(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
6 May 2016 (06.05.2016)

WIPO | PCT

(10) **International Publication Number**
WO 2016/066382 A1

(51) **International Patent Classification**:
C02F 1/44 (2006.01) ***B01D 61/12*** (2006.01) ***B01D 61/04*** (2006.01) *C02F 103/06* (2006.01) ***B01D 65/02*** (2006.01)

(21) **International Application Number**:
PCT/EP2015/073029

(22) **International Filing Date**:
6 October 2015 (06.10.2015)

(25) **Filing Language**: English

(26) **Publication Language**: English

(30) **Priority Data**:
14190656.0 28 October 2014 (28.10.2014) EP

(71) **Applicant** *(for all designated States except AE, AG, AU, BB, BH, BN, BW, BZ, CA, CY, EG, GB, GD, GH, GM, IE, IL, IN, KE, KN, LC, LK, LS, MT, MW, MY, NA, NG, NZ, OM, PG, QA, RW, SA, SC, SD, SG, SL, SZ, TT, TZ, UG, US, VC, ZA, ZM, ZW)*: **UNILEVER N.V.** [NL/NL]; Weena 455, NL-3013 AL Rotterdam (NL).

(71) **Applicant** *(for AE, AG, AU, BB, BH, BN, BW, BZ, CA, CY, EG, GB, GD, GH, GM, IE, IL, IN, KE, KN, LC, LK, LS, MT, MW, MY, NA, NG, NZ, OM, PG, QA, RW, SA, SC, SD, SG, SL, SZ, TT, TZ, UG, VC, ZA, ZM, ZW only)*: **UNILEVER PLC** [GB/GB]; a company registered in England and Wales under company no. 41424 of Unilever House, 100 Victoria Embankment, London Greater London EC4Y 0DY (GB).

(71) **Applicant** *(for US only)*: **CONOPCO, INC., D/B/A UNILEVER** [US/US]; 800 Sylvan Avenue AG West, S. Wing, Englewood Cliffs, NJ New Jersey 07632 (US).

(72) **Inventors**: **CHATTERJEE, Jaideep**; Hindustan Unilever Ltd,Research Centre 64, Main Road, Whitefield, Bangalore 560 066 (IN). **PRATAP, Shailendra**; Hindustan Unilever Ltd, Research Centre 64 Main Road, Whitefield, Bangalore 560 066 (IN). **SUBBIAH, Senthilmurugan**; Indian Institute of Technology Guwahati Amingaon,Guwahati, Assam 781 039 (IN).

(74) **Agent**: **WARNER, Guy, Jonathan**; Unilever Patent Group Olivier van Noortlaan 120, 3133 AT Vlaardingen (NL).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC,

[Continued on next page]

(54) **Title**: A WATER PURIFIER AND A PROCESS OF CLEANING THE MEMBRANE

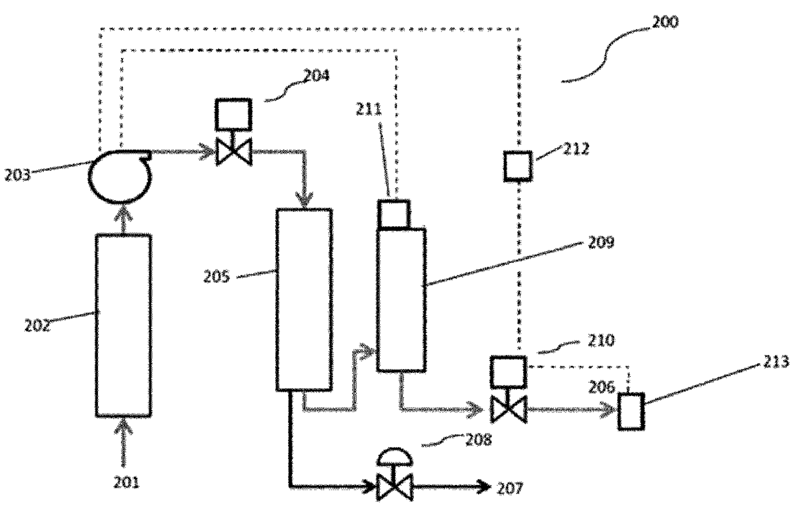

Figure 2

(57) **Abstract**: The present invention provides a water purifier (200) comprising, a pump (203); a membrane module (205) where the membrane is spiral wound membrane including reverse osmosis, nanofilter, ultrafilter and microfilter membranes; a first valve (204) to control the water flow into the membrane module (205); and a permeate line for purified water and a reject line for discarded water; wherein the reject line comprises a valve (208); and wherein the water purifier comprises a closed chamber (209) and a second valve (210) in sequence downstream the membrane module (205) in the permeate line and wherein said reject line is downstream of said membrane module (205). The invention also provides a process for cleaning the membrane module (205) of the water purifier (200), said process comprising, operating the purifier (200) with the pump (204) powered and the first (204) and second valves (210) open; closing the second valve (210) to initiate shut-down of the purifier (200) and to allow a pressure build up in the closed chamber (209); allowing the pump (203) to continue operation with the first valve (204) open; and shutting off the pump (203) and the first valve (204) to force purified water in the closed chamber (209) through the membrane module (205) in the reverse direction until the pressure in the closed chamber (209) dissipates to<l psig pressure.

WO 2016/066382 A1

SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

A WATER PURIFIER AND A PROCESS OF CLEANING THE MEMBRANE

Field of the invention

The present invention relates to a water purifier and a process of cleaning the membrane. Particularly the invention relates to a process for enhancing the recovery of purified water by a process of cleaning the membrane module.

Background of the invention

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

A large population of people in the world live in developing and under-developed countries where there is a severe shortage of hygienic potable water. A high percentage of these people live in rural areas where there are no water purification systems like the ones provided by urban municipal drinking water treatment plants. Many people have to depend directly on ground and/or surface water sources like wells, tube-wells, ponds and rivers. Often these water sources are contaminated by sewage, industrial and agricultural wastes.

A large number of physical and chemical methods of purifying water have been known and used at municipal, local and domestic levels.

Water purifiers based on membrane module systems is the most popular technology for water purification as it can remove biological, colloidal, organic and dissolved salts from water. The main drawback of such purifiers is that for example more than 50 % of the input water cannot be recovered and is rejected during the purification process such as by reverse osmosis.

The process of water purification by reverse osmosis and similarly other membrane module based systems involve extracting pure water with no or minimal dissolved salts from an input water which contains a significantly higher level of dissolved salts and may contain other impurities like dissolved organic compounds as well as colloids and microorganisms. In the process of extracting relatively salt free water, the reverse osmosis process produces concentrated reject water, which has a significantly higher salt concentration compared to the input water. Higher the recovery of pure water the higher is the concentration of the dissolved salts in the reject. In essence water purification by reverse osmosis necessarily produces a concentrate water stream which is wasted and it would be highly beneficial to reduce this water wastage. If water recovery is increased without increasing energy consumption, the energy efficiency of the system improves significantly which would have a positive environmental impact. In reverse osmosis and other devices that involve membranes for the purposes of water purification, it is essential to clean the membrane by removing the particles that get deposited on the membrane and retard the buildup of scale. This is generally ensured by changing the membrane or by frequent washing of the membrane by pressurized input water.

EP 0768112 A1 (Christ AG, 1995) shows that the permeate can be used to clean the membrane by flowing the permeate backwards through the membrane. However the driving force for the permeate is the osmotic pressure difference between the permeate and the water on the reject side of the membrane. This method however is time consuming as it is based on the natural principal of difference in osmotic pressure.

JP 2011110439 (Toray Industries, 2009) shows that the permeate can be used to backwash the membrane module, by using a second pump to pump the permeate in the reverse direction. This system thus requires a second pump and additional instrumentation for powering and controlling the same.US3786924 B1 (Delro Inc, 1974) discloses a reverse osmosis unit further having a concentrate outlet which is upstream from the membrane structure in fluid communication with the feed water inlet. In such a configuration, the concentrate outlet point is upstream of the membrane module when the system is in operation. This publication is primarily addressing the technical problems of fiber modules or bundles. In addition, the permeate holding chamber has at least one valve upstream of the chamber and two valves and downstream of the chamber, which makes the system a bit complicated.

DE10302014 A1 and EP0768112 A1, both disclose a separate chamber for holding a part of the permeate to be used for backwashing. There is a branch line to the backwash permeate tank with associated valve system.

Therefore, there is a need to provide an efficient device and a process for cleaning a water purifier membrane which works faster than the dynamics of cleaning based on osmotic pressure difference.

There is also a need to provide an efficient high flux backwash process for cleaning a water purifier membrane which avoids employment of additional equipment like a backwash pump and the extra power required to operate it, or other additional pumps and control system components for the membrane cleaning.

There is also a need to provide a process for cleaning a water purifier membrane with a controlled backwash frequency as too frequent backwash can lead to water wastage and infrequent backwash can lead to irreversible scaling and fouling thereby reducing the life of the membrane.

Also, there is a need to provide a process for cleaning a water purifier membrane which can be used for cleaning both spiral-wound and hollow fiber membrane modules.

The object of the present invention is also to provide a process for cleaning membrane module in a membrane based water purifier.

Another object of the present invention is to enhance recovery of purified water.

Yet another object of the present invention is to provide a process for enhancing the life of a water purifier membrane.

Another object of the present invention is to provide a process for cleaning a water purifier membrane module by avoiding the use of an additional mechanical fluid pressurizing device such as a pump for backwash cleaning and thus reducing power consumption.

Yet another object is to provide a process to reduce scaling and fouling of the membrane module and yet achieve higher purified water recovery.

Summary of the invention

According to an aspect of the present invention is provided a water purifier comprising, a pump; a membrane module where the membrane is spiral wound membrane including reverse osmosis, nanofilter, ultrafilter and microfilter membranes; a first valve to control the water flow into the membrane module; and a permeate line for purified water and a reject line for discarded water; wherein the reject line comprises a valve; and wherein the water purifier comprises a closed chamber and a second valve in sequence downstream the membrane module in the permeate line and wherein said reject line is downstream of said membrane module.

According to another aspect of the present invention is provided a process for cleaning the membrane module of a water purifier comprising, a pump; a membrane module where the membrane is spiral wound membrane including reverse osmosis, nanofilter, ultrafilter and microfilter membranes; a first valve to control the water flow into the membrane module; and a permeate line for purified water and a reject line for discarded water; wherein the reject line comprises a valve; and wherein the water purifier comprises a closed chamber and a second valve in sequence downstream the membrane module in the permeate line and wherein said reject line is downstream of said membrane module;

said process comprising,

operating the purifier with the pump powered and the first and second valves open; closing the second valve to initiate shut-down of the purifier and to allow a pressure build up in the closed chamber; allowing the pump to continue operation with the first valve open; and shutting off the pump and the first valve to force purified water in the closed chamber through the membrane module in the reverse direction until the pressure in the closed chamber dissipates to <1 psig pressure.

Detailed description of the invention

The present invention relates to a water purifier and a process for cleaning the membrane. The invention also provides a method for enhancing the recovery of purified water by the process of cleaning the membrane module.

The membrane based water purifiers over a period of time see decline in pure water flow rate or the permeate flow rate and the salt concentration in this permeate is a measure of the “health” of the membrane. The membrane can be fouled by bio-films, organics or colloids deposited on its surface. However the most significant reason for permeate flow-rate decline is the formation of scales, which are usually deposits of calcium salts on the membrane surface. This leads to a decline in the flow of permeate as well as the total flow through the system. This may lead to an increase in pure water recovery due to a higher drop in the reject water flow rate, leading to a higher salt flux through the membrane. This also leads to an increase in the concentration of salt in the pure water. Hence high permeate water flow rate in combination with a low concentration of salt in the same demonstrates that the membrane surfaces are clean and the system is operated optimally.

The present invention provides a membrane based water purifier with a membrane cleaning apparatus and a membrane cleaning process thereof.

Throughout the description of the invention, the word ‘control’ is used in a general sense of the word to describe the apparatus or device or process which connotes the experimental control which is similar to the device and the process of the present invention but without the key features and proposition which is/are tested.

Throughout the description of the invention, the term ‘closed chamber’ preferably refers to the chamber downstream the membrane module and upstream the second valve where the purified water flows in from the membrane module and which is closed to enable the pressure to build up in the chamber.

Throughout the description of the invention, the term ‘reverse direction’ means the flow of water in the direction opposite to that of the flow of the purified water or opposite to the direction of flow of the permeate in the permeate line from the water purification device.

Throughout the description of the invention, the term ‘reject line’ means the line for flow of waste water or discarded water from the water purification device.

Throughout the description of the invention, the term ‘permeate line’ means the line for flow of purified water recovered from the water purification device.

The present invention provides a water purifier comprising, a pump; a membrane module; a first valve to control the water flow into the membrane module where the membrane is spiral wound membrane including reverse osmosis, nanofilter, ultrafilter and microfilter membranes; and a permeate line for purified water and a reject line for discarded water; wherein the reject line comprises a valve; and wherein the water purifier comprises a closed chamber and a second valve in sequence downstream the membrane module in the permeate line and wherein said reject line is downstream of said membrane module.

A preferred embodiment of the present invention provides a water purifier (200) comprising, a pump (203); a membrane module (205); a first valve (204) to control the water flow into the membrane module (205); and a permeate line (206) for purified water and a reject line (207) for discarded water; wherein the reject line (207) comprises a valve (208); and wherein the water purifier (200) comprises a closed chamber (209) and a second valve (210) in sequence downstream the membrane module (205) in the permeate line (206) and wherein said reject line is downstream of said membrane module.

The inlet water enters a spiral wound filter at one end and exits through the other end. During its journey from the one end to the other end, the water slows down, as some fraction of it permeates into the central core of the filter element. The water in the membrane outside the core gets concentrated significantly during this journey. Hence the end of the membrane near the other end, it is significantly more fouled with scale than the end at which it enters. The water purifier and process in accordance with the invention is configured such the maximum pressure of the permeate used for backwash is available at the other end where the scaling is the maximum.

The pump may be selected from the standard types of commercially available pumps and preferably from a positive displacement pump.

Preferably the water purifier has the valve selected from on-off, solenoid or throttle type valve. More preferably the first and second valves are solenoid type valve and the valve provided at the reject line is a throttle type valve.

The membrane is spiral wound membrane modules including reverse osmosis, nanofilter, ultrafilter and microfilter membranes.

It is preferable that the first valve is operably connected to pump such that the first valve is open when the pump is powered and closed when the pump is switched off.

In a preferred embodiment the water purifier comprises volume sensor operably connected to the second valve and the output of purified water from the permeate line.

In another preferred embodiment the water purifier comprises a pressure switch operably connected to the closed chamber and the pump. Any standard type pressure switch can be employed.

It is also preferred that the water purifier comprises a timer operably connected to the second valve and the pump.

An embodiment of the present invention provides a method of purifying water using the water purifier of the invention.

The present invention also provides for a process for cleaning the membrane module of a water purifier comprising, a pump; a membrane module; a first valve to control the water flow into the membrane module; and a permeate line for purified water and a reject line for discarded water; wherein the reject line comprises a valve; and wherein the water purifier comprises a closed chamber and a second valve in sequence downstream the membrane module in the permeate line and wherein said reject line is downstream of said membrane module;

said process comprising,

operating the purifier with the pump powered and the first and second valves open; closing the second valve to initiate shut-down of the purifier and to allow a pressure build up in the closed chamber; allowing the pump to continue operation with the first valve open; and shutting off the pump and the first valve to force purified water in the closed chamber through the membrane module in the reverse direction until the pressure in the closed chamber dissipates to <1 psig (<0.068 bar) and more preferably 0-0.99 psig

A preferred embodiment of the present invention provides a process for cleaning the membrane module of a water purifier comprising, (200) comprising, a pump (203); a membrane module (205); a first valve (204) to control the water flow into the membrane module (205); and a permeate line (206) for purified water and a reject line (207) for discarded water; wherein the reject line (207) comprises a valve (208);and wherein the water purifier (200) comprises a closed chamber (209) and a second valve (210) in sequence downstream the membrane module (205) in the permeate line (206) and wherein said reject line is downstream of said membrane module;

said process comprising,

operating the purifier (200) with the pump (203) powered and the first (204) and second (210) valves open; closing the second valve (210) to initiate shut-down of the purifier and to allow a pressure build up in the closed chamber (209); allowing the pump (203) to continue operation with the first valve (204) open; and shutting off the pump (203) and the first valve (204) to force purified water in the closed chamber (209) through the membrane module (205) in the reverse direction until the pressure in the closed chamber dissipates to <1 psig pressure.

The point at which the second valve is closed to start the process of cleaning the membrane module is preferably determined by the volume of output of purified water from the permeate line or the pump running time taken for obtaining a predetermined volume of purified water. It is more preferable to use the output volume of purified water from the permeate line as the parameter for closing the second valve to start the process of cleaning the membrane module.

Preferably a purified water chamber is placed downstream the second valve and more preferably a liquid float sensor which senses the volume of the purified water is located inside the purified water chamber. Therefore, it is preferred that the predetermined volume at which the second valve closes is dependent on the capacity of the purified water chamber. This predetermined volume is designed depending on the capacity of the purified water chamber.

In a preferred embodiment of the process of the present invention, the second valve is closed when the volume sensor located downstream of the second valve senses a predetermined output volume of purified water. In a more preferred embodiment the second valve is closed after the volume sensor senses predetermined output volume of purified water in the range of 2 to 200 litres.

In an alternative embodiment of the process for cleaning the membrane module wherein the second valve is closed after a predetermined time period of 10 minutes to

20 days of operation of the purifier. It is preferred that the time is determined depending on the output volume of purified water.

After the closure of the second valve the pump is allowed to continue operation with the first valve open preferably until a predetermined pressure is built up in the closed chamber or a predetermined volume of water is collected in the closed chamber or by pre-determining the time required for the pressure build up or for the predetermined volume of water collection in the closed chamber.

Preferably the time required to close the pump after the closure of the second valve depends on the pressure build up in the closed chamber. More preferably the pressure which is required to be achieved in the closed chamber is selected and the time is recorded which takes to reach to that pressure and the timer is then set at this predetermined time to achieve the desired pressure.

After the closure of the second valve, the pump is allowed to continue operation with the first valve open more preferably until a predetermined pressure is built up in the closed chamber. In a more preferred embodiment the pump is allowed to continue operation with the first valve open by pre-determining the time required for the pressure build up in the closed chamber.

In a preferred embodiment, after closing of second valve the pump is allowed to continue operation until the pressure switch senses a predetermined pressure in the closed chamber in the range of 1 (0.068 bar) to 180 psig (12.41 bar). More preferably the pump is allowed to continue operation untill the pressure in the closed chamber is in the range of 5 to 100 psig (0.34 bar to 6.89 bar) and yet more preferably 20 to 100 psig (1.37 bar to 6.89 bar) and most preferably the pump is allowed to continue operation until the pressure in the closed chamber is in the range of 30 to 50 psig (2.06 bar to 3.44 bar).

In another preferred embodiment of the process of present invention, the pump is allowed to continue operation until the timer senses a predetermined time period of 0.30 minutes to 120 minutes more preferably from 0.5 minute to 60 minutes.

In another preferred embodiment of the process of the present invention, the pump is allowed to continue operation until 10 ml to 2 liters more preferably 100 ml to 500ml of water is collected in the closed chamber. This water is utilised to clean the membrane module.

Preferably the purified water is driven through the membrane module in the reverse direction till the built-up pressure in the closed chamber dissipates to <1 psig (<0.068 bar) pressure or more preferably pressure of 0 to 0.99 psig.

It is preferred that the operation of the first and second valves may be efficiently controlled using electronic control systems.

In another preferred embodiment, the purified water recovery is at least 50% of the input water. In a more preferred embodiment, the purified water recovery is in the range from 50% - 85% of the input water.

The present invention provides a process for cleaning the membrane module wherein preferably the life of the membrane module is increased by 2 to 10 times.

In another embodiment of the present invention, it preferably takes at least 2 minutes to complete the membrane cleaning process and more preferably 5 to 15 minutes

Yet another embodiment of the present invention provides that the process of the present invention is suitable for membrane based water purifiers with spiral wound membrane modules including reverse osmosis, nanofilter, ultrafilter and microfilter membranes.

Typical home use reverse osmosis devices reject ~ 70% of the input water while recovering only 30%. This is done as increasing the recovery of water in membrane filtration / separation introduces the following complexities. Higher the recovery of pure water, the more concentrated is the reject water. Higher concentration of dissolved salts in water leads to more scale formation. Higher the scale formation, shorter will be the life of the membrane. Hence low recovery of pure water is practiced to ensure high life of the membrane, which is the critical and expensive component in a reverse osmosis based water purifier. The object of the invention is aimed at maintaining membrane and providing simple sustainable ways to prevent scaling and fouling while maintaining high recovery.

Brief description of drawings

Fig.1 is a schematic representation of the control apparatus

Fig.2 is a schematic depiction of the apparatus of the present invention

Detailed description of drawings

Figure 1 shows a control water purifier system (100). Under the operation of a powered pump (103), the raw water/ input stream (101) enters a pre-filter (102) and is made to pass through the membrane module (105) via a valve (104). The water flows out of the membrane module (105) as a permeate water line (106) and a reject (107) water line.

Figure 2 shows the membrane cleaning apparatus (200) of the present invention. Under the operation of a powered pump (203), the raw water/ input stream (201) enters a pre-filter (202) and is made to pass through the membrane module (205) via a valve (204). The water flows out of the membrane module (205) as a permeate water line (206) and made to pass through a closed chamber (209), the permeate line from the closed chamber (209) is further made to pass via another solenoid valve (210). The reject water flows out of the membrane module (205) passing through a valve (208) through a reject line (207). The pressure switch (211) is operably connected to the pump (203) and the closed chamber (209. The timer (212) is operably connected to the second valve (210) and the pump (203). The volume sensor (213) is located downstream of the second valve and is operably connected to the output of purified water and the second valve (203). The reject line (207) is downstream of the membrane module (205). In other words, water flows out of the reject line in the direction of the flow of the purified water or along the direction of flow of the permeate in the permeate line.

Examples

<u>Control water purifier system</u>

The input water (101) was made to enter the pre-filter (102) and then pass through the membrane module (105). Dow's Filmtec 75 GPD membranes were used as a membrane module. Hi Tech's Pre-carbon filter (Max Flow-1.0 GPM, Max Pressure 125 psi), and Hi- Tech's Sediment Filter (Max Flow-1.0 GPM, Max Pressure 125 psi) were used as pre-filters. The experiments were initially setup to operate at ~70 % recovery by regulating the reject flow rate through a flow regulator (Throttle valve – TV) (108). The pressure in the input water line (101) and reject water line (106) were measured with pressure gauges. Delta's Hydraulic Pressure Gauge (Range- 0 to 150 psig) was used. The total dissolved salt concentration (TDS), flow rate and water hardness of the input water (101), permeate stream (106) and the reject stream (107) were measured at regular intervals of every ~35 liters of permeate (purified water) collected. The TDS of input water (101) varied from 800-1000 ppm. Figure 1 shows the schematic representation of the control apparatus.

Water purifier of the Invention

Setting the predetermined volume for closure of second valve depends on the capacity of the purified water chamber. In the experimental set up the purified water chamber had a capacity of 30 liters. Therefore the volume sensor (213) was set at a predetermined value of 25 liters for closure of second valve (210).

Setting the predetermined time for allowing pump (203) to operate after the closure of second valve (210) was timed so that a pressure of ~35psig was achieved. Therefore a value of two minutes was set in the timer (212) for allowing the pump (203) to run after the closure of second valve (210).

The input water (201) from the pre-filter (202) was passed through a first solenoid valve (204) and allowed to enter the membrane module (205). Dow's Filmtec 75 GPD membranes were used as a membrane module. Hi Tech's Pre-carbon filter (Max Flow-1.0 GPM, Max Pressure 125 psi), and Hi- Tech's Sediment Filter (Max Flow-1.0 GPM, Max Pressure 125 psi) were used as pre-filters. The permeate line (206) for water coming out of the membrane (205) was made to pass through a closed chamber (209). This permeate line (206) was further connected to a second solenoid valve (210). The set-up was operated in such a way that initially both first and second solenoid valves (204) and (210) were open and the whole set-up was operated as a conventional membrane based water purifier. After the output of every ~25 liters of permeate (treated water) (206), the second valve (210) was closed. As a result purified water started to accumulate in the closed chamber (209) and pressure started to build up. After 2 minutes of the closure of the second valve (210) based on the predetermined time set in the timer (212), the pressure in the closed chamber (209) raised to ~35 psig and the pump (203) was switched off. As a result the purified water (206) at higher pressure in the closed chamber (209) started flowing in the reverse direction towards the reject side through the membrane module (205) thereby resulting in cleaning of the membrane from within. It took ~ 5 minutes for the pure water collected in the closed chamber (209), which was roughly 0.25 L, to completely drain out. In this way for ~ every 25 liters of treated water one cycle of permeate back-flushing took place. The experiments were initially set-up to operate at ~70 % recovery by regulating the reject flow rate through a valve (208) after which no change was made to the regulator setting. The pressure in the input water line, reject water line and pressurizing space/closed chamber (209) were measured with pressure gauges. Delta’s Hydraulic Pressure Gauge (Range- 0 to 150 psig) was used. The TDS, flow rate and water hardness of the feed water, permeate stream (206) and the reject stream (207) were measured at regular intervals of every ~35 liters of permeate (purified water) collected. The TDS of input water (201) varied from 800-1000 ppm. Figure 2 shows the schematic representation of the water purifier with a membrane cleaning system of the present invention.

Example 1

Control system and the water purifier of the invention were operated at permeate recovery of 70%: The control was operated without any system for cleaning of the membrane, or any other scale prevention technology. The input water used was ground water which had a very high level of hardness of around 75 FH and a total salt concentration of ~ 850 ppm. This constitutes a “torture” test for the membrane since both total dissolved salts and hardness are very high.

Table 1- Recovery of purified water in the control system

*Permeate/ (L)	Qp (ml/min)	Qt (ml/min)	Salt conc. (ppm)
20	290	410	45

356	210	309	49
775	190	279	54
1125	175	249	55
1510	55	65.5	109

*Permeate- the total volume of permeate obtained from the system
Qp- the flow-rate of the permeate obtained from the system
Qt- the total flow rate entering the membrane module
Salt conc- salt concentration in the purified water (TDS)

The data in table 1 show that the permeate water flow rate through the system dropped steadily from 290 ml/min, when the membrane is new, to 175 ml/min by the time 1125 liters of pure water was obtained from the system. Since the recovery of purified water was maintained at 70% which was approximately double of the recovery used in typical home-use reverse osmosis based purifiers, the salt concentration in the purified water stream was slightly higher than normal i.e., 55 ppm. However, after 1510 liters of purified water was extracted from the system, the flow rate of permeate dropped to 55 ml/min, signifying end of useful life of the membrane. This was coupled with an increase in TDS of the purified water to 109 ppm, confirming the above.

Table 2- Recovery of purified water in the water purifier of the invention

*Permeate (L)	Qp (ml/min)	Qt (ml/min)	Salt conc. (ppm)
26	320	455	39
1076	247	377	34
2389	238	358	27
3889	220	350	27
5439	208	336	27

*Permeate- the total volume of permeate obtained from the system
Qp- the flow-rate of the permeate obtained from the system
Qt- the total flow rate entering the membrane module
Salt conc- salt concentration in the pure water (TDS)

The data in table 2 show that the permeate water flow rate through the system dropped slightly from 320 ml/min, when the membrane was new, to 247 ml/min by the time 1076 liters of purified water had been obtained from the system. Although the recovery of purified water was maintained at 70% which was approximately double of the recovery used in typical home-use reverse osmosis based purifiers, the salt concentration in the pure water stream was only 34 ppm, which is very low for such high recovery, indicating excellent membrane condition. Even after 2389 Liters of pure water extracted from the system, the flow rate of pure water was 238 ml/min, signifying a clean, “as good as new” membrane. This coupled with the TDS of the pure water of 29 ppm confirms the above. With further testing it was observed that even after 5439 liters of pure water extracted from the membrane, the flow rate of permeate water was still 208 ml/min and the salt concentration was 27 ppm, both of which indicate very good membrane condition.

In summary, the data in tables 1 and 2 which were obtained under identical experimental conditions, show that the membrane life in the control is only ~ 1500 L of pure water, while the water purifier with the membrane cleaning system disclosed herein has lasted at least 5500 L, which represents a minimum enhancement of life by 3.5 times.

Claims

1. A water purifier (200) comprising,
    a. a pump (203);
    b. a membrane module (205) where the membrane is spiral wound membrane including reverse osmosis, nanofilter, ultrafilter and microfilter membranes;
    c. a first valve (204) to control the water flow into the membrane module (205); and
    d. a permeate line (206) for purified water and a reject line (207) for discarded water;

   wherein the reject line (207) comprises a valve (208); and
   wherein the water purifier (200) comprises a closed chamber (209) and a second valve (210) in sequence downstream the membrane module (205) in the permeate line (206) and wherein said reject line is downstream of said membrane module.

2. A water purifier (200) as claimed in claim 1, wherein the first valve (204) is operably connected to pump (203).

3. A water purifier (200) as claimed in claims 1 and 2, wherein the valve is selected from on-off, solenoid or throttle type valve.

4. A water purifier (200) as claimed in any of the preceding claims, wherein the water purifier (200) comprises volume sensor (213) operably connected to the second valve (210) and the output of purified water from the permeate line 206.

5. A water purifier (200) as claimed in any of the preceding claims, wherein the water purifier (200) comprises a pressure switch (211) operably connected to the closed chamber (209) and the pump (203).

6. A water purifier (200) as claimed in any of the preceding claims, wherein the water purifier (200) comprises a timer (212) operably connected to the second valve (209) and the pump (203).

7. A process of purifying water using the water purifier (200) as claimed in any of the preceding claims.

8. A process for cleaning the membrane module (205) of a water purifier (200) as claimed in claim 1, said process comprising:
    i. operating the purifier (200) with the pump (203) powered and the first (204) and second (210) valves open;
    ii. closing the second valve (210) to initiate shut-down of the purifier (200) and to allow a pressure build up in the closed chamber (209);
    iii. allowing the pump (203) to continue operation with the first valve (204) open; and
    iv. shutting off the pump (203) and the first valve (204) to force purified water in the closed chamber (209) through the membrane module (205) in the reverse direction until the pressure in the closed chamber dissipates to <1 psig (<0.068 bar) pressure.

9. A process for cleaning the membrane module (205) as claimed in claim 8, wherein the second valve (210) is closed after the volume sensor (213) senses predetermined output volume of purified water from the permeate line (206) in the range of 2 to 200 litres.

10. A process for cleaning the membrane module (205) as claimed in claim 8, wherein the pump (203) is allowed to continue operation until the pressure switch (211) senses a predetermined pressure in the closed chamber (209) in the range of 1 (0.068 bar) to 180 psig (12.41 bar).

11. A process for cleaning the membrane module (205) as claimed in claim 8, wherein the pump (203) is allowed to continue operation after the closing of second valve until the timer (212) senses a predetermined time period of 0.30 minutes to 120 minutes.

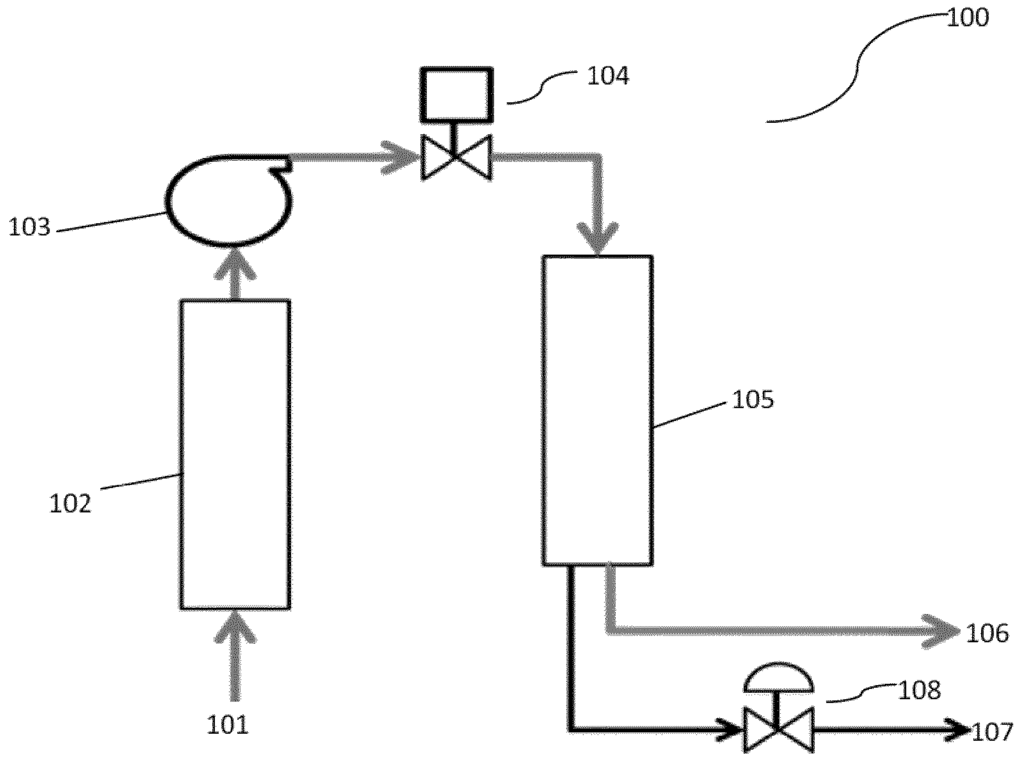

Figure 1

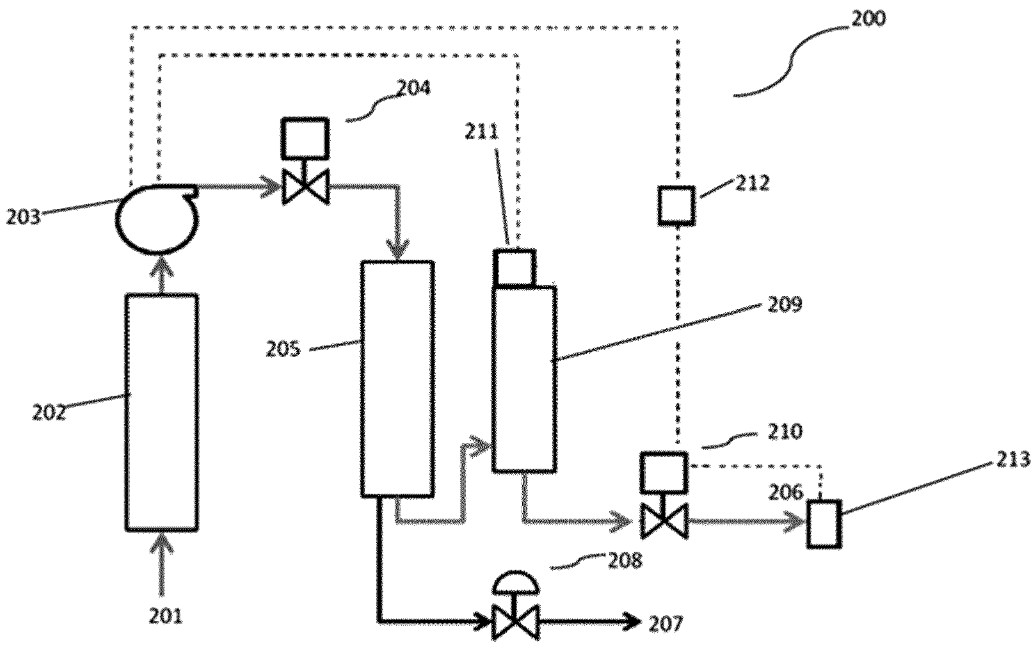

Figure 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/073029

A. CLASSIFICATION OF SUBJECT MATTER
INV. C02F1/44 B01D61/04 B01D65/02 B01D61/12
ADD. C02F103/06

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)
C02F B01D

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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 786 924 A (HUFFMAN L) 22 January 1974 (1974-01-22) figure 1 column 1, line 5 - line 26 column 1, line 46 - column 2, line 32 column 2, line 48 - column 7, line 16 -----	1-7
X	FR 2 979 628 A1 (DUFLOS MICHEL [FR]) 8 March 2013 (2013-03-08) figure 1 page 1, line 6 - page 2, line 31 -----	1-7
X	DE 103 02 014 A1 (W E T WASSER EN TECHNOLOGIE GM [DE]) 29 July 2004 (2004-07-29) figure 1 paragraph [0001] - paragraph [0018] claims 1-5 -----	1-11
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] 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 application or patent but 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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 January 2016	22/01/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Zsigmond, Zoltán

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/073029

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2012/019059 A2 (GLOBAL SOLAR WATER AND POWER SYSTEMS INC [US]; SNYDER MARK [US]) 9 February 2012 (2012-02-09) the whole document -----	1-11
A	WO 01/23076 A1 (ZENON ENVIRONMENTAL INC [CA]) 5 April 2001 (2001-04-05) the whole document -----	1-11

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2015/073029

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 3786924	A	22-01-1974	NONE			
FR 2979628	A1	08-03-2013	NONE			
DE 10302014	A1	29-07-2004	NONE			
WO 2012019059	A2	09-02-2012	US	2013142677	A1	06-06-2013
			US	2015239753	A1	27-08-2015
			WO	2012019059	A2	09-02-2012
WO 0123076	A1	05-04-2001	AU	7501800	A	30-04-2001
			BR	0007181	A	04-09-2001
			CA	2352242	A1	05-04-2001
			CN	1322149	A	14-11-2001
			CN	1618506	A	25-05-2005
			EP	1140329	A1	10-10-2001
			HU	0105012	A2	29-04-2002
			JP	2003510177	A	18-03-2003
			KR	20010086063	A	07-09-2001
			MX	230492	B	09-09-2005
			PL	347883	A1	22-04-2002
			TW	496768	B	01-08-2002
			US	6589426	B1	08-07-2003
			US	2003057155	A1	27-03-2003
			US	2004251200	A1	16-12-2004
			US	2006081536	A1	20-04-2006
			WO	0123076	A1	05-04-2001
			ZA	200103787	A	26-06-2002