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(54) **Title**: SYSTEM AND METHOD FOR DESALINATION

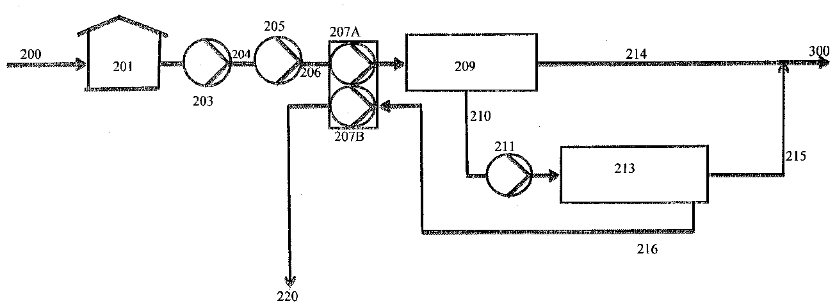

FIGURE 1

(57) **Abstract**: The present invention provides a system for continuous desalination of saline water having variable salinity, the system comprising: (a) a RO stage comprising one or more reverse osmosis pressure vessels, said first RO stage configured to receive a feed stream of saline water to thereby produce a first reject stream and a first permeate stream, wherein the permeate stream contains less salinity relative to the reject stream; (b) a second RO stage comprising one or more reverse osmosis pressure vessels, said second RO stage being configured to receive the first reject stream to thereby produce a second reject stream and a second permeate stream; (c) a variable pressurizing means located upstream of said RO stages, said variable pressurizing means capable of adjusting the pressure of said feed stream; and (d) a pressure recovery means configured to recover energy from said second reject stream, said pressure recovery means capable of adjusting the pressure of said feed stream. The present invention further provides a method for performing the same.

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SYSTEM AND METHOD FOR DESALINATION

Technical Field

The present invention generally relates to a method and system for desalinating water with variable salinity.

Background

Reverse osmosis ("RO") desalination systems and methods are commonly used to treat high salinity water, such as, seawater or brackish water. Sea water typically contains from about 25000 to 45000 parts per million (ppm) of total dissolved solids ("TDS") whereas the term brackish water is commonly used to refer to water that has lower salinity compared to sea water but higher salinity compared to fresh water. Brackish water typically contains from about 500 to 5000 ppm TDS.

Reverse osmosis desalination plants that are equipped to treat a full variation of salinity water, for example, salinity water ranging from seawater to brackish water, typically comprise a seawater RO system to treat seawater and a separate brackish water RO system to treat brackish water. This is because, due to its lower salinity, brackish water is usually subjected to reverse osmosis at a lower pressure and high recovery rate as compared to sea water. As such, the seawater RO systems and brackish water RO system are typically operated separately and independently of one another.

Critically, as a result, the seawater RO system and the brackish water RO system in such desalination plants are not individually designed to handle a wide variation of salinity in the feed water. Rather, the treatment of a full spectrum of salinity water requires switching or alternating between the seawater RO system to treat seawater and the brackish water RO system to treat brackish water.

Disadvantages associated with the use of two different types of RO systems to treat a full variation of salinity water include:

- The need to switch or alternate between a seawater RO system to treat seawater and a brackish water RO system to treat brackish water;
- The increased energy expenditure associated with operating the two different types of RO systems and alternating between the two different types of RO systems;
- The required maintenance of two different types of RO systems; and
- The increased costs associated with operating and maintaining the two different types of RO systems.

Therefore, there is a need to provide a desalination system and method that avoids or at least ameliorates one or more of the disadvantages described above.

Summary

Accordingly, in a first aspect, there is provided a system for desalinating saline water, the system comprising:(a) a first reverse osmosis (RO) stage comprising one or more pressure vessels, said first RO stage configured to receive a feed stream of saline water to thereby produce a first reject stream and a first permeate stream, wherein the permeate stream contains lower salinity relative to the reject stream; (b) a second RO stage comprising one or more pressure vessels, said second RO stage being configured to receive the first reject stream to thereby produce a second reject stream and a second permeate stream; (c) a variable pressurizing means located upstream of said RO stages, said variable pressurizing means capable of adjusting the pressure of said feed stream; and (d) a pressure recovery means configured to recover energy from said second reject stream wherein the pressure recovery means is capable of adjusting the pressure of said feed stream.

An advantage of the disclosed system resides in the provision of at least two integrated pressure control means, including the variable pressurizing means and the pressure recovery means, to control and generate optimal pressures of the feed stream entering the first or second RO stage based on the salinity of the feed stream to cause effective desalination. Consequently, the disclosed system can be used to handle feed stream containing a full variation of salinity ranging from 2000 ppm to 45000 ppm of TDS.

Yet another advantage of the disclosed system lies in its improved energy efficiency as the energy of the highly pressurized second reject stream can be substantially recovered by the pressure recovery means. The recovered energy may then be applied to the incoming feed stream to thereby reduce the pressure load on the variable pressurizing means. The pressure recovery means also acts as an integrated pressure controller to provide improved flexibility in overall pressure control of the desalination system.

A further advantage of the above disclosed system is its robustness in desalinating feed water of variable salinity, thereby obviating the need to provide separate seawater RO systems and brackish water RO systems. The desalination process can be performed continuously and real-time adjustments can be made to the operating pressures of the reverse osmosis modules through the ~~variable pressurizing means and energy recovery means~~ to accommodate and react to changes in the salinity of the feed water without having to take the system offline or to switch to another membrane system.

In one embodiment, the disclosed system may further comprise an inter-stage pressurizing means located between the first and second RO stages. The inter-stage pressurizing means may be configured to further pressurize the reject stream exiting the first RO stage before the reject stream is passed into the second RO stage. An advantage of doing so is that it allows the second RO stage to desalinate effectively the reject stream, which understandably would contain higher salinity than the feed stream.

Importantly, the aforementioned three pressurizing means, including the variable pressurizing means, the pressure recovery means and the inter-stage pressurizing means, can be operated in combination to provide rapidly adjustable pressure conditions for the first and/or second RO stages and thereby allow the system to meet the required pressure variation for treating feed water of variable salinity.

In a second aspect, there is provided a continuous method for desalinating saline water, the method comprising the step of: (a) providing a feed stream of saline water; (b) variably adjusting the pressure of said feed stream in response to the salinity of the feed stream; (c) subjecting said feed stream to a first RO step to thereby produce a first reject stream and a first permeate stream, said first permeate containing lower salinity relative to said first reject stream; and (d) subjecting said first reject stream to a second RO step to thereby produce a second reject stream and a second permeate stream.

Similar to the system of the first aspect, the disclosed method also provides numerous advantages including the ability to treat feed water having salinity ranging from 2000 to 45,000 ppm without having to provide separate treatment protocols, improved energy efficiency due to the energy recovering step and the flexibility to variably adjust the pressures of the first and second RO stages, in accordance with the salinity of the feed water, to provide optimal pressures for effective desalination.

The above disclosed system and method may provide desalinated water having a TDS of 500 ppm or lower. In one embodiment, the desalinated product water has a TDS of lower than 300 ppm.

Definitions

The following words and terms used herein shall have the meaning indicated:

The term "total dissolved solids" as used in the context of the present specification, refers to the sum of the dissolved inorganic salts and organic matter dissolved in water in molecular and ionized form. TDS is typically used as a measurement of the "salinity" of a given body of water and is expressed in units of parts per million (ppm) or milligrams per litre (mg/L). Therefore, the term "salinity" should be construed accordingly.

The word "substantially" does not exclude "completely" e.g. a composition which is "substantially free" from Y may be completely free from Y. Where necessary, the word "substantially" may be omitted from the definition of the invention.

Unless specified otherwise, the terms "comprising" and "comprise", and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, unrecited elements.

As used herein, the term "about", in the context of concentrations of components of the formulations, typically means +/- 5% of the stated value, more typically +/- 4% of the stated value, more typically +/- 3% of the stated value, more typically, +/- 2% of the stated value, even more typically +/- 1% of the stated value, and even more typically +/- 0.5% of the stated value.

Throughout this disclosure, certain embodiments may be disclosed in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Disclosure of Optional Embodiments

Exemplary, non-limiting embodiments of the desalination system of the first aspect will now be disclosed.

In one embodiment, the feed water to be treated by the disclosed system is water pumped from a river mouth or directly from the sea or a mixture of both. In one embodiment, the feed water is sea water having salinity from 2,000 to 40,000 ppm.

In one embodiment, the variable pressurizing means of the disclosed system comprises a variable speed high pressure pump that is fluidly communicated with the first RO stage. Preferably, the variable speed high pressure pump is capable of being electronically adjusted to provide continuous increments or reductions in the generated pressure. In one embodiment, the variable speed high pressure pump is capable of being adjusted in 1% increments or reductions in pressure output.

In one embodiment, the pressure recovery means of the disclosed system comprises a Turbo-Charger device. Turbo-charger devices are well known in the art and typically comprise at least two hydraulic-powered components mounted on a common shaft. The two hydraulic-powered components are typically isolated from each other. In operation, one of the components may be a turbine which recovers energy from the highly pressurized second reject stream. The recovered energy is then transferred to the other hydraulic-powered component through rotation of the common shaft and the recovered energy may be used to pressurize the incoming feed water. The advantage of the Turbo-charger device is that it allows the disclosed system to recover energy, which would otherwise have been lost following the discharge of the reject stream. More importantly, the turbo-charger also serves as an integrated, variable speed pump which provides additional control over the pressure of the feed stream entering the RO stages. This feature directly contributes to the disclosed system's ability to handle feed water of variable salinity.

The inter-stage pressurizing means may comprise a pressure booster pump that is electronically and/or manually adjustable in its pressure output. In one embodiment, the inter-stage pressurizing means is an electrically driven inter-stage booster pump provided with a variable speed drive. Similar to variable speed high pressure pump disclosed earlier, it is preferred that the inter-stage booster pump is capable of being electronically adjusted in small, step-wise increments or reductions in pressure output. In one embodiment, the pressure output of the inter-stage booster pump is adjustable in 1% increments or reductions.

The disclosed system may further comprise recycling means to recycle the second reject stream to the feed stream. This may be done to increase the salinity of the feed water. For example, while the system is in continuous operation and a drop in the salinity of the feed water is experienced, rather than reducing the pressures of the RO stages, an operator may simply choose to partially or fully recycle the second reject stream to mix with the incoming feed stream. An advantage of doing so is that it would reduce the pressure variation required and increase overall recovery of sea water.

The disclosed system may further comprise recycling means capable of recycling the first or second permeate stream or both to the feed stream. This may be done where a reduction of the salinity of feed water is desired. For example, while the system is in continuous operation and an increase in salinity is experienced, rather than increasing the pressures of the RO stages (which would entail increased energy costs), an operator may choose to at least partially recycle the permeate streams back to the feed stream to reduce the salinity of the feed water. As discussed above, an advantage of doing so is that it would reduce the pressure variation required in operating this system.

The disclosed system may further comprise sampling means capable of measuring and transmitting salinity data of the feed stream. In one embodiment, the sampling means may comprise a sensor capable of measuring electrical conductivity may be placed in fluid contact with the feed water to measure its conductivity and wherein the sensor is capable of converting conductivity data to salinity data.

The disclosed system may further comprise an online control system configured to receive the salinity data transmitted from the sampling means, wherein the control system may be electronically coupled to one or more of the variable pressurizing means, inter-stage pressurizing means and pressure recovery means, to adjust pressures in the first and/or the second RO stages in response to a change in salinity of the feed water.

In yet another embodiment, the control system may be further configured to activate the either one of the recycling means described above, to thereby adjust the salinity of said feed water. For instance, electronically-actuated valves may be installed to direct at least a part of the reject stream or the permeate stream back to the feed stream for mixing. The open/close configuration of these valves may be suitably controlled by electronic signals transmitted from the control system in response to the salinity data collected by the sampling means.

The disclosed system may further comprise a bypass means configured to allow the second reject stream to at least partially bypass the pressure recovery means. For instance, where the salinity of the feed water experiences a drop during continuous operation, the bypass means may be activated such that the proportion of the reject stream passed to the Turbocharger is reduced and correspondingly, the additional pressurization to the feed stream is reduced. The bypass means may comprise an arrangement of valves capable of directing at least a portion of the reject flow away from the Turbocharger. In one embodiment, the system may be operated such that the Turbocharger is completely bypassed, i.e., no reject stream is directed to the Turbocharger at all.

In one embodiment, the total number of pressure vessels provided in each of the first and second RO stages of the disclosed system may be the same (i.e. a non-tapered, two-stage array design). Advantageously this non-tapered arrangement improves overall operational flexibility for handling feed water of variable salinity.

In one embodiment, each of the first and second RO stages contains no more than seven RO pressure vessels within each stage. Each pressure vessel may house one or more RO membrane modules therein. The number of RO membrane modules in each pressure vessel are independently same or different.

The pressure vessels housed within each of the first and second RO stages may comprise the same type of RO membranes. The RO membrane modules used may be seawater-type membrane modules. In one embodiment, the RO membrane modules are composed of composite polyamide membranes.

One or more of the above disclosed system may be arranged to work in co-operation in a desalination plant to achieve a desired water production output per day.

Exemplary, non-limiting embodiments of the desalination method according to the second aspect will now be disclosed.

The continuous method for desalinating saline water may comprise the steps of: (a) providing a feed stream of saline water; (b) variably adjusting the pressure of said feed stream in response to the salinity of said feed stream; (c) subjecting said feed stream to a first RO step to thereby produce a first reject stream and a first permeate stream, said first permeate containing lesser salinity relative to said first reject stream; and (d) subjecting said first reject stream to a second RO step to thereby produce a second reject stream and a second permeate stream.

Prior to the provision step (a), the feed water may be subject to pre-treatment steps to remove undissolved matter. Such pre-treatment steps may include but are not limited to, sedimentation, equalization, coagulation, flocculation, clarification followed by sedimentation, dissolved air flotation, media filtration, microfiltration, ultrafiltration, and a combination of one or more pre-treatment steps mentioned above.

The method may further comprise a step (e) of recovering pressure energy from the second reject stream. This can be done, for instance, through passing the second reject stream to an energy recovery device, such as a turbo-charger.

The method may further comprise a step (f) of applying the recovered pressure energy in step (e) to variably adjust the pressure of the feed stream in step (b).

The pressurizing step (b) may be undertaken to generate a feed stream with pressures from about 20 bars to about 60 bars, from about 20 bars to about 50 bars, from about 20 bars to about 40 bars, from about 20 bars to about 30 bars, from about 30 bars to about 50 bars, from about 30 bars to about 40 bars, from about 40 bars to about 50 bars, depending on the salinity of the feed stream.

In one embodiment, the pressure under which step (c) is performed is about 20 to 50 bars.

The disclosed method may further comprise a step (c1) of increasing pressure of the first reject stream before step (d). This may be accomplished by providing one or more inter-stage booster pumps along the flow path of the first reject stream. The adjusted pressure of the first reject stream may be in a range of from about 30 bars to about 70 bars, from about 30 bars to about 60 bars, from about 30 bars to about 50 bars, from about 30 bars to about 40 bars, from about 40 bars to about 60 bars, from about 40 bars to about 50 bars and from about 50 bars to about 60 bars, prior to undergoing step (d). The actual pressure may depend on the salinity of the reject stream and the desired recovery rate.

The disclosed method may further comprise a recycling step (g) of recycling the second reject stream to the feed stream to increase salinity of the feed stream. An advantage of doing this, as also discussed previously, is that it reduces the pressure variation required when the salinity of the feed stream changes.

The disclosed method may also comprise a recycling step (h) of recycling said first or second permeate stream or both to the feed stream to decrease the salinity of the feed stream.

The disclosed method may further comprise a sampling step (i) of measuring salinity data of the feed stream. The sampling step (i) may be accomplished by the provision of a sensor capable of measuring electrical conductivity. The sensor may be placed into fluid contact with the feed stream to measure its conductivity.

Preferably the sensor is one that is capable of converting the conductivity data to corresponding salinity data. In one embodiment, salinity data collected by the sensor is transmitted to an online control system. The method may further comprise operating the control system to set pressure values for the one or more of the following steps (b), (c1) and (f), in response to the salinity data. In another embodiment of the disclosed method, the control system may be further operated to set recycle rates of step (g) and/or step (h) to improve the control of the salinity of feed water.

In one embodiment of the disclosed method, step (e) may comprise a partial recovery of the pressure energy of the second reject stream. This may be due to a variety of reasons, for instance, the salinity of the feed stream to be treated is substantially low and therefore the pressure requirement is reduced for effective desalination. In this case, the pressure energy of the second reject stream may only be partially recovered via by-passing a fraction of the reject stream to be discharged without passing through an energy recovery device, such as a turbo-charger. In yet another embodiment, step (e) may comprise completely discharging the second reject stream via a by-pass conduit without recovering any pressure energy.

Brief Description Of Drawings

The accompanying drawings illustrate a disclosed embodiment and serves to explain the principles of the disclosed embodiment. It is to be understood, however, that the drawings are designed for purposes of illustration only, and not as a definition of the limits of the invention.

Fig. 1 shows one embodiment of the desalination system of the present invention, where energy is recovered via a turbo-charger device.

Fig. 2 shows yet another embodiment of the desalination system of the present invention, where the turbo-charger device is partially bypassed.

Fig. 3 shows another embodiment of the desalination system of the present invention, with recycle of the reject stream back to the feed stream.

Fig. 4 shows a further embodiment of the desalination system of the present invention, where feed stream with TDS exceeding 25000 ppm is treated

Fig. 5 shows a further embodiment of the desalination system of the present invention, where feed stream with TDS exceeding 25000 ppm is treated, and wherein the permeate product is partially recycled.

Detailed Description of Drawings

Referring now to Fig. 1, there is shown one embodiment of the desalination system according to the present invention. Feed stream 200 is water that has been drawn from a natural water body, such as an estuary, and has been pre-treated with one or more of the following pretreatment steps, settling, sedimentation, clarification, and filtration. Feed stream 200 is stored in a filtered water tank 201 which is fluidly communicated with the desalination system of the present invention. In this embodiment, the feed stream 200 may have TDS in the range of 10,000 to 25,000 ppm.

During operation, a fixed speed pump 203 pumps feed water stored in tank 201 towards a reverse osmosis system. The reverse osmosis system is a non-tapered, two-stage array design comprising a first RO stage 209 and a second RO stage 213. Both RO stages 209 and 213 comprise pressure vessels housing one or more sea water membrane modules capable of treating high salinity water. In this embodiment, the fixed speed pump 203 pressurizes the feed water 200, forming a pressurized stream 204. Pressurized stream 204 is then further pressurized by a variable speed pump 205 to form a pressurized stream 206. Pressurized stream 206 is thereafter subjected to further pressurization by a turbocharger 207. The pressurized feed water is subsequently passed towards the first RO stage 209.

In RO stage 209, feed water 200 is passed through a plurality of membrane modules wherein the water is forced through a reverse osmosis membrane to form a permeate stream 214 whereas dissolved salts are retained in a concentrate (or "reject") stream 210. The permeate stream is post-treated (not shown) for pH correction and chlorination before being distributed to users as product water 300.

The reject stream 210 is then passed towards the second RO stage 213. Prior to entering pressure vessels in the second RO stage 213, the reject stream 210 may undergo further pressurization by an inter-stage, variable speed booster pump 211. As the salinity of reject stream 210 is expected to be higher than feed stream 200, the additional pressurization by the variable speed booster pump 211 ensures that there is sufficient pressure to drive a second reverse osmosis step.

Inside second RO stage 213, the reject stream 210 is passed through an identical number of membrane pressure vessels as the first RO stage 209, to recover additional water in a permeate stream 215. The dissolved salts are then discharged via reject stream 216. Permeate stream 215 may be mixed downstream with the first permeate stream 214 to lower the salinity of the mixed stream relative to permeate stream 214.

At this point, the reject stream 216 remains highly pressurized and is made to pass through a turbocharger 207. The turbocharger 207 comprises at least two hydraulic-powered turbines 207A and 207B, which are mounted on a common shaft. During operation, turbine 207B recovers energy from the highly pressurized reject stream 216. The recovered energy is then transferred to the other turbine 207A via rotation of the common shaft. The recovered energy is then used to pressurize the incoming feed water 206 as described above. After having its pressure reduced by the turbocharger 207, the reject stream 216 forms a low pressure, high salinity discharge stream 220 which may be discharged back into the environment.

In this embodiment, water recovery rate ranges from about 55% to about 60%. The system may provide a sensor (not shown) to measure the conductivity of the feed water to thereby determine its salinity. The sensor then transmits these data to an online control system (not shown) which then controls the pressure output of the variable speed pump 205, the inter-stage booster pump 211 and the turbocharger 207A. Operated in combination, the three variable pressure devices provide the required pressure variation to effectively and continuously desalinate water having TDS of 10000 to 25000 ppm.

Figs. 2 and 3 show another embodiment of the disclosed desalination system, but differs from the embodiment of Fig. 1 in that the feed water treated contains lower than 10,000 ppm TDS. For clarity, the same reference numerals are used in Figs. 2 and 3 to refer to corresponding elements described in Fig. 1. Reverse osmosis is primarily a pressure-driven process and higher salinity in the feed water will require higher pressures for effective desalination. Conversely, when feed water experiences a drop in salinity, provisions are made to reduce the system pressure correspondingly.

In the embodiments of Figs. 2 and 3, where the feed the pressure requirement is lower. Therefore, a by-pass valve 217 is provided such that at least a fraction of the reject stream 216 does not pass through the turbocharger 207B, which allows for a partial or no recovery of the pressure energy. In some embodiments, it is possible for the turbocharger 207B to be entirely by-passed and the reject stream 216 is discharged directly without energy recovery. Accordingly, the by-pass valve provides additional pressure control to the system by controlling the additional pressure (if any) that is applied to feed water stream 206 before it enters the first RO stage 209.

In this regard, the variable speed pump 205 and the inter-stage booster pump can also be simultaneously adjusted to apply lower pressures to the system flow. Typically, in such embodiments (i.e. lower then 10000 TDS feed water), the variable speed pump 205 is configured to pressurize the water to about 10 to 18 bars; the turbo-charger 207A is configured to pressure the water to about 10 to 25 bars; and the inter-stage booster pump 211 is configured to pressurize the reject stream 210 to about 10 to 30 bars.

Notably, as shown in Fig. 3, the system may also provide a recycle stream 218 where at least a portion of the reject stream 216 is recycled back to the feed stream

200 to artificially boost the salinity content. By artificially boosting the salinity content, the requirement for pressure variation can be substantially reduced. For instance, if salinity of the feed water decreased from 25,000 ppm to less than 10,000 ppm, it may be more efficient to recycle reject stream 216 to feed stream 200 to artificially boost the salinity to a higher value than to drastically decrease the pressure output of the variable pressure components 205, 207A and 211 to accommodate the low salinity feed water. The recycle of reject stream 216 affords improved flexibility of the desalination system.

Typically, for feed streams that contain 10,000 ppm TDS or lower, it is possible to operate the desalination system at a recovery rate of 60-67%. This can be achieved by continuously monitoring the salinity of the feed water by an online control system and adjusting the recycle rate of the reject stream 216, the fraction of by-pass, and pressure output in the variable pressure devices 205, 207A and 211.

Figs. 4 and 5 show yet another embodiment of the presently described desalination system, wherein the feed water may have variable salinity higher than 25,000 ppm. For clarity, the same reference numerals are used in Figs. 4 and 5 to refer to corresponding elements described in Fig. 1.

Where the salinity of feed water 200 is greater than 25,000 ppm, additional provisions are provided in the design to control the pressure variation requirement in the desalination system.

In such embodiments, the desalination system is operated at a reduced recovery rate of 50% to 55%. For processing high salinity feed water 200, variable speed pump 205 is typically configured to pressurize feed water 204 to about 20 to 36 bars; the inter-stage booster pump 211 is configured to pressurize the reject stream 210 to about 50 to 70 bars; all of the reject stream 216 is channeled to the turbocharger 207B without bypass to recover substantially all the pressure energy in the reject stream 216; and, applying the recovered pressure, turbocharger 207A then pressurizes the feed stream 206 to about 35 to 50 bars.

Fig. 5 further provides for a permeate recycle stream 219, wherein the permeate 219 is recycled back to the feed stream 200 to artificially lower the salinity of the feed stream. This achieves the effect of reducing the pressure variation requirement during operation when the salinity of the feed water is increased. This recycling step reduces the overall pressure required for effective desalination and reduces the pressure load on the variable pressure devices, such as the variable speed pump 205 and the inter-stage booster pump 211.

Accordingly, the disclosed system is capable of operating continuously to accommodate feed water of inconsistent salinity varying from less than 10,000 ppm to greater than 25,000 ppm. The provisions of variable pressure components, coupled with optional by-pass and recycle streams, which are in turn controlled by an online control system that is continuously fed data on the salinity of feed water, allow the disclosed system to effectively adjust itself to desalinate water of varying salinity.

Applications

As described above, the disclosed system and method overcomes a significant technical problem in the prior art, namely that separate treatment systems and protocols are required for desalinating sea water (high salinity) and brackish water (low to moderate salinity) respectively. This is typically a problem, for example, when the water to be treated is obtained from an estuary which is composed in part of sea water, and in part of fresh river water and therefore may exhibit a high degree of variance in its salinity. The disclosed system and method overcomes this technical problem by operating a combination of variable pressure devices and providing optional recycling streams that are capable of being adjusted / activated in response to changes in the salinity of the feed water. Advantageously, the disclosed system and method allows variable salinity water to be treated in an unitary system or plant, which is especially useful where there are significant space constraints.

It will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims.

Claims

1. A system for desalinating saline water, the system comprising

(a) a first reverse osmosis (RO) stage comprising one or more pressure vessels, said first RO stage configured to receive a feed stream of saline water to thereby produce a first reject stream and a first permeate stream, wherein the permeate stream contains less salinity relative to the reject stream;

(b) a second RO stage comprising one or more pressure vessels, said second RO stage being configured to receive the first reject stream to thereby produce a second reject stream and a second permeate stream;

(c) a variable pressurizing means located upstream of said RO stages, said variable pressurizing means capable of adjusting the pressure of said feed stream; and

(d) a pressure recovery means configured to recover energy from said second reject stream, said pressure recovery means capable of adjusting the pressure of said feed stream.

2. The system of claim 1, further comprising an inter-stage pressurizing means located between said first and second RO stages, said inter-stage pressurizing means configured to increase the pressure of the first reject stream.

3. The system of claims 1 or 2, further comprising a recycling means to recycle said second reject stream to the feed stream.

4. The system of any one of the preceding claims, further comprising a recycling means capable of recycling said first or second permeate stream or both to the feed stream.

5. The system of any one of the preceding claims, further comprising sampling means capable of measuring and transmitting salinity data of the feed stream.

6. The system of claim 5, further comprising an online control system configured to receive salinity data transmitted from said sampling means, said control system being electronically coupled to one or more of said variable pressurizing means, inter-stage pressurizing means and pressure recovery means, to adjust pressures in the first and second RO stages in response to a change in salinity of said feed water.

7. The system of claim 6, wherein said control system is further configured to activate the recycling means as defined in claims 3 or 4, to thereby adjust the salinity of said feed water.

8. The system of any one of the preceding claims, further comprising a bypass means configured to allow said second reject stream to at least partially bypass said pressure recovery means.

9. The system of any one of the preceding claims, wherein the total number of pressure vessels present in said first and second RO stages is the same.

10. The system of claim 9, wherein each of said first and second RO stage contain no more than seven pressure vessels.

11. The system of any one of the preceding claims, wherein the pressure vessels within said first and second RO stages comprise the same type of RO membranes.

12. A continuous method for desalinating saline water, the method comprising the steps of:

(a) providing a feed stream of saline water;

(b) variably adjusting the pressure of said feed stream in response to changes in salinity of said feed stream;

(c) subjecting said feed stream to a first RO step to thereby produce a first reject stream and a first permeate stream, said first permeate containing lesser salinity relative to said first reject stream; and

(d) subjecting said first reject stream to a second RO step to thereby produce a second reject stream and a second permeate stream.

13. The method of claim 12, further comprising a step (e) of recovering pressure energy from said second reject stream.

14. The method of claim 13, wherein step (b) further comprises a step (f) of applying said recovered pressure energy in step (e) to variably adjust the pressure of the feed stream.

15. The method of claim 14, further comprising a step (c1) of increasing pressure of the first reject stream before step (d).

16. The method of any one of claims 12 to 15, further comprising a recycling step (g) of recycling said second reject stream to the feed stream to increase salinity of the feed stream.

17. The method of any one of claims 12 to 15, further comprising a recycling step (h) of recycling said first or second permeate stream or both to the feed stream to decrease the salinity of the feed stream.

18. The method of any one of claims 12 to 17, further comprising a sampling step (i) of measuring salinity data of the feed stream.

19. The method of claim 18, wherein said sampling step (i) further comprises transmitting the salinity data to a control system, wherein the control system is operated to

set pressure values in one or more of steps (b), (c1) and (f) in response to the salinity data.

20. The method of claim 19, further comprising operating the control system to set the recycle rates of step (g) or step (h) in response to the salinity data.

21. The method of any one claims 13 to 18, wherein step (e) is bypassed.

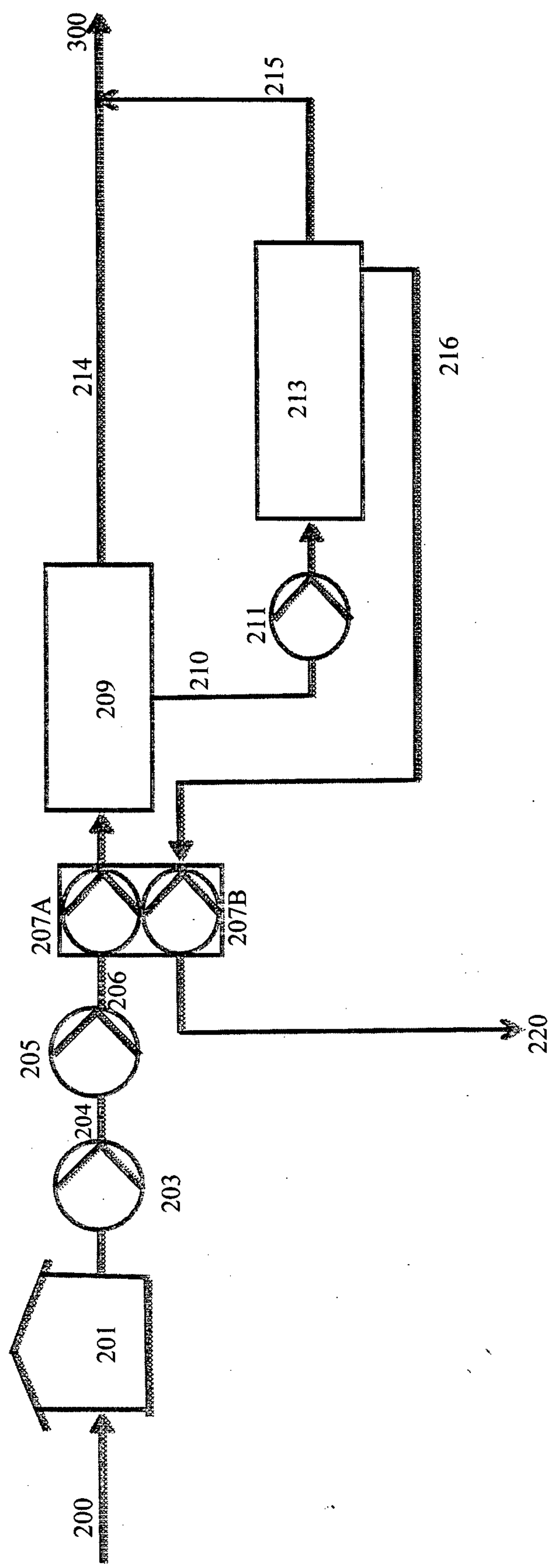
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FIGURE 1

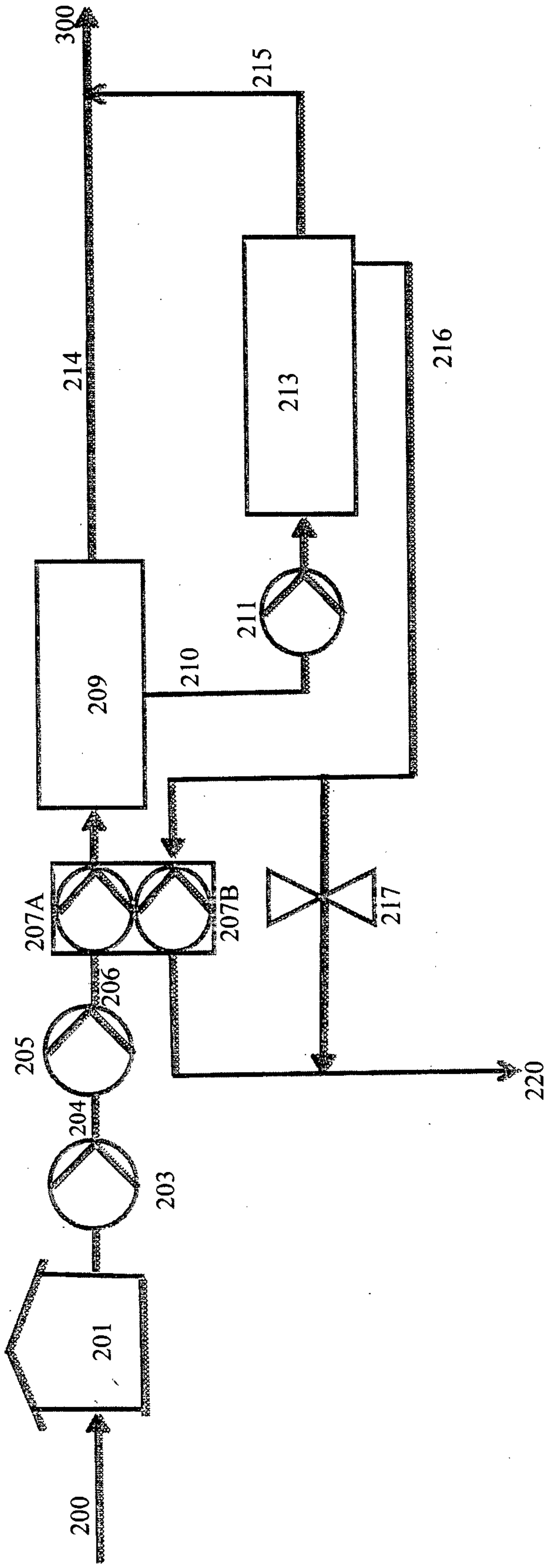
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FIGURE 2

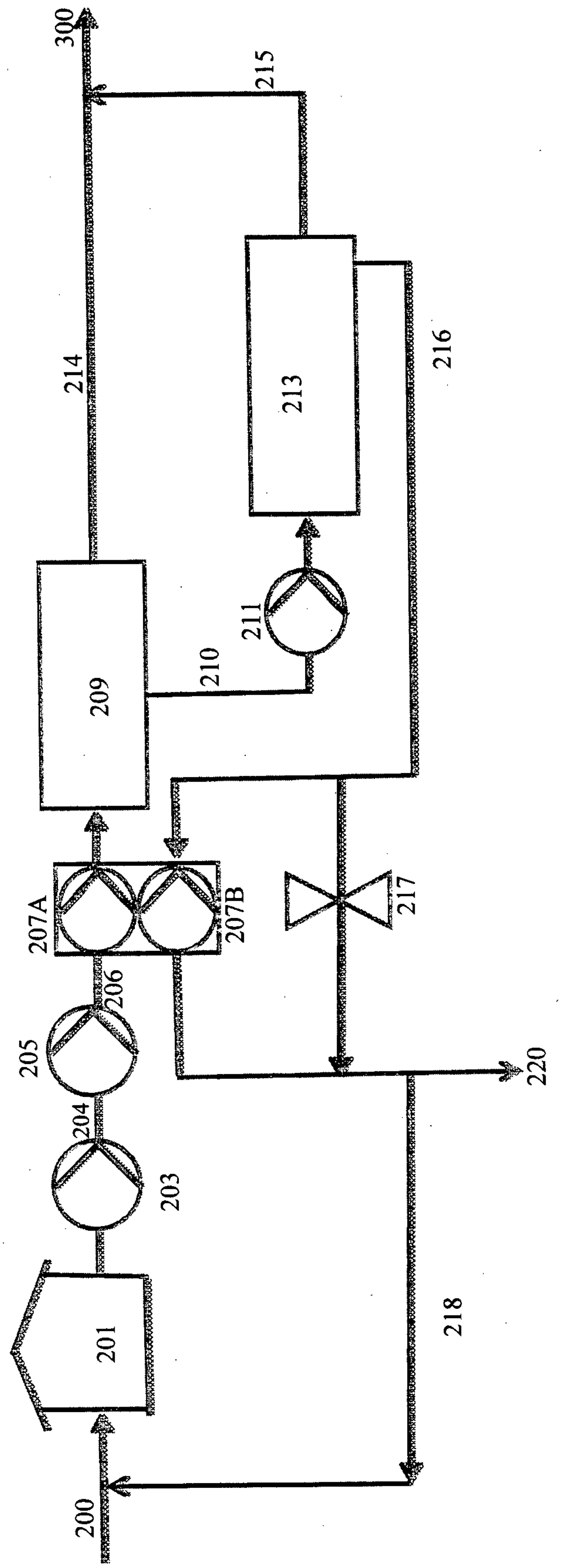
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FIGURE 3

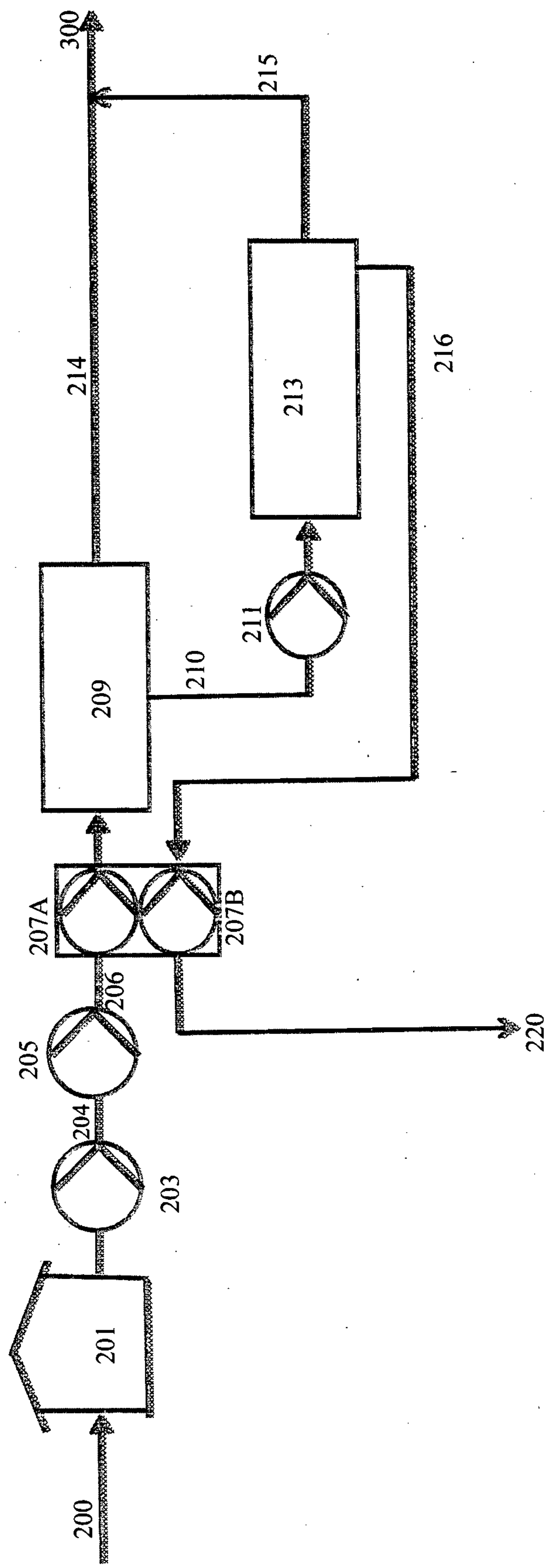
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FIGURE 4

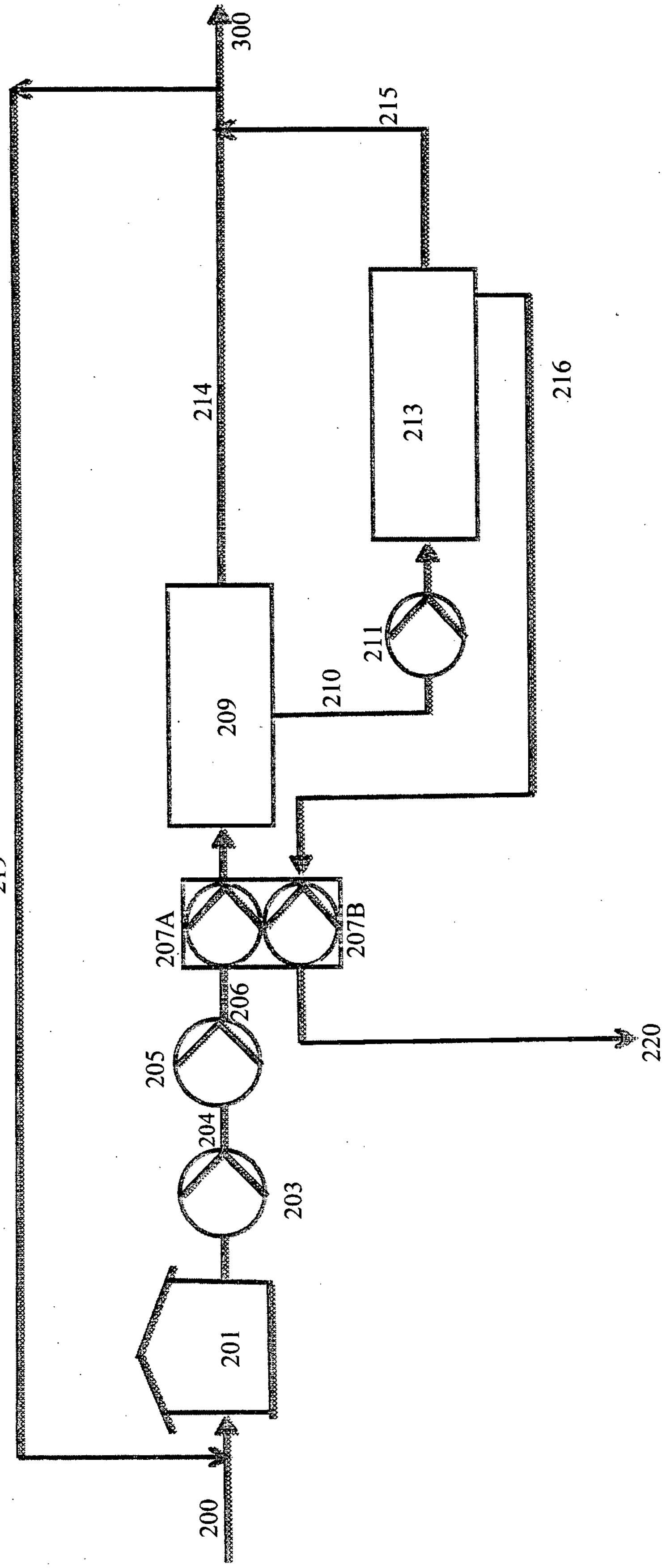
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FIGURE 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2012/000110

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

B01D 61/02 (2006.01) ***B01D 61/04*** (2006.01) ***B01D 61/58*** (2006.01)

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)

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)
WPI & EPODOC; IPC/EC: B01D61/02/low, 61/36, 61/02B, 61/58, C02F 1/44, 1/44B & keywords (pressure, force, pump, compressor, turbocharger, vary, change, alter, recovery, recycle, recirculate, loop, feedback); Google Patents & Patent Lens; keywords (reverse osmosis, turbocharger, variable speed pump, energy recovery, recycle, permeate, reject stream)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2002/009855 A1 (PUMP ENGINEERING, INC.) 7 February 2002 Abstract; page 3, line 2 to page 5, lines 27; page 12, line 10 to page 14, line 9; page 15, line 3 to page 16, line 27; claims 1, 6; figs. 3-6	1-2, 5-6, 8-15, 18-21 3-4, 7, 16-17
Y	US 6113797 A (AL-SAMADI) 5 September 2000 Abstract; col 1, lines 5-10; col 4, lines 15-50; figs. 2-4, 6-8	3-4, 7, 16-17
A	US 5207916 A (GOHEEN et al.) 4 May 1993 Abstract; col 2, line 46 to col 6, line 35; fig. 1	1-21

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

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 May 2012	18 May 2012

Name and mailing address of the ISA/AU	Authorized officer
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This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	0209855	EP	1315552	JP	2004504929	US	6139740
US	6113797	AU	2009210363	CA	2186963	US	6461514
		US	2011094965	US	7981295	US	2011266224
US	5207916	NONE					

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX