

DESALINATION ASSEMBLY

PRIORITY STATEMENT

[0001] This application claims priority to U.S. Provisional Patent Application 60/984,417 filed on November 1, 2007.

FIELD OF THE INVENTION

[0002] The present invention relates to desalination assemblies, and more particularly to desalination assemblies capable of operating using diverse sources of energy.

BACKGROUND OF THE INVENTION

[0003] Water is one of the most abundant resources on the earth. Approximately 75% of the earth's surface is covered by water. Water is used in almost all human activities. However, much fresh water exists in the form of glaciers or is located in underground basins and is therefore relatively inaccessible. Further, nearly 97.5% of all water on earth is seawater and therefore not directly fit for human consumption due to its high salt and mineral content. Therefore, it will be very convenient if potable water could be economically extracted from seawater.

[0004] Desalination is a generic term for the process of removing salt and other minerals from seawater. The purpose of a desalination system is to purify seawater and produce potable water with total dissolved solids within a permissible limit of 500 parts per million (ppm) or less. In general, known desalination processes are classified as thermal or phase-change processes, and membrane-based process where no phase change takes place. In the phase-change processes thermal energy is used to distillate salty water and produce salt-free vapors. The most common phase change processes are Multi-Stage Flash (MSF), Multi-Effect Distillation (MED), and Vapor Compression (VC). The common desalination methods in single phase processes are the Reverse Osmosis (RO) and electrodialysis (ED). RO uses membranes to remove salt from seawater, while electrodialysis uses electricity to ionize brackish water before it is cleaned using membranes.

[0005] Heat pumps have also been considered for use in a desalination process. However, both in thermal and heat pump-assisted processes, a significant quantity of thermal energy is required. It would be desirable to provide the thermal energy needed for desalination from as many sources as are readily convenient.

SUMMARY OF THE INVENTION

[0006] In accordance with a first aspect, a desalination assembly for producing potable water from seawater comprises a seawater line adapted to transfer seawater, a refrigerant line containing refrigerant, and a desalination chamber connected to the

seawater line and to the refrigerant line, wherein the refrigerant line is in thermal communication with the seawater line. A condenser is positioned in the chamber and is adapted to transfer heat from the refrigerant line to seawater and evaporate seawater to produce water vapor, and an appliance which produces waste heat is operatively positioned in the refrigerant line. The refrigerant line is adapted to receive waste heat generated by the appliance.

[0007] From the foregoing disclosure and the following more detailed description of various preferred embodiments it will be apparent to those skilled in the art that the present invention provides a significant advance in the technology of desalination assemblies. Particularly significant in this regard is the potential the invention affords for providing a high quality, low cost desalination assembly capable of using thermal energy from multiple sources. Additional features and advantages of various preferred embodiments will be better understood in view of the detailed description provided below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Fig. 1 is a schematic diagram of a desalination assembly in accordance with a preferred embodiment, showing the use of waste heat to help convert seawater into potable water.

[0009] Fig. 2 is a schematic diagram of another preferred embodiment of a desalination assembly.

[0010] Fig. 3 shows a schematic diagram of a first embodiment of a solar pond.

[0011] Fig. 4 shows a schematic diagram of a second embodiment of a solar pond.

[0012] Fig. 5 shows a preferred embodiment of evaporator-collector.

[0013] Fig. 6 shows a heat pump assembly using the evaporator collector of Fig. 5.

[0014] It should be understood that the appended drawings are not necessarily to scale, presenting a somewhat simplified representation of various preferred features illustrative of the basic principles of the invention. The specific design features of the desalination assembly as disclosed here, including, for example, the specific dimensions of the evaporator collector, will be determined in part by the particular intended application and use environment. Certain features of the illustrated embodiments have been enlarged or distorted relative to others to help provide clear understanding. In particular, thin features may be thickened, for example, for clarity of illustration. All references to direction and position, unless otherwise indicated, refer to the orientation illustrated in the drawings.

DETAILED DESCRIPTION OF CERTAIN PREFERRED EMBODIMENTS

[0015] It will be apparent to those skilled in the art, that is, to those who have knowledge or experience in this area of technology, that many uses and design variations are possible for the desalination assembly disclosed here. The following detailed discussion of various alternative and preferred features and embodiments will illustrate the general principles of the invention with reference to a desalination assembly suitable for use with other heat generating and heat using devices, such as air conditioning, dryers, water heaters, etc. Other embodiments suitable for other applications will be apparent to those skilled in the art given the benefit of this disclosure.

[0016] Turning now to the drawings, Fig. 1 shows a diagram of a desalination assembly 10 in accordance with a preferred embodiment. Advantageously, energy required to convert seawater into potable water is provided from several sources; from solar thermal energy 100, from ambient thermal energy and from waste heat from a waste heat generating appliance 90 such as an air conditioning unit. Capturing waste heat is highly advantageous in that such an energy source is readily available, especially in tropical and equatorial locations which make widespread use of air conditioning units.

[0017] At the upper right hand corner of Fig. 1, seawater is pumped into a solar pond 20 by circulation pump 22 via seawater line 16. The seawater line 16 is understood to be the flow path of seawater from a seawater inlet 15, through solar pond 20, desalination chamber 35 and back to the inlet. In a similar manner a refrigerant line 18 is

understood to be the flow path of refrigerant into and out of the desalination chamber 35 (through both entrance 98 and refrigerant line inlet 78) through waste heat generating appliance 90, an evaporator collector 60, appliances 70, 80, compressor 30 and back to distillation chamber 35. A distillate line 17 collects condensed water vapor from the desalination chamber 35. Finally, a vacuum line 19 draws at least a partial vacuum in the distillation chamber, to help increase thermal energy transfer. Excess evaporation may also be collected along line 19.

[0018] In the solar pond 20, the pumped in seawater absorbs the thermal energy of the sun 100 for a predetermined period, advantageously pre-heating the seawater.

Preferably the bottom of the pond is painted with black paint or otherwise colored black to help absorb energy from the sun. The heated seawater is then routed through the seawater line 16 to the desalination chamber 35. The desalination chamber 35 may preferably comprise a series of at least two effects, and preferably three effects 36, 37, 38 which the sea water flows through. Multiple sequential effects help increase heat transfer from the refrigerant to the seawater. Nozzles 33 spray seawater from the seawater line over condensers 40. The seawater line 18 can be split up as shown in the Figs. so that a portion of the seawater is introduced at each effect. The condenser 40 is positioned in the refrigerant line 18 and most preferably is an extension of the refrigerant line 18 that is coil shaped. The condenser 40 condenses refrigerant in the refrigerant line by transferring heat from the refrigerant to the seawater. As a result of this heat transfer, some of the seawater is evaporated and the remainder brine solution collects near a lowers end 66 of the desalination chamber 35. As shown in Fig. 1, a

condenser 40 is positioned under each nozzle 33 in each effect, so the process can be repeated in several stages. At the first effect 36, water vapor is collected and transferred to the second effect 37. At the second effect, water vapor is cooled sufficiently to form potable water which can be carried away in the distillate line 17.

[0019] Water vapor distillate condensers 50 are positioned in the second effect 37 and in the third effect 38. Preferably such condensers are positioned near the lower end 66 of the desalination chamber and in normal operation the distillate condenser is submerged below the non-evaporated or brine portion of the seawater (shown as a dotted line) in Figs. 1-2. Advantageously, this allows the thermal energy of the water vapor to be transferred to the seawater, condensing water vapor into potable drinking water which is carried out of the desalination chamber via potable water flow line 17.

[0020] To help speed heat transfer between the refrigerant and the seawater, it is desirable to modify the conditions of the seawater to speed evaporation. This can be accomplished by use of a vacuum line 19. Each effect 36, 37, 38 may be separately connected to line 19, allowing for at least a partial depressurization of the effect. With a lower than atmospheric pressure, seawater can be converted to water vapor at with a lower amount of energy. In addition, excess water vapor may also be drawn off the effects, as needed.

[0021] The refrigerant in the refrigerant line 18 is a compound which undergoes a phase change from a gas to a liquid and back again. Suitable refrigerants have good

thermodynamic properties, are noncorrosive and safe. The desired thermodynamic properties include a boiling point somewhat below the maximum normal operating temperature of the desalination assembly, a high heat of vaporization, a moderate density in liquid form, a relatively high density in gaseous form, and a high critical temperature. Since the boiling point and the gas density are affected by gas pressure, refrigerants may be made more suitable for the intended application by control of the operating pressure. A suitable refrigerant for use herein is R-134a, but not water. Other refrigerants suitable for use with the present invention will be readily apparent to those skilled in the art, given the benefit of this disclosure.

[0022] Now considering the refrigerant line 18, starting at a position on the line immediately prior to entry into the compressor 30. Prior to arriving at the compressor 30, refrigerant in the refrigerant line 18 is in the form of a slightly superheated gas. That is, the temperature of the gas is above the boiling point of the gas. Where R134a is used, for example, the temperature of the refrigerant may be about 25-30°C and the pressure of the refrigerant inside the line 18 is somewhat below 1 bar. Once the refrigerant is compressed by the compressor 30, the pressure may be increased to about 5 bar and the temperature increases to about 80-85°C. Flow of the refrigerant is from the compressor positioned in the refrigerant line to the condenser 40 in the first effect 36 of the desalination chamber 35.

[0023] Flow through the desalination assembly is from the entrance 98 to the exit 99 as shown in Fig. 1. Between the entrance 98 and the exit 99 of the refrigerant line 18 into

and out of the desalination chamber, preferably the refrigerant cools by an amount sufficient to convert from the superheated gas to a liquid. Where R134a is the refrigerant, for example, the refrigerant may exit the desalination chamber at about 30-40°C and still about 5 bar in pressure. Sequential flow of refrigerant through the desalination chamber effects sequentially cools the refrigerant and heats the seawater. The temperature changes at each effect may be relatively uniform. As shown in Fig. 1, a first condenser 40 is positioned in the refrigerant line 18 and in the first effect 36. Seawater is sprayed from nozzle 33 over condenser 40, heat is transferred from the refrigerant to the seawater. Preferably each nozzle 33 is positioned between an upper end 67 of the desalination chamber 35 and the corresponding condenser 40. The seawater line 16 and the refrigerant line 18, although physically isolated from one another, are in thermal communication with one another. Water vapor is collected and routed to the second effect 37. Brine or seawater with some increased salinity, collects at a bottom end 66 of the desalination chamber. The briny seawater is routed back to the seawater line 16. Optionally, the briny seawater may be routed back to the seawater line between the inlet 15 and the solar pond 20, such as prior to the circulation pump 14 as shown in the embodiments of Figs. 1-2. Routing the briny seawater back in this manner helps capture some of the residual heat of the assembly.

[0024] At the second effect 37, a process to that at the first effect occurs. Seawater is sprayed from nozzle 33 over condenser 40, heat is transferred from the refrigerant to the seawater, producing water vapor, briny seawater collecting near the bottom end, and cooler refrigerant. As the refrigerant line flow is sequential, the temperature of the

refrigerant at each effect is lower than the temperature at the previous effect and at entrance 98. In addition to the condensers 40 and as noted above, water vapor distillate condensers 50 are positioned in the distillate line 17 in the second effect 37 and in the third effect 38. With the energy transfer from the water vapor to the briny seawater, potable water is collected from second effect 37 and third effect 38.

[0025] At the third effect 38, preferably not only is a condenser 40 positioned in the refrigerant line 18, and distillate condenser 50 positioned in distillate line 17, but also an evaporator/vapor condenser 55 is shown. Evaporator 55 is positioned in the refrigerant line 18, but connected between a refrigerant line inlet 78 and a refrigerant line outlet 79. The evaporator is preferably positioned between the upper end 67 of the desalination assembly 35 and the nozzles 33. Preferably an expansion valve 44 is positioned between exit 99 and inlet 78 such that the refrigerant is cooled to a temperature sufficient to cause heat transfer in the third effect from the water vapor to the refrigerant, condensing the water vapor into potable water. The refrigerant is at least partially evaporated in the evaporator 55. The potable water is collected and routed to distillation line 17. Preferably, when the refrigerant passes through expansion valve 44 the temperature of the refrigerant drops. Also, flashing can occur at the expansion valve, where the refrigerant enters a superheated two-phase mixture and the temperature drops by about 8 degrees.

[0026] After exiting the exit 99 of the desalination chamber 35, the refrigerant in the refrigerant line flows to one of several expansion valves 44; one which connects to inlet

78 as noted above, another which connects to waste heat generating appliance 90 such as air conditioning unit or units, and another which connects to an evaporator collector 60, discussed in greater detail below. That is, as can be seen in Fig. 1, the inlet 78, waste heat generating appliance 90 and evaporator collector 60 are all connected in parallel in the refrigerant line. Refrigerant can flash at each expansion valve. Thermal expansion valves can operate, for example by use of a temperature sensing bulb filled with a similar gas as in the line that causes the valve to open against the spring pressure in the valve body as the temperature on the bulb increases. As temperature decreases so does the pressure in the bulb and therefore on the spring. This causes the valve to close.

[0027] In accordance with a highly advantageous feature, some of the waste heat energy from appliance 90 is transferred to the refrigerant and routed to the compressor 30. Some solar thermal energy and ambient energy is captured by the evaporator collector 60 and routed to the compressor 30. In a similar manner, some of the heat or enthalpy of condensation is captured by the evaporator 60 and routed to the compressor 30.

[0028] Fig. 2 shows an alternate preferred embodiment of a desalination assembly further comprises at least a water heater 70, a dryer 80, or both positioned in the refrigerant line 18. As shown in Fig. 2, the water heater 70 and dryer 80 are connected in series with a second evaporator condenser 62. A second compressor 32 in parallel with the first compressor compresses refrigerant in the refrigerant line 18 in a manner

and amount similar to compressor 30. Flow regulating valves 31 control flow of refrigerant between the compressors 30, 32. Flow of refrigerant is from compressor 32 (where the refrigerant is compressed) to water heater 70, where heat from the refrigerant is transferred to the water, to dryer 80, where additional heat is transferred from the refrigerant line to the air used to dry clothes. From there, flow of refrigerant is to second evaporator collector 62, where either solar thermal energy, ambient thermal energy, or most preferably both are absorbed by the refrigerant. As shown in Fig. 2, the two evaporator collectors 60, 62 are preferably connected in the refrigerant line in parallel, and flow of refrigerant from the two collectors recombines prior to introduction at flow regulating valves 31.

[0029] Figs. 3-4 show two types of solar ponds 20, salt gradient solar pond 21 (Fig. 3) and shallow solar pond 22 (Fig. 4). For salt gradient solar pond 21, the top layer 23 is near ambient temperature and has a low salt content. The bottom layer 25 is hot – typically 71-100°C – and is very salty. The important gradient zone 24 separates these zones. The gradient zone acts as a transparent insulator, permitting sunlight to be trapped in the hot bottom layer (from which useful heat is withdrawn). This is because the salt gradient, which increases the brine density with depth, counteracts the buoyancy effect of the warmer water below (which would otherwise rise to the surface and lose its heat to the air). Preferably the bottom surface 27 of the solar pond is black to enhance absorption of solar thermal energy. The shallow solar pond 22 is preferably a layer of a generally homogeneous body of water covered with a transparent layer 26 which allows solar thermal energy (radiation) to pass through it and also to prevent

evaporation. The bottom surface 27 of the pond is painted black to enhance absorption of solar thermal energy.

[0030] Fig. 5 shows a preferred embodiment of the improved evaporator collector 60 (or 62). Solar thermal energy strikes a top layer comprising a thermal energy absorbing coating 29 such as a black matt paint applied to one side or surface of a substrate. The coating 29 is applied to the substrate 28, most preferably applied to a surface of the substrate opposite the refrigerant line. The refrigerant line 18 is in thermal communication with the substrate. Preferably the substrate is a metal such as copper or other material with high thermal conductivity which can be formed as a flat plate. The refrigerant line can form a serpentine passageway crossing back and forth across the substrate, advantageously increasing heat transfer to the refrigerant line. The combination of a copper or metal substrate, black matt paint and a serpentine refrigerant line 18 in the evaporator collector advantageously enhances the amount of thermal energy transferred, such that thermal energy may be transferred to the refrigerant line even when the sun is down or blocked behind clouds.

[0031] The overall assembly acts a heat pump assembly, transferring heat from an area of lower temperature to an area of higher temperature. Such a heat pump assembly can be used in a wide variety of applications. Where the assembly is located in the tropics or in equatorial climates and makes use of waste heat from air conditioning units and/or other waste heat generating appliances, the waste heat captured can be substantial. Such heat pump assemblies can be used for other applications, such as

space cooling (air conditioning), water heating and drying, so called 3:1 heat pump assemblies. That is, instead of using solar thermal energy and ambient energy captured in an improved evaporator collector and waste heat energy for desalination; such energy may be used for other thermal energy or heat-using appliances, including water heaters and/or dryers, etc. Fig. 6 shows an example of a so-called 3:1 heat pump assembly where ambient energy and solar thermal energy are captured by improved evaporator collector 60 and waste heat from an appliance 90 is also transferred to a refrigerant in a refrigerant line. This thermal energy is then supplied to one or more heat-using appliances 70, 80. During normal operation of the appliances thermal energy is transferred from the refrigerant line to the heat-using appliance. As before preferably the waste heat generating appliance and the evaporator collector are connected in the refrigerant line in parallel.

[0032] From the foregoing disclosure and detailed description of certain preferred embodiments, it will be apparent that various modifications, additions and other alternative embodiments are possible without departing from the true scope and spirit of the invention. The embodiments discussed were chosen and described to provide the best illustration of the principles of the invention and its practical application to thereby enable one of ordinary skill in the art to use the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

CLAIMS

1. A desalination assembly for producing potable water from seawater comprising, in combination:
a seawater line adapted to transfer seawater;
a refrigerant line containing refrigerant;
a desalination chamber connected to the seawater line and to the refrigerant line, wherein the refrigerant line is in thermal communication with the seawater line;
a condenser positioned in the chamber, adapted to transfer heat from the refrigerant line to seawater and evaporate seawater to produce water vapor; and an appliance which produces waste heat operatively positioned in the refrigerant line, wherein the refrigerant line is adapted to receive waste heat generated by the appliance.
2. The desalination assembly of claim 1, further comprising a compressor positioned in the refrigerant line, adapted to compress refrigerant in the refrigerant line prior to introduction of the refrigerant to the desalination chamber.
3. The desalination assembly of claim 1, further comprising a solar pond positioned in the seawater line, adapted to transfer solar thermal energy to the seawater.
4. The desalination assembly of claim 3, wherein the solar pond is positioned between an inlet for seawater and the desalination chamber, comprises one of a salt gradient solar pond and a shallow solar pond, and a bottom surface of the solar pond is black.
5. The desalination assembly of claim 4, wherein the seawater line extends from the solar pond to the desalination chamber, exits the desalination chamber and connects with the seawater line between the solar pond and the inlet.
6. The desalination assembly of claim 1, further comprising an evaporator collector positioned in the refrigerant line, wherein one of solar thermal energy, ambient thermal energy, and both solar thermal energy and ambient energy are transferred to the refrigerant line at the evaporator collector.
7. The desalination assembly of claim 6, wherein the evaporator collector comprises

a thermal energy absorbing coating attached to a substrate, and the refrigerant line is in thermal communication with the substrate.

8. The desalination assembly of claim 6, wherein the evaporator collector and the appliance are positioned in parallel in the refrigerant line.

9. The desalination assembly of claim 6, further comprising at least one of a dryer and a water heater positioned in the refrigerant line;
a second compressor positioned in the refrigerant line, adapted to compress refrigerant in the refrigerant line prior to introduction of the refrigerant to the at least one of a dryer and a water heater; and
an evaporator collector positioned in the refrigerant line, between the first compressor and the at least one of a dryer and a water heater, wherein one of solar thermal energy, ambient thermal energy, and both solar thermal energy and ambient energy are transferred to the refrigerant line at the evaporator collector.

10. The desalination assembly of claim 1, further comprising a vacuum line operatively connected to the desalination chamber, wherein the vacuum line is adapted to draw a partial vacuum in the desalination chamber.

11. The desalination assembly of claim 1, further comprising a distillate line adapted to transfer potable water from the desalination chamber, and a distillate condenser positioned in the distillate line and in the desalination chamber, wherein the distillate condenser converts the water vapor to potable water.

12. The desalination assembly of claim 1, further comprising an evaporator positioned in the refrigerant line and in the desalination chamber, wherein the refrigerant is adapted to be evaporated in the evaporator.

13. The desalination assembly of claim 1, wherein the desalination chamber comprises multiple sequential effects, the seawater line extends separately into each of the effects, and the refrigerant line extends sequentially into each of the effects.

14. The desalination assembly of claim 13, wherein at least one of the multiple sequential

effects contains a distillate line adapted to transfer potable water from the desalination chamber, and a distillate condenser positioned in the distillate line and in the desalination chamber, wherein the distillate condenser converts the water vapor to potable water; and a condenser in the refrigerant line adapted to transfer heat from the refrigerant line to the seawater line.

15. The desalination assembly of claim 1, wherein the refrigerant line enters the desalination chamber at an entrance and at an inlet, and exits at an exit and an outlet, and a first expansion valve is positioned in the refrigerant line between the exit and the inlet.

16. The desalination assembly of claim 1, wherein the appliance is at least one air conditioning unit.

17. The desalination assembly of claim 1, further comprising a nozzle at each effect where seawater is sprayed over the corresponding condenser;
a distillate line adapted to transfer potable water from the desalination chamber, .
and a distillate condenser positioned in the distillate line and in at least one of the effects, wherein the distillate condenser converts the water vapor to potable water.

18. The desalination assembly of claim 11, wherein the distillate condenser is positioned near a lower end of the at least one effect such that in normal operation the distillate condenser is submerged below a non-evaporated portion of the seawater such that thermal energy is transferred from the water vapor to the non-evaporated seawater, condensing the water vapor to potable water.

19. The desalination assembly of claim 17, wherein the desalination chamber has an upper end, the seawater line has a nozzle at each effect where seawater is sprayed over the corresponding condenser, and further comprising an evaporator positioned in the refrigerant line and in one of the effects between the upper end and the nozzle, wherein the refrigerant is adapted to be evaporated in the evaporator.