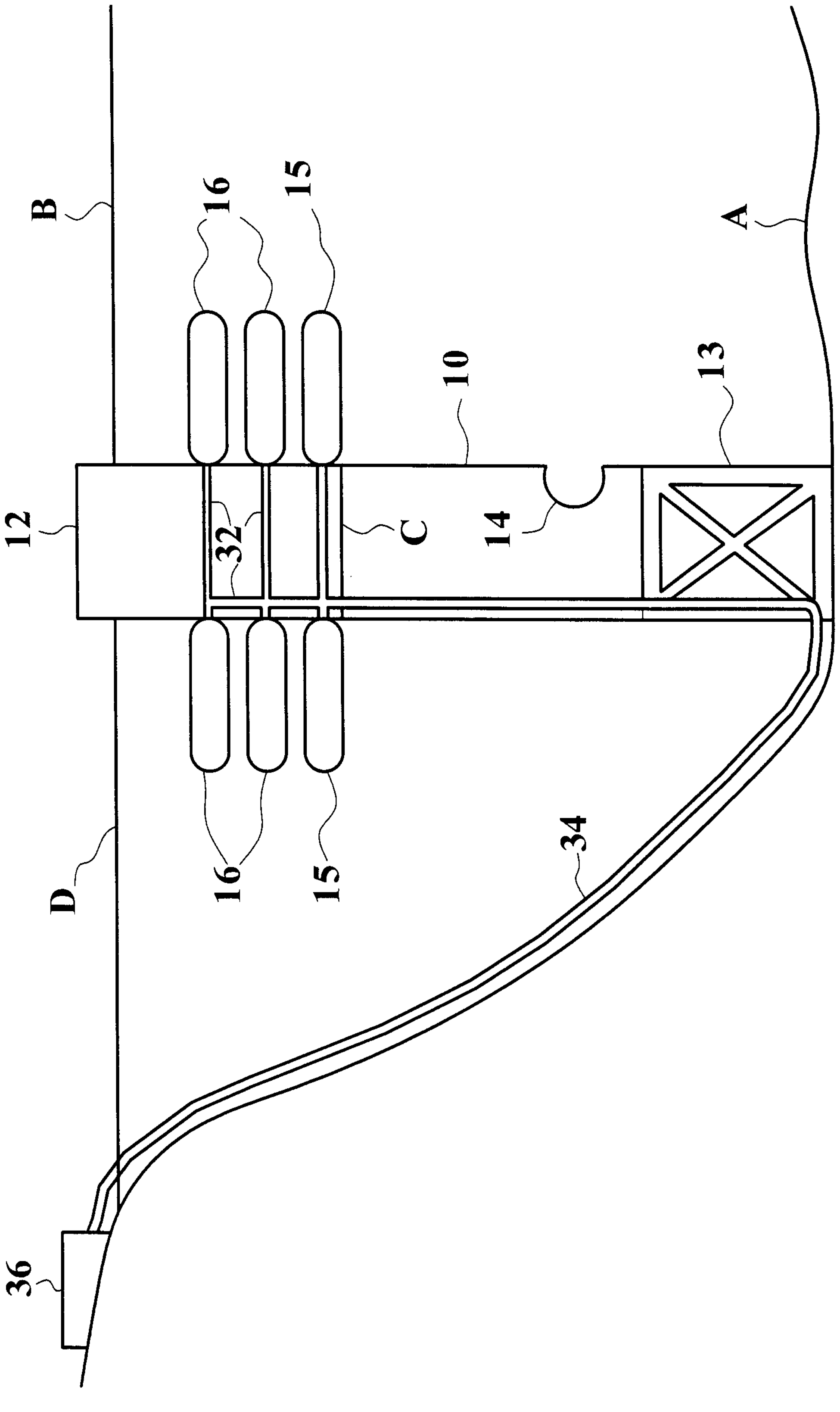

FIG. 1

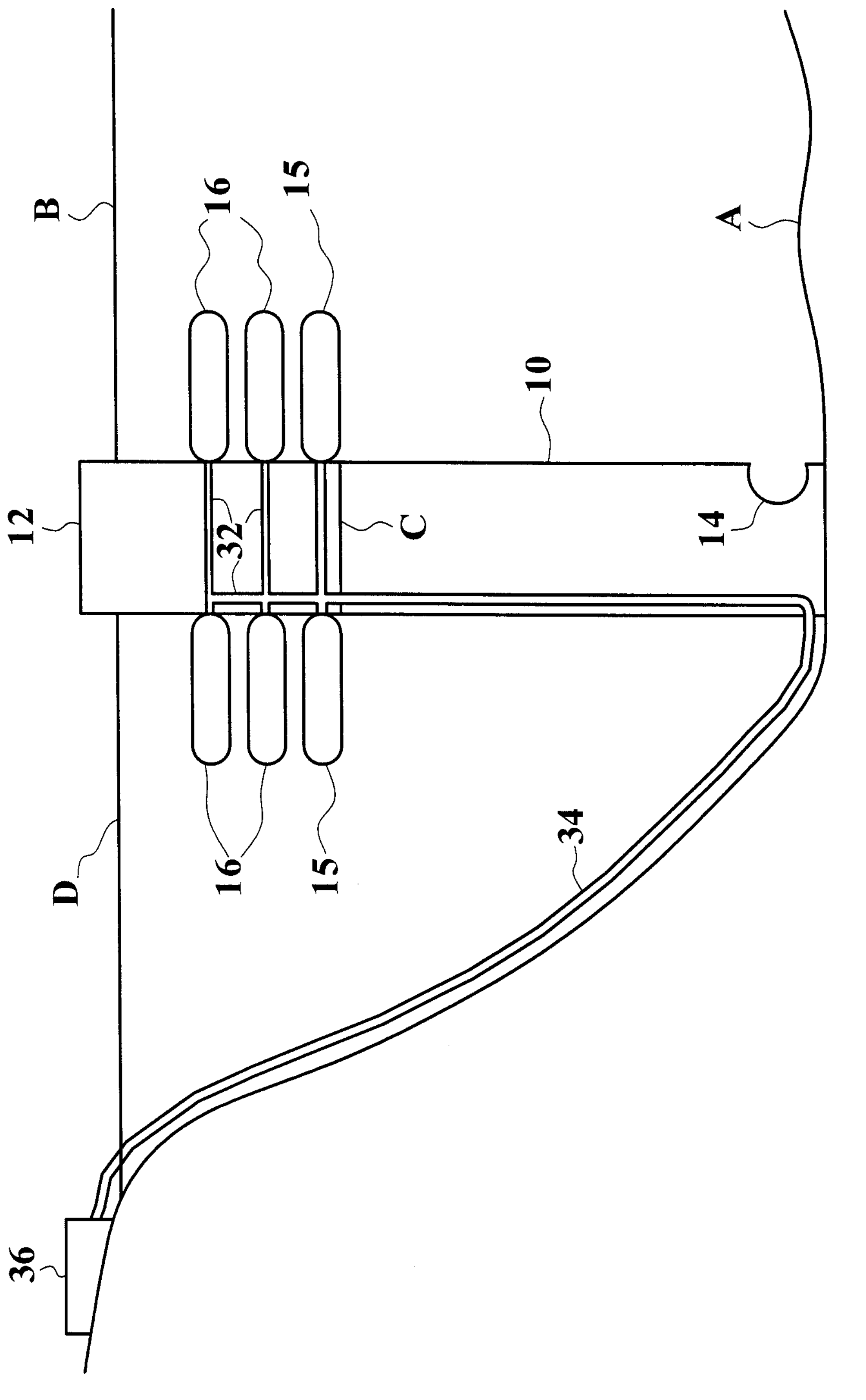

FIG. 2

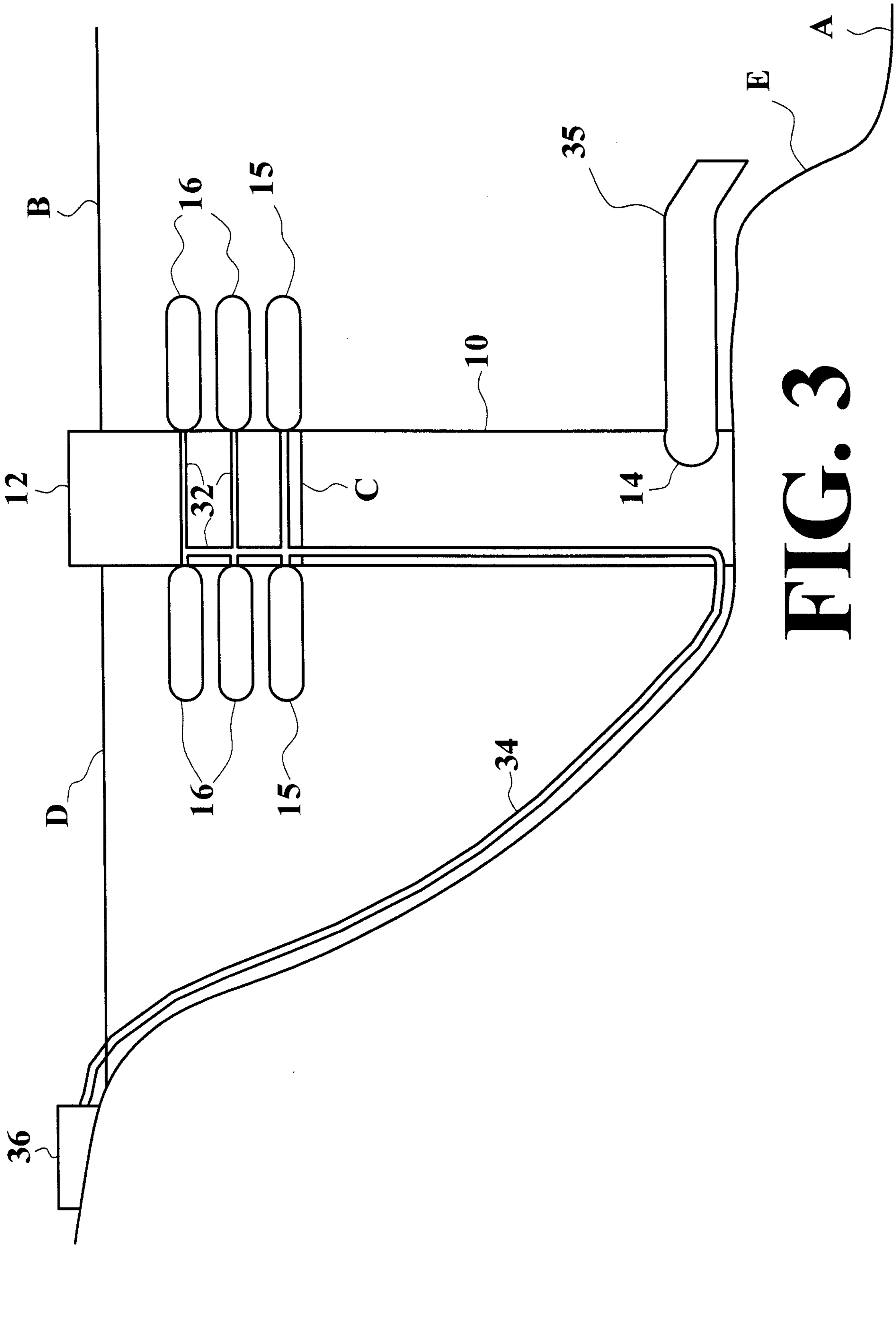

FIG. 3

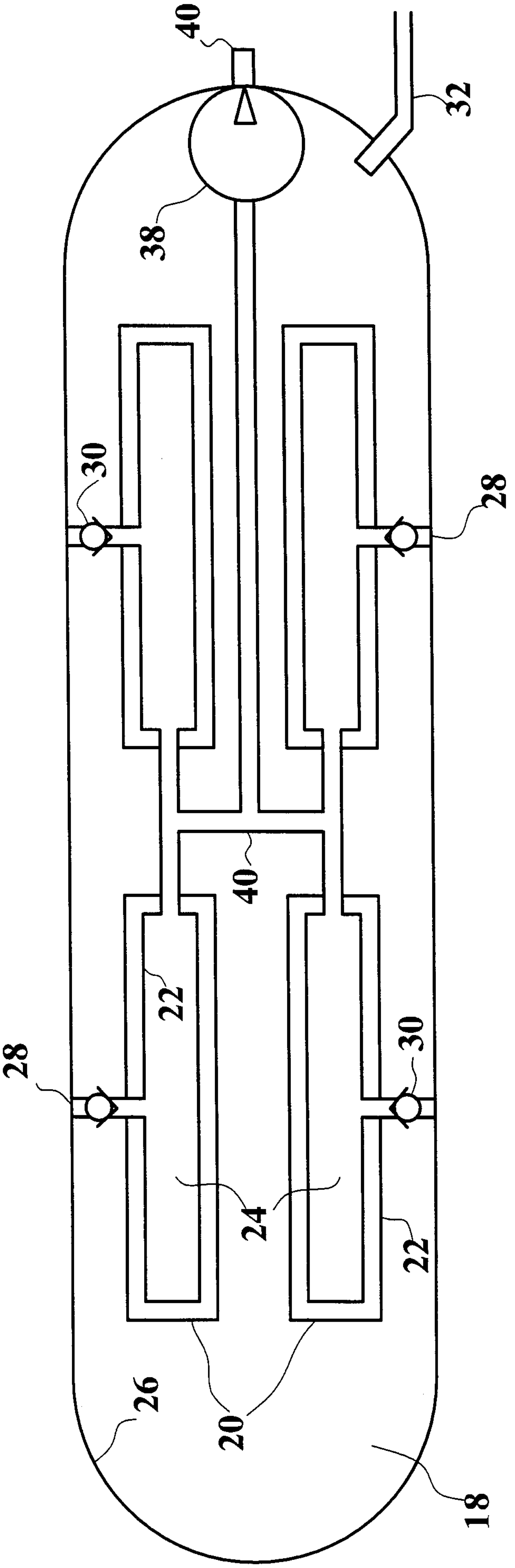

FIG. 4

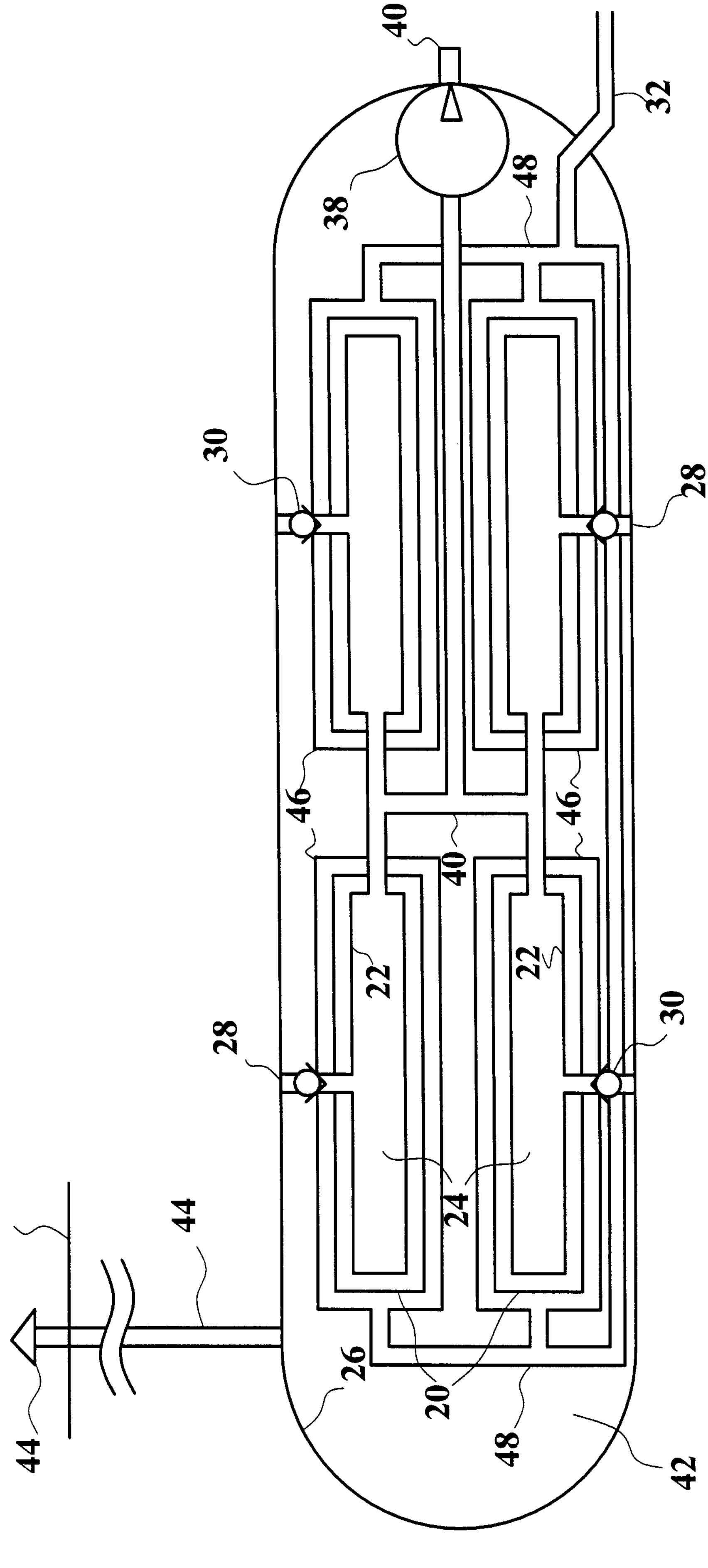

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/26025

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :B01D 61/00, 63/00; C02F 1/44, 7/00
US CL :Please See Extra Sheet.
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. : 210/651, 652, 747, 104, 137, 170, 242.1, 248, 321.66, 34 416.1, 416.3; 60/390

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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3,456,802 A (COLE) 22 July 1969, see entire document, especially figures and columns 3-5.	1-7, 18-22
X	US 4,125,463 A (CHENOWETH) 14 November 1978, see figures 1-2 and columns 3-6.	1-3, 18-19, 22
X	US 5,366,635 A (WATKINS) 22 November 1994, see figure 3 and columns 3-4.	1-3, 18-19, 21-22
A	LEVENSPIEL ET AL. The Osmotic Pump. Science. 18 January 1974 .Vol 183. No. 4121. pages 157-160, especially page 160, columns 2-3.	23-24

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

* Special categories of cited documents

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"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)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" 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

"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

"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

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Date of the actual completion of the international search	Date of mailing of the international search report
19 JANUARY 2000	14 FEB 2000

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/26025

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

210/651, 652, 747, 104, 137, 170, 242.1, 248, 321.66, 345, 416.1, 416.3; 60/390