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(54) **Title:** WATER TREATMENT AND DESALINATION MACHINE USING THE MOVEMENT OF THE MOVABLE DEVICES WITH CONSTANT AND CONTINUOUS PRESSURE SUPPLY BY THE ACCUMULATOR

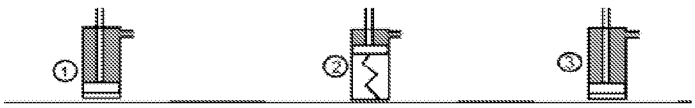

Figure 5. Operation of the return spring jack

(57) **Abstract:** Converting the rotational movement to a reciprocal movement, the device supplies the required pressure for the water desalination process by reverse osmosis membranes. The jack produces the needed pressure. The saltwater enters the jack and is compressed due to the force exerted by the jack piston (the reciprocal movement supplies the for). To prevent the decrease or increase in the pressure within the jack and the production line, some pressure regulating devices are employed in the device including accumulators, and pressure-reducing valves. An irregular pressure in the membrane causes its efficiency and life to decrease. Furthermore, using the mentioned equipment and considering a given cycle, a backwashing process is employed to wash the membrane so that the fouling and sedimentation problem is reduced. The goal of this invention is to reduce the costs of water desalination by eliminating the need for electrical power.

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Description

Title of Invention : Water treatment and desalination machine using the movement of the movable devices with constant and continuous pressure supply by the accumulator

[1]

Technical Field

[2] Mechanics and water treatment

Background Art

[3] Today, reverse osmosis is the main method for the seawater desalination process that outperforms its everlasting competitors such as distillation and electrodialysis. The method application ranges from producing the water on a laboratory scale to producing a large volume of water for urban and industrial applications [1-3]. Excluding various dissolved ions in water to make it suitable for use in powerplant boilers and producing pure water needed for the electronic industry is another application of the reverse osmosis process. The reverse osmosis process is more applied than the water treatment one. It is used to remove the organic and toxic materials from wastes, and the treatment of various wastes such as papermaking and chemical industries. Concentrating various materials in the food and drink industries is also considered as another application of the reverse osmosis process [4-7].

[4] Using membrane for filtration dates back to the early 1900s. it was about 1930 that the first paper was published about what we now refer to as reverse osmosis. At that time, it was observed that if an aqueous solution having a little salt content enters a nitrate cellulose nitrate membrane with high pressure, the membrane output contains less salt content. The issue gained little attention and was forgotten for a while. Reid in Florida university began a series of studies regarding reverse osmosis about 1950. It was in the 1960s that Leob, Sourirajan at Florida university built the first high efficiency cellulose acetate reverse osmosis membrane [8-10].

[5] U.S. national saltwater organization which has been called U.S. water research and technology sponsored some studies in the field of reverse osmosis. Due to the cellulose acetate limitations such as hydraulic instabilities, the first studies focused on employing polymers instead of cellulose acetate which resulted in producing various reverse osmosis membranes in a commercial scale.

[6] There exist some devices that are employed for water treatment without electricity, some of which are installed on bicycles [12-14]. However, the newly invented device is somewhat different. One of these differences is that the system pressure is controlled by pressure regulator devices such as accumulators, and pressure-reducing valves. In the cases that there is a need for additional pressure or where the device has no activity for a while and remains inactive, the stored pressure in the accumulator can be used, in which case the accumulator acts as a capacitor. On the other hand, the device can be used for water desalination on large scale (i.e. industrial scale). It can produce pressures as high as about 84 bars. Another notable difference is that a backwashing cycle has been considered for the invented device so that the membrane fouling is reduced, and the membrane fouling can be delayed.

[7] Economic evaluation of fossil fuel based water desalination processes [11]

[8] The costs of the seawater desalination plan employing RO technique in which fossil fuels are used, are as follows:

[9] Table 1. direct capital costs ($)

[10]

[11] Table 2. Captial costs for installation ($)

[12]

[13] Table 3. Total captial costs ($)

[14]

[15] Table 4. Indirect captial costs ($)

[16]

[17] Table 5. Annual operational costs ($)

[18] The proposed method costs are as follows:

[19]

[20] Figure 2. Operational costs (OPEX) for seawater desalination plans using common methods

[21]

[22] Figure 3. Fixed capital costs (CAPEX) for seawater desalination plans using the common RO method

[23]

[24] Figure 4. Operational costs (OPEX) for seawater desalination plans using the common RO method

[25]

[26] In this method, the electricity power supply costs which comprise about 44% of the total OPEX costs of seawater desalination plans (i.e. about 0.24$) are eliminated. As well, 8% of the electricity power in the fixed costs (CAPEX) is also eliminated. Thereby, according to fig. 6, the current costs for 1 m^3 of seawater desalination will be about (note that the electricity costs are eliminated):

[27] 0.76-0.24= 0.52$

[28]

[29]

Summary of Invention

[30] Converting the rotational movement to a reciprocal movement, the device supplies the required pressure for the water desalination process by reverse osmosis membranes. The jack produces the needed pressure. The saltwater enters the jack and is compressed due to the force exerted by the jack piston (the reciprocal movement supplies the for). To prevent the decrease or increase in the pressure within the jack and the production line, some pressure regulating devices are employed in the device including accumulators, and pressure-reducing valves. An irregular pressure in the membrane causes its efficiency and life to decrease. Furthermore, using the mentioned equipment and considering a given cycle, a backwashing process is employed to wash the membrane so that the fouling and sedimentation problem is reduced. The process is carried out without any need for

electricity or electrical pumps. The goal of this invention is to reduce the costs of water desalination by eliminating the need for electrical power.

[31]

Technical Problem

[32] Freshwater resources are so limited worldwide. The water demand will never end. However, producing fresh water from seawater and brackish water by current technologies requires high costs. Given the shortage of freshwater resources as well as the high costs of saltwater desalination implies a need to have a modern, low-cost, and more efficient method more than ever.

[33] Today, about 44% of water desalination costs can be attributed to the power supply requirements. In this patent, eliminating the electrical pumps which supply the required pressure for the reverse osmosis process in water desalination systems, the costs of water desalination have been significantly reduced. The proposed water desalination system uses a slider-crank mechanism to convert the rotational forces from means such as the wheels of vehicles, bicycles or bikes, ship engines, wheels, aircraft engines, etc. to a reciprocal movement which will then be transferred to a single-jack piston that is located within the saltwater. This causes the saltwater within the jack to compress so that the required pressure for the saltwater desalination is produced. However, it should be noted that the produced pressure by the jack is not a stable and steady one which in turn causes the membrane life to reduce and a decrease in saltwater desalination efficiency. To solve the problem, one can use pressure regulator devices such as accumulators, one-way valves as well as relief valves. Another problem that should be addressed is the reduced life of the reverse osmosis membrane during the water desalination process due to the fouling phenomenon. Using no electricity and applying a cycle that employs a jack, accumulators, and one-way and relief valves, the backwashing process is carried out which reduces the fouling in the membrane. In short, our goal is to reduce water desalination costs. To reach the goal, we focus on the electrical power aspect which almost incurs the most costs to the process, and so we aim to eliminate this part.

Solution to Problem

Figure 1. Invented device drawing

According to drawing 1, at first, the spring in jack no. 1 is compressed, and the piston which is driven by the rotational movement of the vehicles which then be converted to a reciprocal movement by the slider-crank mechanism is lowered. Thereby, passing through the one-way valve (2), the saltwater is sucked into the jack from the tank. Then, the jack is again compressed by the reciprocal movement from the conversion of the rotational movement of the vehicle wheels, and the saltwater passes the one-way valve (3) and enters the circuit. The process continues until the water pressure behind relief valve no. 7 reaches a certain limit (that is equal to 8 bars for home applications and 81 bars for industrial ones). It should be noted that the pressure should be slightly higher than the mentioned figures so that accumulator no. 5 is also charged. Once the required pressure is supplied (i.e. 8 bars for home, and 81 bars for industrial applications), the relief valve no. 7 that acts as a regulator opens and allows the fluid to exit. It should be mentioned that an appropriate jack must be selected depending on the system application. For example, a jack having a capacity to produce a pressure of 100 bars is considered suitable for industrial applications, whereas, for home applications, a jack with a capacity to produce 15 bars is enough. This is because that the additional pressure could be reduced using a relief valve, however, a low pressure due to the capacity limitations of the jack may cause the total process to fail. Then, relief valve no. 4 begins to discharge the saltwater so that the tank pressure remains constant. (Essentially, the saltwater enters the jack and exits by each reciprocal movement of the piston inside the jack. The reciprocal movement needed is supplied by the conversion of rotational movements of the vehicle wheels or any other moving part in the vehicle. A slider-crank mechanism is used to convert the rotational movement into the reciprocal one).

The treatment process

As mentioned earlier, once the pressure behind the relief valve no. 7 reaches a certain limit (i.e. 8 bars for home applications and 81 bars for industrial ones), the valve opens and allows the saltwater to exit so that it enters into the membrane. Thereby, the water directs into the treatment line or the backwash line. The membrane specifications are summarized below. It should be noted that the created pressure in the accumulator tank is assumed to be higher than the required pressure in the membrane so that when the jack is refilled and is compressed - which lasts some seconds- the membrane entrance pressure would be not less than a certain limit (a pressure of 10 bars inside the accumulator is considered for home applications, whereas a pressure of 82 bars is considered for industrial ones). Thereby, the membrane can carry out the treatment operation continuously.

Table 6. General membrane specifications for the home and industrial applications

The treatment line

To run the treatment process, the valves no. (9) and (13) are closed, and the valves no. (6), (11), and (8) are opened. The pressured water stored in the accumulator passes valve no. (6), and relief valve no. (7) and reaches the pressure needed to enter the membrane. Passing the membrane, the saltwater is desalinated. Then, a little amount of freshwater is stored in cylinder no. (12) for the backwashing process, while the rest pass through valve no. (8) to store in tank no. (15) for use.

The backwashing process

The process aims to increase the membrane life and to reduce the current costs. During the process, valves no. (6), (11), and (8) are closed by an electrical stimulation which is applied according to a schedule from a PLC. The valves no. (9) and (13) are remained open. Passing the relief valve no. (10), and reaching the required pressure (that is about 10 bars for home applications, and 83-85 bars for industrial ones -the backwashing process needs a higher pressure than the desalination process), the saltwater applies pressure behind the jack no. (12). So, the already stored freshwater in the cylinder passes through the membrane in the reverse direction and is discharged by valve no. (13).

Accumulator no. (5) is designed to reduce the rate of pressure loss during the jack filling process.

The valve no. (11) helps the jack no. (12) to return, and to discharge the compressed saltwater behind it.

It should be noted that the two-way jack no. (12) is returned to its original position with the help of the spring so that we could again store the freshwater. Figure 5 shows the mechanism of the return spring jack.

Figure 5. Operation of the return spring jack

Fig. 1 shows that the jack is filled with saltwater and is ready to work. In fig. 2, the piston moves up, during which the water is sucked into the desalination line under pressure and is getting ready to enter the membrane. In fig. 3, the saltwater is again injected into the jack so that the cycle repeats.

It is a continuous and automated process that needs no operator to work.

The physical specifications (pressure) for employed equipment are summarized in table 7.

Table 7. the equipment input and output pressures

If the pressure inside the system exceeds 100 bars for industrial applications or 15 bars for home applications, or if it is less than the membrane activity ranges that is for example less than 45 bars for industrial membranes, the relief valve no. 4 doesn't allow the fluid to exit. As well, the fluid isn't allowed to enter the line until the additional pressure is reduced by relief valve no. 4, or till the pressure shortage is supplied by the jack and/or the accumulator.

The valve 2-2 (the direction control valve) no. (8) is responsible for the fluid direction control, and the maximum output pressure in the membrane behind the valve is 1 to 2 bars.

The input and output water specifications with regard to the selected membrane type (for home and industrial applications)

Table 8. Specifications of the invented device input water (Persian Gulf seawater)- industrial

The Persian Gulf water salinity is about 50,000 to 60,000 mg in a litre.

Table 9. Specifications of the invented device input water (District 14 of Tehran municipality)- home

Table 10. Quality of the invented device output water (input water is the Persian Gulf water)

Table 11. Quality of the invented device output water (input water is the 14^{th} distrct of Tehran manicipality)

All the operational pressures reported in table 1 are according to the membrane type used, as mentioned earlier. The type of the membrane determines whether the device is used for home applications or industrial ones. It also specifies the operational pressure for each device. The membrane specifications were derived from manufacturer brochures published on their websites. The output water quality and specifications are obtained from the membrane output water information. To obtain the information, the device should be set up experimentally, and the output water quality should be investigated. However, in this step, we refer to the reports of the membrane output water quality published by the manufacturer. As well, depending on the membrane type used for the device (both for industrial and home applications), the quality and minerals in the membrane output and input water is reported. To ensure that a constant pressure enters each piece of equipment, and also to prevent sudden increases or decreases in pressure, some sets of equipment have been considered including relief or pressure-reducing valves so that the fluid can't exit if its pressure exceeds a certain adjusted limit. As well, an accumulator is arranged so that the line pressure remains constant. The accumulator operates such that if the line pressure drops, the compressed water stored in the accumulator is injected into the system (the compression limit for the water inside the accumulator is adjusted based on the membrane type). In such a case, the accumulator plays the role of a capacitor. The accumulator stores the compressed water or injects it as necessary. As mentioned earlier, the accumulator type and its functionality range depend on the membrane type (the pressure inside the accumulator as a reserve has been assumed to be 10 bars for home applications, and 82 bars for industrial ones). A list of the accumulator functions, as well as the reasons for its usage in the production line, is described below.

Accumulator functions

Generally, accumulators have 4 main functions as follows.

1) Storing energy

The accumulator acts as a support. That is when the system activity is low, it stores the under-pressure fluid, whereas, in the system peak activity, it feeds the system, and passing the peak, the jack (the supplier of the device pressure) recharges the system.

2) Absorbing sudden strokes

At the pressure peaks, the accumulator absorbs the additional fluid and returns it to the system after the peak state, which in turn causes the system noises and vibrations to decrease.

3) Producing gradual pressure

For example, absorbing some amount of the fluid pressure of which is increasing, it deceases the fluid velocity.

4) Producing fixed pressure

In cases where the changes in the fluid volume cause the pressure to change, it absorbs or adds some amount of the fluid so that a fixed pressure is reached.

Last but not the least, regarding the working pressure, all equipment depends on the membrane type for home and industrial applications. That is, in cases such as home applications where the TDS is below 100 ppm, equipment like valves are bought that operate in a pressure range between 8-10 bars as our selected membrane works at this pressure range.

On the other hand, in industrial applications having a TDS equal to 45,000 ppm, equipment like valves are used that operate in the pressure ranges between 80-81 bars.

The membrane life and Flux-time diagram according to the claimed water resources and behind conductive membrane in the claimed system

Figure 6. Impact of feed concentration on the RO membrane rejection

Table 12. Operational conditions and its impact on the RO system performance

Table 13. Impact of the feed pH on the RO membrane rejection

The concentration of total dissolved solids (TDS) in the feed water, the operational pressure, and temperature are the three factors influencing the RO membrane performance. There exist other factors such as pH and some kinds of non-organic ions which influence on the performance, too. The impacts of these three factors are shown below.

Figure 7. Impact of the operational pressure

Increasing the working pressure, more treated water produces, and the percentage of the membrane rejection increases, provided that other parameters such as the feedwater TDS and its temperature remain constant. However, the manufacturer design guidelines should be followed. Otherwise, working at high pressures causes the membrane to destruct earlier and its life to decrease.

Figure 8. Impact of working temperature

The amounts of the penetrating flow and the salt content passed are proportional to the temperature. Increasing the temperature, the velocity of the penetration flow, and the percentage of the salt passed increase, too. Therefore, given other parameters such as the feedwater TDS and the efficiency pressure, in cases such as winters that the feedwater is colder, the amount of penetrating flow and the salt passing through the RO membranes are lower (this implies a better water quality). On the other hand, in summers when the feedwater is warmer, given other parameters such as the feedwater TDS and the efficiency pressure, the amount of penetrating flow and the salt passing through the RO membranes increase.

Figure 9. Impact of the feed concentration

The higher the feedwater concentration, the higher the osmosis pressure will be. Given other parameters such as the feedwater temperature and the efficiency pressure, increasing the feedwater concentration causes the penetrating flow and the percentage of the RO membrane rejection to increase.

Figure 10. Impacts of various factors on the reverse osmosis

According to the manufacturers, the maximum lifetime of the membranes is five years, provided that the input water is pre-treated. In this device, the backwashing process is carried out during the daytime. Given the backwashing process, if the input water is pre-treated before entering the device, the lifetime of the membrane is expected to be 4-5 years.

The water can be separately pre-treated before entering the device, using common processes (i.e. carbon filters, UF, and NF membranes. As well, the pressure supply system of the invented device can be used for water pre-treatment. In such a case, it is enough to adjust the relief valves according to the operational pressures in the pre-treatment membranes (as all the relief valves are adjusted manually), and there is no need to change the jack because the jack itself produces the previous pressure (the pressure required for the RO membrane) which is higher compared to the pressures in the UF and NF membranes. In this case, the only change is the replacement of the membrane type such that the pre-treatment membranes are installed instead of the RO membrane. The pressure-reducing valves are also adjusted manually according to the operational pressures in the pre-treatment membranes. These valves adjust (reduce) the exact pressure according to the pre-treatment membrane operational pressures. It should also be noted that all the pre-treatment membranes can't be used simultaneously, as each membrane decreases the pressure so that its output can't be directly entered into the next membrane. Therefore, the type of the membrane inside the system should be changed, each of them should be separately inserted into the device, and then enters the membrane output water separately into another membrane (the membrane type, as well as the valves settings, should be changed). Then, before completing the pre-treatment process, the RO membrane should be inserted, and the pressure should be adjusted according to the operational pressures. Rather, to eliminate the need for the membrane replacement, one can use 3 to 4 pressure supply devices, each of which works sequentially so that at first, the pre-treatment devices operate, and the output of each device enters the next pressure supply device. In this case, 4 devices are arranged sequentially, each of which operates separately. The final output water of each device enters the next, only if it uses special membrane types. By devices, we mean any complete one having the invented pressure supply system.

Kinds of fouling (i.e. biological, etc.) in membranes during its use, and supplying additional forces needed for the proposed pressure supply system

This reduces the sedimentation or accumulation of penetrating materials. This phenomenon is known as fouling. In an isobaric process, the sedimentation in the membrane causes the penetration flux to decrease, whereas in a constant flow one, filtering the sedimentation needs more pressure so that the process runs. Therefore, not only the sedimentation increases the capital costs, but also decreases the membrane life. Fouling is a process that causes a loss in the membrane performance due to the settlement of suspension or dissolved materials on the outer surface, pores' openings, or pores [16]. The membrane sedimentation is determined by flux irreversible reduction. Depending on the system, the flux may be reduced in one or more steps so that it occurs fast in the first minutes, and then the flux is gradually reduced. The membrane fouling is due to the sedimentation and accumulation of suspended particles, impermeable solutes, and even permeable solutes that generally settled on the membrane surface or in its pores [17]. The possible root causes for fouling are as follows [18]:

- The sedimentation of any material which has a solubility more than the product.
- The sedimentation of fine or colloidal dispersed materials.
- The chemical reaction of salts in the membrane border layer (e.g. the formation of ferric hydroxides from ion solution forms).
- The chemical reaction of salts with membrane polymers.
- Absorbsion of chemical compounds having low molecular mass in the membrane polymers, the formation of gels from macromolecule materials.
- Colonization by bacteries (the most hydrophobic interaction).

The membrane fouling is the largest barrier in the RO membrane processes that can have many destructive impacts on the processes including a decrease in the penetration flux or an increase in the operational pressure, the need to clean the membranes, and a reduction in the membrane life [19]. Fig. 11 shows the membrane fouling curve for the device used here.

Figure 11. Fouling curve [16].

The concentration polarization which is considered as a flux reducing factor is not assumed to cause fouling. The difference between polarization and fouling is seen in fig. 16 [20]. Fig. 12 shows the membrane polarization and sedimentation in the device.

Figure 12. Impact of the concentration polarization and sedimentation on the flux reduction

Various kinds of fouling and methods to solve them are summarized in table 14.

Table 14. Proposed solutions to remove various kinds of fouling [15].

The limitations for the feedwater quality parameters are summarized in table 15. It is recommended to consider the limitations to ensure the successful performance of the membrane system. Otherwise, more cleaning or frequent cleaning may be required. Therefore, regardless of any physical specifications of the device feedwater, the specifications shown in the table should be reached using pre-treatment so that no damage occurs to the RO membrane for water desalination.

Table 15. Physical specifications for the water enters the RO membrane after pre-treatment

As mentioned earlier, the operating pressure should be increased after a while, as the fouling itself causes the pressure to increase. Therefore, the pressure increase has been considered in the proposed device. Indeed, the jack (the pressure supply system) in the device can produce pressures higher than the membrane required. For example, in the case of industrial membranes, the jack used can produce pressures of about 100 bars (given the membrane selected, the industrial process requires a pressure of about 81 bars). However, at the beginning of the RO membrane activity, the pressure-reducing valves are adjusted manually on 81 bars. After a while, when the flux decreases, the valves are readjusted manually. For example, they are adjusted on 85 bars or any other value. Thus, it is possible to adjust the valves manually so that the pressure increases.

[34]

Advantageous Effects of Invention

[35] Not employing any electrical pumps to supply the pressure, the proposed device can reduce the costs of water desalination. As well, the backwashing process in the device (without any need for electrical power and electrical pumps) helps to solve the membrane fouling problem which in turn increases the life of the reverse osmosis membranes. The device uses pressure regulator equipment such as accumulators, one-way valves, as well as relief valves. Thereby, no sudden pressure changes occur in the jack and other pressure supply equipment. As well, in cases where the pressure is low, additional pressure is supplied (the accumulator function), as if the pressure is not regular, the membrane is damaged.

Brief Description of Drawings

Figure 1. Invented device drawing

Invented device components:

Table 1. direct capital costs ($)

Table 2. Captial costs for installation ($)

Table 3. Total captial costs ($)

Table 4. Indirect captial costs ($)

Table 5. Annual operational costs ($)

Figure 2. Operational costs (OPEX) for seawater desalination plans using common methods

Figure 3. Fixed capital costs (CAPEX) for seawater desalination plans using the common RO method

Figure 4. Operational costs (OPEX) for seawater desalination plans using the common RO method

Table 6. General membrane specifications for the home and industrial applications

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Figure 10. Impacts of various factors on the reverse osmosis

Figure 11. Fouling curve [16].

Figure 12. Impact of the concentration polarization and sedimentation on the flux reduction

Table 14. Proposed solutions to remove various kinds of fouling [15].

Table 15. Physical specifications for the water enters the RO membrane after pre-treatment

[36]

Industrial Applicability

The invention can be employed in the water desalination industry. It can also be used to supply the pressure required for the reverse osmosis membrane in the industry.

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Description of at least one procedure to apply the invention

Employing the device in water desalination centers, water desalination by the device and selling its produced water, selling the device to the governmental offices or for home applications. The device components are sold as COTS, and it is enough to assemble them.

Claims

[Claim 1] What is claimed is "the device for water desalination and treatment, using moving means without any need to electrical pump to supply the pressure required for reverse osmosis process". The components include a one-way jack with a return spring, two-way jack, 2 one-way valves, relief valve, five 2-2 valves (the direction control valve), pressure relief valve, accumulator, reverse osmosis membrane, water tank (for saltwater or non-treated water), water tank (for desalinated water).

[Claim 2] (according to claim no. 1) A one-way jack having a returning spring is connected to the train or bicycle wheel with an arm. The rotational movement is converted to a reciprocal one with the help of a slider-crank mechanism so that the jack situation can be changed (i.e. charged or discharged). When the moving mean (the wheel of a vehicle, train, etc.) moves, takes the piston back so that the water is sucked into the jack from the saltwater tank. Another rotation of the moving equipment causes the piston to take inside which makes the saltwater inside the jack compressed and pressurized. A relief valve located after the jack doesn't allow the saltwater to exit until its pressure reaches a certain limit. Once the pressure reaches the predefined limit, the relief valve opens, and the saltwater exits the jack having the interested pressure value. Then, the jack returns to its early situation so that new saltwater can be injected. The desalinated water is collected in the tank.

[Claim 3] (according to claim no. 2) To stabilize the pressure and ensure a uniform pressure in the system (for the membrane appropriate performance and increasing its life), as well as to ensure a constant pressure inside the treatment line, an accumulator, a few relief valves, and pressure relief valves are employed. The accumulator used in the device can store and inject a pressure more than one needed in the freshwater production process by reverse osmosis membrane (it can store pressures from 12 to 15 bars for home applications, and pressures up to 100 bars in industrial applications) so that the appropriate pressure can be injected by the accumulator. The relief and pressure-reducing valves control and adjust the pressure, as the reverse osmosis membrane is sensitive to the pressure so that a pressure lower or higher than a certain limit must not be applied to them.

[Claim 4] (according to claim no. 3) As the membrane needs a specific time to desalinate the water, and due to a need for a certain pressure inside the membrane, an accumulator and a relief valve are used to ensure that the pressure enters the membrane remains at a specific range and is also constant (it is worth mentioning that the jack supplies the pressure, however, an accumulator is employed to ensure the pressure enters is constant). As well, a one-way valve is used to prevent the desalinated water inside the membrane to return to the treatment line. This valve also prevents the salt water inside the treatment line to enter the jack.

[Claim 5] (according to claim no. 4) Employing a jack having a returning spring, injecting the desalinated water, and exerting pressure behind the jack by salt water, the freshwater enters the membrane so that the backwashing process is carried out. The process is performed according to a PLC program, and so there is no need for any operators. Using PLC, the treatment input and output valves are closed at certain times, and the backwashing line valves are opened instead.

[Claim 6] (according to claim no. 5) To carry out a part of the pre-treatment of the input water by membranes such as MF, UF, etc., the membrane used in the device can be changed. In such a case, the mentioned membranes can be inserted at the membrane location. Then, the valve pressures should be manually adjusted based on the pressure required for the pre-treatment membranes so that the same device can be employed to run the process (of course, the relief and pressure-reducing valves should be adjusted again in this case). To insert the mentioned membranes in the membrane-specific location in the device, some conversion connectors (e.g. connectors to convert 1/4 inch to 1/2 inch, and vice versa) can be used. Thereby, regardless of the sizes of the pre-treatment membrane input and output containers, one can use these connectors to covert the sizes so that there is no need to change the device connectors.

[1] Table 1. direct capital costs ($)

Cost ($) Energy	Diesel energy
Capital costs of seawater consumption before treatment	1748.928571
Capital costs of high-pressure pumps	387.8571429
Costs of energy restoration system	288.9285714
Capital costs of reverse osmosis	198.2142857
Costs of water storage tank	1928.571429
Land costs	1339.285714
Site development costs	1944.285714
Direct capital costs	7836.428571

[2]

[3] Table 2. Captial costs for installation ($)

Cost ($) Energy	Diesel energy
Direct capital cost	7836.428571
Cost of installation and launching	560.7142857
Cost of capital installation	8397.5

[4]

[5] Table 3. Total captial costs ($)

Cost ($) Energy	Diesel energy

Cost of capital installation	8397.5
Indirect capital costs	783.5714286
Total capital costs	9181.071429

[6]

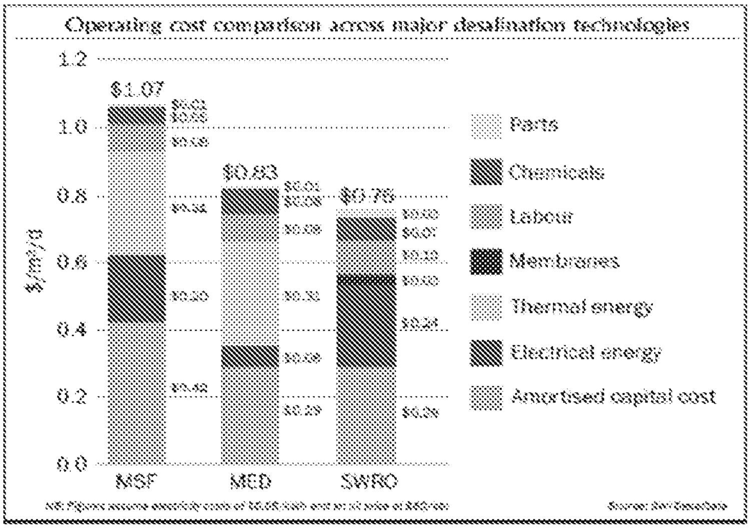
[7] Table 4. Indirect captial costs ($)

Cost ($) Energy	Diesel energy
Indirect capital costs	783.5714286

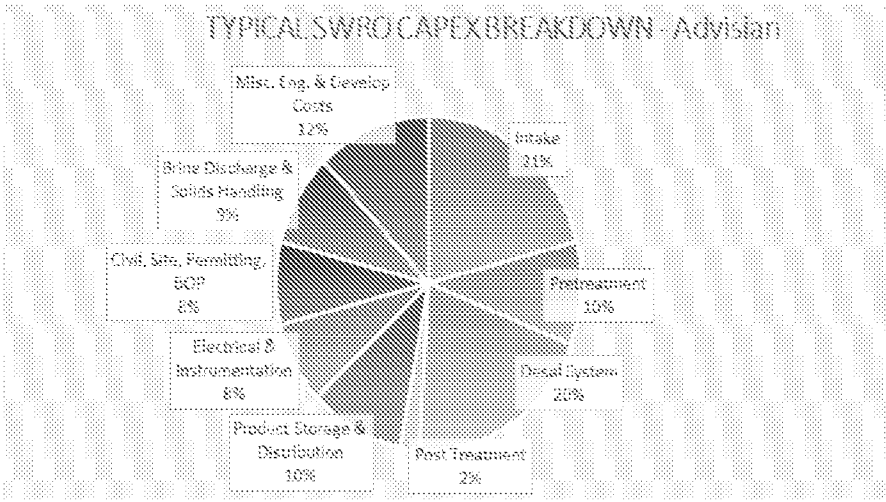
[8]

[9] Table 5. Annual operational costs ($)

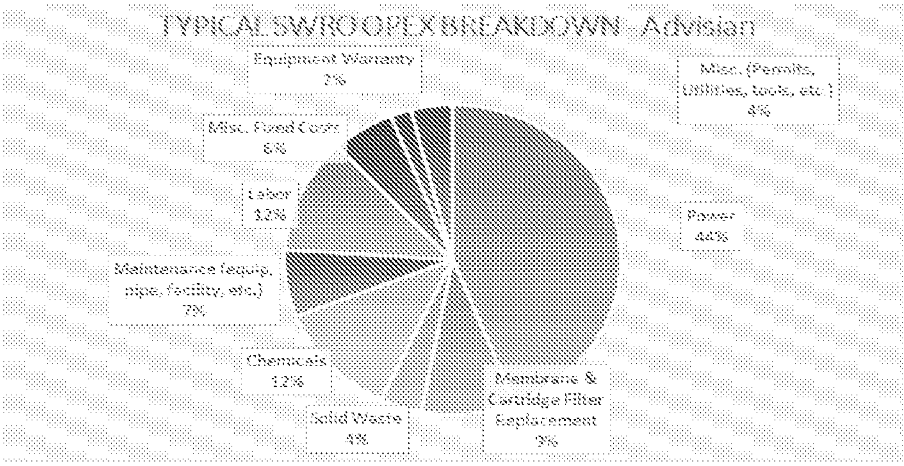
Cost ($) Energy	Diesel energy
Alternative operational costs	793.5714286
Spare parts operational costs	232.1428571
Chemical treatment operational costs	496.7857143
Labour annual costs	2140.357143
Annual operational energy costs	13132.85714
Annual operational costs	16796.07143

[10] 

[11] Figure 2. Operational costs (OPEX) for seawater desalination plans using common methods

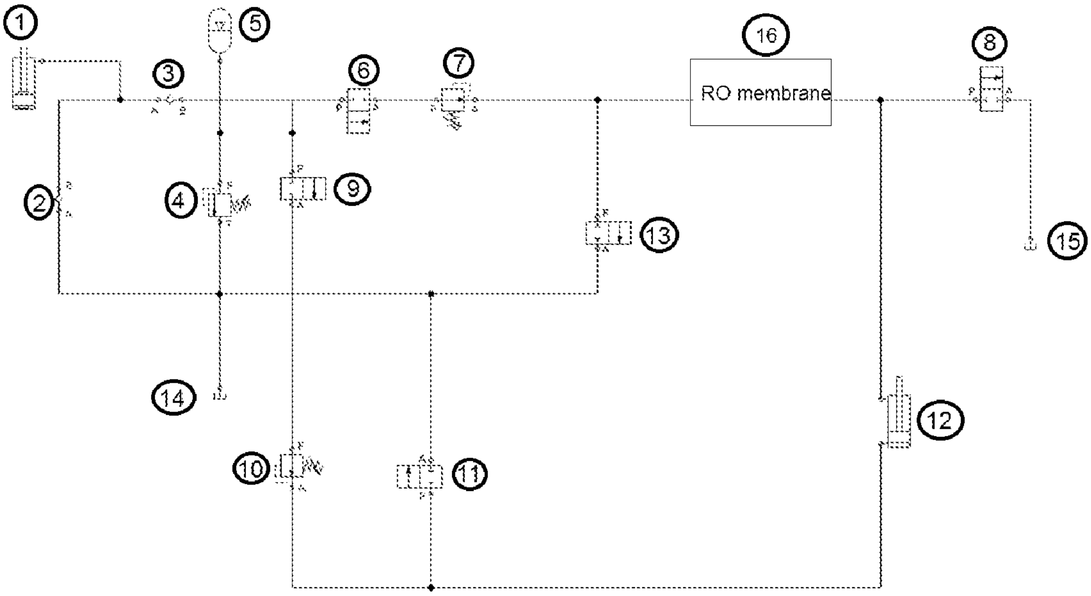
[12] 

[13] Figure 3. Fixed capital costs (CAPEX) for seawater desalination plans using the common RO method

[14] 

[15] Figure 4. Operational costs (OPEX) for seawater desalination plans using the common RO method

[16]



[17]

[18]

[19]

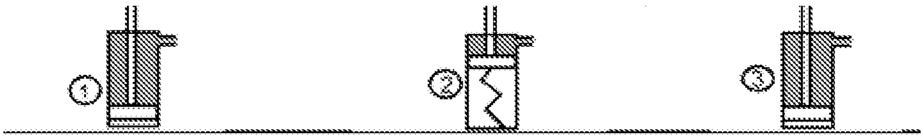
[20] Figure 1. Invented device drawing

[21]

[22] Table 6. General membrane specifications for the home and industrial applications

Membrane type	Maximum operational pressure	Optimized temperature range	TDS Performance range	Freshwater production capacity	pH range	Material	Price
Home	8 bars	25 °C	Max. 1000 ppm	75 gallons per a day	3-10	Cellulose acetate - cellulose	14.29 $
Industrial	80-81 bars	25 °C	45,000-46,000	28 m^3 per a day	2-11	Poly mide Thin Film Composite	392.86 $

[23]



[24]

[25] Figure 5. Operation of the return spring jack

[26]

[27] Table 7. the equipment input and output pressures

Component no. in drawing	Component name	Input pressure	Output pressure
1	Returning spring one-way jack	Charges by vehicle moving and/or jack rotational means	Industrial: 100 bars Home (a TDS less than 1000 ppm): 15 bars
2	One-way valve	1 bar	1 bar
3	One-way valve	Industrial: 90-100 bars Home (a TDS less than 1000 ppm): 10-15 bars	Industrial: 90-100 bars Home (a TDS less than 1000 ppm): 10-15 bars
5	Accumulator	Industrial: 90-100 bars Home: 10-15 bars	Industrial: 82 bars Home: 10 bars
6	2-2 valve (direction control valve)	Industrial: 90-100 bars Home: 10-15 bars	Industrial: 90-100 bars Home: 10-15 bars
7	Pressure-reducing valve	Industrial: 90-100 bars Home: 10-15 bars	Industrial: 81 bars Home: 8 bars
9	2-2 valve (direction control valve)	Industrial: 90-100 bars Home: 10-15 bars	Industrial: 90-100 bars Home: 10-15 bars
10	Pressure-reducing valve	Industrial: 90-100 bars Home: 10-15 bars	Industrial: 83-85 bars Home: 10-15 bars
12	Two-way jack	Industrial: 83-85 bars Home: 10 bars	Industrial: 83-85 bars Home: 10 bars
16	Reverse osmosis membrane	Industrial: 81 bars Home: 8 bars	Maximum pressure loss: 1-2 bars

[28]

[29] Table 8. Specifications of the invented device input water (Persian Gulf seawater)- industrial

Chemical name (ion)	Chemical symbol	Concentration (mg/l) (ppm)
Potassium	K	277.6
Sodium	Na	13969
Magnesium	Mg	1710
Calcium	Ca	136.3
Bicarbonate	HCO_3	103.7
Sulfate	SO_4	2402
Chloride	Cl	25703
Boron	B	9
Total dissolved solids	TDS	44359
Acidity	pH	8.3

[30]

[31] Table 9. Specifications of the invented device input water (District 14 of Tehran municipality)- home

Analysis parameter	Nitrate (mg/L)	Sulfate (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Chloride (mg/L)	pH	EC (Ds/m)	TSS (mg/L)	TDS (mg/L)
Average	96.106	69.2	0	85.4	23.4	65.4	242.1	5	7.548
Maximum	297	95.5	0	96.6	94.9	5	592.1	5	707
Minimum	33	66.1	0	95.2	99.2	5.4	590.1	5	481
Mod	15.102	35.2	0	91.4	97.3	5.4	245.1	5	542

[32]

[33]

[34] Table 10. Quality of the invented device output water (input water is the Persian Gulf water)

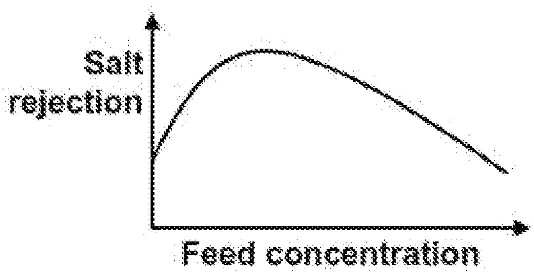
TDS (mg/l)	T.H (mg/l)	Na (mg/l)	Cl (mg/l)	Nitrate (mg/L)	SO_4 (mg/l)
Less than 500	Less than 250	Less than 115	Less than 175	Less than 50	Less than 145

[35]

[36] Table 11. Quality of the invented device output water (input water is the 14th distrct of Tehran manicipality)

TDS (mg/l)	T.H (mg/l)	Na (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Nitrate (mg/L)
Less than 200	Less than 100	Less than 50	Less than 50	Less than 50	Less than 50

[37]



[38]

[39] Figure 6. Impact of feed concentration on the RO membrane rejection

[40]

[41] Table 12. Operational conditions and its impact on the RO system performance

Increase in conditions	Context		Cause of change in the membrane performance
	Rejection	Flux	
Feed pressure	↗	↗	Penetration flux is proportional to pure driving pressure. The amount of solid penetration doesn't increase with the pressure. As a result, the flux and salt rejection increase.
Feed concentration	↘ ↗	↘	Net driving pressure doesn't decrease by the osmosis pressure. In low salinity (e.g. lower than 400 mg/L), the salt rejection decreases due to the charged effect of the RO membrane.
Temperature	↘	↗	As the temperature increases (3 °C), the penetration flux also increases due to a decrease in water viscosity. Increasing the temperature, the dissolved solid penetration rate increases more than the flux penetration one.
Flow concentration	↗	↗	In low flow rate, the concentration polarization occurs. As a result, the concentratin at the membrane surface increases, and the osmosis pressure decreases.

[42] Table 13. Impact of the feed pH on the RO membrane rejection

Chemicals	pH range (Acidity)	pH range (alkaline)	Reason for the change in membrane rejection
Acid compounds	Low	High	Acidic compounds in alkaline pH cause the rejection to increase, because the repulsion of charges occurs between compounds and the

			membrane surface.
Essential compounds	High	Low	Alkaline compounds in acidic pH cause the rejection to increase, because the repulsion of charges occurs between compounds and the membrane surface.
SiO_2	Low	High	Increase in pH leads to silica ionization from silica acid to silicate, so the repulsion occurs.
Bor	Low	High	Increase in pH leads to boron ionization from boric to borate, so the repulsion increases.

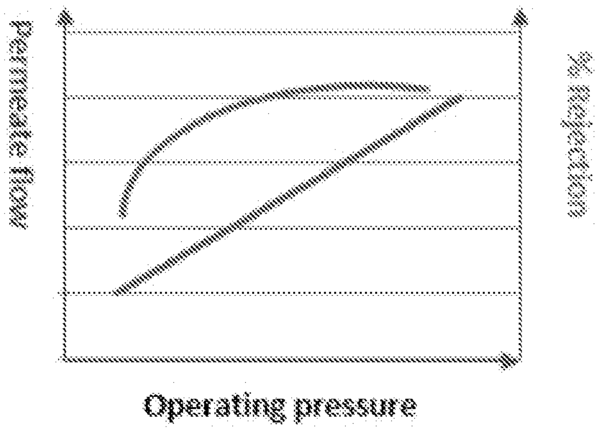


Figure 7. Impact of the operational pressure

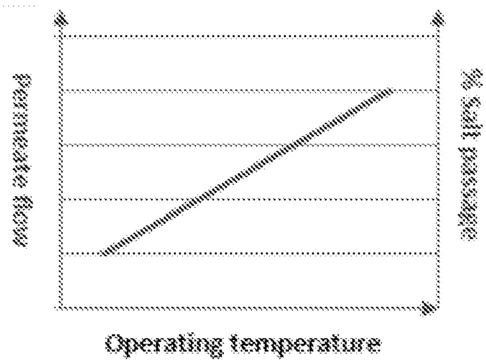


Figure 8. Impact of working temperature

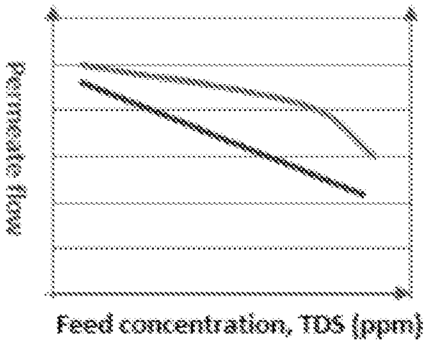


Figure 9. Impact of the feed concentration

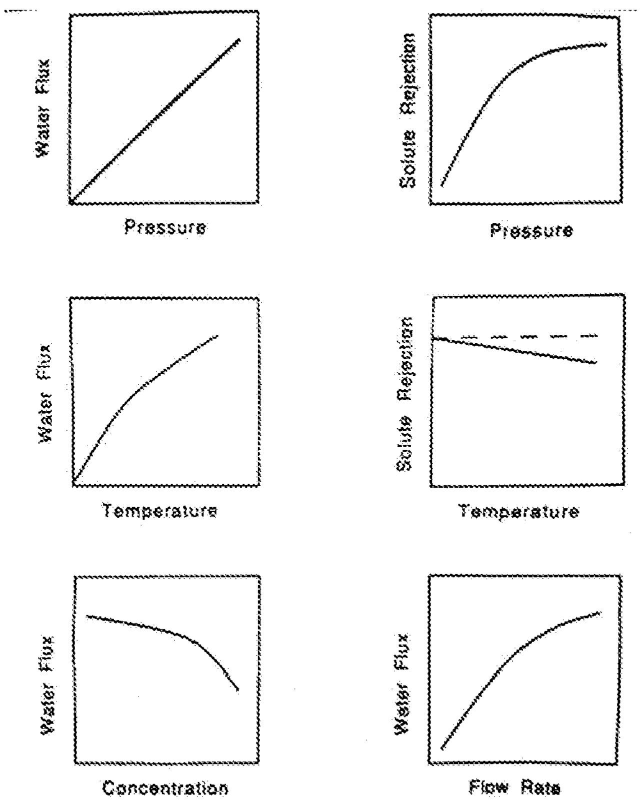


Figure 10. Impacts of various factors on the reverse osmosis

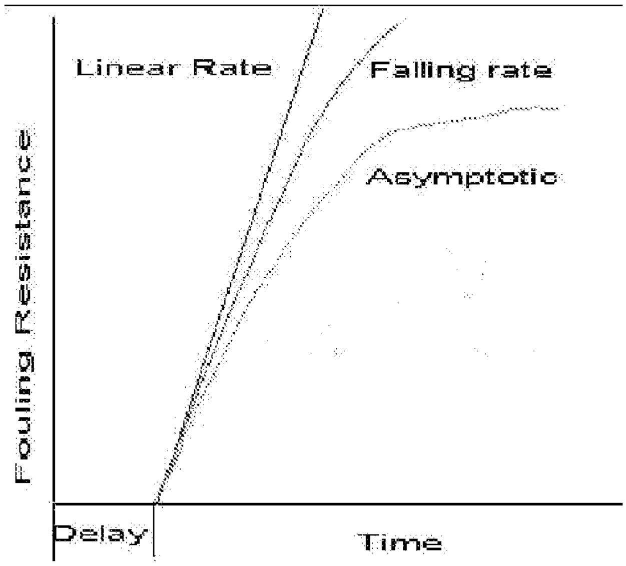


Figure 11. Fouling curve [16].

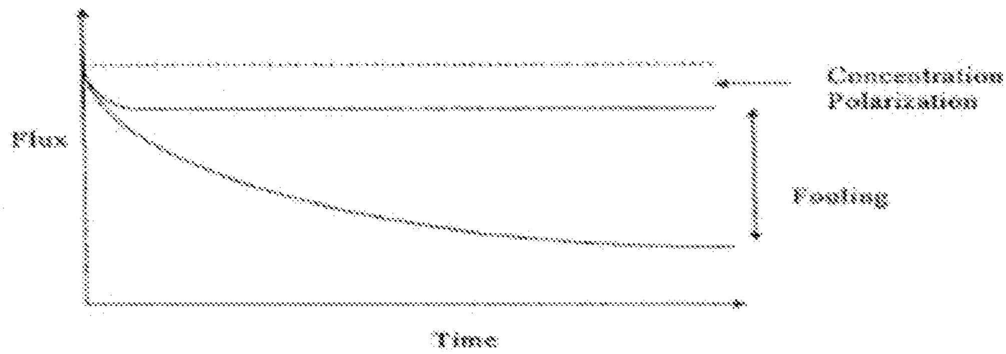


Figure 12. Impact of the concentration polarization and sedimentation on the flux reduction

Table 14. Proposed solutions to remove various kinds of fouling

Pretreatment	$CaCO_3$	$CaSO_4$	$BaSO_4$	$SrSO_4$	CaF_2	SiO_2	SDI	Fe	Al	Bacteria	Oxid. agents	Org. matter
Acid addition	●							○				
Scale inhibitor antifoulant	○	●	●	●	●	○		○				
Softening with IX	●	●	●	●	●							
Dealkalization with IX	○	○	○	○	○							
Lime softening	○	○	○	○	○	○	○	○				○
Preventive cleaning	○					○	○	○	○	○		○
Adjustment of operation parameter	○	○	○	○	○	●						
Media filtration						○	○	○	○			
Oxidation filtration							○	●				
In-line coagulation							○	○	○			○
Coagulation-flocculation						○	●	○	○			●
Microfiltration/Ultrafiltration						●	●	○	○	○		●
Cartridge filtration						○	○	○	○	○		
Chlorination										●		
Dechlorination											●	
Shock treatment										○		
Preventive biocidal treatment										○		
GAC filtration										○	●	●

○Possible ●Very effective

Table 15. Physical specifications for the water enters the RO membrane after pre-treatment

Component	Unit	Max. level	Comments & conditions
SDI	1	5	
$MFI_{0.45}$	1	4	Target: <1
Oil and grease	mg/L	0.1	
TOC	mg/L	3	Synthetic organic compounds (SOC) have generally more adverse effects on RO/NF membranes compared with natural organic matters (NOM).
COD	mg/L	10	
AOC	µg/l Ac-C	10	Target: <5
BFR	pg/cm² ATP	5	Target: <1
Free chlorine	mg/L	0.1	Under certain conditions, the presence of chlorine and other oxidizing agents will cause premature membrane failure. Since oxidation is not covered under warranty, FilmTec recommends removing residual free chlorine by pretreatment prior to membrane exposure.
Ferrous iron	mg/L	4	pH <6, oxygen <0.5 ppm
Ferric iron	mg/L	0.05	
Manganese	mg/L	0.05	
Aluminum	mg/L	0.05	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2021/060527

A. CLASSIFICATION OF SUBJECT MATTER
B01D61/02,C02F1/44 Version=2022.01

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)

C02F

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)

PatSeer, IPO Internal Database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	AU2017276843A1 (ONEKA TECH) 24 Jan 2019 (24/01/2019) Paragraph [0013],[0019],[0095],[0101],[0102],[0104],[0105]; Figure 6A	1-6
Y	GB2524066A (GOFLOW PTE LTD) 16 Nov 2015 (16/09/2015) Abstract, Line 19-20 in page-2 of the Description; Figure 1,2	1-6

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

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Date of the actual completion of the international search	Date of mailing of the international search report
31-01-2022	31-01-2022

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Citation	Pub.Date	Family	Pub.Date
AU 2017276843 A1	24-01-2019	CN 109562961 A	02-04-2019
		EP 3468921 A1	17-04-2019
		MA 45256 A	17-04-2019
		US 11130097 B2	28-09-2021
		WO 2017210800 A1	14-12-2017
GB 2524066 A	16-09-2015	CN 104906860 A	16-09-2015
		SG 10201501960 WA	29-10-2015