

DESCRIPTION**DESALINATION APPARATUS, DESALINATION METHOD,
AND FLOATING POROUS CARRIER**

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Technical Field

The present invention relates to a desalination apparatus and a desalination method for desalting saline water such as seawater or salt water, and more particularly to a desalination apparatus and a desalination method suitably used in an arid land, a desert, and an isolated island for extracting fresh water from saline water by utilizing natural energy. The present invention also relates to a floating porous carrier for use in such a desalination apparatus and a desalination method.

Background Art

A desalination apparatus for desalting seawater or saline groundwater is indispensable in a desert, an isolated island, and the like. At present, however, the desalination apparatus generally uses petroleum or a reverse osmosis (RO) membrane, thus consuming a large amount of energy. Such apparatus itself causes environmental pollution.

On the other hand, there has been known a desalination apparatus utilizing solar heat which is natural energy. For example, Japanese laid-open patent publications No. 11-156341 and No. 11-207318 disclose this kind of desalination apparatus. However, this apparatus has a complicated structure, and therefore incurs an increased installation cost. There is also an evaporator having a condenser which collects sunlight to generate heat energy for evaporation.

Japanese laid-open patent publications No. 56-130291 and No. 56-133088 disclose a system for producing condensed water. In this system, seawater is introduced into an evaporation tank floating on the seawater, and solar heat is collected by a solar collector disposed on a bottom of the tank so as to evaporate the seawater. In addition to this, Japanese laid-open patent publication No. 57-21976 discloses a desalination method using a dome-like film structure comprising a translucent sheet which airtightly

covers a surface of seawater. In this desalination method, carbon dioxide is introduced into the film structure and heated by radiant heat of the sun, so that the seawater under the carbon dioxide is evaporated. Thereafter, condensed water is collected during the nighttime when an outside air temperature is lowered. In this manner, the seawater is desalted.

However, although the above-mentioned conventional apparatus does not require a large installation space, it has a complicated structure, which causes a high installation cost. Further, the use of electricity or fossil fuel incurs an increased running cost. Although the desalination apparatus utilizing solar heat can achieve a low cost, efficiency is not high enough.

Disclosure of Invention

The present invention has been made in order to solve the above drawbacks. It is an object of the present invention to provide a desalination apparatus and a desalination method for desalting saline water by efficiently evaporating the saline water with use of the solar heat, i.e., natural energy, and then efficiently condensing the vapor. Another object of the present invention is to provide a desalination apparatus and a desalination method which can desalt the saline water with a simple structure at a low running cost. Further, another object of the present invention is to provide a floating porous carrier for use in such a desalination apparatus and a desalination method.

In order to achieve the above objects, according to an aspect of the present invention, there is provided a desalination apparatus for desalting saline water. The apparatus comprises a structural body in which a hermetically enclosed interior space is formed; a partition dividing the interior space into an evaporation chamber and a condensation chamber; a sunlight-permeable member constituting an upper surface and a front surface of the evaporation chamber; and at least one of a fin and a cooling water passage provided on a wall of the condensation chamber for improving a condensation effect. The evaporation chamber and the condensation chamber communicate with each other at an upper portion of the interior space. The evaporation chamber has an inlet of saline water and an outlet of the saline water which has been evaporated and

concentrated, and the condensation chamber has an output port of condensed water.

In a preferred aspect of the present invention, the desalination apparatus further comprises multistage trays provided in the evaporation chamber; and a gutter provided on an uppermost one of the trays for introducing the saline water to the trays. The trays
5 are inclined so that the saline water flows down the trays in the form of a thin film.

In a preferred aspect of the present invention, the evaporation chamber and the condensation chamber are disposed on both sides of the partition. The evaporation chamber is positioned at sunny side, and the condensation chamber is positioned at an opposite side of the sunny side. The condensation chamber is positioned in the shade of
10 the partition.

In a preferred aspect of the present invention, an inner surface of a wall of the condensation chamber forms a condensation surface, and the condensation surface has a wavy plate or a number of small irregularities so as to increase a condensation area.

In a preferred aspect of the present invention, the sunlight-permeable member is
15 made of glass.

According to another aspect of the present invention, there is provided a desalination apparatus comprising: an enclosing vessel installed on a water surface of saline water so as to hermetically enclose the water surface; and a floating porous carrier floating on the water surface enclosed by the enclosing vessel. The floating porous
20 carrier is moved by wave force to form thin films of the saline water on a surface and an inner portion of the floating porous carrier.

In a preferred aspect of the present invention, the enclosing vessel has a dome-like shape.

In a preferred aspect of the present invention, the floating porous carrier
25 comprises a material having pyrogenicity and thermal storage capability.

In a preferred aspect of the present invention, the material is zirconium carbide.

According to another aspect of the present invention, there is provided a desalination method for desalting saline water. The method comprises installing an enclosing vessel on a water surface of saline water so as to hermetically enclose the water
30 surface; floating a floating porous carrier on the water surface enclosed by the enclosing

vessel; moving the floating porous carrier by wave force to form thin films of the saline water on a surface and an inner portion of the floating porous carrier; evaporating the saline water to produce vapor in the enclosing vessel; condensing the vapor to produce condensed water on an inner surface of the enclosing vessel; and collecting the condensed water.

In a preferred aspect of the present invention, the inner surface of the enclosing vessel is inclined so that the vapor is convected and the condensed water is led into a condensed water collecting tank provided on an end portion of the enclosing vessel.

In a preferred aspect of the present invention, the enclosing vessel has a dome-like shape.

In a preferred aspect of the present invention, the floating porous carrier comprises a material having pyrogenicity and thermal storage capability.

In a preferred aspect of the present invention, the material is zirconium carbide.

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In a preferred aspect of the present invention, the material is zirconium carbide.

According to the present invention described above, because the apparatus has a simple structure and uses only sunlight and solar heat, it is possible to desalt water containing salt and the like at a low cost. Furthermore, because the floating porous carrier and the wave force are used to form the thin films, the desalination can be performed economically and effeciently compared with a conventional method.

Brief Description of Drawings

FIG. 1 is a cross-sectional view showing a desalination apparatus having cooling fins attached to a wall of a condensation chamber according to a first embodiment of the present invention;

FIG. 2 is a plan view schematically showing a wall of a condensation chamber with a cooling water pipe of a desalination apparatus according to a second embodiment of the present invention;

FIG. 3A is a cross-sectional view schematically showing an example of a wavy

condensation surface;

FIG. 3B is a cross-sectional view schematically showing an example of a condensation surface having irregularities;

FIG. 3C is a front view of the condensation wall shown in FIG. 3B; and

5 FIG. 4 is a schematic view showing a desalination apparatus according to a third embodiment of the present invention.

Best Mode for Carrying Out the Invention

Embodiments of the present invention will be described below with reference to
10 the drawings.

As shown in FIG. 1, a desalination apparatus (structural body) 1 comprises a partition 4 dividing a hermetically enclosed interior space of the desalination apparatus into two compartments which communicate with each other at an upper portion of the interior space. One of the two compartments serves as an evaporation chamber 2
15 having an inlet 9 of saline water (sea water) and an outlet 10 of the saline water which has been evaporated and concentrated, and the other serves as a condensation chamber 3 having an output port 13 of condensed water. The desalination apparatus comprises a sunlight-permeable member 5, e.g., a glass plate, constituting an upper surface and a front surface (at an evaporation chamber side), both of which constitute a roof portion of
20 the desalination apparatus. Although a glass plate is used in FIG. 1, the present invention is not limited to this structure. For example, a plastic plate made of polyethylene, polypropylene, or acrylic resin may be used. That is, it is possible to use all types of materials which are easy to use, capable of transmitting the sunlight to collect the solar heat in the evaporation chamber 2, and excellent in strength and weather
25 resistance. A material of the partition 4 is also not limited and can be selected from all types of gas non-permeable materials.

In order to increase the condensation efficiency, cooling fins 8 are provided on an outer surface of the wall of the condensation chamber 3. In a second embodiment shown in FIG. 2, a cooling water passage (cooling water pipe) 15 is provided on the outer
30 surface 14 of the wall of the condensation chamber 3. Seawater (cooling water) is

introduced through a cooling water inlet 16 into the cooling water passage 15, and is discharged through a cooling water outlet 17. Since the seawater is discharged with an increased temperature, the seawater is introduced from the cooling water outlet 17 directly into the seawater inlet 9 of the evaporation chamber 2.

5 The air-cooling fins (cooling fins) 8 cool the evaporated water to an outside air temperature for thereby condensing the evaporated water. The air-cooling fins 8 are made of a highly heat-conductive material such as copper or aluminum. A shape, an area, and the like of the air-cooling fins 8 are appropriately designed according to a required amount of the fresh water to be condensed by the desalination apparatus.

10 Deep water may be used as the cooling water to be introduced into the cooling water passage 15. In this case, the cooling water with a low temperature can be obtained at a low cost. A combination of the air-cooling fins 8 and the cooling water passage 15 can be employed.

 In a further detailed embodiment, multistage trays 6 are provided in the evaporation chamber 2. The trays 6 are inclined so that the saline water (seawater) flows down the trays 6 in the form of a thin film. A gutter 6a for introducing the saline water to the trays 6 is provided on an uppermost one of the trays 6. Any material having a smooth flat surface can be used for the trays 6. Examples of such a material include a metal plate made of iron, copper, or aluminum, a plastic plate made of polyethylene, polypropylene, or polyvinyl chloride, a fabric, and a nonwoven fabric.

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 The desalination apparatus is installed in such a state that the condensation chamber 3 is positioned in the shade. Specifically, the desalination apparatus is installed such that the evaporation chamber 2 faces toward the south (opposite in Southern Hemisphere) from which the sunlight L comes, and the condensation chamber 3 faces toward the north. Since these chambers are divided from each other by the partition 4, the condensation chamber 3 is positioned in the shade of the partition 4.

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 With the above-mentioned structure, the saline water is evaporated in the evaporation chamber 2 to form water vapor 11. The water vapor 11 ascends as an upward flow and moves from the evaporation chamber 2 into the condensation chamber 3 through the upper portion of the apparatus. Thereafter, the water vapor 11 is cooled

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and condensed by an inner surface (a condensation surface 7) of the wall of the condensation chamber 3 to form water droplets 12. As shown in FIGS. 3A through 3C, it is preferable to increase a condensation area by providing a wavy plate or a number of small irregularities on the inner surface of the wall of the condensation chamber 3 to form the condensation surface 7.

[Example 1]

The present invention will be further described in detail with an example given below. It should be noted that modifications may be made without departing from the concept of the present invention. Therefore, the scope of the present invention is not limited to the example described below.

The desalination apparatus used in an experiment had a depth of 2,000mm (the evaporation chamber: 1,500mm, the condensation chamber: 500mm) and a width of 2,000mm. A height of a rear end at the condensation-chamber side was 1,800mm, and a height of a front end at the evaporation-chamber side was 1,200mm. A height of the partition disposed between the evaporation chamber and the condensation chamber was 1,500mm, and the roof portion was made of transparent glass. The desalination apparatus was installed in such a state that the evaporation chamber was positioned on the south side and the condensation chamber was positioned on the north side. The condensation chamber had a wall of a detachable panel type so that experimental results could be compared between the air-cooling type using the fins and the water-cooling type using the cooling water pipe (cooling water passage) through which seawater flowed. In the case of the water-cooling type, the seawater was introduced into the cooling water pipe through the cooling water inlet located on the upper portion of the wall, as shown in FIG. 2. Five trays were disposed in the desalination apparatus in such a state that each tray (1,800mm×1,000mm) was inclined at an angle of 5 degree to a horizontal plane. An outside air temperature was 28°C, and a temperature of seawater to be supplied to the evaporation chamber and the cooling water pipe was 20°C.

The experimental results were as follows: In the case of the air-cooling type, an amount of the condensed water recovered (an amount of water recovered as fresh water) was 19 liters per day, and was 10.6 liters per unit area (square meters) of the

uppermost tray in the evaporation chamber per day. On the other hand, in the case of the water-cooling type, an amount of the condensed water recovered was 24 liters per day, and was 13.3 liters per unit area (square meters) of the uppermost tray in the evaporation chamber per day.

5 With the desalination apparatus for desalting water containing salt and the like according to the present invention, the saline water was efficiently evaporated by the solar heat, i.e., natural energy, and the evaporated water was condensed to form fresh water. The experimental results show that the desalination apparatus of the present invention can produce a large amount of fresh water at a low cost in arid regions such as
10 an isolated island and a desert where fresh water is lacking all the times.

Next, a desalination apparatus according to a third embodiment of the present invention will be described with reference to FIG. 4 illustrating a schematic view thereof.

In this embodiment, a dome-like enclosing vessel 22 is installed on a water surface of saline water 21 such as seawater so as to hermetically enclose the water
15 surface. A plurality of floating porous carriers 23 float on the water surface enclosed by the dome-like enclosing vessel 22. The floating porous carriers 23 are moved by wave force to form thin films of the saline water on surfaces and inner portions of the carriers, and the saline water are thus evaporated in the dome-like enclosing vessel 22. Thereafter, the vapor is condensed to form condensed water on an inner surface of the
20 dome-like enclosing vessel 22. The condensed water flows down the inner surface of the dome-like enclosing vessel 22 and is then collected.

When the floating porous carriers 23, which float on the water surface enclosed by the dome-like enclosing vessel 22, are moved and rotated vertically and laterally by the movement of wave, the thin films of the saline water are formed on the surfaces and
25 inner portions of the carriers. Because the thin films of the saline water are formed on the surfaces and the inner portions of the floating porous carriers 23, the saline water can be easily evaporated and dispersed in the dome-like enclosing vessel 22.

In the dome-like enclosing vessel 22, during the daytime, the evaporation of the saline water is accelerated by radiant heat of the sun, and the supersaturated water vapor
30 is convected. On the other hand, during the nighttime, the vapor is condensed to form

water droplets on the inner surface of the dome-like enclosing vessel 22.

Storing tanks 24 are provided on an end portion of the inner surface of the dome-like enclosing vessel 22. The water droplets on the inner surface of the dome-like enclosing vessel 22 flow down the inner surface and are collected in the storing tanks 24.

5 Floating bodies 25 are provided on the lower end portion of the dome-like enclosing vessel 22 so that the dome-like enclosing vessel 22 can be installed on the water surface.

The floating porous carriers 23 have a lower density (specific gravity) than the saline water to be desalted, and therefore float on the saline water. Since the saline water to be desalted has a higher density than pure water (having a density of 1), the
10 floating porous carriers 23 to be used do not necessarily have a density of less than 1.

According to a temperature and a concentration of the saline water such as salt water to be desalted, the floating porous carriers 23 are designed to have a most suitable porous diameter for forming the thin films. With this structure, the thin films can be formed efficiently. The floating porous carriers 23 are preferably made of a mixture of
15 a base material and a material having pyrogenicity and thermal storage capability such as zirconium carbide.

The dome-like enclosing vessel 22 serves to enclose the water vapor produced from the water surface by the radiant heat of the sun, condense the water vapor to produce water droplets on the inner surface thereof when the outside air temperature is
20 lowered, e.g., during the nighttime, and allow the water droplets to flow down the inner surface thereof to collect them in the storing tanks 24. Material, structure, shape, and size of the dome-like enclosing vessel 22 are not particularly limited so long as the dome-like enclosing vessel 22 has the above-mentioned functions.

[Example 2]

25 The third embodiment of the present invention will be described in detail with an example given below. It should be noted that the scope of the present invention is not limited to the example described below.

Two dome-like enclosing vessels as illustrated in FIG. 4 (hereinafter referred to as a first dome and a second dome), each having a diameter of 500mm, were used and
30 floated on seawater retained in a water bath (2,000mm×2,000mm×500mm). The

floating porous carriers (material: polystyrene, ϕ : 20mm, specific gravity: 0.3, the number of carries: 200) were introduced into the first dome so as to cover the entire water surface. On the other hand, no floating porous carriers were introduced into the second dome. The seawater in the water bath was agitated by an agitator so that the water surface was ruffled. The outside air temperature was set at 28°C, and the temperature of the seawater was set at 20°C.

The experimental results were as follows: An amount of the condensed water recovered in the second dome was 0.7 liters per day, and was 3.6 liters per unit area (square meters) of the seawater surface enclosed by the second dome per day. On the other hand, an amount of the condensed water recovered in the first dome was 2.7 liters per day, and was 13.8 liters per unit area (square meters) of the seawater surface enclosed by the first dome per day.

As described above, the desalination apparatus for the saline water according to the present invention can produce fresh water with a simple structure at a low cost, and is thus effective in solving a shortage of water.

Industrial Applicability

The present invention is applicable to a desalination apparatus and a desalination method used in an arid land, a desert, an isolated island, and the like for extracting fresh water from saline water, such as seawater or salt water, by utilizing natural energy.

CLAIMS

1. A desalination apparatus for desalting saline water, said apparatus comprising:

5 a structural body in which a hermetically enclosed interior space is formed;
a partition dividing the interior space into an evaporation chamber and a condensation chamber, said evaporation chamber and said condensation chamber communicating with each other at an upper portion of the interior space;

10 a sunlight-permeable member constituting an upper surface and a front surface of said evaporation chamber; and

at least one of a fin and a cooling water passage provided on a wall of said condensation chamber for improving a condensation effect;

wherein said evaporation chamber has an inlet of saline water and an outlet of the saline water which has been evaporated and concentrated; and

15 wherein said condensation chamber has an output port of condensed water.

2. A desalination apparatus according to claim 1, further comprising:

multistage trays provided in said evaporation chamber; and

20 a gutter provided on an uppermost one of said trays for introducing the saline water to said trays;

wherein said trays are inclined so that the saline water flows down said trays in the form of a thin film.

3. A desalination apparatus according to claim 1 or 2, wherein:

25 said evaporation chamber and said condensation chamber are disposed on both sides of said partition;

said evaporation chamber is positioned at sunny side;

said condensation chamber is positioned at an opposite side of the sunny side;

and

30 said condensation chamber is positioned in the shade of said partition.

4. A desalination apparatus according to any one of claims 1 to 3, wherein:
an inner surface of a wall of said condensation chamber forms a condensation
surface; and

5 said condensation surface has a wavy plate or a number of small irregularities so
as to increase a condensation area.

5. A desalination apparatus according to any one of claims 1 to 4, wherein said
sunlight-permeable member is made of glass.

10 6. A desalination apparatus for desalting saline water, said apparatus
comprising:

an enclosing vessel installed on a water surface of saline water so as to
hermetically enclose the water surface; and

15 a floating porous carrier floating on the water surface enclosed by said enclosing
vessel;

wherein said floating porous carrier is moved by wave force to form thin films
of the saline water on a surface and an inner portion of said floating porous carrier.

20 7. A desalination apparatus according to claim 6, wherein said enclosing vessel
has a dome-like shape.

8. A desalination apparatus according to claim 6 or 7, wherein said floating
porous carrier comprises a material having pyrogenicity and thermal storage capability.

25 9. A desalination apparatus according to claim 8, wherein said material is
zirconium carbide.

10. A desalination method for desalting saline water, said method comprising:

30 installing an enclosing vessel on a water surface of saline water so as to

hermetically enclose the water surface;

floating a floating porous carrier on the water surface enclosed by said enclosing vessel;

5 moving said floating porous carrier by wave force to form thin films of the saline water on a surface and an inner portion of said floating porous carrier;

evaporating the saline water to produce vapor in said enclosing vessel;

condensing the vapor to produce condensed water on an inner surface of said enclosing vessel; and

collecting the condensed water.

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11. A desalination method according to claim 10, wherein the inner surface of said enclosing vessel is inclined so that the vapor is convected and the condensed water is led into a condensed water collecting tank provided on an end portion of said enclosing vessel.

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12. A desalination method according to claim 11, wherein said enclosing vessel has a dome-like shape.

20 13. A desalination method according to any one of claims 10 to 12, wherein said floating porous carrier comprises a material having pyrogenicity and thermal storage capability.

14. A desalination method according to claim 13, wherein said material is zirconium carbide.

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15. A floating porous carrier, comprising:

a material having pyrogenicity and thermal storage capability.

30 16. A floating porous carrier according to claim 15, wherein said material is zirconium carbide.