IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

UNITED STATES FILTER CORPORATION, AND U.S. FILTER/IONPURE INC., Plaintiffs,	
v.	CIVIL ACTION NO.
IONICS, INCORPORATED Defendants.	00CV11157REK

COMPLAINT AND JURY DEMAND

1. Plaintiff United States Filter Corporation ("U.S. Filter") is a Delaware corporation with its principal place of business at 40-004 Cook Street, Palm Desert, California.

2. Plaintiff U.S. Filter/Ionpure Inc. ("U.S. Filter/Ionpure"), a wholly owned subsidiary of U.S. Filter, is a Massachusetts corporation with its principal place of business at 10 Technology Drive, Lowell, Massachusetts.

3. Defendant Ionics, Incorporated ("Ionics") is a Massachusetts corporation with its principal place of business at 65 Grove Street, Watertown, Massachusetts.

4. This action arises under the patent laws of the Untied States, Title 35 of the United States Code.

5. This Court has subject matter jurisdiction pursuant to 28 U.S.C. § 1338(a).

6. Ionics conducts substantial business in the Commonwealth of Massachusetts and has continuous and systematic contacts with this state. Venue in this district is proper pursuant to 28 U.S.C. § 1400(b).

COUNT 1

7. U.S. Filter/Ionpure is the owner of U.S. Patent 4,574,049, entitled "Reverse Osmosis System," which issued on March 4, 1986. Reexamination certificate B1 4,574,049 issued for this patent on February 2, 1999 (the "'049 Patent"). A copy of the '049 Patent, including its reexamination certificate, is attached as Exhibit A.

8. U.S. Filter wholly owns U.S. Filter/Ionpure. Many of the officers and directors of U.S. Filter/Ionpure are officers and directors of U.S. Filter.

9. Ionics has infringed, is continuing to infringe, is contributing to infringement by others and is inducing others to infringe the '049 Patent by making, selling, offering to sell and using within the United States, reverse osmosis systems covered by one or more of the claims of the '049 Patent.

10. Ionics' infringement of the '049 Patent is and has been willful, has caused and will continue to cause the plaintiffs to suffer substantial damages, and has caused and will continue to cause the plaintiffs to suffer irreparable harm for which there is no adequate remedy at law.

United States Patent [19]

Pittner

[11] **Patent Number: 4,574,049**

[45] **Date of Patent: Mar. 4, 1986**

[54] **REVERSE OSMOSIS SYSTEM**

[75] Inventor: **Gregory A. Pittner**, Danville, Calif.

[73] Assignee: **Arrowhead Industrial Water, Inc.**, Los Angeles, Calif.

[21] Appl. No.: **616,729**

[22] Filed: **Jun. 4, 1984**

[51] **Int. Cl.⁴** **B01D 13/00**

[52] **U.S. Cl.** **210/639**; 210/641; 210/195.2; 210/433.2

[58] **Field of Search** 210/639, 641, 259, 321.1, 210/206, 195.2, 433.2

[56] **References Cited**

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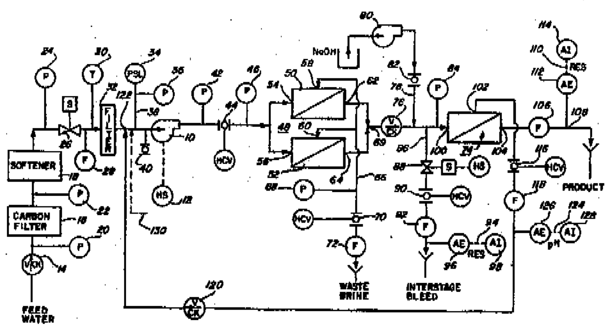
Primary Examiner—Frank Spear

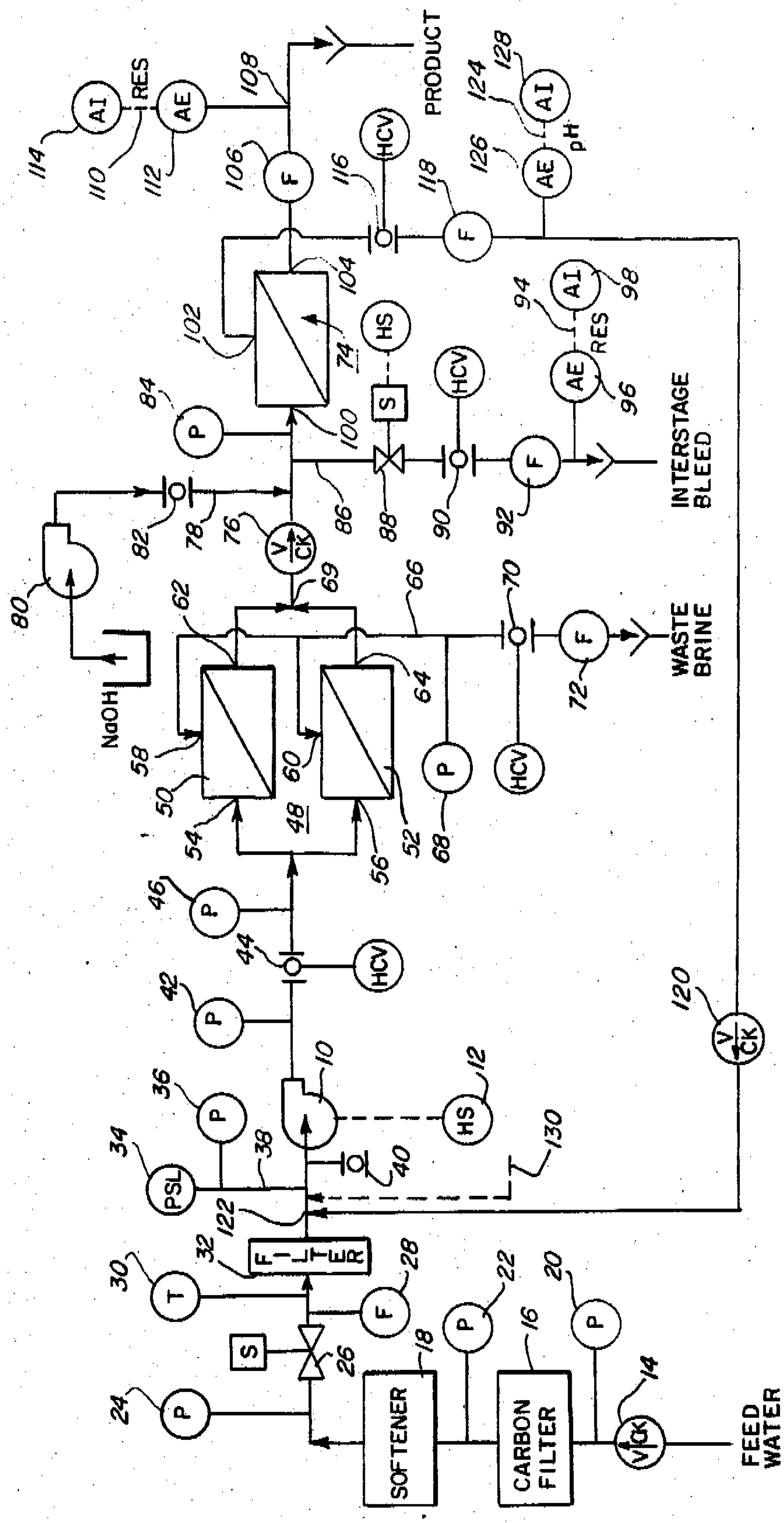
Attorney, Agent, or Firm—George H. Gerstman

[57] **ABSTRACT**

A chemically enhanced reverse osmosis water purification system and process is provided in which the inlet of a second reverse osmosis unit is coupled in series to the product water outlet of a first reverse osmosis unit. Water to be purified is conditioned by an ion exchange resin type water softener and pumped to the inlet of the first reverse osmosis unit. The product from the first reverse osmosis unit is treated with a chemical treatment agent, such as a sodium hydroxide solution, upstream of the inlet to the second reverse osmosis unit. The brine from the brine outlet of the second reverse osmosis unit is recirculated to the water flow line upstream of the first reverse osmosis unit.

10 Claims, 1 Drawing Figure




PRODUCT
INTERSTAGE BLEED
WASTE BRINE
FEED WATER
SOFTENER
CARBON FILTER
FILTER
NaOH
RES
pH

REVERSE OSMOSIS SYSTEM

BACKGROUND OF THE INVENTION

The present invention concerns a novel system and process for separating impurities from water using reverse osmosis membranes.

The process of reverse osmosis is currently in widespread use for the treatment of water. Its value is derived from the ability of a semipermeable membrane to preferentially reject the passage of most salts, a high percentage of organic contaminants, and nearly all particulate matter. The process, as it is typically designed and operated, has limitations though, in that both the dissolved salt and organic passage is too great for the process to be used as a stand-alone treatment, and the seals separating the raw and treated water sides of the membrane are not sufficiently reliable to assure consistently high rejection of particulates.

Additionally, it is customary, and in many cases imperative, to pretreat the water supply ahead of reverse osmosis to avoid fouling of membrane surfaces. Doing so in many cases limits the performance of the unit because the required pretreatment can reduce the ability of the membranes to reject contaminants.

In the majority of raw water supplies, calcium and alkalinity levels are sufficiently high that direct treatment by reverse osmosis would cause precipitation of calcium carbonate on membrane surfaces, reducing productivity. To avoid precipitation, pretreatment by softening, or by acid addition, is practiced. Both processes reduce the effectiveness of the reverse osmosis membrane. When softening is employed, the divalent ions of calcium and magnesium are exchanged for the monovalent ion sodium. Sodium is not as well rejected by the membrane, thus the treated water salt level is increased and the cost of further removal of dissolved solids downstream of the reverse osmosis system is increased. If acid is added to reduce alkalinity, the alkalinity is converted to carbonic acid, which passes freely through the membrane and thus also increases the cost of downstream treatment.

It is an object of the present invention to provide a system and process which significantly alleviates the aforementioned difficulties.

Another object of the present invention is to provide a system and process for purifying water that is relatively low in cost and simple to produce and use.

A further object of the present invention is to provide a water purification system and process, using reverse osmosis techniques, that is reliable in operation and achieves high particle rejection.

A still further object of the present invention is to provide a reverse osmosis type water purification system and process which enables the operator to tailor the system and process to performance improvement.

Other objects and advantages of the present invention will become apparent as the description proceeds.

SUMMARY OF THE INVENTION

In accordance with the present invention, a reverse osmosis water purification system is provided. The system includes a first reverse osmosis unit having an inlet, a product outlet and a brine outlet. Means are provided for pumping water to be purified to the inlet of the first reverse osmosis unit. A second reverse osmosis unit is provided in series with the first reverse osmosis unit and downstream therefrom. The second reverse osmosis unit has an inlet, a product outlet and a brine outlet. A conduit couples the product outlet of the first reverse osmosis unit to the inlet of the second reverse osmosis unit.

Means are provided for treating the product from the first reverse osmosis unit at a location upstream of the second reverse osmosis unit. Means are provided for directing the product from the second reverse osmosis unit toward a point of use or storage for purified water.

In the illustrative embodiment, an ion exchange type water softener is provided upstream of the first reverse osmosis unit for conditioning the water to be purified. the treating means referred to above comprises introducing a solution having a pH that exceeds 7, such as a sodium hydroxide solution. The pumping means comprises a pump located upstream of the first reverse osmosis unit.

In the illustrative embodiment, a carbon filter is located upstream of the water softener and a 5 micron cartridge filter is located downstream of the water softener and upstream of the pumping means. The brine outlet of the second reverse osmosis unit is coupled to the water flow line upstream of the first reverse osmosis unit by a recirculation conduit.

The water purification process of the present invention comprises the steps of providing a first reverse osmosis unit having an inlet, a product outlet and a brine outlet; providing a second reverse osmosis unit having an inlet, a product outlet and a brine outlet; locating the second reverse osmosis unit downstream of the first reverse osmosis unit with the product outlet of the first reverse osmosis unit being coupled to the inlet of the second reverse osmosis unit; pumping water to be purified to the inlet of the first reverse osmosis unit; treating agent into the product from the first reverse osmosis unit at a location upstream of the second reverse osmosis unit; and directing the product from the second reverse osmosis unit toward a point of use or storage for purified water.

In the illustrative embodiment, the process includes the step of conditioning the water to be purified upstream of the first reverse osmosis unit and recirculating the brine from the brine outlet of the second reverse osmosis unit back to the water flow line upstream of the first reverse osmosis unit.

A more detailed explanation of the invention is provided in the following description and claims, and is illustrated in the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The drawing FIGURE is a schematic flow diagram of a reverse osmosis water purification system constructed in accordance with the principles of the present invention.

DETAILED DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

Referring to the drawing, a reverse osmosis water purification system is shown therein, including a pump **10**, connected to an on/off/automatic hand switch **12** which is used to pump, through the system, feed water from a municipal water supply or the like. The feed water flows through a check valve **14**, a carbon filter **16**, and the water is conditioned by an ion exchange resin type water softener **18**. Pressure gauges **20**, **22** and **24** are located, respectively, upstream of carbon filter **16**, between carbon filter **16** and softener **18**, and downstream of softener 20. Pressure gauge 24 is used to check that there is adequate pressure upstream of pump 10 in order to provide adequate net positive suction head.

A solenoid valve 26 is connected in the water line to shut down flow when the system is off. A flow indicator 28 is provided to check flow in order to get a complete water balance across the system. A temperature indicator 30 is provided to check the temperature of the water in order to correct the performance of the downstream reverse osmosis membranes since the performance of the membranes will vary in response to the temperature of the water.

A 5 micron cartridge filter 32 is provided to reduce the level of suspended solids in the water to the reverse osmosis membranes, thus alleviating the possibility that fouling by suspended solids will cause erroneous readings in performance.

Downstream of the cartridge filter 32 there is a low pressure switch 34 which operates if the pressure goes below a predetermined amount. A pressure gauge 36 is in line with low pressure switch 34 to monitor pressure in the low pressure switch line 38. A ball valve 40 is provided to enable sampling of the water in order to measure the water quality. The next item downstream is pump 10, shown connected to hand switch 12. The hand switch has three functions: on, off or automatic.

Downstream of pump 10 there is another pressure gauge 42 to measure the output from pump 10. Downstream of pressure gauge 42 is hand-controlled ball valve 44, which allows adjusting the pressure of water to the first stage reverse osmosis unit. Another pressure valve 46 is provided to indicate the pressure of the first stage reverse osmosis unit.

The first stage reverse osmosis unit 48 comprises a pair of parallel connected reverse osmosis membrane units 50 and 52. Inlet 54 of reverse osmosis membrane unit 50 and inlet 56 of reverse osmosis membrane unit 52 are connected together. Likewise, brine outlet 58 of reverse osmosis membrane unit 50 and brine outlet 60 of reverse osmosis membrane unit 52 are connected together. Likewise, product outlet 62 of reverse osmosis membrane unit 50 and product outlet 64 of reverse osmosis unit 52 are connected together. Although no limitation is intended, reverse osmosis unit 50 comprises two Film-Tec BW30-4040 reverse osmosis modules. Likewise, reverse osmosis unit 52 comprises two Film-Tech BW30-4040 modules. It can thus be seen that in this embodiment, the first reverse osmosis unit 48 comprises four reverse osmosis modules, in order to obtain optimum water flow for the downstream system.

Although no limitation is intended, the flow rate at flow meter 28 is preferably about 12 gpm, the pressure at the pressure gauge 42 is preferably 475 psig, the water at inlet 54 preferably has a flow rate of 6 gpm and a pressure of 450 psig and the water at inlet 56 preferably has a flow rate of 6 gpm and a pressure of 450 psig.

Brine outlets 58 and 60 are coupled to waste line 66 having a pressure gauge 68 in the line and also having a hand-controlled ball valve 70 and flow indicator 72 in the line.

The product water outlets 62 and 64, which are connected together at point 69, are directed toward a second reverse osmosis unit 74 through a check valve 76. At point 69 the water is preferably flowing at 3.3 gpm with a pressure of 225 psig.

Second reverse osmosis unit 74 preferably comrpises two Film-Tec BW30-4040 reverse osmosis modules. Downstream of check valve 76 but upstream of reverse osmosis module 74 there is provided the introduction of a chemical treatment agent via line 78. The chemical treatment agent is pumped through line 78 by pump 80 and through a shutoff valve 82.

It is preferred that the chemical treatment agent be a base, i.e., a solution having a pH greater than 7. A 20 percent sodium hydroxide solution has been found most advantageous. The primary purpose for the sodium hydroxide solution is as follows. I have discovered that treatment of water with two reverse osmosis units in series will not provide water that is twice as high in quality as using one reverse osmosis module. This is because the sodium bicarbonate from the upstream treatment of the water going to the first reverse osmosis unit 48, disassociates into sodium carbonate and carbon dioxide. Although the disassociation is normally less than 10 percent, there is still an appreciable amount of carbon dioxide provided. The carbon dioxide passes through the reverse osmosis membrane. Thus, any carbon dioxide which is generated is not removed but is present in the treated water. By placing a second reverse osmosis unit in series with the first reverse osmosis unit, the carbon dioxide passing the first reverse osmosis unit will also pass the second reverse osmosis unit. However, by adding sodium hydroxide the carbon dioxide is converted back to bicarbonate and preferably back to carbonate. Carbonate is rejected more readily by the reverse osmosis membrane than is bicarbonate. By converting the carbon dioxide to carbonate, a substantially improved performance is achieved.

Other bases may be used for removing the carbon dioxide. For example, sodium carbonate may be used although this solution would not remove as much of the carbon dioxide as sodium hydroxide would remove. Trisodium phosphate may be used and may outperform the sodium hydroxide solution, but trisodium phosphate is more expensive than sodium hydroxide.

In addition to the conversion of the carbon dioxide to carbonate, the introduction of sodium hydroxide will also ionize certain otherwise difficult to remove chemical compounds, most notably silica and various organics. Silica is normally not ionized below a pH of approximately 9.5. Since it is not ionized, it is not as well rejected by the reverse osmosis membrane. However, by use of the sodium hydroxide solution, raising the pH above 9.5 the silica can be ionized, thus increasing its rejection by the reverse osmosis membrane and reducing the level of silica in the treated water.

Similarly, organic molecules that are known to be present and difficult to remove from water supplies include a large variety of carboxilic acids. Carboxilic acids will ionize at various pH levels, all above 5, but an increasing percentage of them will ionize as the pH is increased. By addition of the sodium hydroxide, a much larger percentage of the organic molecules will be ionized as compared with a system without the sodium hydroxide addition.

Again, other solutions may be useful. Other bases, such as sodium bicrabonate, sodium carbonate, disodium phosphate, trisodium phosphate, ammonium hydroxide, potassium hydroxide, calcium hydroxide and magnesium hydroxide may be utilized.

A pressure gauge 84 is located upstream of second reverse osmosis unit 74 in order to check the pressure of this stage.

Slightly downstream of chemical treatment line 78 there is an interstage bleed line 86. The interstage bleed line includes a solenoid valve 88 controlled by a two-

5. A process as described in claim 1, including the step of bleeding the product downstream of said treatment but upstream of said second reverse osmosis unit.

6. A process as described in claim 1, including the step of treating the water to be purified upstream of said reverse osmosis unit to adjust its pH to below about 5.

7. A process as described in claim 1, including said treating step comprising the step of adjusting the pH of the product water from said first reverse osmosis unit to above about 9.

8. A water purification process for removing dissolved solids of the type that are normally present in a municipal water supply or the like, which comprises the steps of:

providing a first reverse osmosis unit having an inlet, a product outlet and a brine outlet;

providing a second reverse osmosis unit having an inlet, a product outlet and a brine outlet;

locating said second reverse osmosis unit downstream of said first reverse osmosis unit with the product outlet of said first reverse osmosis unit being coupled to the inlet of said second reverse osmosis unit;

pumping water to be purified to the inlet of said first reverse osmosis unit;

treating the water to be purified upstream of said first reverse osmosis unit to adjust the pH to below about 5;

introducing a chemical treatment agent into the product from said reverse osmosis unit to adjust its pH to below about 5;

introducing a chemical treatment agent into the product from said first reverse osmosis unit at a location upstream of said second reverse osmosis unit to adjust the pH of the product water from said first reverse osmosis unit to above about 9 to reduce carbon dioxide concentration of the product by chemical conversion and to ionize certain otherwise difficult to remove chemicals; and

directing the product from said second reverse osmosis unit toward a point of use or storage for purified water.

9. A process as described in claim 8, including the steps of:

recirculating the brine from the brine outlet of said second reverse osmosis unit back to the water flow line upstream of said first reverse osmosis unit; and

bleeding the product downstream of the chemical treatment agent introduction but upstream of said second reverse osmosis unit.

10. A water purification process for removing dissolved solids of the type that are normally present in a municipal water supply or the like, which comprises the steps of:

providing a first reverse osmosis unit having an inlet, a product outlet and a brine outlet;

providing a second reverse osmosis unit having an inlet, a product outlet and a brine outlet;

locating said second reverse osmosis unit downstream of said first reverse osmosis unit with the product outlet of said first reverse osmosis unit being coupled to the inlet of said second reverse osmosis unit;

providing water to be purified to the inlet of said first reverse osmosis unit;

treating the product from said first osmosis unit at a location upstream of said second reverse osmosis unit with a chemical treatment agent comprising a solution having a pH that exceeds 7 to reduce carbon dioxide concentration of the product by chemical conversion and to ionize certain otherwise difficult to remove chemicals;

said second reverse osmosis unit inlet receiving product water from said first reverse osmosis unit product outlet at substantially the same flow rate and pressure as the flow rate and pressure of the product water from said reverse osmosis unit product outlet; and

directing the product from said second reverse osmosis unit toward a point of use or storage for purified water.

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