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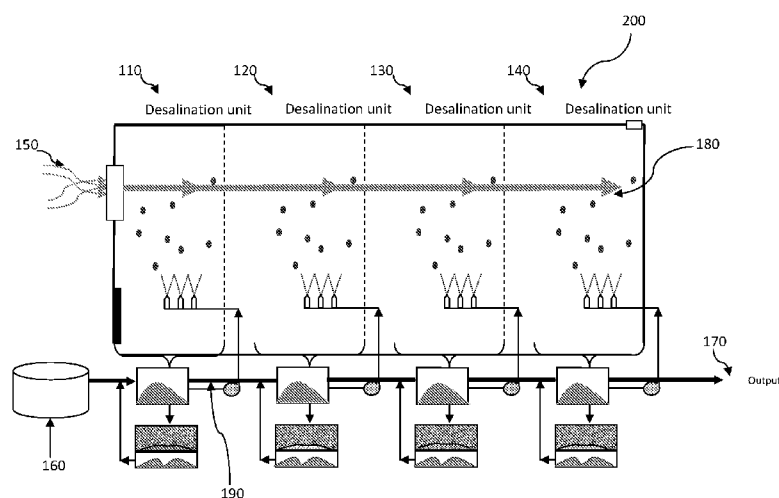


Fig. 2

(57) Abstract: The invention provides an apparatus for desalination of water, the apparatus comprises at least one desalination unit in the form of a closed container having a gas inlet, at least one ventilation unit and at least one means for atomizing a saline solution.

DEVICE AND METHOD FOR DESALINATION

TECHNOLOGICAL FIELD

The invention generally concerns an apparatus for desalination of saline waters and a method for desalination.

BACKGROUND OF THE INVENTION

The available methods of desalination may be roughly divided into two major groups wherein the desalination process may be performed by a designated device or by using open reservoirs while exploiting natural environment conditions, such as wind and temperature, for initiation of evaporation.

Some of the commonly used devices and methods relay on providing external energy for initiation of water evaporation and re-condensing the saline water and further separating the fresh water from the saline water. The most frequently used methods require high temperatures and/or high pressure conditions (e.g. thermal desalination) to initiate evaporation of the saline water first, and further to condense them, and "collect" the fresh water.

CN102179056A [1] discloses a five-stage high-efficiency flash evaporating, concentrating and drying machine.

Some of these techniques are preformed over several separated stages, where each stage addresses a different element of the desalination process, e.g., thermal evaporation, condensation, separation of the water solution and collection of the desired fresh water.

GB1147726A [2] discloses a process and an apparatus for distillation of a liquid and the production of soft water from sea water.

These known techniques which relay on thermal desalination require great amounts of energy for each of the steps, a fact which reduces the efficiency of the process.

Further techniques utilizing reverse osmosis membranes and filters are also commonly used to separate salts from the saline water.

Other techniques for water desalination involve forming of small droplets of the saline solution by rapid passage of the solution through a pneumatic nozzle as presented in CN103193285A [3], which demonstrate a spraying-type multi-stage flash-evaporation sea-water desalination equipment.

These techniques exploit high pressured solutions compressed through nozzles to atomize the solution into micron-size droplets which significantly enhances their rate of evaporation.

WO03013682A1 [4] describes an apparatus and method for thermal desalination based on pressurized formation and evaporation of droplets and US7340845B2 [5] further describes evaporation apparatus.

Although such methods can separate salt (sodium chloride, as well as other chemical salts such as potassium chloride) from seawater, large production rates have not been achieved or predicted at economical advantages.

DE202004017383U1 [6] demonstrates a desalination apparatus, having a fan which blows hot air from a heat exchanger through a convection drum, into which salt water is sprayed, water vapor produced is condensed, with all energy requirements being provided by solar units.

The primary setback of methods such as those mentioned hereinabove is the need for pre-heating of the chamber medium to a high temperature, in order to achieve sufficient evaporation rate and commercial levels of fresh water production.

REFERENCES

- [1] CN102179056
- [2] GB1147726
- [3] CN103193285
- [4] WO03013682
- [5] US7340845
- [6] DE202004017383

SUMMARY OF THE INVENTION

The present invention provides an apparatus and a process for desalination of saline water, which can efficiently desalinate large volumes of saline waters, such as seawater or waste waters produced by any existing industry with very low energy consumption. Such industries may be the food industry, chemical industry, petrochemical industry, fertilizers and salts industry, landfills and mines.

The apparatus of the invention generally comprises at least one desalination unit, wherein said unit is in the form of a closed container having a gas inlet, at least one ventilation (exhaust) unit and at least one means for atomizing a saline solution,

said gas inlet being adjusted to flow a gas into said container, said means for atomizing a saline solution being directionally oriented and operable to spray droplets of said saline solution toward said gas flow, wherein upon contact of said droplets with said gas, partial evaporation of water from said droplets ensues. The flow of gas may be at any angle to the spray of droplets.

The apparatus according to the invention comprises a first desalination unit and an end (last) desalination unit. In cases where the apparatus comprises only two desalination units, one of said two units is designated the first unit and the other of said units being designated the end (last) unit.

In some embodiments, each of said desalination units comprises a main feed container which is in liquid and/or gas communication with a main feed container of an adjacent unit. The main feed container of the first unit is connected to a saline reservoir and to the main feed container of the second unit; the main feed container of the second unit is similarly connected to the main feed container of the first and to the main feed container of a third unit; and each subsequent main feed container is connected to a main feed container of a preceding and subsequent containers. The main feed containers thus form a main feed line permitting continuous flow of saline from one unit to the other. The main feed line connects the various main feed containers via inlet and outlet members present on each container.

Within each unit, the main feed container is equipped with a collecting unit (trap, basin) for collecting droplets exiting the air flow and/or droplets rich in salt (i.e., after having been partially or wholly stripped of water). The collecting unit is typically positioned between the main feed container and the means for atomizing a saline solution; thereby permitting efficient collection of saline droplets exiting the air flow, and directing them back into the main feed container.

Thus, saline exiting the saline reservoir through an outlet member on the saline reservoir enters the main feed container of the first unit through an inlet on the container and after the saline solution has been treated as explained further below, it exits the main feed container of the first unit through an outlet member on the main feed container of the first unit and flows through to the main feed container of the next unit.

Each main feed container has an inlet element through which liquid flows therinto, e.g., from a preceding unit, and an outlet element which is connected to the

inlet of an adjacent main feed container. Each main feed container may additionally be equipped with an outlet to a salt collection unit.

In some embodiments, the apparatus of the invention is in the form of a closed container comprising a gas inlet, an exhaust unit (i.e., for releasing excess gas pressure or humidity of air) and one or more desalination units, each of said one or more units being adjacently positioned, each unit comprising at least one means for atomizing a saline solution, said means being directionally oriented towards a gas flowing through said gas inlet, as detailed herein, each of said one or more units comprising a main feed container and means to withdraw and inject saline solution from the main feed container towards the air flow via said at least one means for atomizing the saline solution; the main feed containers being connected to each other via a main feed line.

As a person versed in the art would understand, droplets of saline water, having exited the air flow or having been stripped, partially or wholly, of water, are gravitationally collected in the collection unit (trap) and communicated to the main feed container, and subsequently to (a) the main feed container of a subsequent unit, or (b) to a salt collection unit for collecting salt-rich droplets, or (c) are withdrawn and injected back towards the air flow.

The at least one means for atomizing the saline solution is connected to at least one means for withdrawing the saline solution from the main feed container and injecting the solution into the means for atomizing the solution. The at least one means for withdrawing the saline solution is typically a pump which is used to withdraw the saline solution and inject, communicate or deliver the solution through an assembly of nozzles which direct the atomized liquid, droplets, towards the direction of the gas flow.

The pump may be selected from any available pumps. Such a pump may be selected from a rotary positive displacement pump, a reciprocating positive displacement pump, a gear pump, a screw pump, a progressing cavity pump, a roots-type pump, a peristaltic pump, a plunger pump, a triplex-style plunger pump, a compressed-air-powered double-diaphragm pump, a rope pump, a flexible impeller pump and a rotoliptic pump.

The pump may also be selected from impulse pumps such as hydraulic ram pumps; a centrifugal pump, a radial-flow pump, an axial-flow pump, a mixed-flow pump, an eductor-jet pump, a gravity pump, a steam pump and a valve-less pump.

In some embodiments, the pump may operable to provide pressure in the range of 0.5 to 10 bars.

The at least one means for atomizing the saline solution into droplets, mist or spray are selected to facilitate dispersion of liquid into a spray or a mist. In some embodiments, the spray or mist is formed by one or more spray nozzles which breakup the saline solution flown therethrough. Generally, the spray nozzles can have one or more outlets and may be in the form of a compound nozzle having multiple outlets.

In some embodiments, each unit comprises an assembly of nozzles, connected to the pump which pushes the saline solution through the assembly of nozzles to provide droplets of a tunable average diameter (derived from the nozzle diameter and the injection pressure).

In some embodiments, the nozzle used is a fluid nozzle and may be selected from plain-orifice nozzle, shaped-orifice nozzle, surface-impingement single-fluid nozzle, pressure-swirl single-fluid spray nozzle, pressure-swirl single-fluid spray nozzle, solid-cone single-fluid nozzle, compound nozzle, rotary atomizer nozzle, ultrasonic atomizer nozzle and electrostatic nozzle.

The assembly of nozzles may comprise between 1 and 10 nozzles, which may or may not be identical or may vary based on their position in the salination unit, the number of other nozzles, the volume of the salination medium, the concentration of the salt in the solution and other parameters. The nozzle may be selected based on the nozzle orifice size.

In some embodiments, the orifice has a diameter in the range of 0.2 to 50 mm.

The nozzles in the assembly may be arranged in a linear or non-linear manner.

The assembly of nozzles may be positioned at the bottom of the closed container and spray the atomized liquid toward the direction of the gas flow from the bottom and/or may be positioned at the top of the closed container and spray the atomized liquid toward the direction of the gas flow from the top.

In accordance with the invention, the apparatus may comprise one or more pumps to withdraw and deliver saline solution from one container to another. For example, the apparatus comprises at least two different types of pumps: a first type is positioned to withdraw a saline solution from the reservoir and deliver the solution into the first main feed container. A second pump may be used with each of the desalination units to withdraw an amount of the saline solution from the main feed

container and force the solution through the nozzle assembly. A further pump may be used along the main feed line to withdraw saline solution from one feed container to another. Another pump may be used in each desalination unit to withdraw saline solution from the salt collection unit back into the corresponding feed container.

The pump(s) utilized may be formed into an assembly or may be selected to control withdrawal and/or delivery of solution from one or more different sources into one or more different containers, within the same unit.

Thus, in general, the pumps are used to withdraw saline solutions from a source and inject, communicate or deliver the solution to a recipient container or member. The solution is typically fed under pressure into the at least one means for atomizing the solution, which by itself may operate under pressure. The pump may be selected from any available pumps. Such a pump may be selected from a rotary positive displacement pump, a reciprocating positive displacement pump, a gear pump, a screw pump, a progressing cavity pump, a roots-type pump, a peristaltic pump, a plunger pump, a triplex-style plunger pump, a compressed-air-powered double-diaphragm pump, a rope pump, a flexible impeller pump and a rotoliptic pump.

The pump may also be selected from impulse pumps such as hydraulic ram pumps; a centrifugal pump, a radial-flow pump, an axial-flow pump, a mixed-flow pump, an eductor-jet pump, a gravity pump, a steam pump and a valve-less pump.

In some embodiments, the pump may press the saline water in various pressures, in the range of 0.5 to 15 bar.

The plurality of desalination units are typically arranged in a cascading fashion such that a concentration of salt in the saline solution increases as the solution passes from the first unit to the last unit (end unit) through the plurality of units (0, 1 or more) positioned therebetween. In other words, stripping the saline droplets from water leads to an increase in the solute concentration and to re-crystallization of the salts in each droplet, which subsequently falls down towards the trap and therefrom communicated either to a subsequent unit, or to a salt collection unit for collecting salt-rich droplets and repetitively re-circled.

Thus, each unit of the apparatus further comprises means for collection salt sediments resulting from the continuous removal of water and the resulting increase in the saline salt saturation. Sediments which form in the feed containers may be separated from the container into a salt collection unit. The separation between the

solid material (salt sediments) and the liquid medium, which at the saturation level comprises soluble salts, may be by a solid-liquid clarifier. The sediments may be collected and removed from the apparatus and the liquid medium may be fed back into the feed container of the respective unit.

In some embodiments, the salt sediments may be separated from the saline solution by means of filtering, mechanic collection of solids, suckling and/or absorbing the solids away from the solution or by any other known method for separating solids from liquids.

In some embodiments, the solution is returned to the feed container by any means, such as pumping the solution back to the container via a pipe which connects the salt collection unit to the feed container.

As a person of skill would understand, upon certain saturation levels, particular types of salts begin to aggregate and salt-out from the liquid medium, thereby permitting selective separation of different salts at the bottom of the salt collecting unit.

The exhaust unit may be in the form of a demister, for allowing the release of vaporized water and for preventing release of the spray droplets. In some embodiments, the exhaust unit is a valve operated outlet for releasing gas or liquid pressure above a desired set pressure limit.

In some embodiments of the invention, the apparatus may generally be structured as an array of desalination units, wherein each of said units being as defined herein.

The container has an inlet which allows gas to enter the chamber.

The gas inserted into the chamber is being horizontally pushed inside the chamber from the outer environment by a blower and/or a fan.

The gas flow entering the apparatus of the invention may be a pre-warmed gas or a gas at room temperature, which is blown in by a blower at a predetermined flow rate. In order to prevent increase in the positive pressure in the closed container, the apparatus further comprises a gas outlet for venting out excess gas. The gas flow may be of any gas or gaseous mixture. In some embodiments, the gas is air, oxygen, nitrogen, carbon dioxide, nitrogen gas and others, or any combination thereof.

The saline solution may be any type of a salt solution, containing any salt type, any combination of salts, at any concentration or at any relative ratio.

In some embodiments, the saline solution is an industrial salt water, sea water, mineral water, wastewater, brackish water and mining water.

In some embodiments, the saline solution (salt containing waters) may contain any salt, at any concentration; and in some embodiments comprises at least one dissolved inorganic salts based on or comprising halides, carbonates, phosphates and sulfates, e.g., sodium, potassium, calcium, lithium, magnesium, zinc or copper from aqueous mixtures.

Thus, the term “*desalination*”, as used herein, refers to complete or partial removal of dissolved mineral salts, such as the above identified, from saline solutions or otherwise aqueous mixtures.

The invention further contemplates a process for desalination of saline solutions, the process comprising use of an apparatus according to the invention.

In another aspect the invention provides a process for desalination of saline solutions, the process comprising passing a saline solution through a desalination unit, wherein said unit is in the form of a closed container having a gas inlet, at least one ventilation unit and at least one means for atomizing a saline solution, said gas inlet being adjusted to flow a gas into said container, wherein the solution is atomized into a plurality of saline droplets and directionally oriented and operable sprayed toward said gas flow, wherein upon contact of said droplets with said gas, partial evaporation of water from said droplets ensues.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1-Fig. 3 – provide different embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Turning to **Fig. 1**, an exemplary apparatus **100** according to the present invention is provided.

The apparatus of the invention **100** generally comprises at least one desalination unit **10**, wherein said unit being in the form of a closed container having a gas inlet **20** and at least one means for atomizing a saline solution, depicted as a nozzle assembly **80** comprising 3 nozzles. Gas, such as air, is blown into the container using a blower **90**, the gas being flown at any direction relative to the main plane of the container, provided that the means for atomizing the solution is directionally oriented and operable to spray droplets **30** of a saline solution toward the gas flow,

wherein upon contact of said droplets with said gas, partial evaporation of water from said droplets ensues.

The apparatus may comprise one or more such units, as depicted in **Fig. 2**, wherein an apparatus **200** comprises 4 desalination units (**110**, **120**, **130** and **140**), which are structured as a single continuous container. The desalination units may be separated as free-standing units, as depicted in the array of **Fig. 3**.

Each of desalination unit (**Fig. 1**- apparatus **100**: unit **10**; **Fig. 2**- apparatus **200**: units **110**, **120**, **130** and **140**; **Fig. 3**- apparatus **300**: units **210**, **220**, **230** and **240**) comprises a main feed container **50** which is in liquid communication with a main feed container of an adjacent unit. The main feed container of the first unit **110** or **210** is connected to a saline reservoir **160** or **260** and to the main feed container of the second unit **120** or **220**; the main feed container of the second unit is similarly connected to the main feed container of the first and to the main feed container of the third unit; and each subsequent main feed container is thus connected to the main feed container of the preceding and subsequent containers. The main feed containers thus form a main feed line **190** or **290** permitting continuous flow of saline from one unit to the other. The line connects the various main feed containers via inlet and outlet members present on each container.

Within each unit, the main feed container is equipped with a collecting unit (trap, basin) for collecting droplets exiting the air flow and/or droplets rich in salt (i.e., after having been partially or wholly stripped of water). The collecting unit is typically positioned between the main feed container **50** and the nozzles assembly **80**.

Thus, saline exiting the saline reservoir **40** through an outlet member on the saline reservoir enters the main feed container **50** of the first unit **10** through an inlet on the container and after the saline solution has been treated as explained herein, it exits the main feed container of the first unit through an outlet member on the main feed container of the first unit and flows through to the main feed container of the next unit.

The pump **70** is used for withdrawing the saline solution and injecting, communicating or delivering the solution through an assembly of nozzles. In accordance with the invention, the apparatus may comprise one or more pumps to withdraw and deliver saline solution from one container to another.

Each unit of the apparatus further comprises means for collection salt sediments resulting from the continuous removal of water and the resulting increase in

the saline salt saturation. Sediments which form in the feed containers **50** may be separated from the container into a salt collection unit **60**. The separation between the solid material (salt sediments) and the liquid medium, which at the saturation level comprises soluble salts, may be by a solid-liquid clarifier, e.g., filter. The sediments may be collected and removed from the apparatus and the liquid medium may be fed back into the feed container of the respective unit.

CLAIMS:

1. An apparatus for desalination of water, the apparatus comprising at least one desalination unit, wherein said unit is in the form of a closed container having a gas inlet, at least one ventilation unit and at least one means for atomizing a saline solution, said gas inlet being adjusted to flow a gas into said container, said means for atomizing a saline solution being directionally oriented and operable to spray droplets of said saline solution toward said gas flow, wherein upon contact of said droplets with said gas, partial evaporation of water from said droplets ensues.
2. The apparatus according to claim 1, comprising at least two desalination units, one of which being a first desalination unit and another one of which being the end desalination unit.
3. The apparatus according to claim 1, wherein each of said desalination units comprises a main feed container being in liquid and/or gas communication with a main feed container of an adjacent unit.
4. The apparatus according to claim 3, wherein the main feed container of the first unit is connected to a saline reservoir and to the main feed container of a second unit; the main feed container of the second unit is similarly connected to the main feed container of the first and to the main feed container of a third unit; and each subsequent main feed container is connected to a main feed container of a preceding and subsequent containers.
5. The apparatus according to claim 4, wherein the main feed containers form a main feed line permitting continuous flow of saline from one unit to the other.
6. The apparatus according to claim 5, wherein the main feed container is equipped with a collecting unit for collecting droplets exiting the air flow and/or droplets rich in salt.
7. The apparatus according to claim 6, wherein the collecting unit is positioned between the main feed container and the means for atomizing a saline solution.
8. The apparatus according to claim 3, wherein each the main feed containers has an inlet element through which liquid flows thereinto and an outlet element connected to the inlet of an adjacent main feed container.
9. The apparatus according to claim 3, wherein each main feed container being additionally equipped with an outlet to a salt collection unit.
10. The apparatus according to claim 1, the apparatus being in the form of a closed container comprising a gas inlet, an exhaust unit and one or more desalination

units, each of said one or more units being adjacently positioned, each unit comprising at least one means for atomizing a saline solution, said means being directionally oriented towards a gas flowing through said gas inlet, each of said one or more units comprising a main feed container and means to withdraw and inject saline solution from the main feed container towards the air flow via said at least one means for atomizing the saline solution; the main feed containers being connected to each other via a main feed line.

11. The apparatus according to claim 1, wherein the at least one means for atomizing the saline solution is connected to at least one means for withdrawing the saline solution from the main feed container and injecting the solution into the means for atomizing the solution.

12. The apparatus according to claim 11, wherein the at least one means for withdrawing the saline solution being a pump for withdrawing the saline solution and deliver the solution through an assembly of nozzles which direct the atomized liquid towards the direction of the gas flow.

13. The apparatus according to claim 12, wherein the pump being selected from a rotary positive displacement pump, a reciprocating positive displacement pump, a gear pump, a screw pump, a progressing cavity pump, a roots-type pump, a peristaltic pump, a plunger pump, a triplex-style plunger pump, a compressed-air-powered double-diaphragm pump, a rope pump, a flexible impeller pump and a rotoliptic pump.

14. The apparatus according to claim 12, wherein the pump being selected from impulse pump, centrifugal pump, radial-flow pump, axial-flow pump, mixed-flow pump, eductor-jet pump, gravity pump, steam pump and valve-less pump.

15. The apparatus according to claim 12, wherein the pump being operable to provide pressure in the range of 0.5 to 10 bars.

16. The apparatus according to claim 1, wherein the at least one means for atomizing the saline solution into droplets being selected to facilitate dispersion of liquid into a spray or a mist.

17. The apparatus according to claim 16, wherein the spray or mist being formed by one or more spray nozzles.

18. The apparatus according to claim 17, wherein each of the one or more spray nozzles having one or more outlets.

19. The apparatus according to claim 1, wherein each unit comprises an assembly of nozzles.
20. The apparatus according to any one of claims 1 to 17, wherein the nozzle is selected from plain-orifice nozzle, shaped-orifice nozzle, surface-impingement single-fluid nozzle, pressure-swirl single-fluid spray nozzle, pressure-swirl single-fluid spray nozzle, solid-cone single-fluid nozzle, compound nozzle, rotary atomizer nozzle, ultrasonic atomizer nozzle and electrostatic nozzle.
21. The apparatus according to claim 19, wherein the assembly of nozzles comprises between 1 and 10 nozzles.
22. The apparatus according to any one of the preceding claims, comprising a plurality of desalination units arranged in a cascade, wherein the concentration of salt in the saline solution increases as the solution passes from the first unit to the last unit through the plurality of units positioned therebetween.
23. The apparatus according to claim 1, further comprising means for collection salt sediments.
24. The apparatus according to claim 23, wherein the salt sediments are separated from the saline solution by means of filtering, mechanic collection of solids, suckling and/or absorbing the solids away from the solution.
25. The apparatus according to claim 1, further comprising a demister.
26. The apparatus according to claim 1, the apparatus structured as an array of desalination units.
27. The apparatus according to claim 1, wherein gas inserted into the chamber is horizontally pushed inside the chamber from the outer environment by a blower and/or a fan.
28. The apparatus according to claim 1, wherein the gas flow is a pre-heated gas or a gas at room temperature.
29. The apparatus according to claim 1, wherein the gas being a neat gas or a gaseous mixture.
30. The apparatus according to claim 29, wherein the gas is selected from air, oxygen, nitrogen, carbon dioxide and nitrogen gas or any mixture thereof.

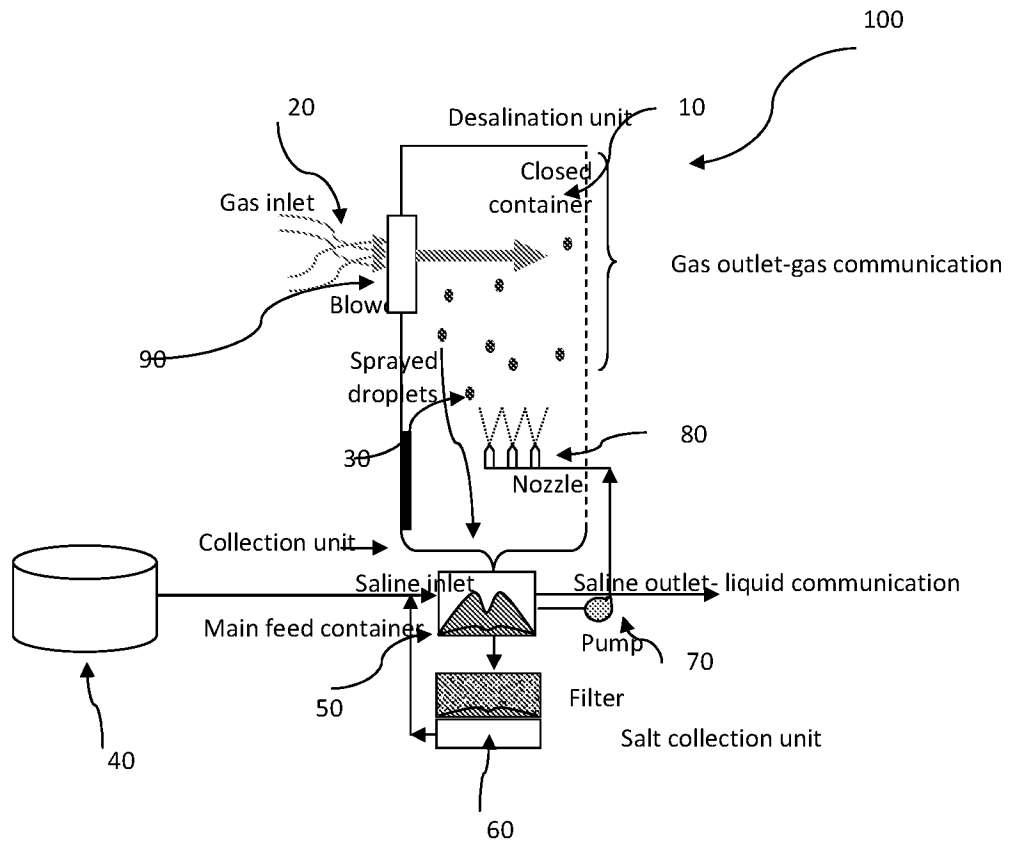


Fig. 1

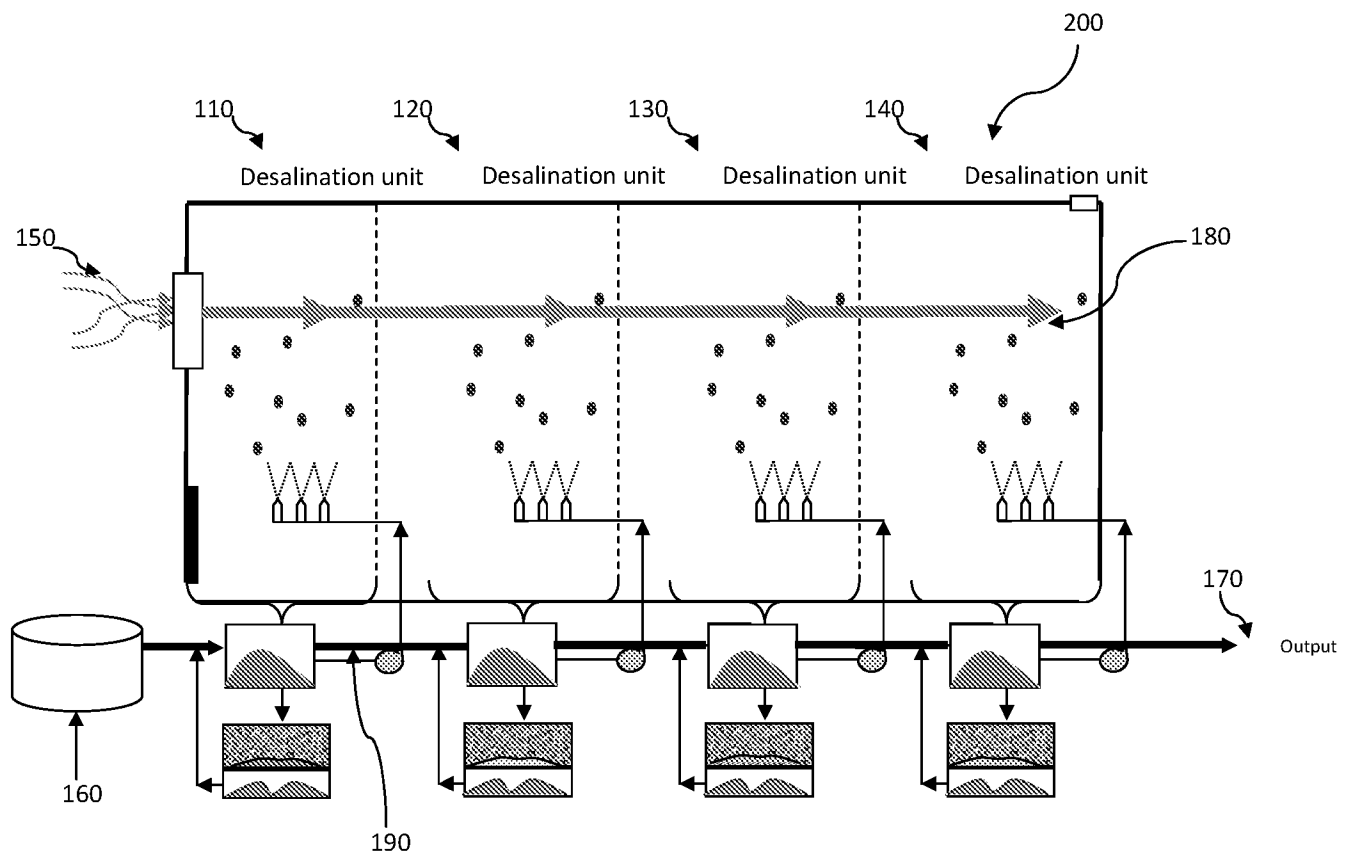


Fig. 2

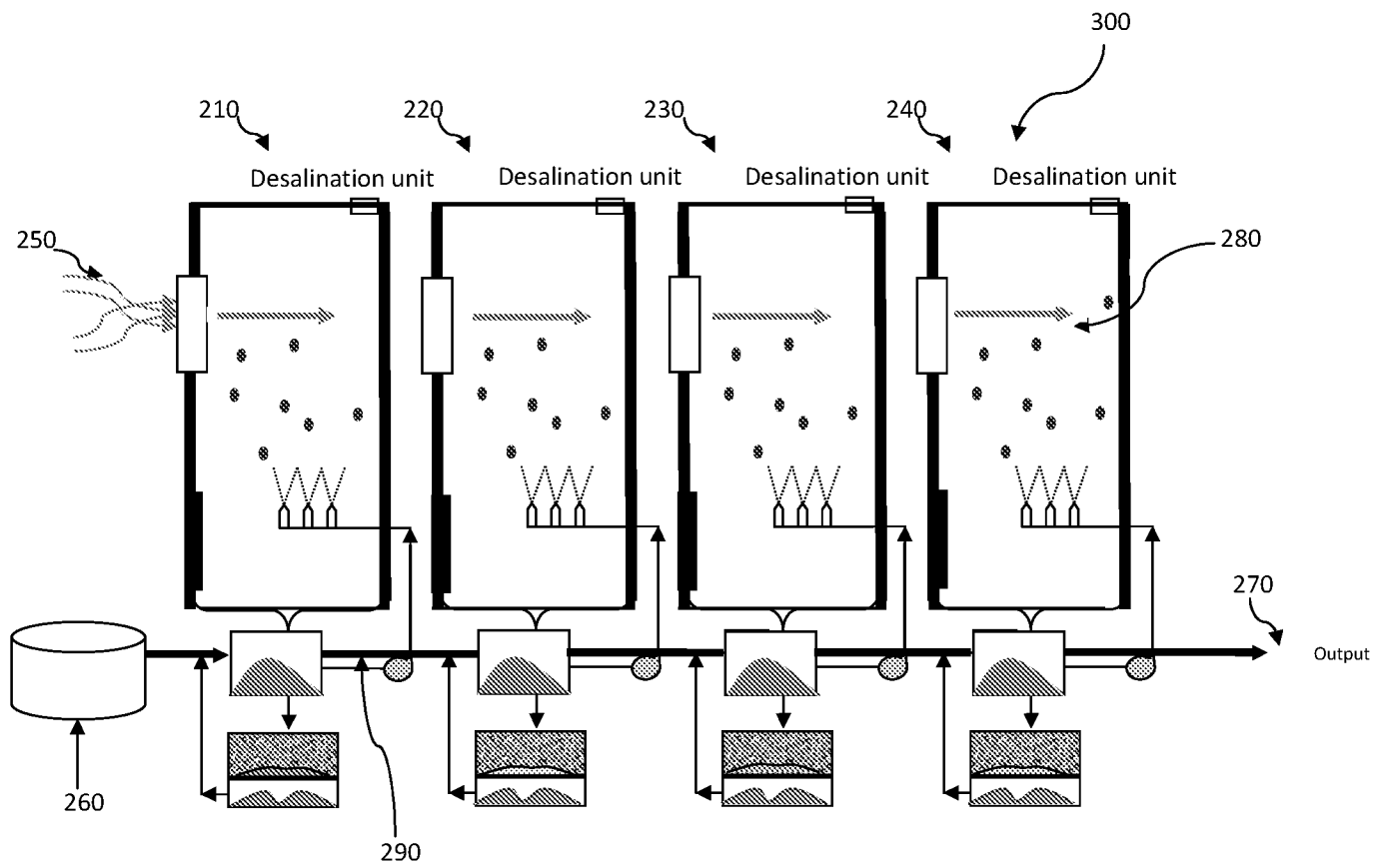


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IL2015/050374

A. CLASSIFICATION OF SUBJECT MATTER

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ADD.

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)

B01D 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)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/263616 A1 (PUNGTRAKUL CHALOKE [TH]) 10 October 2013 (2013-10-10) paragraphs [0029], [0035], [0042]; figures 1,5,11 -----	1-8, 11-22, 26-30
X	US 2012/210592 A1 (ZMOOD RONALD BARRY [AU] ET AL) 23 August 2012 (2012-08-23) paragraphs [0042] - [0052], [0063] - [0068]; figures 1-5 -----	1,2,10, 22,25,26
X	GB 2 094 951 A (WIEGAND KARLSRUHE GMBH) 22 September 1982 (1982-09-22) fig.2, page 1 line 115 - page 2 line 71 ----- -/--	1,2,10, 13-15

☒ Further documents are listed in the continuation of Box C.

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