

[54] **DISTILLER AND EVAPORATOR FOR SEA WATER**

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[52] U.S. Cl. **202/197; 55/186; 122/492; 202/176; 203/1; 203/2; 203/10; 203/40; 159/DIG. 26**

[58] **Field of Search** 203/40, 1, 2, 99, 100, 203/10, 11; 202/197, 176, 234; 55/185, 186; 159/27 A, DIG. 26, DIG. 1; 122/492

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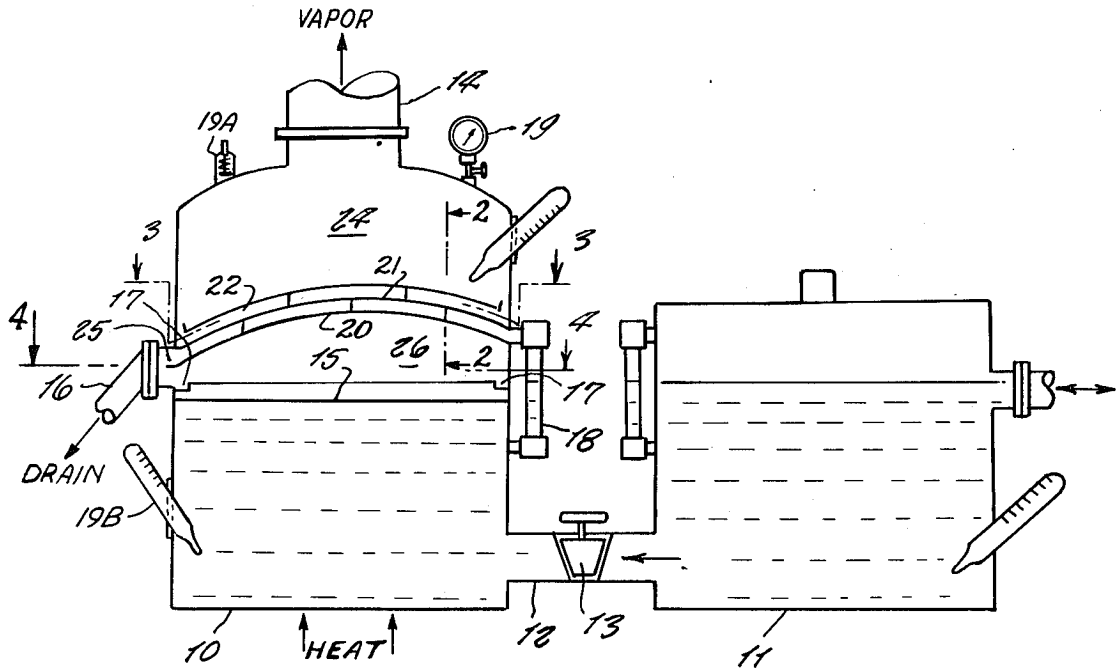
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Primary Examiner—Wilbur L. Bascomb, Jr.

[57] **ABSTRACT**

An apparatus for the distilling and evaporating of sea water so to produce pure fresh water on a large production basis; the apparatus including an evaporator having a baffle system of novel design therein so as to separate evaporated steam from non-evaporated water drops, a duct for conveying the evaporated steam to a condenser and a pure water supply tank; the evaporator being supplied by sea water.

2 Claims, 6 Drawing Figures



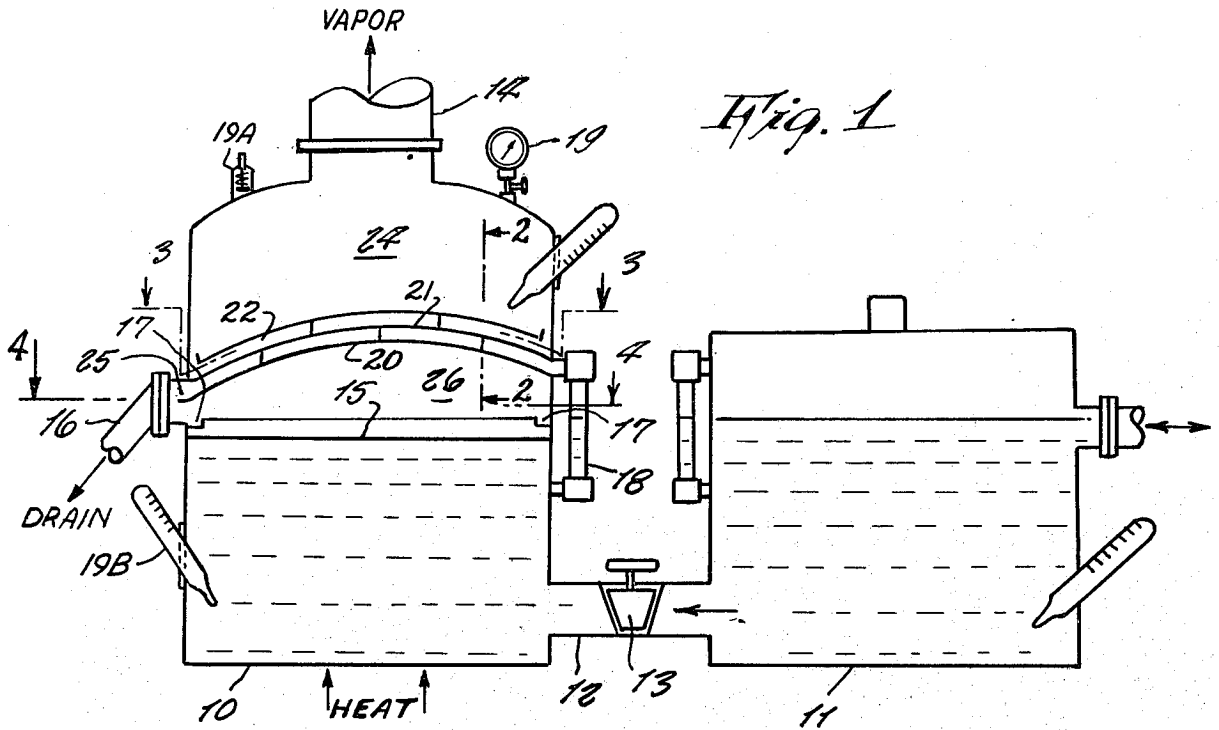


Fig. 1

Fig. 2

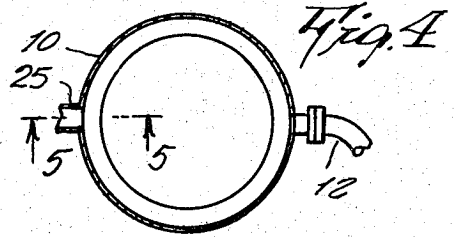
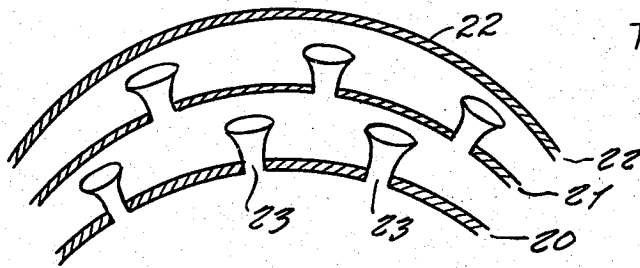


Fig. 4

Fig. 3

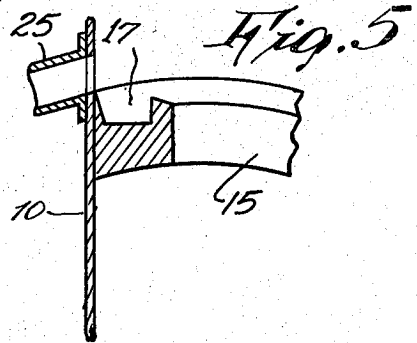
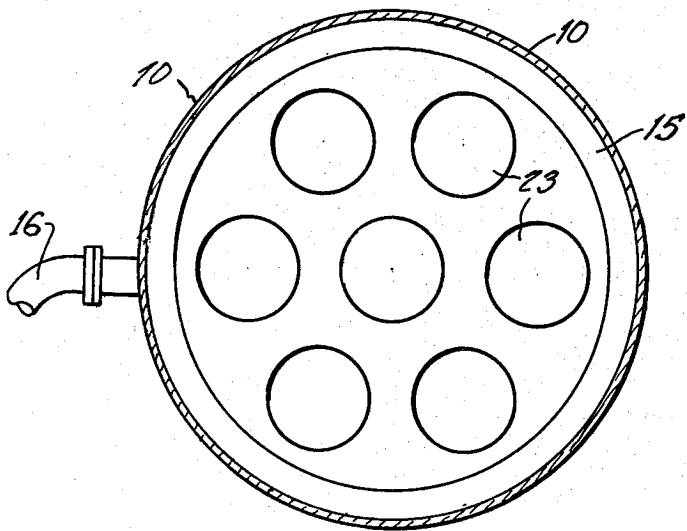


Fig. 5

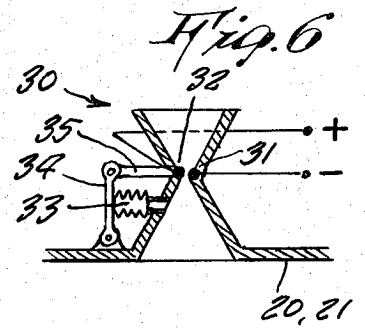


Fig. 6

DISTILLER AND EVAPORATOR FOR SEA WATER

This invention relates generally to equipment for the distillation and evaporation of sea water.

It is well known that with increasing population there is an increasing consumption of drinking water, and with a greater industrialization, there is a larger amount of pure water required in various enlarged and new phases of manufacturing production. Accordingly, there is becoming a more need to find other sources of pure water than is presently being obtained from lakes, rivers and the like, particularly in view that more and more of it is becoming polluted due to chemicals of industry and waste of modern living being dumped therein, destroying the natural purity of such water bodies. It is, therefore, natural that attention is now being given to obtain pure, fresh water out of salty sea water so to meet the present day requirements. In some countries fresh water is rationed particularly in dry or hot seasons.

Accordingly, it is a principal object of the present invention to provide an improved distiller and evaporator for converting sea water to pure fresh water.

Another object is to provide a distiller and evaporator for sea water which in one particular design can be used aboard a ship wherein at this time there is a great waste of heat by the exhaust gases of the large engines passing out of the ship funnel and into the atmosphere, and wherein this wasted heat in the funnel can be harnessed to produce all of the ship's requirement of fresh water during an ocean voyage, without any additional expense. The sea water used to cool the engines can be used as it is already pre-heated 40 to 45 degrees centigrade, so it is ready for evaporation.

Other objects are to provide a distiller and evaporator for sea water which is simple in design, inexpensive to manufacture, rugged in construction, easy to use and efficient in operation.

These and other objects will be readily evident upon a study of the following specification and the accompanying drawing wherein

FIG. 1 is a diagrammatic side view of a system of the present invention.

FIG. 2 is an enlarged detail in cross section of the interior baffle construction of the invention, taken along section 2—2 of FIG. 1.

FIG. 3 is a top view of the baffle construction inside the evaporator, as viewed in direction 3—3 of FIG. 1.

FIG. 4 is a cross sectional view on line 4—4 of FIG. 1.

FIG. 5 is an enlarged cross sectional view on line 5—5 of FIG. 4, showing a peripheral drainage canal.

FIG. 6 is a modification of the invention showing a cross section through a modified diffuser.

The present invention is shown in FIG. 1 to include an evaporator 10 and a sea water supply water tank 11 which are interconnected by a supply pipe 12 having a supply valve 13, which is automatically regulated by the water level within the evaporator. The top of the evaporator is connected with a condenser (not shown) by a pipe 14 for conducting evaporated steam into the condenser where a vacuum is obtained by vacuum ejectors, (not shown). Condensed water from a condensed suction pump (not shown) takes water and discharges it in drinking water tanks (not shown). A drain pipe (not shown) in the bottom of the evaporator periodically

drains water from the evaporator when it becomes heavily saturated with brine. Another drainpipe 16 with a collection canal 17 in a ring plate 15 collects non-evaporated brine water droplets.

The evaporator is provided with a water level gauge 18, vacuum gauge 19, a manometer 19A and a salinometer.

In the evaporator, the steam space 24 is installed with baffles 20, 21 and 22, for the evaporated steam. The purpose of the baffles is to separate evaporated steam from non-evaporated water drops which are not as jet-pure as distilled steam. Each baffle 20 and 21 as shown in FIG. 2, has openings 23 of diffuser shape. Such diffuser-shaped openings accelerate the separation of saturated steam. The last component baffle 22 forms a last barrier for non-evaporated water drops and for distilled steam before entering steam space 24. The baffle surface is equal in area to the inside transverse area of the evaporator, and is arcuate for more effective separation of distilled steam. The lowermost baffle 20 has the largest surface, and on its peripheral edge has a collecting vault 25 in which non-evaporated water drops collect and are conveyed to the drain canal 17 in ring plate 15. Evaporated steam from area 26 passes through the diffuser shaped openings 23 and then impinge on the second component baffle 21 while changing course and being partly divested of water drops. After going through the openings 23 of the second baffle 21 pure steam and non-evaporated water drops are separated, the pure steam then leaving steam space 24 through outlet pipe 14 to the condenser.

Two or more baffles in a same evaporator may be employed, as may be required for maximum effect.

In FIG. 6, a modified design of diffuser opening 23 is provided by a diffuser 30 of Venturi shape with electric contacts 31 and 32 on opposite sides so that large water drops entering the same will close an electric circuit that will thus cause a spark that will vaporize the water drop. Thus preventing water drop passage there-through. Contact 31 is stationary while contact 32 is slidable closer thereto where steam pressure inside area 26 is increased, at which time there are larger concentration of water drops so that they must be vaporized. This is accomplished by a hollow accordian shaped, expandable case 33 interconnected to area 26, and which pushes a pivotable lever 34 connected to slide 35 which carries contact 32.

While various changes may be made in the detail construction, it is understood that such changes will be within the spirit and scope of the present invention as is defined by the appended claims.

The following is claimed:

1. A Sea water distiller comprising a sea water supply tank connected by a conduit to the bottom of an evaporator with heating means, including a ring plate mounted around the inside periphery of said evaporator at a predetermined level, said ring plate including a peripheral drainage canal in combination with a plurality of spaced vertically curvate baffles above said plate, the lowermost of said baffles having a peripheral edge positioned above and laterally adjacent said canal whereby moisture is directed and drained from said baffle to said canal, in further combination with a drainage pipe having an inlet in communication with said canal for drainage purposes, said baffles having upward oriented diffusers and an upper solid baffle superimposed over said baffles with the diffusers, said upper

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baffle having an outer edge spaced from evaporator inner surface whereby deflected steam vapor is directed peripherally to the said edge and to a steam space above said upper baffle, including a steam outlet above said steam space wherein said diffusers including means for variably restricting water drops from passing there-through comprising a Venturi section in said diffusers

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with electrical means in the Venturi section for vaporizing water drops upon contact of said electrical means with water drops.

5 2. A distiller as in claim 1 wherein said electrical means include electric contacts, variably spaced responsive to steam pressure.

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- [54] **WATER DEGASIFICATION AND DISTILLATION APPARATUS**
- [76] **Inventor:** John C. Ellis, Jr., 1084 Palmer Ave., Larchmont, N.Y. 10538
- [21] **Appl. No.:** 489,767
- [22] **Filed:** Apr. 29, 1983

Related U.S. Application Data

- [63] Continuation-in-part of Ser. No. 269,880, Jun. 3, 1981, Pat. No. 4,420,374.
- [51] **Int. Cl.⁴** B01D 3/02; C02F 1/04
- [52] **U.S. Cl.** 202/176; 202/180; 202/181; 202/185.5; 202/188; 202/196; 202/197; 202/202; 202/234; 202/264; 99/295; 203/10; 203/20; 203/22; 203/DIG. 16; 203/DIG. 22
- [58] **Field of Search** 202/188, 185.5, 176, 202/190, 264, 197, 181, 180, 83, 190, 194, 196, 195, 202; 203/DIG. 17, 10, 11, DIG. 22, 20, DIG. 16; 99/295

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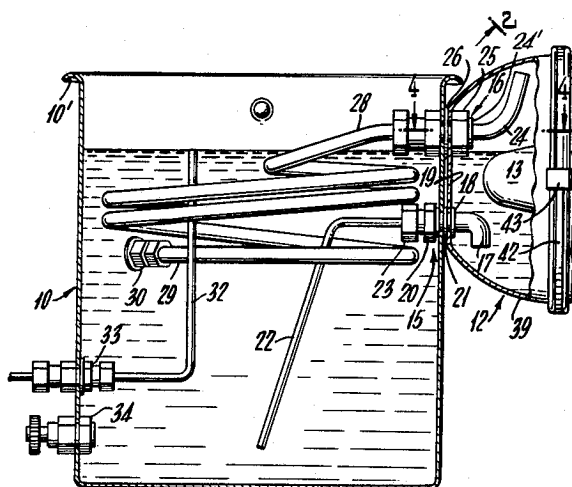
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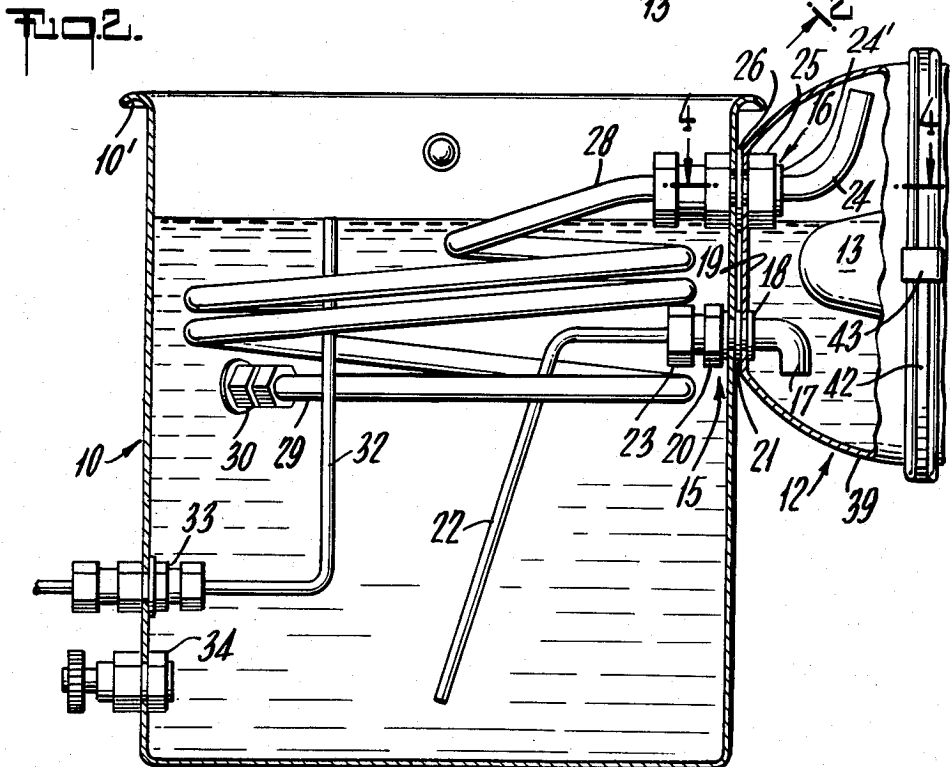
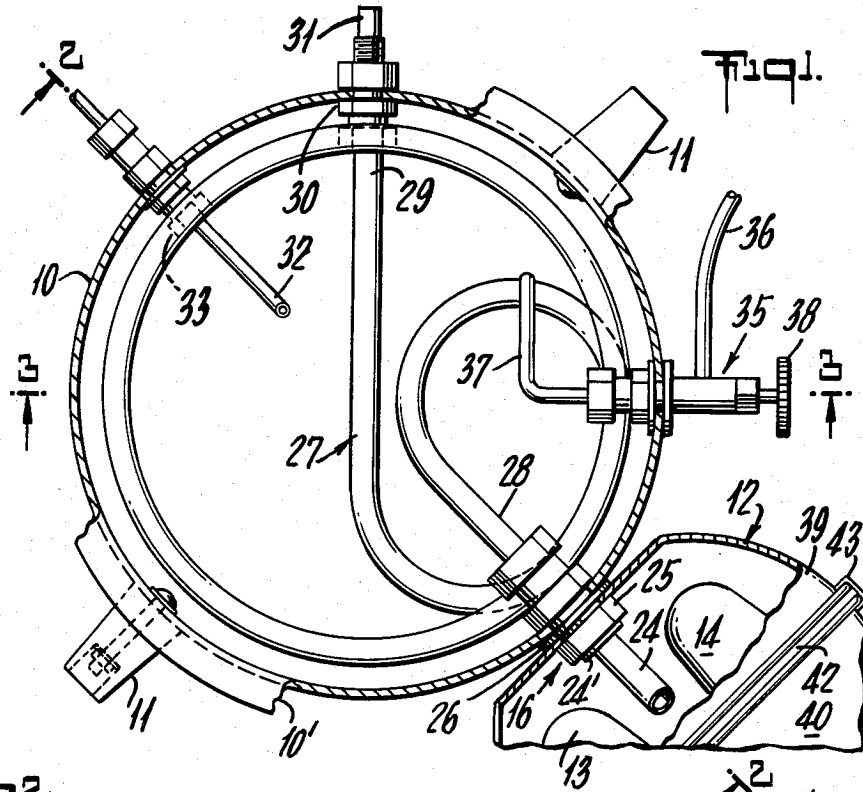
Primary Examiner—Wilbur Bascomb
Attorney, Agent, or Firm—Eugene E. Geoffrey, Jr.

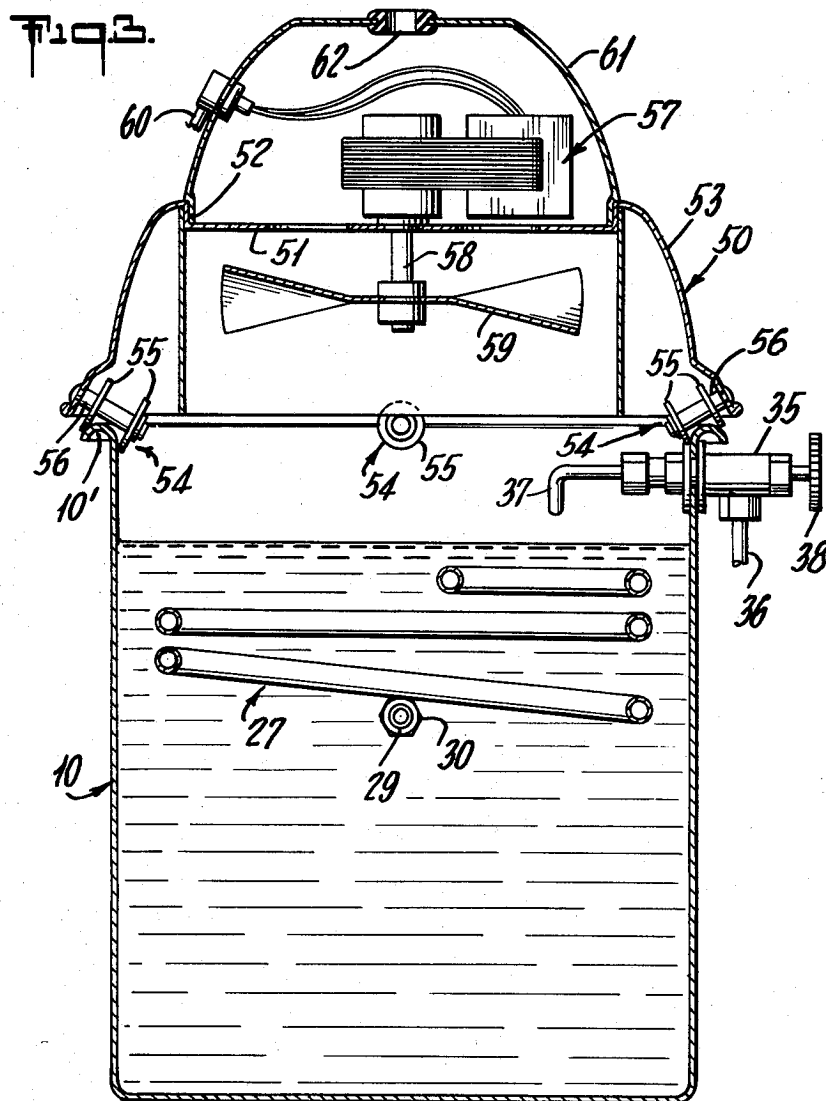
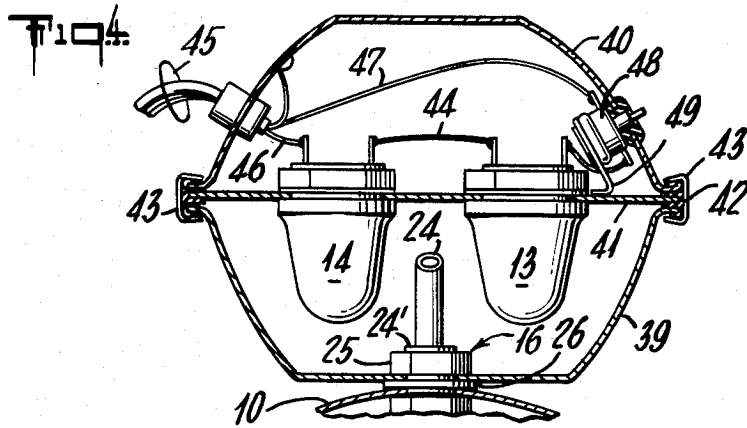
[57] **ABSTRACT**

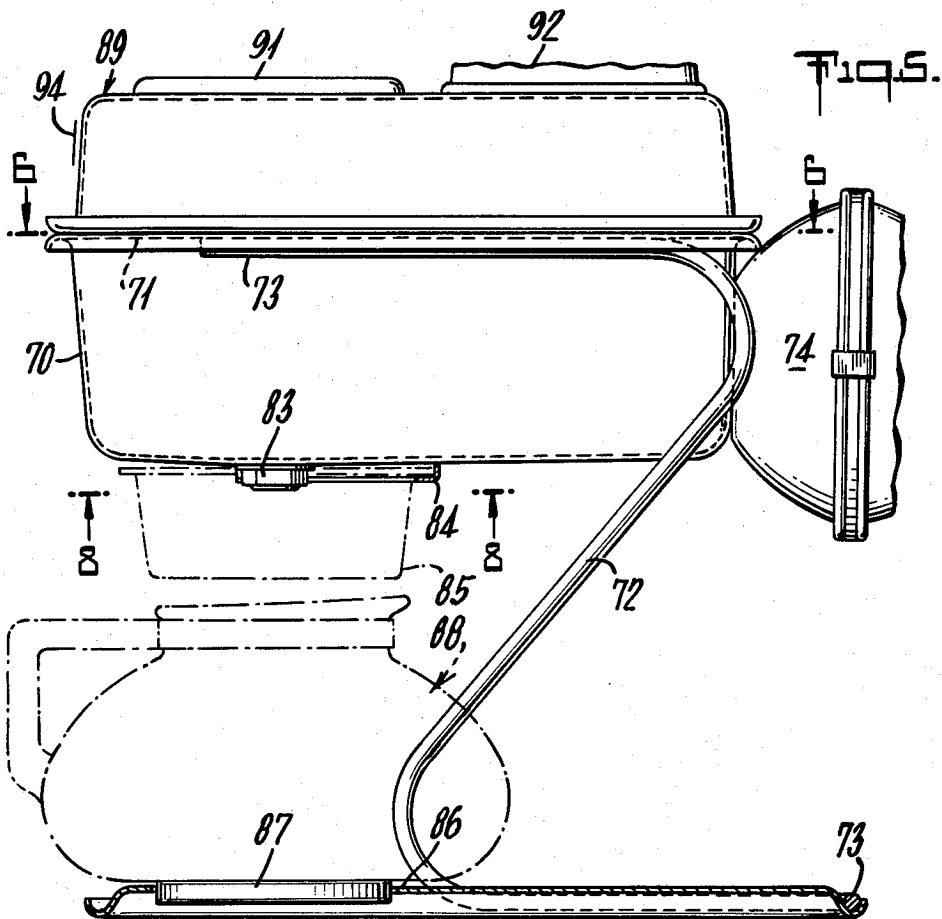
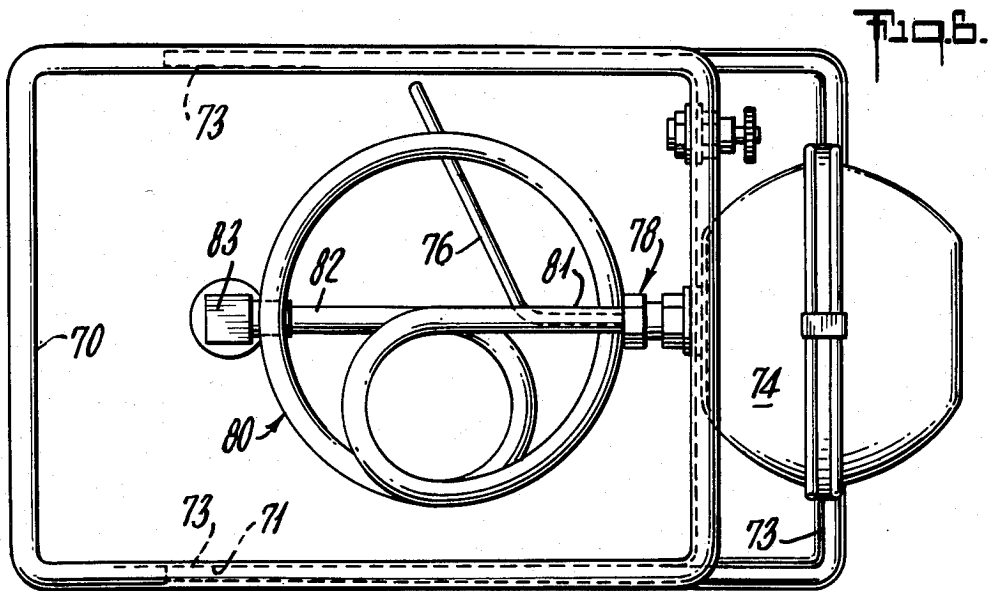
Water degasification and distillation apparatus having a container for water to be degasified and distilled, a relatively small boiler adjoining said container and having a first conduit extending into the container so that a selected water level in the container will fill said boiler to a selected height, a condenser within the container and immersed in the water contained therein, a second conduit extending from the space above the water in said boiler to the inlet of the condenser, an outlet on the condenser extending through a container wall for discharging degasified and distilled water and heating means in said boiler for heating the water therein.

15 Claims, 15 Drawing Figures









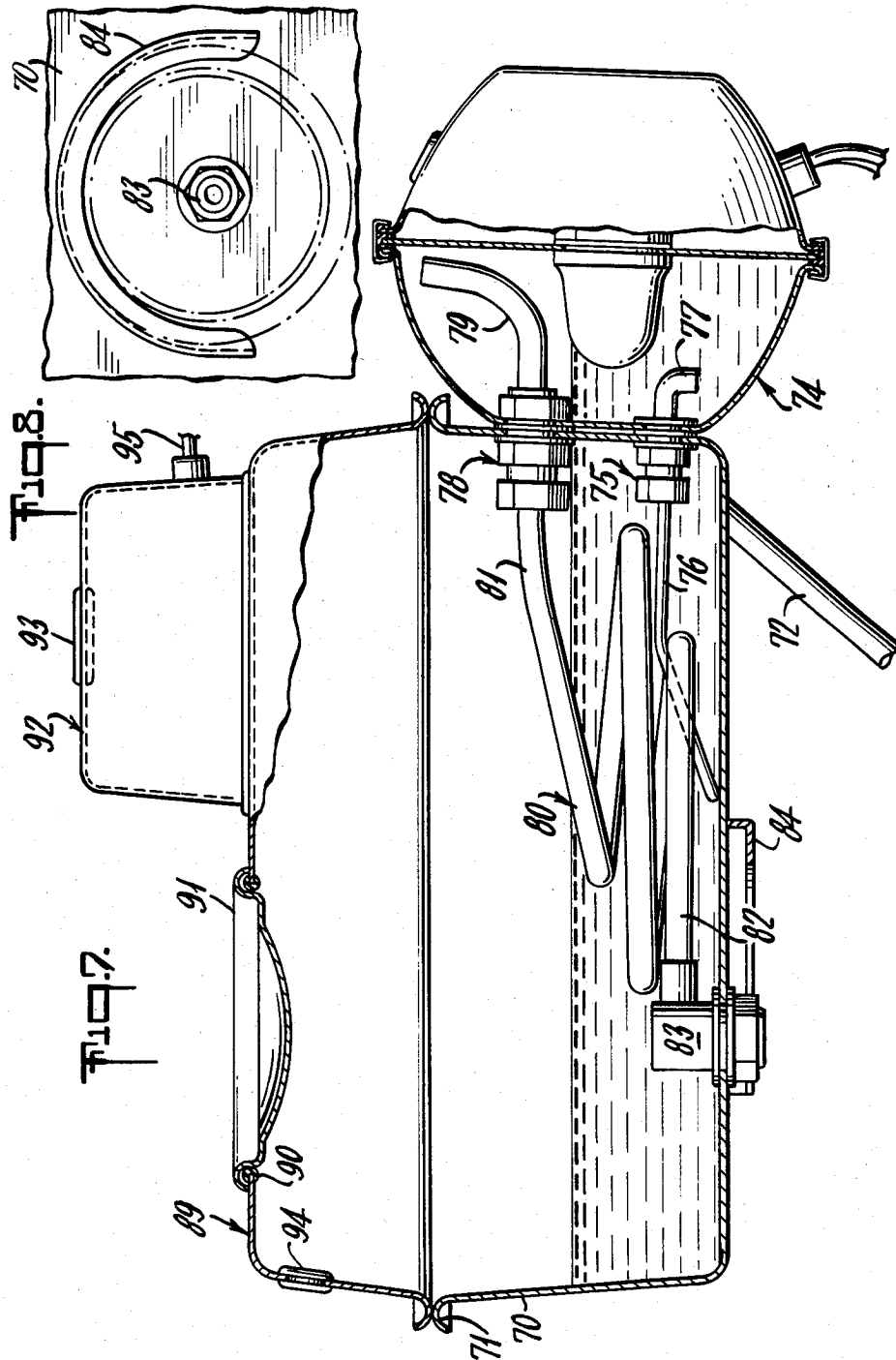
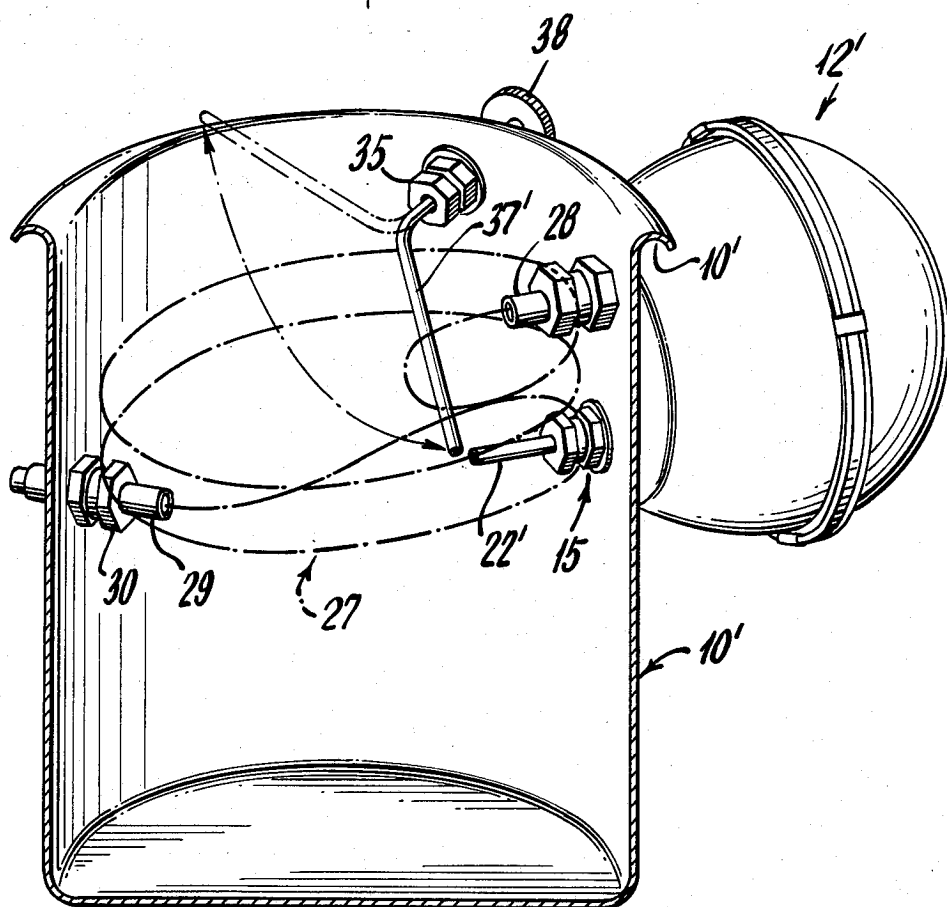


Fig. 8.



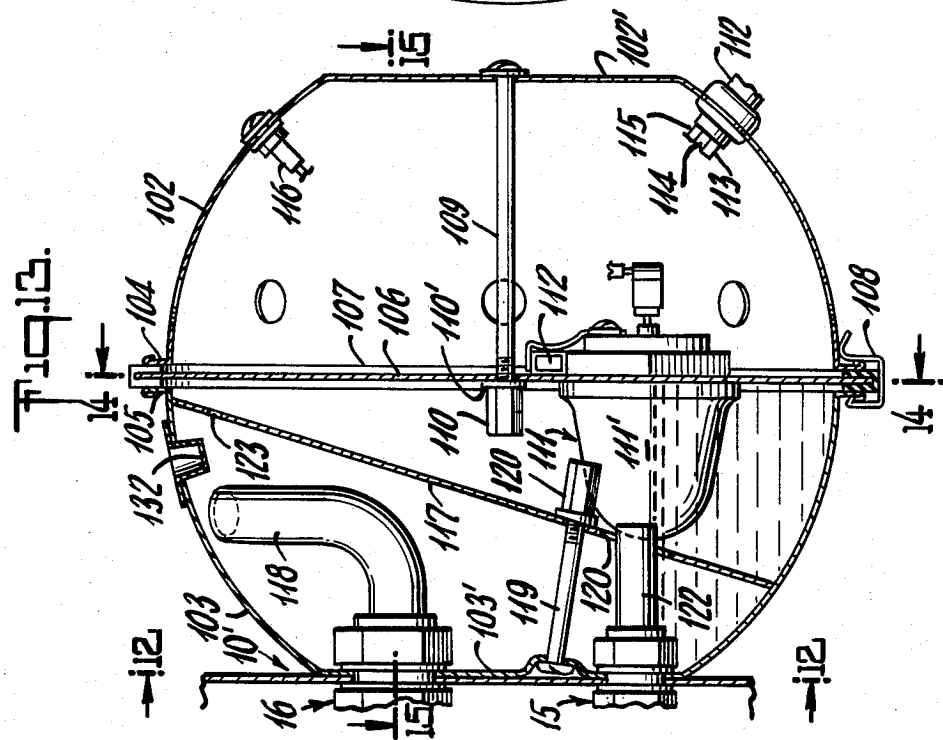
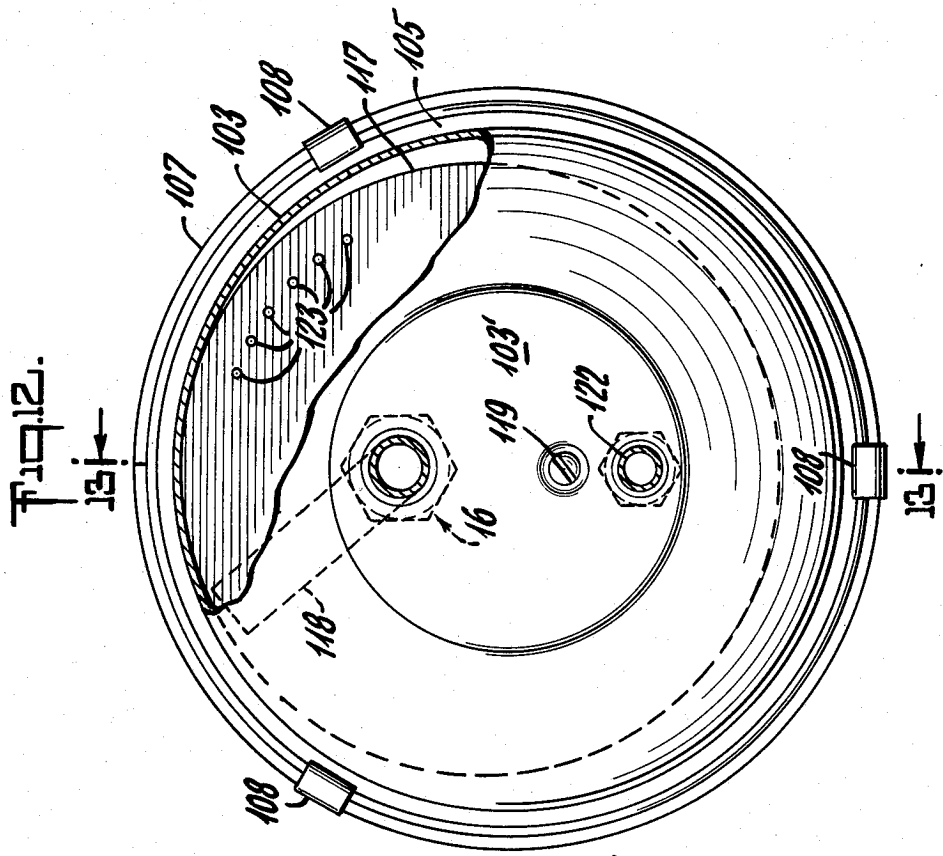


Fig. 14.

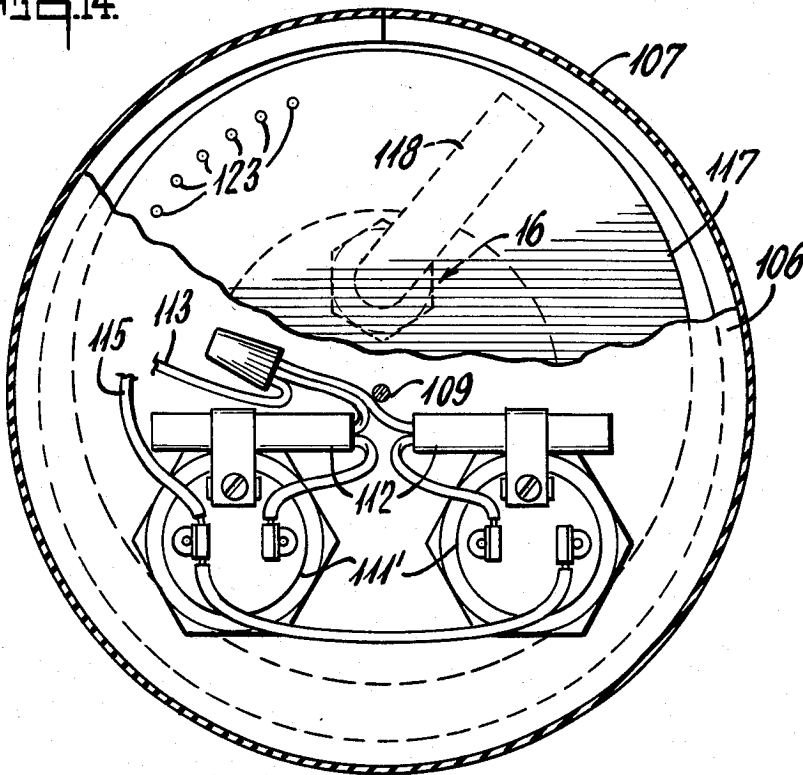
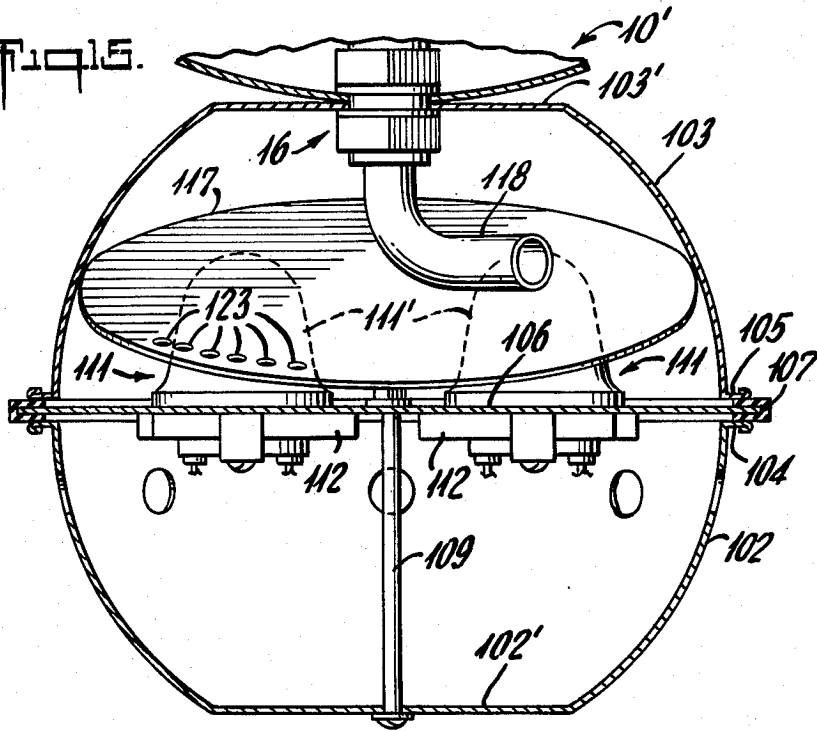


Fig. 15.



WATER DEGASIFICATION AND DISTILLATION APPARATUS

This application is a continuation-in-part of application Ser. No. 269,880 filed June 3, 1981 entitled "Water Degasification and Distillation Apparatus" now U.S. Pat. No. 4,420,374.

This invention relates to distilling apparatus and more specifically to novel and improved water distillation apparatus.

Known distilling apparatus generally involve the utilization of a closed boiler and means for continuously feeding water to the boiler. As the water in the boiler is heated to produce water vapor or steam, volatile chemical components of water having boiling points lower than the water will boil off and combine with the steam. The steam together with the volatile vaporized chemical components will then be condensed in a suitable condenser so that the resultant distillate will contain the volatile chemicals. In cases wherein the water has a disagreeable odor produced by sulphur compounds and the like, known apparatus tends to concentrate the odor and make the water even more distasteful. Applicant's prior U.S. Pat. No. 4,339,307 granted July 13, 1982 entitled: "Distillation Apparatus" discloses distilling apparatus embodying upper and lower chambers with the condensing coil disposed in the upper chamber which is normally filled with water and gradually fed into the lower chamber which is heated by a suitable means in order to produce steam. The steam is then fed upwardly through a condenser in the upper chamber and is then discharged from the condenser as a liquid. By operating the apparatus for a short period of time prior to the collection of the distilled water, the condenser will increase the temperature of the water in the upper chamber and boil off volatile chemical components.

This invention constitutes an improvement over prior known distilling apparatus including the apparatus disclosed in applicant's prior United States patent in that it embodies a novel and improved small boiler including instantaneous heating means, a condenser and a reservoir which provides an automatic supply of water to the boiler and may function to cool the condenser. With this arrangement, the water in the reservoir, as will be shown, circulates to and from the boiler to repeatedly interrupt boiling and heat thus imparted to the water in the reservoir together with the heat at least part of which may be imparted by the condenser will heat the water in the reservoir to a temperature that will effectively boil off chemical constituents of the water and the time required for operation of the distiller in order to produce a distillate free of chemicals and undesirable odors is materially reduced.

Another object of the invention resides in the provision of novel and improved water distillation apparatus which not only avoids control means for feeding water from a reservoir to a boiler but also embodies an arrangement and organization of elements wherein all portions of both the reservoir and boiler are readily accessible for cleaning and maintenance.

A still further object of the invention resides in the provision of hot distilled and substantially odor-free water for the brewing of coffee and tea as well as for use in the preparation of other foods such as soups and the like.

A still further object of the invention resides in the provision of a novel and improved water degasification and distillation apparatus characterized by its simplicity, ease of operation and maintenance and relatively low cost.

A still further object of the invention resides in the provision of a novel and improved boiler for the distillation of water which minimizes the accumulation of foam in the boiler caused by salts, detergents and other water contaminants which can contaminate the water being distilled.

The water degasification and distillation apparatus in accordance with the invention includes a container or tank adapted to receive the water to be distilled. A small boiler having heating elements mounted therein is preferably secured to one side of the tank and a fluid conduit couples the boiler to the tank so that the liquid level in the boiler will be controlled by the liquid level in the tank. A steam or vapor outlet in the boiler is coupled to a condenser preferably disposed within the tank and the outlet of the condenser extends through the wall of the tank. The condenser may be positioned in such a manner that the liquid in the tank will cover part or all of the condenser. With this arrangement and with the heaters in the boiler being energized, the liquid in the boiler will heat almost instantaneously and steam will be fed out through the condenser. As the pressure within the boiler exceeds the capacity of the outlet to receive steam or water vapor, pressure will force water in the lower portion of the boiler back into the tank. When the pressure is relieved, water will again flow into the boiler and this recirculation operation will continue during the operation of the distilling apparatus. Since hot water is being constantly returned to the tank and since heat is constantly removed from the condenser by the water within the tank, the water within the tank will increase in temperature and boil off undesirable chemicals contained in the water prior to distillation thereof. Cold water is preferably fed to the tank at the inlet to the boiler so that the boiler will receive cold water each time the boiler is refilled. Means may also be provided in association with the tank for feeding condensed distilled and degasified water into brewing apparatus for making coffee, tea or merely provide hot water for other purposes.

The above and other objects and advantages of the invention will become more apparent from the following description and accompanying drawings forming part of this application.

IN THE DRAWINGS

FIG. 1 is a fragmentary plan view of one embodiment of the distilling apparatus in accordance with the invention;

FIG. 2 is a cross sectional view of FIG. 1 taken along the line 2—2 thereof;

FIG. 3 is a cross sectional view of FIG. 1 taken along the line 3—3 thereof and illustrates air circulating means carried by the container;

FIG. 4 is a cross sectional view of the boiler and a fragmentary portion of the tank taken along the line 4—4 thereof of FIG. 2;

FIG. 5 is a side elevational view of a modified embodiment of the invention for producing distilled water for coffee and other foods;

FIG. 6 is a cross sectional view of FIG. 5 taken along the line 6—6 thereof;

FIG. 7 is a side elevational view in partial section of the water tank and boiler of FIG. 5;

FIG. 8 is a cross sectional view of FIG. 5 taken along the line 8—8 thereof;

FIG. 9 is a cross sectional view in perspective of a modified embodiment of a distiller in accordance with the invention;

FIG. 10 is a fragmentary cross sectional view of still another embodiment of the invention;

FIG. 11 is an elevational view of the water level control of FIG. 10;

FIG. 12 is an elevational view in partial section taken along the line 12—12 of FIG. 10;

FIG. 13 is a cross sectional view of FIG. 12 taken along the line 13—13 thereof;

FIG. 14 is a cross sectional view of FIG. 13 taken along the line 14—14 thereof; and

FIG. 15 is a top view in partial section of the boiler shown in FIG. 10.

Referring now to the drawings and more specifically to FIGS. 1 through 4, the distilling apparatus in accordance with the invention comprises a cylindrical tank or container 10 having a pair of handles 11 secured to the side thereof. A boiler 12 having instantaneous heating elements 13 and 14 therein is affixed to the side of the tank 10 by the fluid connectors 15 and 16. The fluid connector 15 includes an elbow 17 having a shoulder 18 and a threaded shank extending through cooperating openings in the wall 19 of the boiler 12 and the wall of the tank 10. A nut 20 engages the shank of the fitting 15 and together with a resilient washer 21 provides a water-tight seal for both the tank 10 and the boiler 12. A water inlet tube 22 is fixedly coupled to the fitting 15 by means of a nut 23 so that water within the tank 10 will be automatically fed into the boiler 12 until the water level within the boiler corresponds to the water level in the tank. It will also be observed that the water level in the tank is preferably maintained at a level to effect total or at least substantial immersion of the heating elements 13 and 14 in the water within the boiler.

The steam outlet fitting 16 is of conventional construction and includes an outlet pipe 24, a threaded shank 24' extending through the walls of the tank and the boiler and secured thereto by a nut 25. A sealing washer 26 is disposed between the tank and the boiler to provide a water-tight connection. The condenser 27 in the instant embodiment of the invention is in the form of a coiled tube of metal such as stainless steel, copper or the like and has the inlet end portion 28 sealably connected to the fitting 16 within the tank 10. The outlet 29 of the condenser 27 has a fitting 30 extending through the wall of the tank 10 and provides the fluid outlet 31. The tank further includes an overflow pipe 32 which is connected to a fitting 33 sealed to the wall of the tank 10 and a drain cock 34 for draining liquid from the tank. A water inlet valve 34 is carried at the upper portion of the tank or container 10 and has an inlet 36, an outlet 37 within the tank and a hand-wheel 38 for regulating the water supply in order to maintain substantially constant level of the water within the tank.

The boiler is shown more clearly in FIG. 4 and consists of two housing elements 39 and 40. A circular wall or partition 41 is disposed between the housing elements 39 and 40 and includes a peripheral seal 42 which is releasably clamped between the outer rims of the housing elements 39 and 40 by clips 43 about the periphery of the boiler 12. This arrangement completely seals the chamber formed by the housing portion 39 and the wall

41 and the boiler can be readily disassembled for cleaning. The heating elements 13 and 14 in the instant embodiment of the invention are carried by the wall 41 and are connected in series by a lead 44 connecting one terminal of one heater to one terminal of the other heater. The power line 45 has one lead 46 connected to the other terminal of the heater 14 while the second lead 47 is connected through a thermostat 48 to the other terminal of the heater 13. The thermostat is mounted on a bracket 49 in close proximity to the heater 13 and in the event the heater 13 reaches a temperature above the normal operating temperature, the thermostat will operate to open the circuit and de-energize both heaters 13 and 14. It is evident however that heaters 13 and 14 could be arranged for parallel operation or in the alternative, a single heater may be employed provided however it delivers the quantity of heat necessary for operation of the apparatus.

If desired, the tank or container 10 may be provided with a conventional cover having openings therein or in the alternative may utilize forced air circulation means for the removal of undesirable vapors liberated from the liquid within the tank 10 during the course of the distillation process. One embodiment of air circulating means is illustrated in FIG. 3. The air circulating means includes an inverted dished cover generally denoted by the numeral 50 which includes a flat upper wall 51, an upwardly extending peripheral wall 52 and a downwardly curved peripheral wall 53. The lower peripheral edge of the wall 53 carries three or more angularly disposed rollers 54 each having spaced discs 55 rotatably carried by a shaft 56. The discs 55 engage the rolled edge 10' of the tank 10 and accordingly provide an annular vent between the cover 50 and the edges of the tank 10.

The wall 51 of the air circulating means shown in FIG. 3 includes a motor generally denoted by the numeral 57 which has a shaft 58 extending through the perforated wall 51 and carries a fan 59. Power is fed to the motor 57 by a cable 60 connected in a conventional manner to the motor. If desired, switch means may be provided for operation of the fan. The fan motor is covered by a dome-shaped housing 61 securely fitted to the cover 53 and secured thereto by any suitable means. In the instant embodiment of the invention, the dome-shaped housing 61 is adapted to frictionally engage the peripheral wall 52 of the cover 50. In operation, air is drawn in through an opening 62 and the perforated wall 51 whereupon it is directed downwardly over the water in the container and discharged through the annular opening between the container 10 and cover 50.

In the operation of the distillation apparatus described above, the tank 10 and boiler 12 are first filled with water to a level at least substantially covering the heating elements 13 and 14 as will be observed more clearly in FIG. 2. It will be observed that when filling the tank 10, water will automatically flow through conduit 22 into the boiler so that the level of the water in the tank will be the same as the water level in the boiler. Energy is then supplied to the heating elements 13 and 14 which will function to boil the water within the boiler 12. Steam from the boiler will emerge through the outlet 24 and then flow through the condenser 17 and the condensed steam will then be discharged as a liquid from the outlet 31. When initially operating this apparatus, it is generally desirable to discard the distillate until the water within the tank 10 has attained a normally operated temperature which is rapidly at-

tained in the following manner. Heaters 13 and 14 are designed to heat the water within the boiler at a rate faster than the condenser 27 can accommodate the steam produced. Accordingly, pressure is developed within the boiler 12 and will force liquid from the boiler through the tube 22 back into the tank 10. As soon as the pressure is relieved within the boiler, water will again blow through the tube 22 back into the boiler with the result that there will be a periodic reversal of water flow through the tube 22. This action results in a substantial increase in temperature of the water within the tank 10 and contributes to the heat imparted to the water in the tank 10 by the action of the condenser 27. The temperature of the water tank 10 however is always below the boiling temperature and should preferably be in the range of 180° F. to 190° F. in order to be certain that undesirable components in the water are boiled off prior to actual distillation.

In one form of the invention utilizing a tank 10 having a volume of 1 to 2 gallons of water, a boiler 12 holding approximately 16 ounces of water, heating elements designed to dissipate from 1,500 to 2,000 watts, it will take approximately 15 minutes of operation for the water in the tank to reach a temperature of approximately 180° F. to 190° F. and the boiler will normally heat tap water above the boiling point within about 45 seconds. With this arrangement and after the warm-up period, substantially all volatile chemicals in the water are boiled off prior to distillation with the result that the distillate is substantially odorless and free of all undesirable components. In actual tests, it has been found that with distillation apparatus as described above, distilled water will be produced at the rate of one-half to three-quarters of a gallon per hour.

A modified form of the invention is illustrated in FIGS. 5 through 8. This form of the invention is intended for the brewing of coffee and for the production of hot distilled water for other purposes such as the brewing of tea, making of soups and the like.

It will become apparent from the following description of FIGS. 5 through 8 of the drawings that the operation of the brewer is substantially identical to the operation of the form of the invention shown in FIGS. 1 through 4. More specifically, the brewer comprises a tank or container 70 having an outwardly formed peripheral lip 71. The container is supported by a pair of Z-shaped brackets 72 coupled by a transverse element 72 which maintains the two brackets 72 in spaced relationship. The container 70 is supported by the upper horizontal bracket portions 73 which engage the peripheral lip 71 on the sides of the container 70. A boiler 74 substantially identical to the boiler 12 shown on FIG. 4 is affixed to one end of the container 70. Since the boiler functions in the same manner as the boiler 12 and is substantially identical thereto, a further description is not deemed necessary.

The boiler 74 is coupled to the container 70 by a fitting 75 having a water inlet 76 secured to one side thereof and a water outlet 77 disposed within the boiler 74. A second fitting 78 extends through the walls of the container 70 and boiler 74 and carries a stream outlet 79 on one end thereof. Within the container, the inlet end 81 of the condenser 80 is affixed to the fitting 78 and the outlet end 82 of the condenser is secured to a fitting 83 extending through an opening in the bottom of the container 70.

The underside of the container 70 as shown in FIGS. 5 and 8 includes in the instant embodiment of the inven-

tion a semicircular bracket 84 of L-shaped section for slidably receiving a basket 85 illustrated in broken-lines in FIG. 5 which may normally hold a filter and ground coffee. A base 86 engages and supports the Z-shaped bracket 72 and includes a conventional electric heating element 87. The heating element 87 is provided with suitable energizing conductors and switching means not shown so that it may be turned on and off as desired. The space between the bottom of the basket 85 and the top of the heating element 87 is of sufficient magnitude to receive a suitable receptacle 88 for receiving brewed coffee. It is obvious from the foregoing discussion that the basket 85 may be arranged to accommodate tea leaves for the brewing of tea or in the alternative the distilled water from the fitting 83 can be fed directly into the receptacle 88 for making soup or any other purpose for which purified distilled water may be required.

The container 70 includes a dished cover generally denoted by the numeral 89 which may be affixed to the container 70 by any suitable means. The cover 89 includes an opening 90 for feeding water into the container 70 and a cooperating lid 91. Forced air circulating means generally denoted by the numeral 92 is carried on the top side of the cover 91 and includes an electric motor and fan substantially similar to that illustrated and described in connection with FIG. 3. The air circulating means includes an air inlet opening 93 on the top side thereof and appropriate openings not shown are formed in the top of the cover 89 to permit the introduction of air into the space defined by the container 70 and lid 89. The air is exhausted from one or more outlets 94 in the cover and an electric cable 95 is utilized for energizing the fan and may include appropriate switch means.

The operation of the apparatus illustrated in FIGS. 5 through 8 is substantially identical to that described in connection with the preceding embodiment of the invention. However, since the device is not arranged, though it may be, for the continuous distillation of water, the container is initially filled with water so that the level is just below the position of the inlet 81 of the condenser 80. If the container 70 is of sufficient size, the distillation process can continue until the vessel 88 has been filled. If larger amounts of distilled water are required, additional water can be added through the opening 90 as may be required in order to maintain the level of the water in the container at a height that will cause the heating elements in the boiler 74 to be at least partially covered.

Referring now to the forms of the invention shown in FIG. 9 and FIGS. 10 through 15, it has been found that improved results can be obtained by feeding the water supply controlled by the water inlet valve 35 as shown for instance in FIG. 1, through an elongated tube 37' which terminates adjoining the boiler inlet 22'. The water inlet tube 37' is preferably arranged to swivel as indicated in FIG. 9 so that it can be raised to facilitate adjustment of the water feed to just maintain the desired water level in the container 10 as described in connection with FIGS. 1 and 2. It will be observed that the water inlet 22' to the boiler is a straight tube leading directly to the lower portion of the boiler and in addition to receiving cold inlet water directly from the tube 37', the tube 22' is easier to clean as will be discussed in more detail in connection with FIGS. 10 through 15.

It has been found in the distillation of water that the presence of salts, detergents and other similar chemicals

tend to cause the generation of foam in the boiler which adversely affects the ultimate distillate and also necessitates more frequent cleaning of the apparatus to attain optimum results. A structure for achieving these ends is illustrated in FIGS. 10 through 15 wherein the container for receiving the water supply is generally denoted by the numeral 10' while the boiler is generally denoted by the numeral 12'. The boiler 12' is secured to the container 10' in the same manner as described in connection with FIGS. 1 and 2 in that lower and upper sealed fittings 15 and 16 secure the boiler to the container and at the same time provide a lower water inlet and an upper steam outlet. The end of the fitting 16 disposed with the container 10 is coupled to the inlet of condenser 29 and the outlet of condenser 29 is connected to an outlet fitting 30 which includes distilled water discharge means having a pipe 31, an elastic coupling 100 and an elbow 101 to facilitate collection of the distilled water in a suitable receptacle. The inlet pipe 22' extends through the fitting 15 and into the boiler in a manner to be described in connection with the succeeding figures.

Referring now to FIGS. 12 through 15, the boiler is formed of two truncated hemispherical or bowl-like portions 102 and 103 having integrally formed closed bottom portions 102' and 103' respectively. The boiler section 102 is provided with a peripheral flange 104 while the boiler section 103 is provided with a similar peripheral flange 105. The boiler sections 102 and 103 are separated by a separate plate or partition 106 having a diameter just slightly greater than the diameter of the peripheral flanges 104 and 105. An annular U-shaped gasket 107 is fitted about the edge of the partition 106 and a plurality of clips 108 engage the peripheral flanges 104 and 105 to secure the boiler portions one to the other and at the same time seal the boiler 103. For convenience of assembly, the partition 106 with the gasket 107 is secured in position relative to the boiler section 102 by an elongated screw 109 extending through the end wall 102' of the boiler section 102 and through a central opening in the partition and is secured in place by a suitable nut 110 and sealing washer 110'.

A pair of heaters 111 identical to the heaters 13 and 14 of FIGS. 1 and 2 are carried by the partition 106 and are disposed slightly below the central axis of the boiler. As shown in FIG. 14, each heater includes its individual thermostat 112 with each heater and thermostat being connected in series. The series connected heaters with their associated thermostats are then connected in parallel as shown in FIG. 14 so that line voltage is applied to each heater and each heater is individually protected against overheating. The heating elements of each of the heaters 111 is disposed within the boiler section 103 and is enclosed by a water impervious housing 111' which not only protects the heating element but also seals the heater against the partition 106. The heaters are energized by a power cable 112 having three conductors 113, 114 and 115. The conductor 114 is a ground conductor and is connected to the grounding screw 116 while the conductors 113 and 115 are connected to the heating elements as illustrated in FIG. 14.

As previously pointed out, water for drinking and other purposes often contains relatively large quantities of salts, detergents and other chemicals which produce substantial quantities of foam during the distilling process and it is of course desirable to prevent the foam from entering the condenser 29. For this purpose, a baffle 117 is angularly disposed within the boiler hous-

ing 103. As viewed in FIGS. 10 and 13, the baffle which is of circular configuration is inclined downwardly and to the left so that the L-shaped steam outlet 118 which is coupled to the fitting 16 lies to the left of the baffle as viewed in these figures while the heaters 111 are on the right side of the baffle. The baffle is held in place by a bolt 119 carried by the wall 103' of the boiler section 103 and extending through an opening in the baffle 117 to receive a cooperating nut 120 to hold the baffle in position. The baffle also includes a centrally disposed opening 121 to receive the end of a water inlet tube portion 122 extending inwardly from the fitting 15 previously described. The steam outlet tube as viewed in FIG. 12 preferably lies between 30° and 50° to the left of vertical and the baffle 117 includes a plurality of small holes 123 disposed well to the right of the center line of the boiler 103. With this arrangement, foam will be generated principally on the heater side of the baffle 117 with the result that the baffle will tend to confine the foam with only the steam or water vapor passing through the openings 123 to the steam outlet 118. Furthermore, since the steam outlet 118 is angularly disposed relative to the openings 123, foam which may possibly pass through the openings 123 will not reach the steam outlet 118 easily and accordingly only the steam will pass through the steam outlet. This action results in the attainment of much purer water than in the case where foam can reach the steam outlet and ultimately be recombined with the distillate.

Referring again to FIGS. 10 and 11, the container 10' includes an overflow control assembly generally denoted by the numeral 124. This assembly includes a fitting 125 extending through the wall of the container 10' and carrying an L-shaped tube 126 rotatably disposed within the fitting. A housing portion 127 rotatably receives the tube 126 and supports a fixed scale 128 having soft and hard positions as illustrated more clearly in FIG. 11. A shaft 129 extends from the housing 127 and is mechanically coupled to the tubular member 126 so that rotation of the shaft 129 will rotate the tube 126 to move the angularly disposed end portion 126' of the tube 126 to either a horizontal position or a vertical position as illustrated. A knob 130 having a pointed portion 131 is carried by the shaft 129 and facilitates rotation of the shaft to one or the other of the positions. With this arrangement, should the water be relatively hard, the pointer 130 is moved to the horizontal position to limit the quantity of water delivered to the boiler while at the vertical position, the quantity of water delivered to the boiler is increased. The vertical position is used when relatively soft water is encountered since the vertical position will provide increased water to the boiler and greater output without any adverse affect on the distillate. The horizontal position results in a reduction of the quantity of distillate produced. It is to be understood that the lower water level will always produce the superior distillate.

In order to avoid damage to the gasket 107 surrounding the partition 106 in the event pressure should develop within the boiler 103 exceeding the desired pressure, a plug 132 formed of plastic material is loosely inserted in a cooperating opening at the top of the boiler as will be observed more clearly in FIGS. 10 and 13. The pressure required to dislodge the plug 132 is extremely small so that there is no possibility whatsoever of rupturing the boiler 103 or even dislodging the resilient sealing member 107. In the event one or both of the heating elements 111 should become damaged or

burned out, the section 102 together with the partition 106 can readily be removed from the boiler for replacement or repair. At the same time, it is quite obvious that by reason of the unique arrangement and construction of the distiller in accordance with the invention, that all portions are readily accessible for cleaning.

In the operation of the distiller in accordance with the invention including the forms of the invention shown in FIGS. 1 and 2 as well as FIGS. 10 and 13, the boiler is positioned relative to the container 10 or 10' as the case may be so that the water will completely or substantially immerse the heating elements. The heating elements function to heat the water very rapidly and as a result create a pressure within the boiler which forces the water out of the boiler and back into the container. In FIGS. 1 and 2 since the hot water will rise within the container 10, cooler water will then be fed back into the boiler but in the meantime boiling has been completely interrupted. In FIGS. 10 and 13 while the water does not entirely expose the heaters when discharged from the boiler, upon feeding of cold water from the inlet pipe 37' directly to the inlet 22' to the boiler, the cold water will terminate boiling at least momentarily whereupon the heating and discharging process is again repeated. It has been found in both forms of the invention that exceedingly pure water is obtained which is not obtainable with any other known devices of comparable size and rate of distillation. In the form of the invention shown in FIGS. 10 and 13, when the water level is adjusted to the low level, the purest water is obtainable while at the high level, the water will meet prescribed standards for distilled water. The high level is provided particularly for use with water having low total dissolved solids and other impurities since the apparatus will deliver as much as three quarters of a gallon of distilled water per hour while the apparatus with water at the low level will deliver one-half a gallon per hour.

While only certain embodiments of the invention have been illustrated and described, it is apparent that alterations, changes and modifications may be made without departing from the true scope and spirit thereof.

What is claimed is:

1. Water degasification and distillation apparatus comprising a container for holding water to be degasified and distilled, a condenser in said container having an inlet and outlet, a boiler of relatively small volume, a lower water inlet on said boiler and communicating with said container at a point substantially below the level of the water in said container for feeding water freely to and from said boiler, said boiler being positioned relative to said container to normally maintain a predetermined water level within said boiler, an upper outlet on said boiler above said predetermined water level and communicating with the inlet of said condenser, and means for heating water in said boiler and periodically ejecting it therefrom including a heating element in said boiler and generating heat at a temperature sufficient to produce steam at a greater rate than said steam can be discharged from said upper outlet creating a pressure in said boiler sufficient to force water in said boiler back into said container through said lower water inlet until the pressure in said boiler is relieved and boiling interrupted whereupon water will again flow into said boiler to said predetermined level, said boiler being formed of a single open-sided housing

and a readily accessible cover plate removably sealed to said open side for ready access to the boiler.

2. Water degasification and distillation apparatus according to claim 1 wherein said container includes a cover and air circulating means carried by said cover, said air circulating means directing air into said container and said cover including means for discharging said air from said container whereby vapors produced within said container are discharged into the atmosphere.

3. Water degasification and distillation apparatus according to claim 2 wherein said cover has a convex configuration, said air circulating means is in the form of an electric fan having a fan motor carried by said cover and fan blades affixed to the motor shaft, said cover including openings for the admission of air and means about the edge thereof for engaging said container and holding the edge of said cover in spaced relationship to said container to provide for the discharge of air circulated by said fan.

4. Water degasification and distillation apparatus according to claim 1 including means for supporting said container above a supporting surface, and said condenser outlet extending through the bottom wall of said container whereby a vessel may be disposed beneath said container and in line with said condenser outlet to receive the distilled water.

5. Water degasification and distillation apparatus according to claim 4 including means on the underside of said container and surrounding said condenser outlet for supporting a basket having an opening in the bottom thereof for receiving and holding a filter containing ground coffee, tea or the like whereby said distilled water will first flow into said basket and thence into said vessel.

6. Water degasification and distillation apparatus according to claim 1 wherein said boiler is formed of a hollow, substantially hemispherical housing having a peripheral flange extending from the open end portion and positioned in a vertical plane, said cover plate conforming to the size and configuration of said flange and a gasket disposed between said boiler and plate and means removably securing said plate and gasket to said flange.

7. Water degasification and distillation apparatus comprising a container for holding water to be degasified and distilled, a boiler of relatively small volume, a lower water inlet on said boiler and communicating with said container for feeding water to said boiler, said boiler being positioned relative to said container to normally maintain a predetermined water level within said boiler, a condenser, an upper outlet on said boiler above said predetermined water level and communicating with the inlet of said condenser, and heating means in said boiler and generating heat at a temperature sufficient to produce steam at a greater rate than said steam can be discharged from said upper outlet creating a pressure in said boiler sufficient to force water in said boiler back into said container through said lower water inlet until the pressure in said boiler is relieved whereupon water will again flow into said boiler to said predetermined level, said boiler being formed of a single open-sided housing and a readily accessible cover plate removably sealed to said open side for ready access to the boiler, said boiler being formed of a hollow, substantially hemispherical housing having a peripheral flange extending from the open end portion and positioned in a vertical plane, said cover plate conforming to the size

and configuration of said flange and a gasket disposed between said boiler and plate and means removably securing said plate and gasket to said flange, said heating means being an electric heater carried by said plate with the electrical connections therefor disposed on the outer side of said plate and a second hollow, substantially hemispherical housing including a peripheral flange enclosing said electrical connections and said housings with said cover plate being removably secured one to the others.

8. Water degasification and distillation apparatus comprising a container for holding water to be degasified and distilled, a condenser in said container having an inlet and outlet, a boiler of relatively small volume, a lower water inlet on said boiler and communicating with said container at a point substantially below the level of the water therein for feeding water freely to and from said boiler, said boiler being positioned relative to said container to normally maintain a predetermined water level within said boiler, an upper outlet on said boiler above said predetermined water level and communicating with the inlet of said condenser, and means for heating water in said boiler and periodically ejecting it therefrom including a heating element in said boiler and generating heat at a temperature sufficient to produce steam at a greater rate than said steam can be discharged from said upper outlet creating a pressure in said boiler sufficient to force water in said boiler back into said container through said lower inlet until the pressure in said boiler is relieved and boiling interrupted whereupon water will again flow into said boiler to said predetermined level, said boiler being formed of a single open-sided housing and a readily accessible cover plate removably sealed to said open side for ready access to the boiler, said boiler being formed of hollow, substantially hemispherical housing having a peripheral flange extending from the open end portion and positioned in a vertical plane, and said cover plate conforming to the size and configuration of said flange and a gasket disposed between said boiler and plate and means removably securing said plate and gasket to said flange, said hollow, substantially hemispherical housing including an inclined baffle with said steam outlet lying on one side of the baffle and said heating means on the other side of the baffle, said water inlet feeding water to the heater side of said baffle and said baffle further including at least one opening adjoining the top edge and angular spaced from the steam outlet.

9. Water degasification and distillation apparatus comprising a container for holding water to be degasified and distilled, a condenser in said container having an inlet and outlet, a boiler of relatively small volume, a lower water inlet on said boiler and communicating with said container at a point substantially below the level of the water therein for feeding water freely to and from said boiler, said boiler being positioned relative to said container to normally maintain a predetermined water level within said boiler, an upper outlet on said boiler above said predetermined water level and communicating with the inlet of said condenser, and means for heating water in said boiler and periodically ejecting it therefrom including a heating element in said boiler and generating heat at a temperature sufficient to produce steam at a greater rate than said steam can be discharged from said upper outlet creating a pressure in said boiler sufficient to force water in said boiler back into said container through said lower water inlet until the pressure in said boiler is relieved and boiling inter-

rupted whereupon water will again flow into said boiler to said predetermined level, said boiler being formed of a single open-sided housing and a readily accessible cover plate removably sealed to said open side for ready access to the boiler, said boiler including a baffle dividing said boiler into two portions with said upper steam outlet disposed on one side thereof and said heating means and lower water inlet on the other side thereof and said baffle includes at least one upper opening angularly displaced from said upper steam outlet.

10. Water degasification and distillation apparatus according to claim 1 wherein said boiler is formed of a hollow, substantially hemispherical housing having a peripheral flange extending from the open end, said boiler being affixed to the outer side of said container with at least said lower water inlet extending through said housing and container, a feed water inlet carried by said container for feeding water to said container in the vicinity of the boiler water inlet, and a water overflow outlet carried by said container to maintain a constant water level in said container.

11. Water degasification and distillation apparatus comprising a container for holding water to be degasified and distilled, a boiler of relatively small volume, a lower water inlet on said boiler and communicating with said container for feeding water to said boiler, said boiler being positioned relative to said container to normally maintain a predetermined water level within said boiler, a condenser, an upper outlet on said boiler above said predetermined water level and communicating with the inlet of said condenser, said heating means in said boiler and generating heat at a temperature sufficient to produce steam at a greater rate than said steam can be discharged from said upper outlet creating a pressure in said boiler sufficient to force water in said boiler back into said container through said lower water inlet until the pressure in said boiler is relieved whereupon water will again flow into said boiler to said predetermined level, said boiler being formed of a single open-sided housing and a readily accessible cover plate removably sealed to said open side for ready access to the boiler, said boiler being formed of a hollow, substantially hemispherical housing having a peripheral flange extending from the open end, said boiler being affixed to the outer side of said container with at least said lower water inlet extending through said housing and container, a feed water inlet carried by said container for feeding water to said container in the vicinity of the boiler water inlet, and a water overflow outlet carried by said container to maintain a constant water level in said container, said water overflow outlet comprising a horizontally disposed water discharge tube rotatably carried by a fitting extending through the wall of said container, the inner end of said tube being angularly disposed relative to the remainder of the tube, means on the outside of said container and coupled to said tube for rotation thereof whereby the level of the water in said container can be changed by angularly positioning the inner end of said tube.

12. Water degasification and distillation apparatus comprising a container for holding water to be degasified and distilled, a boiler of relatively small volume, a lower water inlet on said boiler and communicating with said container for feeding water to said boiler, said boiler being positioned relative to said container to normally maintain a predetermined water level within said boiler, a condenser, an upper outlet on said boiler above said predetermined water level and communicat-

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ing with the inlet of said condenser, and heating means in said boiler and generating heat at a temperature sufficient to produce steam at a greater rate than said steam can be discharged from said upper outlet creating a pressure in said boiler sufficient to force water in said boiler back into said container through said lower water inlet until the pressure in said boiler is relieved whereupon water will again flow into said boiler to to said predetermined level, said boiler being formed of a single open-sided housing and a readily accessible cover plate removably sealed to said open side for ready access to the boiler, said boiler comprising a substantially round bowl-shaped housing having an outwardly extending flanged rim and a flattened bottom disposed in a vertical plane and smaller in diameter than said rim, said lower water inlet extends through said bottom, said upper outlet extends through said bottom and carries a tube within said boiler housing curved upwardly and at an angle relative to a vertical plane normal to said bottom and a plate conforming to said flange secured in sealed relationship to said flanged rim.

13. Water degasification and distillation apparatus according to claim 12 wherein said heating means com-

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prises at least one waterproof electric heater carried by said plate with the electric terminals disposed on the outer side of said plate.

14. Water degasification and distillation apparatus according to claim 13 wherein said boiler housing includes a baffle dividing said housing into two separate chambers with said upper outlet being disposed on one side of said baffle, said heating means disposed on the other side of said baffle and said lower water inlet feeding water to the heater side of said baffle and said baffle including at least one opening near the upper edge thereof and angularly positioned relative to said upper steam outlet.

15. Water degasification and distillation apparatus according to claim 14 wherein said condenser is disposed within said container, said boiler housing is secured to the outer wall of said container with the upper outlet and lower inlet extending through the wall of said container, means for feeding water to said container and a container overflow to maintain a water level in said container that will cause said boiler housing to be normally filled to said predetermined level.

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United States Patent [19]
Ellis, Jr.

[11] Patent Number: 5,203,970
[45] Date of Patent: Apr. 20, 1993

- [54] METHOD FOR WATER DEGASIFICATION AND DISTILLATION
- [76] Inventor: John C. Ellis, Jr., 1084 Palmer Ave., Larchmont, N.Y. 10538
- [21] Appl. No.: 486,228
- [22] Filed: Feb. 28, 1990
- [51] Int. Cl.⁵ B01D 3/02; B01D 19/02; C02F 1/04
- [52] U.S. Cl. 203/10; 202/175; 202/176; 202/180; 202/202; 202/203; 202/265; 203/4; 203/22; 203/DIG. 18; 203/DIG. 22
- [58] Field of Search 202/175, 176, 203, 185.5, 202/265, 180, 202, 181, 188, 196; 203/10, 4, 1, 2, 22, DIG. 18, DIG. 22; 55/36

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[57] ABSTRACT

A method for water degasification and distillation in an apparatus having a container for a reservoir of water to be degasified and distilled, a relatively small boiler adjoining the container and having a feed water conduit connecting the container and boiler so that a selected water level in the container will fill the boiler to the same level, a coiled tube condenser within the container immersed in the water therein, the condenser coil having a vertically disposed longitudinal axis, a second conduit in the boiler connecting the space above the water level therein to the inlet of the condenser so that steam flows from the boiler to the condenser, an outlet on the condenser extending through a container wall for discharging the condensed steam as degasified distilled water, a heater in the boiler for heating the water therein, and a motor driven stirrer axially of the coiled tube condenser for generating a swirling movement of the reservoir water with formation of steam bubbles therein.

Optionally, an oversized filter is mounted at the outlet of the condenser.

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2 Claims, 2 Drawing Sheets

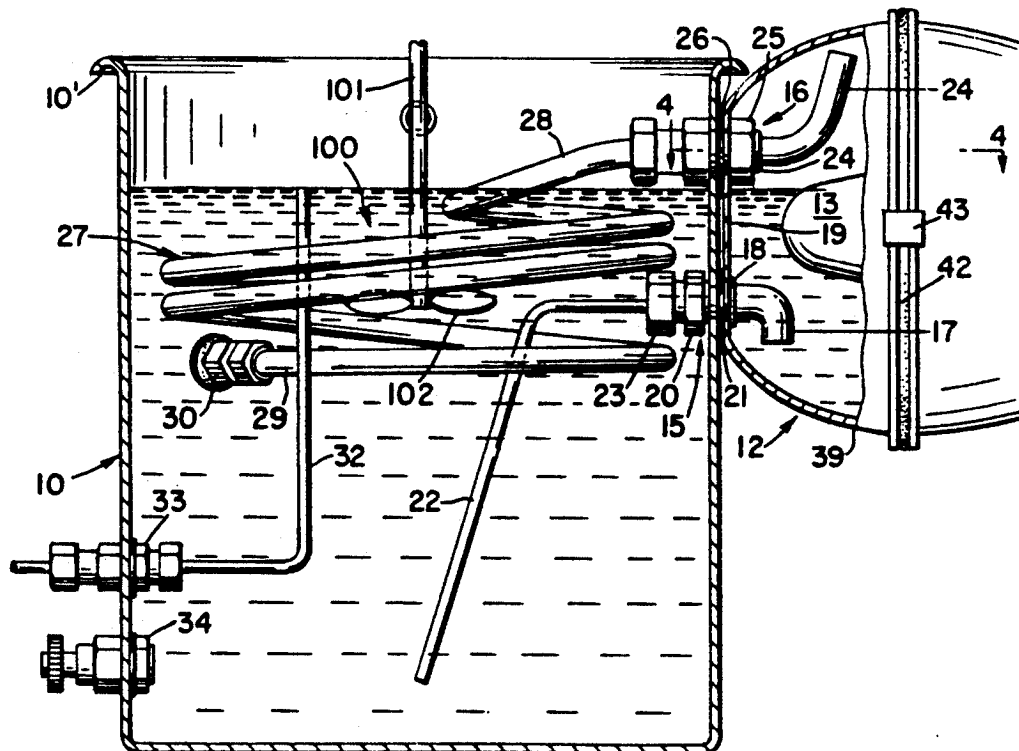


Fig. 3

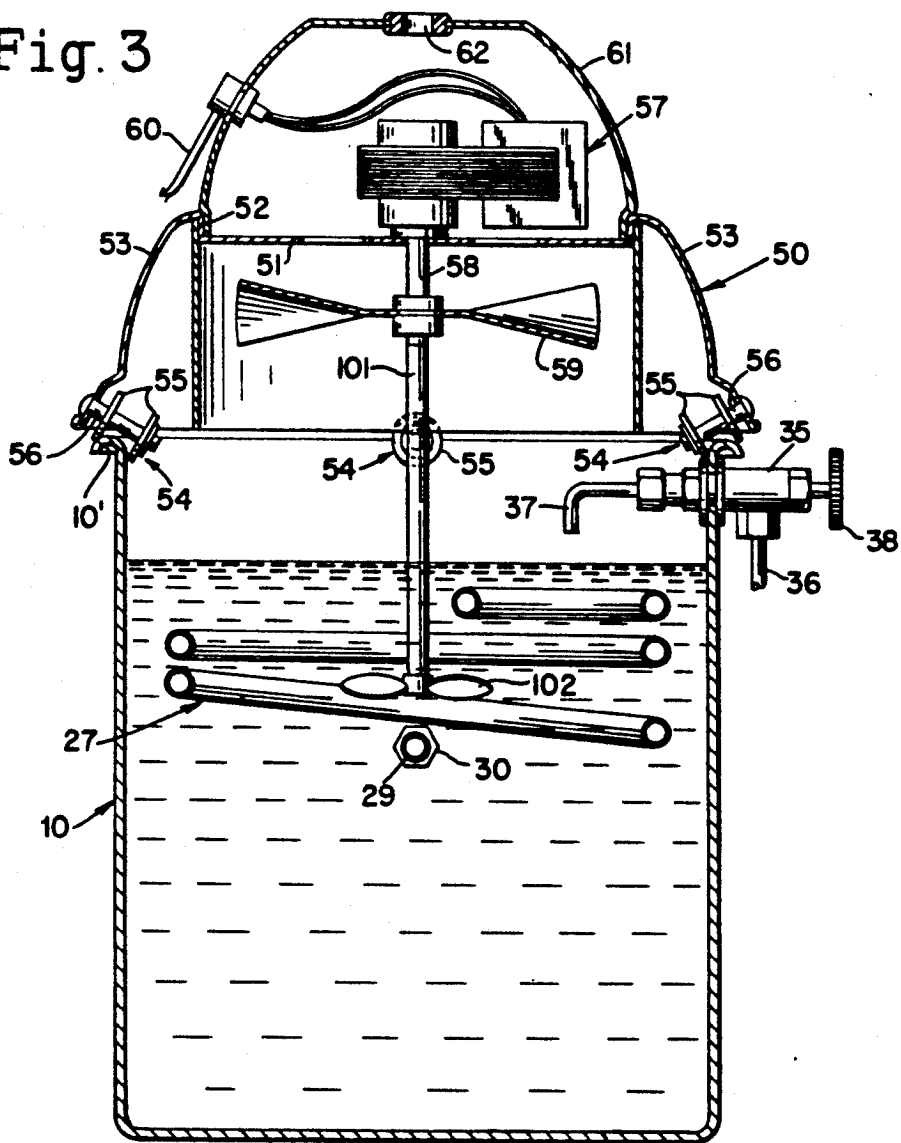


Fig. 4

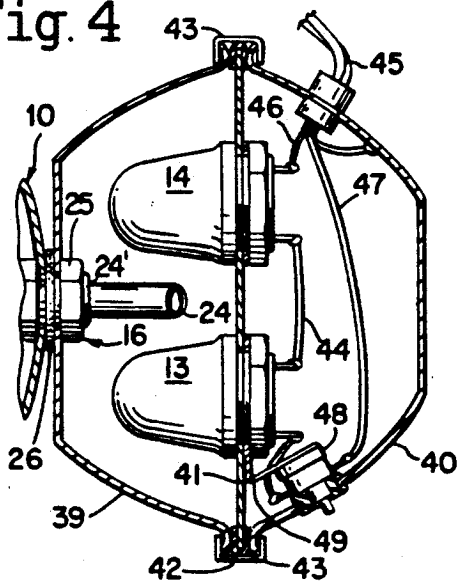


Fig. 5

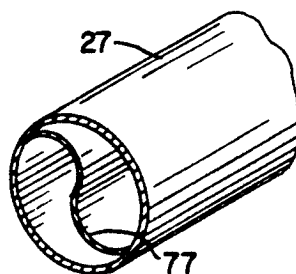
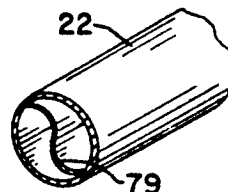


Fig. 6



METHOD FOR WATER DEGASIFICATION AND DISTILLATION

INTRODUCTION

This invention relates to a distilling apparatus and more specifically to a novel and improved water degasification and distillation apparatus embodying improved means for oiling off any volatile constituents present in the water prior to distillation thereof.

Known water distilling apparatus generally comprise: a closed boiler; means for continuously feeding water to the boiler means for removing and means for condensing the steam and other vapors evolved in the boiler. As the water in the boiler is being heated to produce steam, any volatilizable chemical components present in the water will boil off and combine with the steam being evolved. Then the steam together with the volatilized chemical components will become condensed in the condenser so that the resultant distillate will contain therein the (volatile) chemicals. In instances wherein the raw water exhibits a disagreeable odor such as is produced by sulphur compounds and the like, most of the known to the art distillation apparatus will tend to concentrate the odor compound in the distillate and make the distilled water even more distasteful than the raw water. The inventor hereof has long been concerned with this problem and is the inventor of several patents directed to improved water distillation and degasification systems.

The water distilling apparatus of this invention relates to the apparatus described in Applicant's prior patents U.S. Pat. Nos. 4,420,374 and 4,612,090, which patents in turn constitute an improvement over the apparatus disclosed in Applicant's earlier patent U.S. Pat. No. 4,339,307. Briefly, the water distilling apparatus described in the above-referenced patents U.S. Pat. Nos. 4,420,374, 4,612,090 comprises a very small boiler containing therein an instantaneous heating means and a reservoir for the boiler much larger than the boiler. A condensing coil is immersed within the reservoir so the water in the reservoir functions to cool the condenser. An open connection between reservoir and boiler provides an automatic water supply for the boiler.

The water in the reservoir circulates to and from the boiler, and the boiler heat thus imparted directly to the water in the reservoir together with the heat imparted to the reservoir water from the condenser heats the reservoir water to a temperature that will effectively deaerate the water in the reservoir and boil off any volatilizable constituents present in the water in the reservoir.

The water degasification and distillation apparatus in accordance with these above-referenced patents and in accordance with the invention hereof, comprises in more detail, a relatively large reservoir container adapted to receive the water to be distilled and a small boiler mounted on and to one side of the reservoir. A fluid conduit connects the boiler and the reservoir so that the liquid level in the boiler will be controlled to the liquid level in the reservoir. A vapor outlet in the boiler above the water level thereof is coupled to the condenser coil disposed within the reservoir container and the condensate outlet of the condenser coil extends through the wall of the reservoir container. The condenser coil is positioned so that the liquid in the reservoir will cover a major part or all of the condenser coil. With this arrangement and with the heater(s) in the

boiler energized, the water in the boiler will heat to boiling almost instantaneously and the steam generated in the boiler will be fed out to the condenser. Whenever the steam generated within the boiler exceeds the capacity of the boiler outlet to the condenser to remove the steam from the boiler the steam pressure will force water in the boiler through the fluid conduit back into the reservoir. Then, when the steam pressure is relieved (by outflow of water to the reservoir and of steam to the condenser), water will again flow from the reservoir into the boiler. Pulsation and recirculation of water as just described continues throughout during the operation of the distillation apparatus.

Since hot boiler water is returned to the reservoir through the fluid conduit periodically through the pulsation and since heat from the condenser is continuously added to the water within the reservoir, all water fed to the reservoir increases in temperature. In a word, the reservoir water becomes hot. Desirably, all undesirable volatile material contained in the water fed to the boiler is vaporized prior to entry of the water into the boiler and distillation thereof.

The cold water initially fed to the reservoir (at the top thereof) will normally sink to the bottom of the reservoir while hot water periodically recirculated from the boiler back into the reservoir container (near the bottom) will tend to rise. Thus, the water within the reservoir container tank is in constant movement and is mixing so that desirably all the water of the reservoir is maintained at about the same substantially elevated temperature so as to evolve the undesirable volatilizable components from the reservoir water before the water enters the boiler.

THE INVENTION

According to the present invention the water of the reservoir is mechanically stirred so as to agitate the water even more, generating a whirlpool motion and sufficient cavitation to cause bubble formation. Mechanical stirring does much more than just mix the reservoir water more thoroughly.

DISCUSSION OF THE INVENTION

Mechanical stirring by a stirrer blade generates localized high pressures in the water at the upstream blade face where the blade pushes the water aside as it stirs. Conversely, low pressure regions are generated in the water adjacent the stirrer blade at the downstream face thereof. In these localized low pressure regions in the heated reservoir cavitation occurs and steam flashes off into the cavitation bubbles or vaporizes so as to form the bubbles. The bubbles rise through the water and escape overhead from the reservoir. Along with the steam in the bubbles goes any other air and any volatilizable substances evolved from the hot reservoir water.

Operation of the mechanical stirrer generates a surprisingly extensive list of advantageous results. Degasification of the water in the reservoir is much improved. In particular, any relatively volatilizable chemical impurities in the feed water are thoroughly steamed out of the reservoir water before the water enters the boiler as is any air in the feed water. The operation of the distillation apparatus is improved. Less of an excess of (cool) feed water is required for operation of the distillation system, since generation of steam bubbles at the localized low pressure regions of the reservoir serves concomitantly to cool the reservoir water, maintaining

thereby a greater temperature differential between the reservoir water and the steam inside the condenser coil. Also, operation of the condensing coil is improved by the superior heat exchange contact between the condensing coil and the (turbulent) mechanically stirred water in the reservoir.

THE APPARATUS OF THE INVENTION

In the apparatus of this invention, the tubular condenser is a tube coiled somewhat loosely into a cylinder shape so as to be open to flow of water between adjacent coils. The cylindrical coil is disposed with a vertical longitudinal axis, which axis may be coincident with the stirrer rod. It is noteworthy that any suspended solids, such as dust or sediment in the feed water will never become carried over into the boiler because centrifugal forces engendered in the reservoir water by the mechanical stirring pushes the suspended solids between the condenser coils toward the periphery of the reservoir and either is discarded with the excess reservoir water or remains at the periphery until the distillation apparatus is cleaned.

Preferably, the stirrer is made part of a fan assembly such as the fan assembly that forms part of the distillation apparatus described in the related patents U.S. Pat. Nos. 4,420,374 and 4,612,890. Conveniently, the stirrer rod can be made an extension of the fan rotor. Advantageously, the fan removes the steam and gases that bubble up from the reservoir water.

Optionally included in the distillation apparatus of this invention may be a deflector insert in the conduit connecting reservoir and boiler and/or in the condenser coil tubing. The deflector(s) generates spin and turbulence in the water passing between reservoir and boiler, and/or causes turbulent fluid flow adjacent the tubular wall of the condenser coil.

Optionally included in the distillation apparatus may be an oversized filter, desirably a charcoal filter, at the delivery end of the condenser.

The above and other advantages of the invention will become more apparent from the following description and accompanying drawings forming part of this Application.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary plan view of one embodiment of the distilling apparatus in accordance with the invention;

FIG. 2 is a cross sectional view of FIG. 1 taken along the line 2—2 thereof;

FIG. 3 is a cross sectional view of FIG. 1 taken along the line 3—3 thereof and illustrates air circulating means carried by the container; and

FIG. 4 is a cross sectional view showing the boiler and a fragmentary portion of the tank taken along the line 4—4 of FIG. 2.

FIG. 5 is a diagrammatic view showing the condenser tube containing a deflector.

FIG. 6 is a diagrammatic view showing the fluid conduit containing a deflector.

Referring now to the drawings and more specifically to FIGS. 1 and 2 it may be seen that the distilling apparatus in accordance with this invention comprises a cylindrical tank reservoir container 10 having a pair of handles 11 secured to the side thereof. A boiler 12 having instantaneous heating elements 13 and 14 therein is affixed to the side of the tank 10 by the fluid connectors 15 and 16. The fluid connector 15 includes an elbow 17

having a shoulder 18 and a threaded shank extending through cooperating openings in the wall 19 of the boiler 12 and the wall of the container 10. A nut 20 engages the shank of the fitting 15 and together with a resilient washer 21 provides a water-tight seal for both the tank 10 and the boiler 12. A water inlet conduit 22 is fixedly coupled to the fitting 15 by means of a nut 23 so that water within reservoir container 10 will automatically feed into the boiler 12 until the water level within boiler 12 corresponds to the reservoir water level inside reservoir container 10. It will also be observed that the water level is maintained at a level adequate to effect total or at least substantial immersion of the heating elements 13 and 14 in the water of boiler 12.

The steam outlet fitting 16 is of conventional construction and includes an outlet pipe 24, a threaded shank 24' extending through the walls of reservoir container 10 and boiler 12 and secured thereto by a nut 25. A sealing washer 26 is disposed between container and boiler to provide a watertight connection. In the preferred embodiment of the invention herein illustrated the condenser 27 is in the form of a coiled tube of metal such as stainless steel, copper or the like and has the inlet end portion 28 sealably connected to the fitting 16 within container 10. The outlet 29 of the condenser 27 has a fitting 30 extending through the wall of container 10 and provides the condensate outlet 31. Optionally, but desirably an oversized filter 115 is interposed at condensate outlet 31. As best may be seen in FIG. 1, the coiled condenser tubing generates a cylindrical region 100 at the center of the reservoir container 10. Reservoir container 10 further includes an overflow pipe 32 which is connected to a fitting 33 sealed to the wall of the container 10 and a drain cock 34 for draining water from the container (being useful for cleaning and maintenance). A water inlet valve 35 is at the upper portion of the reservoir container 10 and has an inlet 36, an outlet 37 and a hand-wheel 38 for regulating the water supply in order to maintain an appropriate supply of water to the reservoir container 10.

The boiler 12 is shown more clearly in FIG. 4 and in the preferred embodiment illustrated herein consists of two housing elements 39 and 40. A wall 41 disposed between the housing elements 39 and 40 includes a peripheral seal 42 which is releasably clamped between the outer rims of the housing elements 39 and 40 by clips 43 at the periphery of the boiler 12. This arrangement completely seals the boiler formed by the housing element 39 and the wall 41. The whole boiler can be readily disassembled for cleaning. The heating elements 13 and 14 in the illustrated embodiment are carried by the wall 41 and are connected in series by a lead 44 connecting one terminal of one heater to one terminal of the other heater. The power line 45 has one lead 46 connected to the other terminal of the heater 14 while the second lead 47 is connected through a thermostat 48 to the other terminal of the heater 13. The thermostat is mounted on a bracket 49 in close proximity to the heaters 13. In the event the heater 13 reaches a temperature above the normal operating temperature, the thermostat will operate to open the circuit and de-energize both heaters 13 and 14. It is evident, however, that the heaters 13 and 14 could be arranged for parallel operating or in the alternative a single electric heater may be employed in the boiler provided however it delivers the quantity of heat necessary for operation of the distillation apparatus.

In the preferred embodiment of the invention herein illustrated a forced air circulation means assists removal of steam and undesirable vapors liberated from the reservoir water within reservoir container 10. The air circulating means which is shown in FIG. 3 comprises an inverted dished cover generally denoted by the numeral 50 over reservoir container 10 which includes a flat upper wall 51 that is perforated or apertured, an upwardly extending peripheral wall 52 and a downwardly curved peripheral wall 53. The lower peripheral edge of the wall 53 carries three or more diagonally disposed rollers 54 each having spaced discs 55 rotatably carried by a shaft 56. The discs 55 engage the rolled edge 10' of the reservoir container 10 and accordingly provide an annular vent between the cover 50 and the top edge of the reservoir container 10.

The flat apertured wall 51 of the air circulating means supports an electric motor generally denoted by the numeral 57 which powers a shaft 58 extending through the perforated wall 51. The fan 59 is mounted on shaft 58. Power is fed to the motor 57 by a cable 60 connected in a conventional manner to the motor. If desired, switch means may be provided for operation of the fan. The fan motor 57 is covered by a vented dome-shaped housing 61 that is securely fitted to the cover 50 and is attached thereto by any suitable means. In the illustrated embodiment of the invention, the dome-shaped housing 61 frictionally engages the peripheral wall 52 of the cover 50.

In one mode of fan operation, air is drawn into the air circulating means assembly through an opening 62 in the dome-shaped housing 61 and then down through the perforated wall 51 whereupon it is directed downwardly over the reservoir water in reservoir container 10 and thereafter is discharged through the annular opening between the reservoir container 10 and its cover 50. In the reverse mode of fan operation the fan 59 draws air in through the annular opening between reservoir container 10 and its cover 50 up through perforated wall 51 and opening out through vent 62 in motor housing 61.

As may be seen in FIG. 3, a stirrer rod 101 extends from an integral connection with motor shaft 58 at the hub of fan 59 preferably but not necessarily axially of the cylindrical reservoir region 100 inside of condenser coil 27 and terminates at the stirrer blades 102 immersed in the reservoir water. The depth of immersion for stirrer blades 102 is not critical, but preferably, they are not deeper than the bottom of coil condenser 27. In the mode illustrated herein, the stirrer rod was positioned modestly off-center to avoid interference with the outlet bend 29 of condenser coil 27, see FIGS. 1 and 2.

In the operation of the distillation apparatus of this invention, the reservoir container 10 and boiler 12 are first filled with water to a level at least substantially covering the heating elements 13 and 14 as may be observed most clearly in FIG. 2. It will be observed that when filling reservoir container 10, water will automatically flow through conduit 22 into the boiler so that ultimately the level of the water in the reservoir container 10 will be the same as the water level in the boiler 12. When energy is then supplied to the heating elements 13 and 14 they will function to boil the water within the boiler 12. Steam from the boiler will enter the inlet 24 and then flow through the condenser coil 27 to be condensed therein. The condensed steam will then discharge through filter 115 as the distillate (liquid) product from the condenser outlet 31. When first oper-

ating the distillation apparatus, it is generally desirable to discard the distillate product until the water inside reservoir container 10 has attained a normal operating temperature which preferably is 180°-190° F. (which is rapidly attained). Heaters 13 and 14 are designed to heat the water within the boiler at a rate faster than the condenser coil 27 can accommodate the steam produced. Accordingly, a head of steam is developed within the boiler 12 and the steam pressure will force liquid from the boiler back through the conduit 22 into the reservoir container 10 thereby relieving the steam pressure. As soon as the steam pressure within the boiler is relieved, water will again flow through the conduit 22 back into the boiler with the result that there will be a periodic reversal of water flow through the conduit 22. This pulsating action results in a more rapid increase in temperature of the reservoir water within the container 10 by contributing heat over and above the heat imparted to the reservoir water by the action of the condenser coil 27. The temperature of the reservoir water, however, is always below the boiling temperature (of the water in boiler 12) so that distillate will be condensed in condenser 27. Preferably the reservoir water should be kept in the range of 180° F. to 190° F. This temperature level will boil off undesirable components from the reservoir water (prior to actual distillation thereof), and also serves to operate condenser 27 adequately. To maintain proper operation of the apparatus, a substantial proportion of the feed water which enters at the inlet 37 ultimately is discharged as overflow through tube 32 and outlet 35.

Operation of stirrer blades 102 materially changes the dynamics of the distillation apparatus. The stirrer blades 102 generate a whirling turbulent motion of water inside cylindrical space 100 thereby improving heat exchange contact between the reservoir water and the tubing of condenser coil 27. In addition, motion of the stirrer blades generate cavitation which in the distillation apparatus of this invention constitutes formation of steam bubbles beneath the surface of the water. Typically, the bubbles contain both steam and volatilized gases and vapors.

The rapid rotational movement of the stirrer blades 102 generates localized pressure differentials in the reservoir water causing an increased (and super-atmospheric) pressure on the upstream face of the blades and a decreased relatively negative (and sub-atmospheric) pressure on the downstream face of the blades. Since the water in the reservoir is hot, desirably at between 180°-190° F., generation of localized sub-atmospheric pressure regions in the water creates a void space into which steam flashes off from the hot water (forming thereby the bubbles). Evolved along with the steam, is any air still dissolved in the water and any volatilizable components still present in the water. Moreover, as the bubbles pass up through the reservoir water to escape at the water surface, they scavenge air and volatilizable components from the water.

Thus, mechanical stirring of the hot reservoir water assists greatly in deaerating the reservoir water and in removing all volatilizable components therefrom before water from the reservoir enters the boiler 12 to be distilled therein. In addition, mechanical stirring facilitates maintenance of a good heat balance within the reservoir.

In operation of the distillation apparatus, the heat imparted at boiler 12 by the heating elements 13 and 14 can leave the distillation apparatus only as the heat

energy content of the hot (condensed steam) distillate product or of the hot reservoir water discarded through overflow pipe 32 or as the heat energy in the (heated) air and vapors vented by fan 59 (through either the annular vents in cover 50 or the opening 62 in motor housing 61 depending on how fan 59 is operated). To the extent that stirrer 102 causes cavitation and generation of steam bubbles in the reservoir water which bubbles in turn escape the reservoir water to become vented, the proportion of boiler heat vented to the atmosphere is increased. This increase is substantial. Correspondingly, the quantity of heated reservoir water that must be discharged through overflow pipe 32 to maintain a proper heat balance in the reservoir water may be and is reduced.

As a practical matter, operation of stirrer blades 102 distinctly increases the temperature differential between the steam inside condenser coil 27 and the water in reservoir container 10 adjacent condenser coil 27. It should be appreciated that although the decreased pressure zones on the downstream faces of stirrer 102 are localized and are transient in nature, more is not needed to create a bubble wherein part of the heated reservoir water flashes into steam, concurrently significantly cooling the reservoir water adjacent the bubble (through loss therefrom of the heat of vaporization for the steam). Since the steam bubble and the hot reservoir water can coexist at the sub-atmospheric pressure level generated by the stirrer 102, the bubbles form readily and do not collapse immediately when normal pressure is restored. Mostly, the steam bubbles escape over head of the reservoir.

Of course, the stirrer is in constant motion, mixing the reservoir water quite thoroughly so that distinct zones of temperature differences never can become established in the reservoir water. However, generation of the steam from the localized (and transitory) reduced pressure zones is virtually instantaneous. Once the bubble is formed, its collapse, however, is not instantaneous so that the bubbles last long enough to rise up through the reservoir water and escape through the surface thereof. Since the reservoir water is hot, desirably in the 180°-190° F. range, a substantial partial pressure of steam exists, which is to say, that the stirrer generates many steam bubbles and in total the steam bubbles remove a considerable quantity of heat energy from the reservoir water.

Thus, generating a micro environment of transitory sub-atmospheric pressure zones at the downstream face of the stirrer 102 generates a significant change in the macro environment of the reservoir. The temperature of the water in the reservoir as a whole is reduced by the flashing of steam to form the bubbles. Although only the water adjacent the bubbles becomes cooler, the rapid swirling water movement caused by stirrer 102 mixes the water almost immediately so that the temperature of the reservoir water overall has been reduced. Moreover, the cooler reservoir water is adjacent the condenser coil tubing. Thus, a better temperature differential between the condenser coil and the reservoir water is generated and maintained by the stirring improving thereby, the operation of condenser 27.

Another important overall practical effect of the stirring to remove more of the boiler heat overhead of the reservoir is to save water. Less of the boiler heat must be removed by discarding water through overflow pipe 32. The proportion of the feed water in the distillation apparatus that must be discarded through overflow

pipe 32 is reduced substantially by inclusion of stirrer 102 in the distillation apparatus.

A test version mode of the distillation apparatus illustrated herein was made and tested without the stirrer in operation (reservoir depth 5½"). Convection was relied upon for stirring. The temperature at the bottom of the reservoir was 160° F. The temperature at the surface of the reservoir was 180° F. The temperature of the distillate product was 200° F., and an appreciable amount of steam was being produced along with the distillate. About 2.5 gallons of cooling water per gallon of distillate product was being used. Then, when the stirrer was operated the temperature of the distillate rapidly became reduced to below about 155° F. Then, to raise the temperature in the reservoir to above 180° F. the ratio of cooling water to distillate was reduced from the 2.5 to 1 to about 1.2 to 1. The distillate temperature rose to above 190° F. Then, operation of the stirrer was discontinued, whereupon the outlet of the condenser steamed profusely. Then, the stirrer was turned on again and the system returned to normal.

As has already been pointed out, a mechanical expedient to facilitate maintenance of a distinct temperature across the condenser coil tubing is illustrated in FIG. 5. Shown there is an enlarged partial cross-section of condenser coil tubing. Inside the tubing is a deflector 77 whose purpose is to generate spiral flow movement of steam and condensate to the tube wall. Also, flow becomes more turbulent thereby helping heat exchange across the tube wall. A like deflector 79 may be provided in the conduit connecting reservoir container 10 and boiler 12 (see FIG. 6). The purpose of deflector 77 is, of course, to create turbulent mixing of the water so as to avoid any temperature stratification either in reservoir container 10 or in boiler 12.

An additional optional expedient which has been found advantageous in practice of this invention is the provision of a filter, preferably an oversized filter, at the condenser outlet 31. In the embodiment illustrated herein the oversized filter 115 is a carbon filter.

Filter 115 absorbs any organic materials that are carried over with the condensate. It polishes the condensate, so to speak but also it achieves a superior aeration for the condensate.

As has already been pointed out the distillation apparatus of this invention operates in a pulsating fashion causing water to flow through the connecting conduit 22 back and forth between boiler 12 and reservoir 12. The same pulsations affect condenser 27. A pulse of (steam) pressure from boiler 12 passes through the condenser tubing in a forward direction during a steam generation pulse, sending condensate out through filter 115. Then during the reverse suction pulse, air is drawn into the filter 115, and even into the outlet end of condenser 27. Thus, the filter 115 acts as much to filter air drawn into the condenser tubing, as it does to filter distillate leaving the condenser tubing.

Manifestly, the pulses are not equal in their effect. Steam is being generated in boiler 12, then is condensed in condenser coil 27. The distillate is discharged at the outlet 31 through filter 115. A net movement outflow movement of distilled water through filter 115 results. At the same time, a small net inflow of air into filter 115 and condenser 27 results. The distillate, e.g., at 190°-195° F., is hot enough to heat filter 115 and prevents microbial contamination of the filter. This means that air which enters oversized filter 115 during the suction pulses is retained therein and becomes sterilized

by the hot filter before entering condenser 27 and/or becoming absorbed in the distillate. The reason for providing a filter 115 that is oversized is precisely to increase the residence time therein of the inflowing air. Overall, the result is that air heated and sterilized in filter 115 partially aerates the distilled water improving the palatability thereof.

Surprisingly, the operation of filter 115 to sterilize and filter aeration air is connected to the operation of stirrer 102.

Stirring the heated reservoir water is believed to completely deaerate the reservoir water as well as strip any volatilizable materials therefrom before the reservoir water is admitted into boiler 12. Accordingly, the water in the boiler 12 and the steam entering condenser coil 27 and the condensate water in the coil 27 is essentially free of air. Therefore, the condensed distillate is capable of absorbing air or any other gas quite readily. The steam pressure pulses which cause back and forth water flow in conduit 22 and which also generate a comparable back and forth flow of air and condensate in filter 115, and condenser 27. Some of the air seems to pass through the condenser 27 and enters boiler 12. In any event, a small net inflow of air into filter 115 happens.

The net inflow of air into filter 115 is caused by the completely deaerated nature of the distillate. Notwithstanding, that the distillate is hot it absorbs some air. Taste tests on the distillate indicate that the distilled water product from the distillation apparatus of this invention is not as flat as typical distilled water.

It is noted that the condensation product of the distillation apparatus leaves at near to the temperature of the reservoir water, and absent devolatilization due to the stirring would contain about the same air content as remains in the heated reservoir water. This is because (absent the superior deaeration obtained by stirring) the water entering boiler 12 would contain some residual air and then most, if not all, the same residual air would be reabsorbed into the distillate in condenser 27. Since all such residual air has been removed by the stirring, it becomes replaced by sterile filtered air.

While only certain embodiments of the invention have been illustrated and described herein, it is understood that alterations, changes, and modifications may

be made therein without departing from the true scope and spirit thereof.

What is claimed is:

1. A method for producing a distilled water product that is at least partially aerated which comprises providing a distillation apparatus including a water reservoir container having a water inlet and outlet thereto connected so as to create a reservoir of water therein and a boiler smaller than the reservoir container with an open connection between container and boiler for water flow to or from the boiler, a steam line overhead of the water level in the boiler leading to a condenser immersed in the reservoir and an outlet from said condenser for discharge of condensate, the distillation apparatus further including a filter at the outlet of said condenser for filtering the condensate and for sterilizing and filtering any air entering said filter through reverse flow, and a mechanically operated stirrer in the reservoir to cause swirling in the reservoir water and generation of steam bubbles therein; maintaining a predetermined level of reservoir water by introducing feed water into and removing water from said container at a flow rate which maintains a temperature in the range of about 180°-190° F. in the reservoir and heating the water in said boiler to generate steam, the steam passing into said condenser to be condensed therein by heat exchange against the reservoir water whereby the reservoir water becomes heated while at the same time mechanically stirring the water of said reservoir so as to cause generation of steam bubbles in the reservoir water whereby the heated reservoir water becomes devolatilized and deaerated prior to entering said boiler, and passing air into said filter whereby devolatilized water converted into steam in said boiler and thereafter condensed in said condenser to become the distilled water product absorbs filtered and sterilized air during passage through the condenser and through the filter.

2. The method of claim 1 wherein the boiler periodically generates more steam than can be accommodated by the condenser thereby causing a pulsation wherein water is force to flow out of the boiler back into the reservoir by steam pressure, and then the steam pressure pulse is dissipated whereupon water flows back into the boiler from the reservoir, said pulsation also causing periodic flow of condensate out of the condenser and periodic flow of air into said filter.

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United States Patent [19]
Hartman

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[45] **Date of Patent:** **Nov. 10, 1998**

[54] **LOW MAINTENANCE WATER DISTILLER**

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[52] **U.S. Cl.** **203/1**; 202/181; 202/185.3; 202/197; 202/206; 203/4; 203/10; 203/40; 203/100; 392/325

[58] **Field of Search** 203/10, 4, 1, 2, 203/100, 40, 12, DIG. 18; 202/185.3, 206, 197, 181, 193, 196, 266; 159/44, 47.3; 392/234-327, 403; 137/391; 165/182

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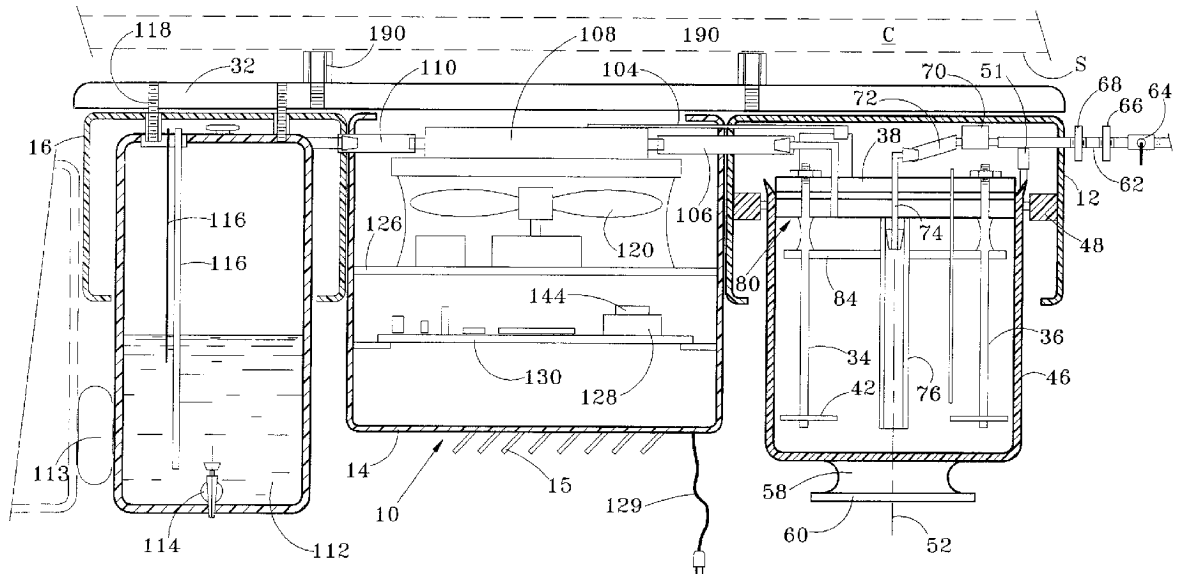
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[57] **ABSTRACT**

The water distiller **10** includes a plurality of housings **12**, **14**, **16** each mounted below a support plate **32**. A voltage regulator **144** maintains a desired voltage potential between heating probes **34** and **36** within a heating bowl **46**. An operator selector **142** automatically regulates the flow of water through inlet valve **70** to control the incoming water flow rate to the heating bowl. Area contact between water in the heating bowl and a substantially horizontal plate **42** at the lower end of each heating probe determines the electrical power used by the distiller, and maintains water in the heating bowl at substantially a constant level. An improved particle trap **80** and vent valve **100** provide reliable and safe operation of the distiller. Heating bowl **46** and a water inlet line **76** may be easily removed for cleaning the distiller.

19 Claims, 3 Drawing Sheets



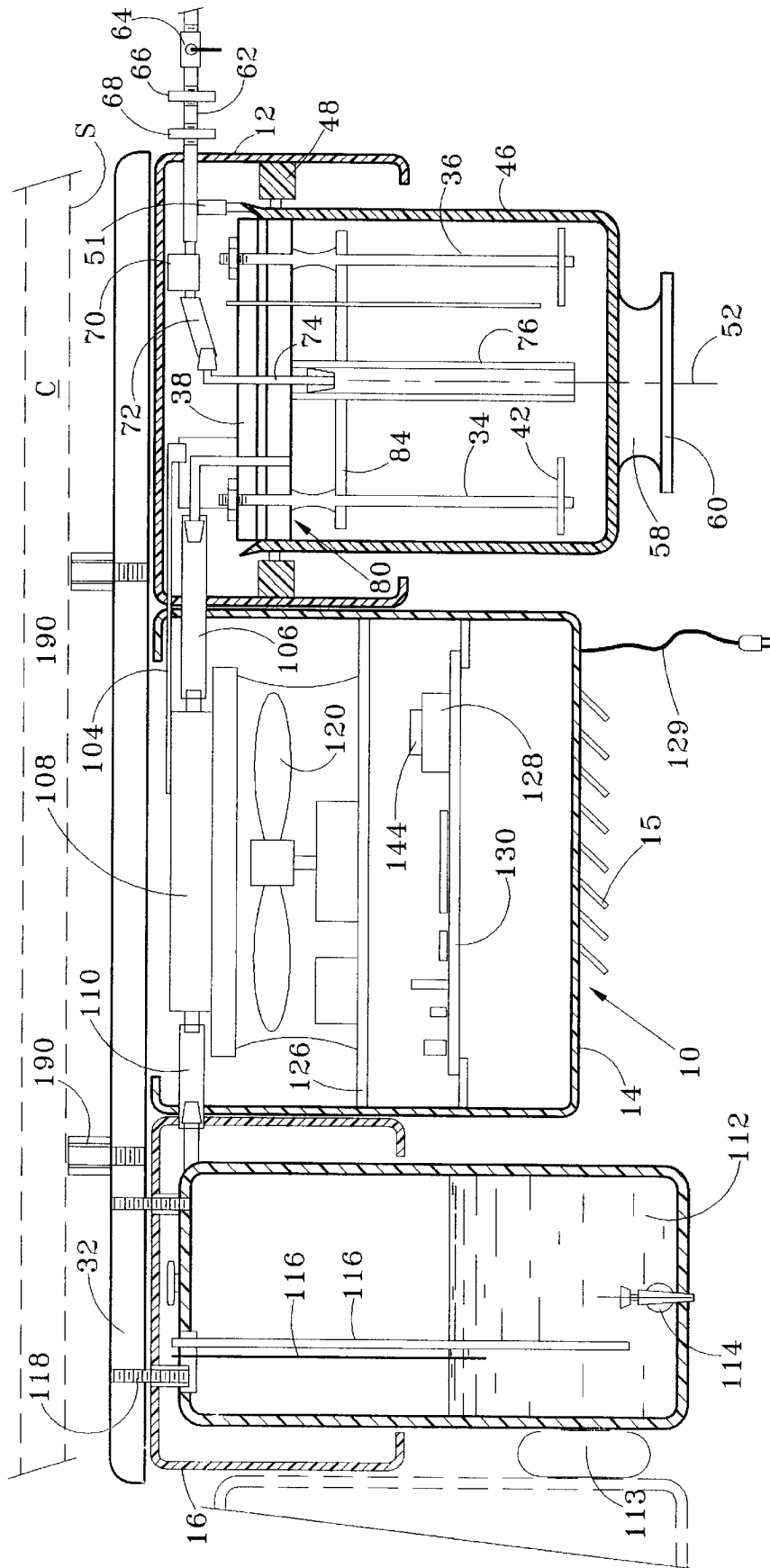
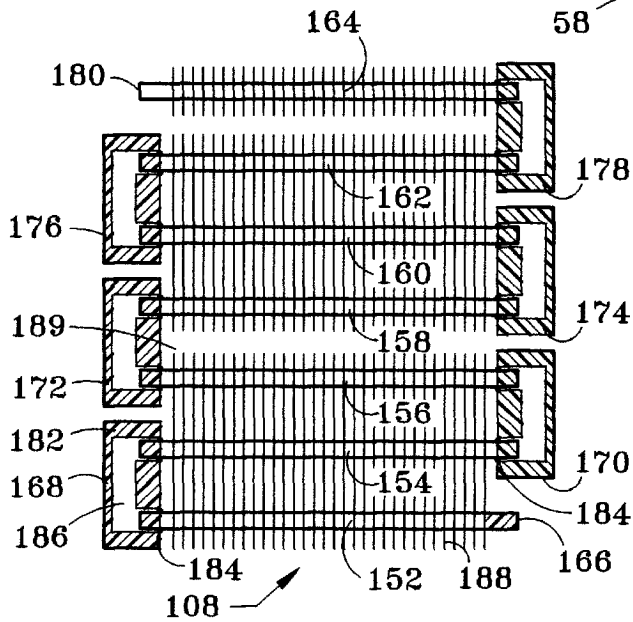
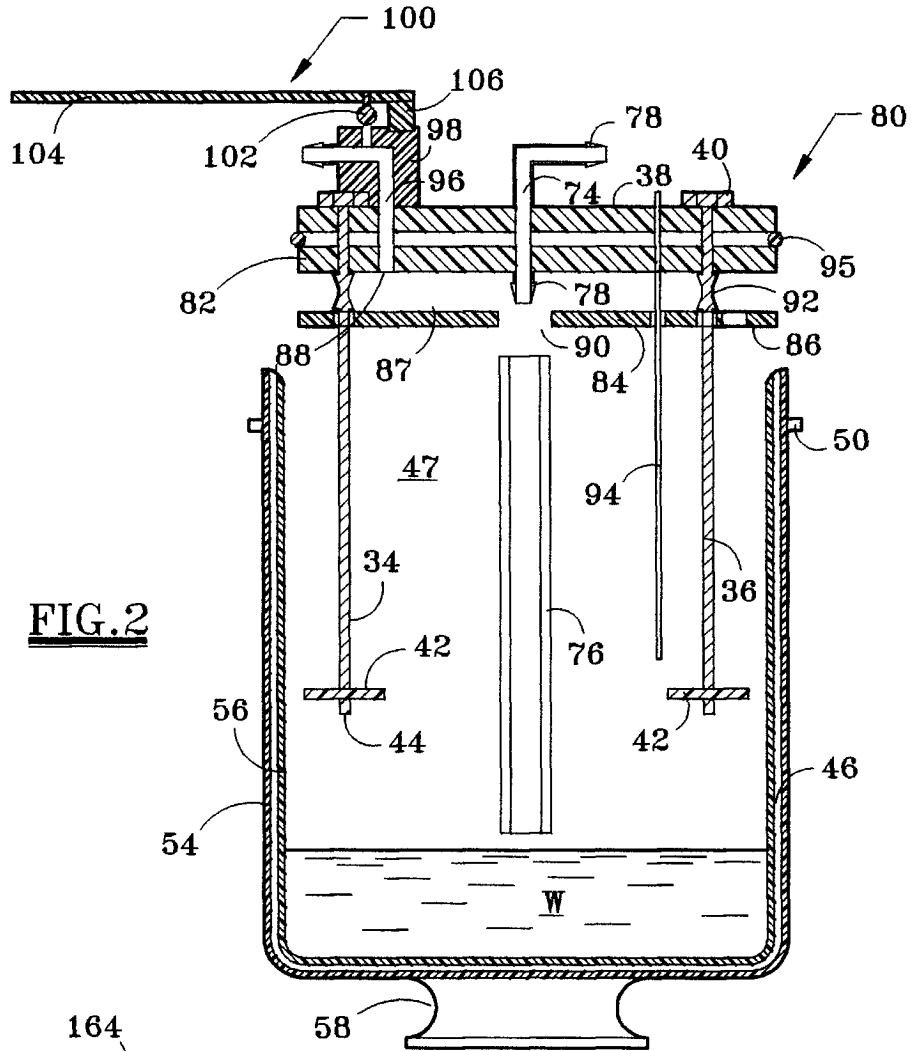


FIG. 1



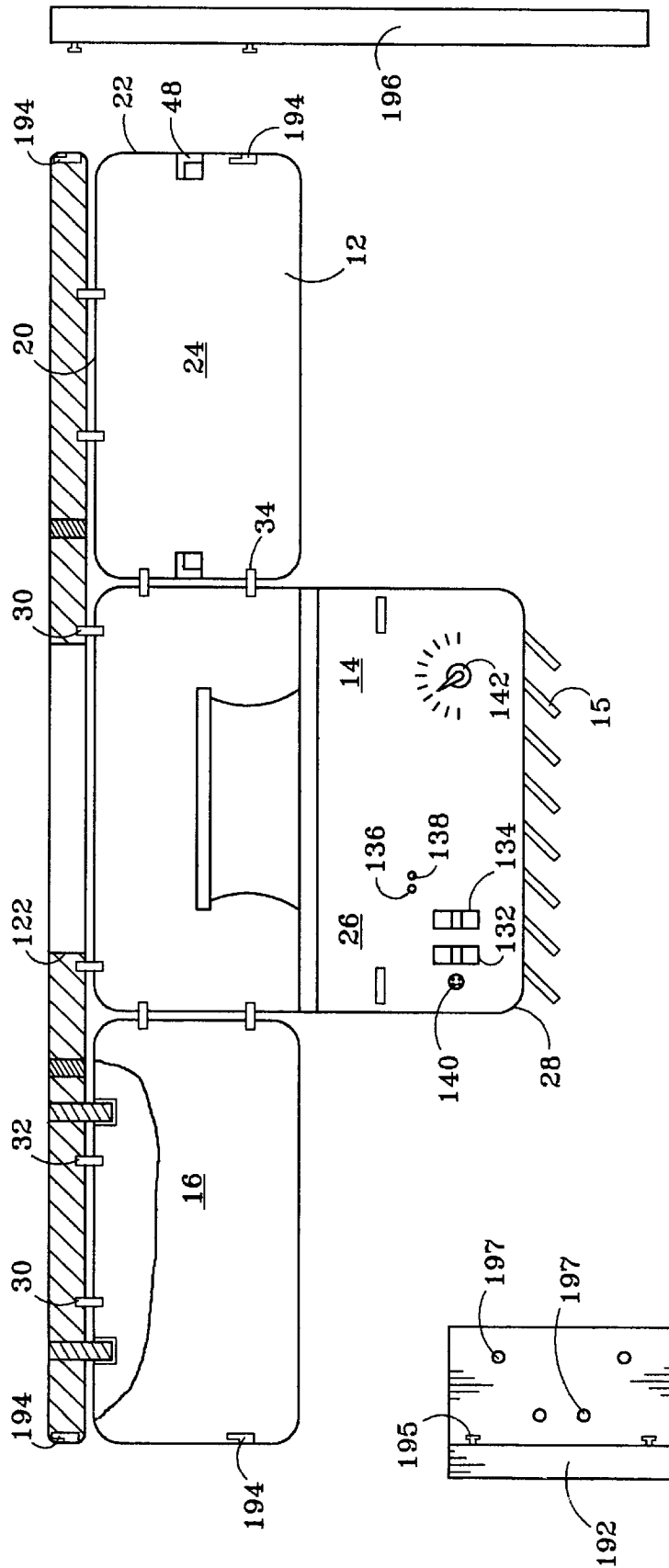


FIG. 4

LOW MAINTENANCE WATER DISTILLER**FIELD OF THE INVENTION**

The present invention relates to a water distiller of a type commonly used in homes or businesses for generating distilled drinking water. More particularly, this invention is directed to a relatively light weight water distiller which may be conveniently mounted in a variety of locations, which requires relatively low maintenance, and which has high safety and reduced noise generation.

BACKGROUND OF THE INVENTION

Various types of water distillers have been devised for generating distilled drinking water. As the public becomes more concerned with the quality of tap water for both drinking and cooking, acceptance of water distillers for home and office use is increasing. One example of a water distiller with improved probes is disclosed in U.S. Pat. No. 5,484,510. Further acceptance of water distillers requires improvements to lower the cost of the distiller, to increase versatility in the locations where the distiller may be installed, and to reduce noise generated by the distiller. Most importantly, significant improvements are required to reduce the required maintenance to reliably and safely operate the water distiller. Most commercially available water distiller manufacturers suggest that the unit be thoroughly cleaned at least once a week, and reliable cleaning is both difficult and labor intensive. Accordingly, distillers are frequently not properly cleaned, contaminants build up in the unit which adversely effect both its operation and the quality of the distilled water, and the user frequently discontinues regular use of the distiller.

One of the problems associated with both the cost and high maintenance of water distillers relates to the use of stainless steel heating bowls and condensing units. Expensive metal distillation components are commonly used to facilitate thorough cleaning by the user, and to withstand the high temperature generated by conventional high resistance heating elements. Deposits commonly accumulate in the heating bowl, and various flow lines and supporting mechanisms must be disconnected to remove and clean the bowl. Both the heating bowl and the condensing unit are often difficult to remove from the distillation assembly, and once removed these components cannot generally be easily cleaned.

Many water distillation assemblies are sized to be supported on a self-supporting distillation stand, thereby increasing the cost of the assembly. Other distillation assemblies have been proposed for positioning on a countertop or other planar support surface, although many individuals wish to keep countertops clean for use as work surfaces. Versatility in positioning a distillation assembly is thus a significant factor in the acceptability of water distillation units for home and office use.

Most distillers allow an operator to control the rate at which water is distilled by regulating the power supplied to the unit. Slower distillation results in less noise generated by the unit, although a fast distillation rate is obviously desired when water consumption is high. High noise is frequently the result of a high speed fan, which is required to generate the air flow required for the type of radiator used in the distiller. Controls which regulate the maximum power to the heating elements of the unit and techniques for controlling the power input to the distillation assembly are, however, expensive and frequently do not provide the level of control desired by the operator.

Those skilled in the art of heating fluids have long recognized that a fluid may be heated by transmitting a current between electrodes emerged in an ionic liquid, such as water with electrolytes added to increase conductivity. U.S. Pat. Nos. 3,584,193, 4,347,430, and 4,382,173 disclose air humidifiers which use water as an electrically conductive medium when heating the water. U.S. Pat. No. 3,423,293 discloses a boiler for distilling saline water wherein steam is compressed adiabatically. U.S. Pat. No. 3,644,929 discloses an electrothermal cell designed for reducing arcing. U.S. Pat. No. 4,431,905 discloses a condensate evaporator which uses a salt impregnated pad to remove condensate from a refrigeration system. U.S. Pat. Nos. 3,944,785 and 4,092,519 discloses steam boilers for providing steam to an air conditioning plant. U.S. Pat. No. 4,394,561 discloses an air humidifier for generating steam for an air distribution system. U.S. Pat. No. 5,305,415 discloses a steam generator for removing wallpaper.

U.S. Pat. No. 3,925,167 discloses a multiple stage still designed for use with saline water. U.S. Pat. No. 4,933,046 discloses the use of light weight materials, such as plastics, for applications involving high temperature fluids. U.S. Pat. No. 5,059,287 discloses a portable water distiller which heats a thin layer of water at a low temperature. U.S. Pat. Nos. 2,816,064, 3,382,156, and 4,770,748 disclose various designs for baffles used in distillation equipment. A complex water distiller is disclosed in U.S. Pat. No. 4,331,514.

The disadvantages of the prior art are overcome by the present invention, and an improved water distiller is hereinafter disclosed which has low maintenance and which may be periodically cleaned in a short amount of time. The distillation assembly is light weight, has a comparatively low manufacturing cost, and is designed either for mounting in various locations or as a self-supporting or stand alone assembly. Improved techniques are used to heat the incoming water to generate steam, and to reliably control the operation of the distillation assembly.

SUMMARY OF THE INVENTION

A preferred embodiment of the water distiller comprises a plastic heater housing, a plastic fan and control housing, and a plastic tank housing each supported below a unitary plate, which in turn is constructed for securing to the lower planar surface of a countertop or cabinet. The light weight distiller assembly has a relatively low manufacturing cost, and may be mounted in a variety of low utility spaces. Water is heated by passing current through the water between at least two partially submerged probes, thereby generating steam without creating hot spots commonly found in distillers with resistive-type heating probes. The heating bowl, the condensing unit, and the tank are each fabricated from plastic for easy cleaning.

By utilizing water as an electrically conductive medium, steam is generated in a manner which reduces contaminants in the heated water from passing with the steam to the condensing unit. A particle trap with a horizontal chamber interconnecting a steam trap inlet and a steam trap outlet further reduce contamination of the condenser. Gasses are given time to separate in the particle trap. The separation of carbon dioxide from steam prevents the formation of carbonic acid in the condenser, which adversely effects the taste in the finished water. Contaminants in the steam adhere to condensate on the particle trap walls, are captured in the condensate, then drop back to the water in the heating bowl. A plastic heating bowl may be easily removed from the heater housing for periodic cleaning, with the heating probes

remaining in place. A water inlet probe transmits incoming water through the particle trap to a lower end of the heating bowl, and may also be easily removed for cleaning once the heating bowl is removed. The condensing unit includes a series of fin and tube heat exchangers fluidly interconnected with plastic end caps for efficient periodic cleaning of the condensing unit.

A microprocessor control unit with an operator input regulates the amount of incoming water to the heating bowl. Each of two heating probes are supported at an upper end within the heater housing, and include a substantially horizontal plate at its lower end for engagement with the surface of the water in the heating bowl. Rather than limiting the electrical power to the heating probes, the distiller of the present invention regulates an inlet water valve to control the water added to the heating bowl and thus the level of water within the heating bowl. Within reasonable limits, the rate of added water is equal to the rate of generated condensate, and accordingly the water level in the bowl remains substantially constant. A slight fluctuation in the water level in the bowl will significantly increase the contact surface area between the substantially horizontal probe plates and the water, thereby allowing more electrical power to be transmitted through the water and generating more steam, which in turn reduces the water level and accordingly the electrical power consumption.

The water distiller includes various safety features which enhance its reliable operation and utilization. An electrical interlock is provided for engagement with the heating bowl, such that electrical power to the heating probes is only provided when the bowl is properly secured within the heater housing. A vent valve provided along the flow line between the particle trap and the condenser unit is automatically opened in response to air flow generated by the fan and moving past the condensing unit. When the fan is not operating, the vent valve is closed to prevent contamination. The heating bowl is insulated for safety. A mechanical interlock may be provided to prevent removal of the heating bowl until the water temperature in the bowl is below a selected value. Relatively cool water is discharged from the condenser unit due to its series design, thereby minimizing the likelihood of hot condensed water injuring the user.

It is an object of this invention to provide an improved water distiller which has a relatively low maintenance. By designing the distiller for reduced maintenance, the acceptability of the distiller is enhanced and its utility in home and office environments is substantially increased.

It is another object of the invention to provide a relatively low cost and compact distiller which may be conveniently mounted in a variety of locations. By minimizing or eliminating floor space and counter space required for the distiller, the number of applications where the distiller may be conveniently used is significantly increased.

Still another object of the invention is that the water input rate to the heating bowl is selectively controlled by the operator. The heating probes include substantially horizontal plates which significantly increase the water contact area when the water level in the bowl rises slightly, so that a substantially constant level of water is provided in the heating bowl. By directly controlling the water input rate, the distiller output is directly controlled in a cost-effective manner. By minimizing the quantity of water in the heating bowl and by reducing the temperature of condensate from the condenser unit, a reduced level of noise is output by the distiller.

A significant feature of the invention is the extensive use of plastic materials, particularly for the heating bowl and the

condensing unit, to lower the cost and weight of the distiller. The use of plastic materials for the heating bowl and the condenser unit further enhances the maintenance of the distiller by allowing the equipment to be periodically cleaned with a minimal amount of time and expertise.

An improved particle trap with a horizontal chamber between the steam inlet and the steam outlet reliably reduces contamination in the distilled water. The particle trap is configured so that condensate on the walls of the trap collect, contaminates, which then drop back to the water in the heating bowl. Another feature of the invention is the use of an improved vent valve to reliably vent gas from the distiller only when the condensing unit fan is operating.

An advantage of the distillation assembly is that it is designed for mounting under a countertop or cabinet. The distillation assembly is relatively compact and light weight. Substantially the same distillation unit may, however, also be wall mounted, or may be supported on a stand.

A significant advantage of the distillation assembly is its ease of use and high safety. The distillation assembly may be reliably used by numerous individuals, and may be easily and quickly cleaned.

These and further objects, features, and advantages of the present invention will become apparent from the following detailed description, wherein reference is made to the figures in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of a suitable embodiment of a distillation assembly, partially in cross-section, according to the present invention.

FIG. 2 is a more detailed view of the removable bowl, the particle trap, and the heating probes generally shown in FIG. 1.

FIG. 3 is a detailed view of a suitable condensing radiator, partially in cross-section, according to the present invention.

FIG. 4 illustrates the distiller housings generally shown in FIG. 1, and an optionally wall mounted bracket and a support stand for interconnection with the housings.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A water distiller 10 as shown in FIG. 1 is specifically designed for mounting underneath a cabinet or countertop generally represented by C and having a lower substantially planar support surface S. The distiller comprises a heater housing 12, a condenser unit and control housing 14, and a tank housing 16 each preferably fabricated from plastic. As shown in FIG. 4, the general configuration of the housings 12 and 16 may be substantially identical, with each housing having a top plate 20 and a cylindrical side plate 22 forming an inverted cup configuration defining an interior cavity 24 therein. The housing 14 includes a cylindrical side plate 26 and louvered bottom plate 28 for passing air upward through the housing 14.

Still referring to FIG. 4, each housing 12, 14 and 16 may be secured by conventional fasteners 30 to a unitary planar mounting plate 32. Accordingly, each housing may be supported directly from the support plate 32. Additional fasteners 34 may be used to attach the side plates of housings 12 and 16 to the side plate of housing 14. Alternatively, each housing 12, 14 and 16 may be supported from and positioned below the support plate 32, with housing 12 and 16 being directly supported by the plate 32 and housing 14 being supported by the housings 12 and 16. Those skilled in

the art will appreciate the various mechanical fasteners may be used to secure the housings below the support plate 32.

Referring again to FIG. 1, the distiller includes first and second heating probes 34 and 36 each secured at an upper end within the interior cavity 24 within the housing 12 and extending downward therefrom. More particularly, a planar disk-shaped probe support plate 38 is securely mounted within the housing 12 by a plurality of conventional securing members (not shown). The upper end of each heating probe passes through an aperture in the support plate 38 and is secured in place by a conventional nut 40 (see FIG. 2). Each heating probe 34, 36 is electrically connected to a power supply as discussed subsequently, although the electrical lines are not shown in FIG. 1 for clarity. The lower end of each rod-like heating probe 34, 36 includes a substantially horizontal plate portion 42 which is also discussed in detail below. Each plate portion 42 may be welded or otherwise affixed to the rod-like heating probe, with a short rod extension 44 extending below the plate portion, as shown.

The heating bowl 46 is removably secured to the housing 12. More particularly, an interlock ring 48 is provided within the housing 12 and adapted for engagement with an arcuate flange 50 secured to and extending radially outward from the upper outer surface of the bowl 46. A mechanical interlock between the bowl 46 and the housing 12 may be made by a simple pushed and twisting motion so that the flange 50 is latched in place. Various other mechanical interconnections may be provided for removably interconnecting the bowl with the housing 12. For example, the upper end of the bowl 46 may be threaded for engagement with internal threads on an interlock ring secured within the housing 12.

Plastic material bowl 46 includes a central axis 52 which is vertical when the bowl is secured to the housing 12. The bowl 46 includes a cylindrical plastic outer wall 54 and a cylindrical plastic inner wall 56 each separated by an air gap. Each wall 54 and 56 also has a cup-shaped configuration, so that an air gap is also provided between the walls in the bottom of the bowl. The air gap between the walls reduces heat loss from the bowl, and also allows the operator to comfortably remove the bowl 46 using the bowl handle 58 with the bowl 46 containing heated water. If desired, an outer insulation layer (not shown) may be provided along the portion of the outer bowl 56. Plastic bowl support or handle 58 is secured to the lower end of the outer wall 54 of the bowl. The bowl support 58 provides a convenient handle for allowing the operator to manipulate the bowl 46 as the bowl is mechanically connected to the housing 12. A planar lower surface 60 on the support 58 also allows the bowl to be supported on a table or countertop in an upright position during periodic bowl maintenance.

Water is input to the bowl through an inlet flow line 62. A conventionally manually operated shutoff valve 64 is provided along flow line 62, so that the water inlet line 62 may be easily connected to and removed from a conventional municipal water system. As explained subsequently, however, a particular feature of this invention is that the distiller 10 may be used to generate distilled water from various types of water supplies, including brine water and water with a high metal content. Accordingly, it should be understood that the flow line 62 may be interconnected with various types of water sources. For remote applications, a pump (not shown) may thus be used for providing contaminated water to the distiller. If desired, a filter 66 may be provided downstream from the valve 64 for removing solid contaminants in the water. A flow controller 68 is also provided along the flow line 62, and serves to provide a substantially stabilized and reduced water flow rate to the

inlet water valve 70, which is discussed in detail below. Those skilled in the art will appreciate that the flow line 62 may be formed from various rigid or flexible flow line materials, such as plastic, and that the shutoff valve 64, the filter 66, and the flow controller 68 may be provided at any suitable location for mounting these components along a flow line 62.

Water passing by the inlet water valve 70 is transmitted by gravity through the inclined tube 72, through the bend tube 74, and through the vertical water inlet tube 76 for discharge into the lower end of the bowl 46. Tapered plugs 78 may be provided at each end of the bend tube 74 for sealing between the bend tube and the inclined tube 72 and water inlet tube 76, respectively. Each of the tubes 72, 74 and 76 may be fabricated from a plastic material. The water inlet tube 76 is preferably fabricated from a non-stick plastic, such as tetrafluoroethylene, which is able to withstand the high temperature within the bowl 46. Input water is thus introduced at the bottom of the bowl 46 at a low flow rate equal to the rate of generated condensate, as explained subsequently. Introduced water in the bowl 46 moves in a substantially toroid pattern about the central axis 52, and is heated by the probes to generate steam.

The generated steam rises within the vaporization chamber 47 spaced within the bowl 46 above the plates 42 and below the particle trap 80. Ideally the vertical length of the vaporization chamber 47 within the bowl 46 is at least two inches, and preferably is from 2.5 to 3.5 inches, so that contaminants carried by the steam tend to fall back into the water W before entering the particle trap, but the distiller 10 is still compact. Particle trap 80 is positioned within the housing 12 and within the upper end of the bowl 46, and includes a disk-shaped plastic top plate 82 and a disk-shaped plastic bottom plate 84. Steam from the vaporization chamber 47 enters the particle trap 80 through the steam inlet 86 provided in the bottom plate 84, and exits the particle trap through the steam outlet port 88 in the top plate 82. It is important according to the present invention that ports 86 and 88 be horizontally spaced apart a substantial distance. For the embodiment as discussed herein wherein the plates 82 and 84 each have a circular configuration, the inlet port 86 is spaced circumferentially opposite the outlet port 88. The plates 82 and 84 are separated by a horizontal gap which forms a substantially planar chamber 87 for transmitting steam between the inlet port 86 and the outlet port 88. It is important that the volume of the horizontal gap in chamber 87 be sized so that steam passing between the plates 82 and 84 moves at a velocity substantially lower than the steam passing through the ports 86 and 88. This low velocity allows contaminants within the steam to adhere to condensate on the lower surface of the top plate 82 and on the upper surface of the bottom plate 84 so that condensate droplets containing contaminants may drop through the vaporization chamber 47 back into the water W within the lower end of the heating bowl 46. The low flow velocity through the chamber 87 also gives gas generated with the steam time to separate from the steam so that this undesirable gas may be vented, as explained below. Oxygen, carbon dioxide and other gasses contained in the incoming water are released with the steam, but separate from the steam in the low velocity particle trap. Once separated from the steam, these gasses are then vented upstream from the condenser unit.

Bend tube 74 passes through the support plate 38 and through the top plate 82 of the particle trap 80. A lower seal 78 between the bend tube 74 and the water inlet tube 76 is positioned within the gap of chamber 87 between the plates 82 and 84. Water inlet tube 76 passes through aperture 90 in

lower plate **84**. Each of the heating probes **34** and **36** include an enlarged sleeve portion **92** for maintaining the desired spacing between the upper and lower plates of the particle trap **80**. Particle trap **80** is thus effectively supported on the heating probes **34** and **36**, which in turn are suspended from the support plate **38**. One or more sensor probes **94** also supported from the plate **38** extend downward through the particle trap **80** and into the vaporization chamber **47**. Sensor probes may be used to monitor the conditions of vapor within the vaporization chamber, and may be similar to the condenser probes described in U.S. Pat. No. 5,484,510.

The outer diameter of the lower plate **84** may be only slightly less than the inner diameter of the bowl **46**, so that substantially all steam entering the particle trap passes through the inlet port **86**. A small amount of steam may pass between the outer diameter of the lower plate **84** and the bowl **46**. Condensate which accumulates within the particle trap may drip back to the water in the heating bowl by passing through the slight annular gap between the lower plate **84** and the bowl **46**, or through the inlet port **86**, or through the slight gap between the outer diameter of the members **34**, **36**, **76**, and **94** and the sides of the respective apertures in the lower plate through which these members pass.

An O-ring seal **95** is provided for sealing between the outer diameter of the support plate **38** and the inner diameter of the bowl **46**. For the embodiment as depicted in FIGS. **1** and **2**, the O-ring seal **95** is spaced between the support plate **38** and the top plate **82** of the particle trap **80**. Those skilled in the art will appreciate that various types of seals may be used to provide a reliable static seal between the support plate **38** and the top of the bowl **46**. Alternatively, a seal may be provided between the top plate **82** of the particle trap and the bowl **46**, so that steam cannot pass upward into engagement with the support plate **38**. Outlet bend tube **96** transmits steam from the particle trap **80** to the block **98**, which in turn is supported on the support plate **38**. Each of the bend tubes **74** and **96** may fit tightly within respective apertures in the support plate **38** so that steam cannot pass upward between the support plate **38** and the exterior surface of these tubes. If desired, various conventional seals (not shown) may be used to provide a reliable static seal between the support plate **38** and each of the bend tubes **74** and **96**.

Referring to FIGS. **1** and **2**, the distiller **10** includes a vent valve **100** for venting gas from the flow line **96** between the particle trap **80** and the condenser. The vent valve **100** may be a simple plug **102** for stopping a vent port in the block **98**. According to the present invention, the plug **102** is mounted on a substantially horizontal flap **104**, which in turn is pivotally connected at **106** to the block **98**. Air from the powered fan moving past the condenser lifts the flap **104** upward, thereby slightly raising the plug **102** and venting gas from the line **96**. When the fan is not operating, the lever action of the relatively light weight flap **104** is sufficient to position the plug **102** for blocking fluid communication out the line **96**, thereby minimizing the likelihood of contamination.

Referring again to FIG. **1**, steam passes from the particle trap **80** through the substantially horizontal tube **106**, and enters the condenser unit **108**. The flow paths in the condenser **108** are each arranged within a substantially horizontal plane, so that condensate formed within condenser **108** passes through the substantially horizontal outlet tube **110** and then into the finished water holding tank **112**. The finished water holding tank includes a manual water valve **114**, so that the user may selectively open the valve **114** to obtain a cup of clean water. The plurality of probes **116** may

be provided within and extend through the top of the tank **112** for monitoring the level and condition of water in the holding tank. The probes **116** may be similar to the tank probes described in detail in U.S. Pat. No. 5,484,510. The probes **116** are interconnected with the distiller controller described subsequently, although again the electrical lines between the controller and the probes **116** are not shown in FIG. **1**. An electrically powered thermal cap **113** such as that manufactured by Melcor, a subsidiary of Nycor, may be used to cool the water in the tank **112**. If desired, an electrically powered heating unit may alternatively be used to heat condensate in the water tank. Due to the substantial weight of water-filled tank **112**, a plurality of tank mounting bolts **118** may be provided for structurally suspending the tank **112** directly from the plate **32**.

FIG. **1** depicts an electrically powered fan **120** for blowing air upward through the condenser unit **108** and through the circular air discharge port **122** (see FIG. **4**) in the support plate **32**. A plastic shroud **124** as shown in FIG. **4** may be provided for increasing the efficiency of air discharged by the fan **120**. It is a particular feature of the present invention that distiller **10** maintain a compact arrangement. To accomplish this objective, the flow lines in the distiller **108** are arranged in a horizontal plane, and the fan **120** blows air upward past the condenser unit **108** then out the port **122**. The fan **120** is supported on an intermediate shelf **126** within the housing **14**, and louvers **15** in the bottom of the housing **14** allow air to enter the housing for being discharged upward past the condenser unit **108**. A distiller controller **130** is also provided within the housing **14**, and preferably is a microprocessor-based controller. Conventional **110** volt electrical power may be provided to the distiller **10** through electric cord **129**. Transformer **128** is provided for outputting electrical power at the desired voltage to power the fan **120**, and to provide a reliable source of power for the controller **130**. A power switch **132** is provided on the housing **14** for selectively terminating electrical power to the distiller. An operator powered sterilization switch **134** is also provided for periodically sterilizing the distiller. Light **136** indicates when power to the distiller is on. A total dissolved solids indicator **138** may be turned on by the controller when the level of total dissolved solids water within the heating bowl rises to a preselected value. Other details with respect to a suitable technique for sterilizing the distiller are disclosed in U.S. Pat. No. 5,484,510. For example, a light may also be provided for indicating to the operator that the distiller should be cleaned.

The housing also includes a remote tank sensor plug **140**. Either the tank **112** or another finished water holding tank may be provided at a remote location. The remote tank may be interconnected by conventional condensate flow lines with the tank **112** or directly to the output from the condenser **108**. The plug **140** thus allows the electrical input from the tank probe assembly including a plurality of probes **116** to be input to the controller, so that the condition of the finished water in the remote holding tank may be monitored. Operator selector **142** provides for controlling the distillation rate of the distiller, as explained subsequently.

The controller includes a voltage regulator **144** for providing a desired voltage potential between the heating probes **34** and **36**. Each probe **34** and **36** may thus be maintained at a desired voltage, as explained hereafter, in order to heat the water and generate steam. It is a particular feature of the present invention that the heating probes are not conventional high resistance probes which generate heat which is then transmitted to the water in a manner conventional with distillers. Instead, the heating concept of the

present invention preferably utilizes a voltage potential between probes, so that electrical current is transmitted through the water between the probes, thereby both heating the water and killing microorganisms within the water. Although the distiller of the present invention may be reliably operated with first and second probes as disclosed herein, those skilled in the art will appreciate that additional probes may also be provided. Accordingly, a larger distiller may comprise a pair of probes each at the same voltage potential on one side of the distiller, and a corresponding pair of probes each at another voltage potential on the opposing side of the distiller, so that the current is passed from either of the probes on one side of the distiller to the probes on the other side of the distiller.

FIG. 3 illustrates in greater detail a suitable condenser 108 for cooling the steam and thereby generating the condensate. Condenser 108 includes a plurality of tubes 152, 154, 156, 158, 160, 162 and 164 each preferably having a central axis which lies within a common horizontal plane. Steam from the particle trap 80 is received in the condenser steam inlet 166 of the tube 152, and passes through the tube 152 and through the plastic end cap 168 to the tube 154. End cap 170 is provided for fluidly connecting tubes 154 and 156. End cap 172 fluidly connects tubes 156 and 158, end cap 174 fluidly connects tubes 158 and 160, end cap 176 fluidly connects tubes 160 and 162, and end cap 178 fluidly connects tubes 162 and 164. Condensate or finished water is thus discharged from the outlet 180 of the tube 164, and is then transmitted to the holding tank.

End cap 168 includes a plastic material block 182 with an inlet port and an outlet port sized to receive the ends of the respective tubes 152 and 154. A conventional O-ring 184 provides static sealing engagement between each tube and the plastic material end block. Flow path 186 in the block 182 fluidly connects the inlet port and outlet port in the block. Tubes 152-164 may each be fabricated from stainless steel, and each tube includes a plurality of spaced aluminum fins 188 in thermal contact with each stainless steel tube. FIG. 3 illustrates tubes 152, 154, and 156 each connected to one bank of fins, tubes 158, 160, and 162 connected to another bank of fins, and tube 164 having its own fins. The gaps 189 between the banks of fins facilitate maintaining the steam or condensate within the tubes in one bank of fins at substantially the same temperature, thereby achieving more effective cooling. The first bank of fins may thus operate at a temperature significantly higher than the second bank of fins. Condensation may occur in the tubes connected with the first bank of fins, so that the second bank of fins cools the condensate (water). The third bank of fins may further cool the condensate, so that the user is not exposed to high temperature water. By providing banks of fins separated by an air gap with each bank of fins structurally connected to an upstream or downstream flow line portion of the condenser unit, the required air flow rate from the powered fan is reduced, thereby allowing the distillation unit to operate at a comparatively low noise level. Those skilled in the art will appreciate that additional tubes may be provided for the last bank of fins, and that both the number of tubes in each fin bank and the number of fin banks may be adjusted for a particular application.

Air from the fan 120 thus blows past and between the substantially vertical fins 180 to cool the tubes and thereby generate condensate from the steam input to the condenser. A particular feature of the present invention is the low cost for manufacturing the condenser. The condenser 108 may be easily removed from the housing 14, and the plastic end caps removed so that each tube may be easily cleaned with a brush or similar cleaning tool.

When mounting the distiller 10 below a countertop or cabinet C, a plurality of spacers 190 are used to provide an air flow gap between the lower surface S of the cabinet C and the support plate 32. Suitable connecting members such as bolts (not shown) may thus pass through each of the spacers 190 and structurally interconnect the cabinet C with the support plate 32. Air discharged through the circular hole 122 in the support plate may thus flow in a substantially horizontal direction between the plate 32 and the cabinet C. It is a particular feature of the present invention that the distiller is designed for mounting beneath a cabinet, countertop, or other substantially horizontal support surface, thereby allowing the distiller to be mounted in a variety of locations which have relatively low utility.

Referring to FIG. 4, it should be understood that substantially the same distiller as previously discussed is depicted, but without the spacers 190 so that the distiller may be mounted on a wall or may be self-supporting. Accordingly, the distiller may be provided with a plate-type wall mounting bracket 192 which is simplistically shown on the left side of FIG. 4. The housing 16 and the horizontal support plate 32 may each be provided with connecting slots 194 for mechanically supporting the distiller from tabs 195 extending from the bracket 192. A plurality of holes 197 may be provided in bracket 192 for securing the bracket to a wall with conventional securing bolts (not shown). Various types of mechanical interconnections between the wall mounting bracket and a distiller are possible. Also shown in FIG. 4 is a simplistic support stand 196 on the right side of the housing 12. The support stand 196 may comprise a pair of identical support plates each on one side of the distiller assembly for supporting the distiller on a countertop or other substantially horizontal surface. Connecting slots 194 as previously described may be provided both on the housing 12, the housing 16 and the ends of the plate 32 for engagement with tabs 195 of the opposing support plates. Alternatively, four support legs may be used rather than two support plates for supporting the distiller on the countertop.

The operation of the distiller will now be described, followed by an explanation of periodic maintenance for the distiller. It will be assumed for purposes of this discussion that the distiller 10 has been interconnected with a municipal water system at shutoff valve 64. The distiller 10 may have a maximum condensate output of, for example, 12 gallons per day. At that condensate generation rate, the unit may use 13 amps of 110 volt electrical current. A higher electrical usage would trip a circuit breaker (not shown) within the housing 14, requiring the checking and resetting of the distiller unit. The flow regulator 18 limits water inlet flow to a selected value which is higher than the maximum condensate output rate of the distiller 10, e.g., 1 gallon per hour, thereby limiting flow to the electrically controlled water inlet valve 70.

The operator turns the distiller 10 on by switch 132, and sets the control selector 142 for a desired condensate output. If the distiller is used in a home, the selector 142 normally may be set at a low distillation rate of 6 gallons per day, thereby resulting in slow distillation and little noise generated by the distiller 10. If a party is planned and the holding tank 112 is nearly empty, or if the distiller is used by numerous individuals in an office, the selector 142 may be set at a higher rate of 12 gallons per day. In either case, the distiller will automatically shut down in response to the sensor 116 when the holding tank 112 is full.

In response to the setting of the selector 142, the controller 130 calculates the desired flow rate of water through the valve 70. Preferably the controller 130 is responsive to

various signals other than the setting from the selector **142** to determine the desired water flow rate. Controller **30** may, for example, be responsive to sensors **116** which provide signals indicative of the level of water in the holding tank **112**, since the desired distillation rate will be lower when the tank is nearly full. Also, the controller **130** may be responsive to the level of electrical power last used during the distillation operation at the same setting of selector **142**. Assuming the water **W** in the heating bowl **46** contains an average level of contaminants, the logic within the controller **130** may calculate a theoretical distiller electrical usage of, for example, four amps of power at that setting. If the distiller used only three amps of electrical power during its last operation at that setting, the amount of electrolytes in the water **W** would likely be higher than normal. Accordingly, the controller **130** may reduce the water input rate which, as explained subsequently, will lower the amperage used by the distiller.

A primary feature of this invention is that the controller **130** determines the desired flow rate through the valve **70** to control the distillation rate, rather than regulating electrical power to the distiller to control the distillation rate. Due to heating by applying a voltage potential between the heating probes and using the conductivity of the water to heat the water, the amount of steam generated is not solely a function of the electrical voltage supplied to the heating probes. The level of electrolytes in the water may vary considerably, and this varying conductivity of the water effects the electrical power required to generate steam. Accordingly, the controller **130** may alter the voltage potential output from the voltage regulator **144**, the frequency of electrical current applied to the heating probes **34** and **36**, and the maximum amperage which may be transmitted to the heating probes. The controller **130** primarily regulates the distillation rate, however, by controlling the flow rate of water through the water inlet valve **70**. While this regulation of valve **70** may be accomplished by various techniques, preferably the controller **130** generates a series of pulses, with each pulse activating the valve **70** to allow a preselected quantity of water to pass through the valve with that pulse. The frequency and/or the duration of the pulses thus determines the flow rate through the valve **70**. Six hundred pulses per minute from the controller **130** will result in flow through the valve which is twice the rate when the valve **70** receives 300 pulses per minute. It should be understood that pulsing of the valve **70** occurs very quickly, and accordingly within a time period of several minutes the output from the valve **70** provides a substantially constant flow rate of incoming water to the bowl **46**, rather than pulses of incoming water.

The water level in the bowl is maintained substantially at the same level as the horizontal plates **42** at the end of the probes. The plates **42** are positioned so that there is a relatively low quantity of water, e.g., one-half inch of water, within the bowl **46**. Depending on the level of minerals, contaminants, and electrolytes within the water, the operator may add a small quantity of salt to the water in the bowl **46** to increase the electrolyte level. No power is used until the water level rises to engage the lowermost end of the probes **34** and **36**, since water contact between the probes **34** and **36** is required to transmit power between the varying potential probes. Once the water rises to engage the rod extensions **44** beneath the plates **42**, a small amount of current will flow through the water, thereby beginning the heating of the water. The surface area provided by the rod extensions **44** in contact with the water is relatively low, so that no significant amount of energy is used and little if any steam is generated at this time. The rod extensions **44** are important, however,

since this initial flow of current through the water begins ionization of the water so that ions are held in suspension and readily available for conducting larger amounts of current when the water level rises to engage the plates **42**.

Although the plates **42** are generally horizontal, it should be understood that at least one of the plates **42** at the lower end of the heating probes **34** and **36** will typically be slightly tilted or inclined relative to the horizontal level of water in the heating bowl **46**. Accordingly, as the water level rises above the rod extensions **44**, the contact area of the lowermost surface of that plate **42** increases dramatically with a slight increase in the water level. As the area contact between one or both plates **42** and the water increases, the amount of current which is transmitted between the varying potential probes increases dramatically, thereby heating water and generating steam. This increased generation of steam lowers the water level slightly in the bowl **46**, thereby reducing the area contact between the plates and the water and thus reducing the amperage transmitted between the probes **34** and **36**. Accordingly, the system of the present invention effectively balances the level of water in the bowl **46**, which is a function of the flow rate of the valve **70**, with the power used by the distiller to generate steam. By providing heating probes with horizontal plates **42** each with a large surface area of, for example, three square inches for engagement with the water, a substantially constant water level is obtained in the bowl. In most applications, the water level in the bowl **46** will never rise vertically above the highest point of the lower surface of the plates **42**. It should be understood, however, that if the water level rises above the lower surface of both plates **42** and contacts the upper surface of the plates **42**, the amount of power transmitted between the probes is significantly increased by doubling the area contact of the plates **42** with the water, thereby generating a substantially higher rate of steam generation and lowering the water level in the bowl **46**.

A significant feature of the present invention is that a substantial horizontal spacing is provided between the probes **34** and **36**, and thus between the plates **42** at the lower end of these probes. By utilizing water as a conductive medium for transmitting electrical current through the water and thereby heating the water, the electrical current is used to both heat the water and to kill bacteria and microorganisms within the water, thereby reducing the level of contaminants in the condenser unit **108** and the holding tank **112**. Since the substantial area of water between the plates **42** is heated by the transmitted current, the generated steam slowly rises within a relatively large surface area. Accordingly, there is less chance of contaminants being caught in a column of fast rising steam which commonly occurred when the water was heated by conventional high resistance heating probes used in prior art distillers. Generated steam rises within the chamber **47** within the heating bowl **46**, and preferably a physical separation of at least two inches exists between the top of the water level in the heating bowl and the horizontal trap **80**, so that contaminants have a high probability of dropping back into the heated water before entering the horizontal particle trap. Because the heating bowl **46** is fabricated from plastic materials and because salt can be added to increase the electrolytes in the water, minerals within the water do not tend to attach to the sides of the inner wall **56** of the heating bowl **46**, but rather are desirably kept in suspension in the water.

Steam rising within the chamber **47** enters the horizontal particle trap **80** through the inlet **86**. Due to the effect of steam passing through a relatively small inlet opening **86** and then expanding into the large volume chamber **86**, the

velocity of the steam increases rapidly when passing through inlet port 86, then slows dramatically within the chamber 87. Contaminants within the steam in the chamber 87 are attracted to condensation on the walls of the plates 82 and 84, and are carried back to the water in the heating bowl as condensate accumulating within the horizontal particle trap 82 slowly drips back to the heated water with the bowl 46.

Steam with a very low level of contaminants passes through the bend tube 96 and continues horizontally through the flow tubes within the condenser unit 108. By providing condenser unit 108 with plastic end caps as shown in FIG. 3, the cost of the condenser unit 108 is substantially reduced. The plastic end caps fluidly interconnecting the stainless steel tubes of the condenser unit 108 also tend to reduce the noise output by the distiller. The distilled condensate then flows to the holding tank 112. Both the water level and the totally dissolved solids level of the condensate within holding tank 112 be monitored by the sensors 116. As previously indicated, the water in the holding tank 112 may be cooled to a desired temperature by the thermal cap unit 113.

When steam is being generated in the heating bowl 46, the controller 130 may automatically activate the fan 120 to pass air upward between the fins of the condenser unit 108, then out the hole 122 in the top support plate 32. This powered upward movement of air by the fan 120 will slightly raise the flap 104, thereby lifting the stopper 102 off its seat and allowing for venting of gasses from the flow line upstream from the condenser unit. The controller 130 will terminate power to the fan 120 when the flow through the water inlet valve and the voltage potential between the heating probes 34 and 36 are simultaneously terminated, thereby allowing the stopper 102 to reseat and automatically resealing the bend flow line 96.

Periodic maintenance of the distiller 10 will enhance its useful life and desirably keep the level of dissolved solids in the holding tank 112 at a satisfactory level. To perform periodic maintenance, the operator will first terminate electrical power to the distiller at switch 132. The ring 48 on the housing 12 and the flange 50 on the holding tank 46 may provide a mechanical interlock to physically prevent removal of the holding tank 46 until the temperature of the holding tank 46, and thus the temperature of water in the heating bowl 46, is reduced to a desired value for safe handling of the heating bowl. This mechanical interlock may be accomplished, for example, by providing a timed solenoid which retracts a stop (not shown) only after the switch 132 has been deactivated for a selected period of time. Until the solenoid retracts the stop, the stop thus physically prevents removal of the heating bowl 46 from the ring 48. The mechanical interlock 48 may also be designed to physically prevent removal of the heating bowl 46 unless switch 132 is activated to terminate electrical power to the distiller 10. Alternatively, the material for the outer layer 54 of the heating bowl 46, the flange 50, and the ring 48 may be selected so that the thermal expansion of these components mechanically prevents removal of the heating bowl 46 until the heating bowl has cooled to a selected value. After the water within the heating bowl 46 cools to a safe value, the thermal contraction of these component allows for the safe removal of the heating bowl.

It is a particular feature of the present invention that the heating bowl 46 may be easily removed for cleaning operations by simply disconnecting the heating bowl 46 from the housing 12, then lowering the heating bowl, as shown in FIG. 2, with the heating probes 34 and 36 remaining attached to the housing 12. The remaining water in the heating bowl 46 may be dumped, and the interior plastic

wall 56 of the heating bowl easily wiped cleaned. If desired, the entire heating bowl 46 may be placed in a dishwasher for periodic cleaning. With the heating bowl 46 removed, the water inlet tube 76 may be pulled downward off the seal 78 at the lower end of the bend tube 74. Tube 76 may also be brushed clean to remove any deposits on the interior surface of the tube 76. Heating probes 34 and 36 may also be inspected, but normally would not be removed.

Less frequently, the condensing unit 108 and the holding tank 112 may be removed and periodically cleaned. To clean the condensing unit 108, the housing 14 may be disconnected from both the support plate 32 and the housings 12 and 16, so that the controller 130 and the fan 120 may be lowered as a subassembly with the housing 14. The horizontal lines 106 and 110 may be disconnected from the condenser 108, and the entire condenser unit 108 as shown in FIG. 3 removed for cleaning. During cleaning of the condenser unit, the plastic end caps may be easily removed from the respective stainless steel flow lines, and the interior of the flow lines brushed clean. The holding tank 112 may be removed from the support plate 32 and cleaned in a conventional manner. The condenser unit 108 and the holding tank 112 may then be reinstalled to their position as shown in FIG. 1.

Once cleaned, the water inlet tube 76 may be returned to its position as shown in FIG. 1, and the bowl 46 re-connected to the housing 12. An electrical interlock 51 is provided, as shown in FIG. 1, for preventing electrical power from being reapplied to the distiller until a signal from electrical interlock 51 to the controller 130 indicates that the bowl 46 is in its proper position with respect to the housing 12. Thus electrical voltage potential cannot be applied between the probes 34 and 36 when the heating bowl 46 is removed from the housing 12, even if the operator accidentally turns the switch 132 back on.

When the cleaned bowl 46 has been replaced on the housing 12, a small amount of salt may be added to the bowl so that the desired level of electrolytes will be present in the incoming water when the distiller unit is turned on. The distiller 10 as described herein may include a plurality of probes 94 within the heating bowl 46 for measuring the total dissolved solids level of the water in the heating bowl. This measurement may be accomplished in a manner described in U.S. Pat. No. 5,484,510. Also, the process of sterilizing the distiller as described in that patent may be used to intermittently sterilize the distiller according to the present invention.

Those skilled in the art should understand that the arrangement of housings supported on the plate 32 as described herein is preferred, although other arrangements are possible. Rather than being placed side-by-side, one or more of the heater housing, the fan and control housing, and the holding tank housing could be placed behind another housing. It is a particular feature of the invention, however, that the steam flowing out the particle trap remain substantially within a horizontal plane until condensate is formed, which may then flow by gravity to the holding tank.

In other embodiments, the cost of the distiller may be further reduced by eliminating the control circuit. Rather than being connected to a pressurized water input line, the distiller may include an upper reservoir for periodic filling by the operator in a manner similar to a conventional coffee maker. A control valve along a gravity line interconnecting the fill reservoir with the bowl 46 may be manually set at a flow rate for dripping incoming water into the bowl. The control valve may be manually set at any desired flow rate,

although the maximum flow rate through the control valve will preferably nevertheless result in the water level in the bowl not rising above the level of the plates 42. The power to the heating probes thus maintains the substantially constant water level in the bowl, as previously discussed. The more economical distiller will likely be self-supporting, and preferably uses a particle trap and a condenser as disclosed herein to reduce contamination. The distiller is also designed for easy cleaning by utilizing an easy removal heating bowl, a removable water inlet tube, and an easy cleaning condenser unit. The fill tank may also be structurally separate from the distiller, so that the user pours contaminate water into the distiller, sets the control valve at a desired flow rate, then places a suitable container under the water outlet from the distiller for receiving the condensate.

The distiller 10 according to this invention is light weight and may be manufactured at a relatively low cost. The extensive use of plastic materials, particularly for the heating bowl, the particle trap, and the end caps of the condenser unit reduce cost and weight, and allow for easy cleaning of the distiller. It should thus be appreciated that various changes in the specifics of construction and distiller operation as disclosed above may be made while still achieving the purposes and objects of this invention.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof, and it will be appreciated by those skilled in the art that various changes in the size, shape and materials, as well as in the details of the illustrated construction or combinations of features of the various elements may be made without departing from the spirit of the invention, which is defined by the following claims.

What is claimed is:

1. A distiller for heating incoming water and generating condensate from steam, the distiller comprising:
 - a heater housing including a top plate and a side plate forming an inverted cup defining an interior cavity therein;
 - first and second heating probes each secured at an upper end within the interior cavity in the heater housing and extending downward therefrom;
 - an electrically non-conductive heating bowl positioned about the first and second heating probes, an upper end of the heating bowl being configured for removable sealing engagement with the heater housing;
 - a water inlet flow line for transmitting incoming water to the heating bowl;
 - a power unit for applying a voltage potential between the first and second heater probes to transmit current through water in the heating bowl and thereby heat the water to generate steam;
 - a condenser unit for receiving the generated steam and outputting condensate;
 - a powered fan for blowing air past the condenser unit;
 - a support plate for supporting the heater housing, the first and second probes, the heating bowl, and the condensing unit each positioned below the support plate, the support plate including an air flow port therein opposite the condenser unit with respect to the powered fan; and
 - a holding tank for receiving condensate from the condenser unit.
2. The distiller as defined in claim 1, further comprising: the holding tank supported by and positioned below the support plate, the condenser unit being positioned horizontally between the heating bowl and the holding tank; and

a plurality of spacers for positioning between the support plate and a mounting surface, the plurality of spacers forming a planar air gap above the support plate for discharging air passing through the air flow port in the support plate.

3. The distiller as defined in claim 1, further comprising: a vent valve positioned along a steam flow line upstream from the condenser unit for venting gas from the distiller; and

a flap movably responsive to the flow of air past the condenser unit by the powered fan for opening and closing the vent valve.

4. The distiller as defined in claim 1, further comprising: a particle trap within the heater housing, the particle trap having a lower substantially horizontal plate with a steam inlet opening, an upper substantially horizontal plate with a steam outlet opening, the steam outlet opening being spaced horizontal from the steam inlet opening, a substantially planar gap between the first and second plates for steam flow between the inlet opening and the outlet opening, and at least one drip opening in the lower plate for dripping contaminant-containing condensate to the water in the heating bowl.

5. The distiller as defined in claim 1, further comprising: an electrical interlock responsive to the position of the heating bowl with respect to the heater housing for automatically terminating electrical power from the power unit to the first and second heater probes when the heating bowl is removed from the heater housing.

6. A distiller for heating incoming water and generating condensate, the distiller comprising:

a heater housing defining an interior cavity therein; first and second heating probes each secured at an upper end within the interior cavity in the heater housing and extending downward therefrom, each heating probe including a plate portion at a lower end thereof;

a heating bowl positioned about the first and second heating probes, an upper end of the heating bowl being configured for removable sealing engagement with the heater housing;

a water inlet flow line for transmitting incoming water to the heating bowl;

an inlet water valve along the water inlet flow line for controlling the flow rate of water to the heating bowl;

a particle trap within the heater housing the particle trap having a lower substantially horizontal plate with a steam inlet opening, an upper substantially horizontal plate with a steam outlet opening and spaced horizontal from the steam inlet opening, and a substantially planar gap between the first and second plates for steam flow between the inlet opening and the outlet opening;

a power unit for applying a voltage potential between the first and second heater probes to transmit current through water in the heating bowl and thereby heat the water to generate steam; and

a condenser unit for receiving the generated steam and outputting condensate.

7. The distiller as defined in claim 6, further comprising: a water inlet tube having an upper end removably positioned within the heater housing and fluidly connected to the water inlet flow line for transmitting incoming water from the heater housing to a lower end of the heating bowl.

8. The distiller as defined in claim 6, further comprising: a vent valve positioned along a steam flow line upstream from the condensing unit for venting as from the distiller;

the condenser unit includes a plurality of banks of fins, a first bank of fins being structurally connected to a first upstream flow line portion of the condenser unit and structurally separate from a second flow line portion of the condenser unit, and a second bank of fins being structurally connected to the second flow line portion of the condenser unit downstream from the first upstream flow line portion and structurally separate from the first flow line portion of the condenser unit;

a powered fan for blowing air past the condenser unit; and

a flap movably responsive to the flow of air past the condensing unit by the powered fan for opening and closing the vent valve.

9. A distiller for heating incoming water and generating condensate, the distiller comprising:

a heater housing defining an interior cavity therein;

first and second heating probes each secured at an upper end within the interior cavity in the heater housing and extending downward therefrom;

a heating bowl positioned about the first and second heating probes, an upper end of the heating bowl being configured for removable sealing engagement with the heater housing;

a water inlet flow line for transmitting incoming water to the heating bowl;

an inlet water valve along the water inlet flow line for controlling the flow rate of water to the heating bowl;

a power unit for applying a voltage potential between the first and second heater probes to transmit current through water in the heating bowl and thereby heat the water to generate steam;

a condenser unit for receiving the generated steam and outputting condensate;

a vent valve positioned along a steam flow line upstream from the condenser unit for venting gas from the distiller; and

a flap movably responsive to flow of air past the condenser unit for opening and closing the vent valve.

10. The distiller as defined in claim 9, wherein the condenser unit comprises:

a plurality of banks of fins, a first bank of fins being structurally connected to a first upstream flow line portion of the condenser unit and structurally separate from a second flow line portion of the condenser unit, and a second bank of fins being structurally connected to the second flow line portion of the condenser unit downstream from the first upstream flow line portion and structurally separate from the first flow line portion of the condenser unit.

11. The distiller as defined in claim 9, wherein each of the heating probes further comprises:

a plate portion at a lower end of each heating probe, the plate portion lying within a plane substantially parallel to an upper surface of the water in the heating bowl.

12. A distiller for heating incoming water and generating condensate, the distiller comprising:

a heater housing defining an interior cavity therein;

first and second heating probes each secured at an upper end within the interior cavity in the heater housing and extending downward therefrom;

a heating bowl positioned about the first and second heating probes, an upper end of the heating bowl being

configured for removable sealing engagement with the heater housing;

a water inlet flow line for transmitting incoming water to the heating bowl;

an inlet water valve along the water inlet flow line for controlling the flow rate of water to the heating bowl;

an electrical interlock responsive to the position of the heating bowl with respect to the heater housing for automatically terminating electrical power to the first and second heater probes when the heating bowl is removed from the heater housing;

a power unit for applying a voltage potential between the first and second heater probes to transmit current through water in the heating bowl and thereby heat the water to generate steam; and

a condenser unit for receiving the generated steam and outputting condensate.

13. The distiller as defined in claim 12, further comprising:

a flow controller upstream from the inlet water valve for controlling the flow rate of the water to the inlet water valve.

14. The distiller as defined in claim 12, further comprising:

a water inlet tube having an upper end removably positioned within the heater housing and fluidly connected to the water inlet flow line for transmitting incoming water from the heater housing to a lower end of the heating bowl.

15. The distiller as defined in claim 12, further comprising:

a vent valve positioned along a steam flow line upstream from the condensing unit for venting gas from the distiller; and

a flap movably responsive to flow of air past the condensing unit for opening and closing the vent valve.

16. A method of controlling the operation of a water distiller comprising: providing first and second heating probes, a heating bowl positioned about the first and second heating probes for receiving incoming water from a water inlet flow line, a power unit for applying a voltage potential between the first and second heater probes, a condenser unit for receiving the generated steam and outputting condensate, and a substantially horizontal plate at a lower end of each heating probe in said water distiller;

positioning an inlet water valve along the inlet flow line;

controlling the water inlet valve to regulate the flow rate of water to the heating bowl;

positioning a vent valve along a steam flow line upstream from the condenser unit for venting gas from the distiller;

powering a fan to move air past the condenser unit;

positioning a flap movably responsive to the flow of air past the condenser unit by the powered fan for automatically opening and closing the vent valve;

activating the power unit as a function of the area contact between the horizontal plates and the water in the heating bowl to maintain a substantially constant level of water in the heating bowl; and

transmitting current through water in the heating bowl and thereby heat the water to generate steam.

17. The method as defined in claim 16, further comprising:

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providing a flow controller upstream from the inlet water valve for controlling the flow rate of water to the inlet water valve.

18. The method as defined in claim **16**, further comprising:
5 automatically terminating electrical power from the power unit to the first and second heater probes when the heating bowl is removed from the heater housing.

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19. The method as defined in claim **16**, further comprising:

removably positioning a water inlet tube within the heating bowl and fluidly connected to the water inlet flow line for transmitting incoming water from the inlet flow line to a lower end of the heating bowl.

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(12) **United States Patent**
Samsonov et al.

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(45) **Date of Patent:** **Jul. 10, 2001**

(54) **SYSTEM AND A ROTARY VACUUM DISTILLER FOR WATER RECOVERY FROM AQUEOUS SOLUTIONS, PREFERABLY FROM URINE ABOARD SPACECRAFT**

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(52) **U.S. Cl.** **202/176; 4/114.1; 4/144.1; 4/459; 159/16.1; 159/901; 159/905; 159/DIG. 8; 202/197; 202/200; 202/202; 202/205; 202/238; 203/10; 203/40; 203/41; 203/49; 203/91; 203/DIG. 4; 203/DIG. 5; 203/100; 210/645; 210/766; 210/767**

(58) **Field of Search** **202/176, 205, 202/202, 238, 197, 200, 172; 203/10, 11, 49, 91, 41, 46, DIG. 4, DIG. 5, 100; 159/901, 905, DIG. 8, DIG. 42, 28.6, 16.1; 210/645, 767, 763, 766, 765, 762; 4/114.1, 144.1, 459**

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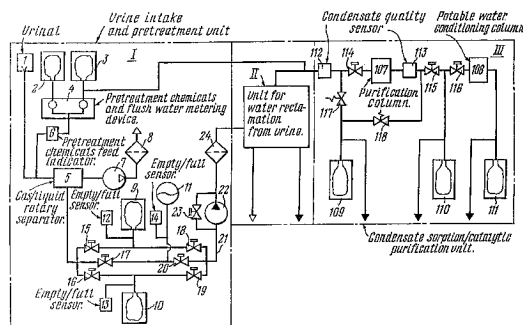
Primary Examiner—Virginia Manoharan

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(57) **ABSTRACT**

The system for the recovery of water from urine aboard spacecraft includes a urine intake and pretreatment unit, a unit for water reclamation from urine and a condensate purification unit. The unit for water reclamation from urine is made on the basis of a rotary multistage vacuum distiller, each stage of which is formed by at least one heat-transfer plate and comprises an evaporation zone and a condensation zone. The stages of the distiller are separated from each other by separation plates, a chamber for collecting condensate and noncondensable gases being disposed downstream of the last stage and communicated with all the condensation zones of all the stages through water seals of condensate overflow and openings for the removal of noncondensable gases in disks mounted in the condensation zones. The distiller also includes a loop for circulation of the aqueous solution being evaporated, a device for supplying heat to the first stage and removing heat from the last stage, and lines for discharging condensate, noncondensable gases, and concentrate of the aqueous solution being evaporated.

30 Claims, 5 Drawing Sheets



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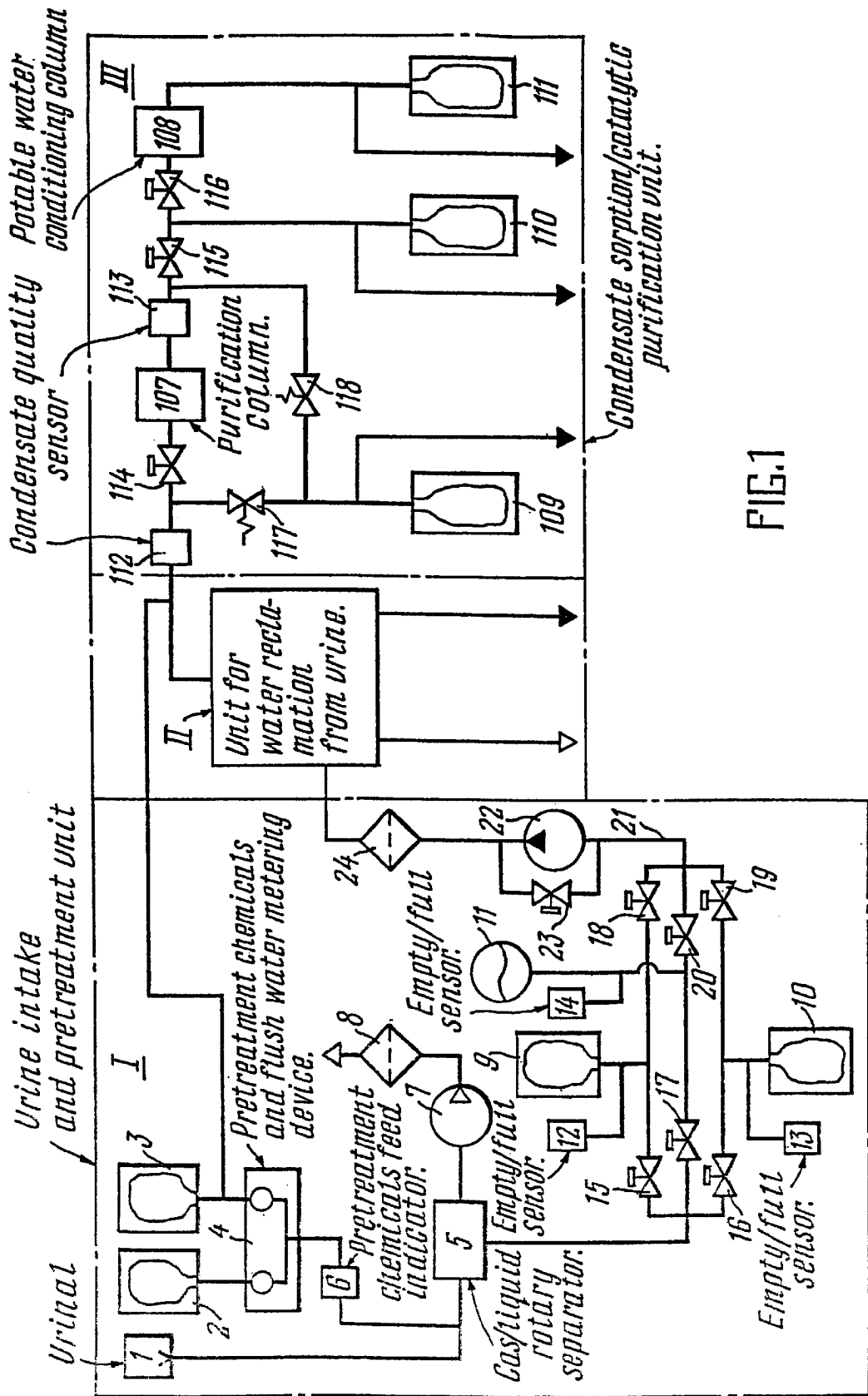


FIG. 1

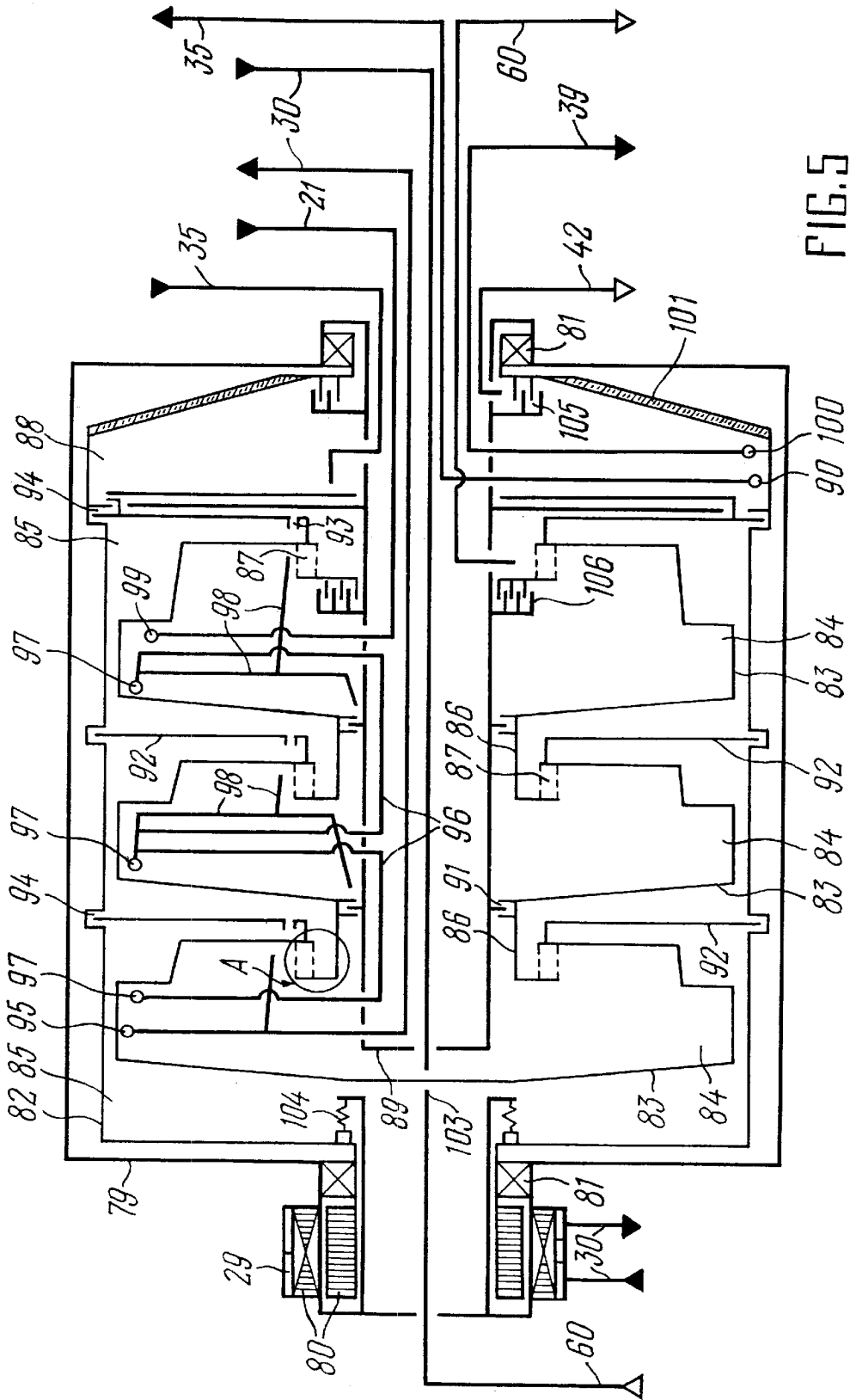


FIG. 5

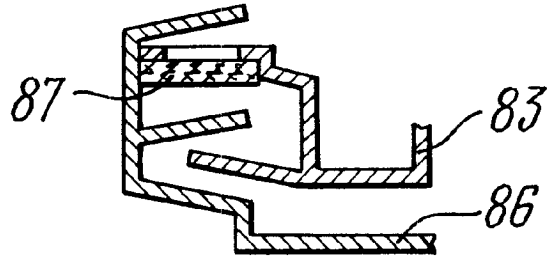


FIG. 6

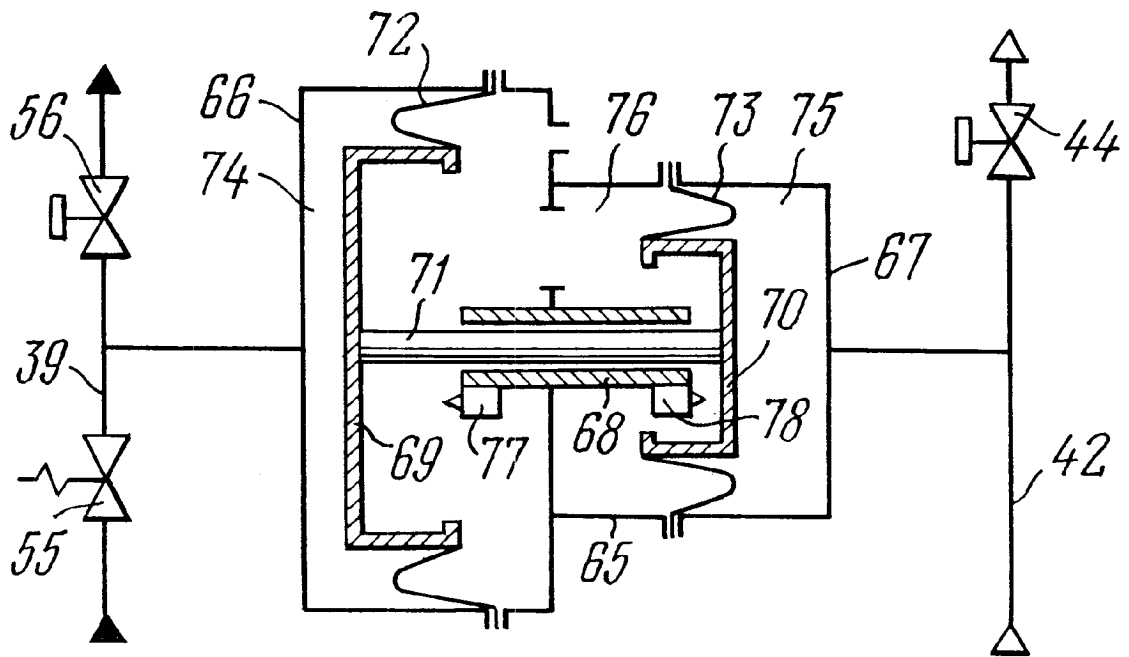


FIG. 7

**SYSTEM AND A ROTARY VACUUM
DISTILLER FOR WATER RECOVERY FROM
AQUEOUS SOLUTIONS, PREFERABLY
FROM URINE ABOARD SPACECRAFT**

TECHNICAL FIELD

The present invention relates to life-support systems of spacecraft and space stations, and more particularly to systems of water recovery from aqueous solutions, preferably from pretreated urine and other aqueous human waste of the crew, and also to a rotary vacuum distiller for water recovery from aqueous solutions.

BACKGROUND ART

Known in the art is a system for water recovery from water-containing waste, particularly from urine, comprising a urine intake and storage unit, a urine and flush water pretreatment unit, a unit for water reclamation from urine [Lawrence D. Noble, Jr., Franz H. Schubert, and Robert P. Werner, "An Update of the Readiness of Vapor Compression Distillation for Spacecraft Wastewater Processing", 22-nd International Conference on Environmental Systems, Seattle, 13-14 July, 1992, No. 921114].

The unit for water reclamation from urine comprises: a distillation assembly, a liquid pump assembly, a vacuum pump, fluids control and pressure control assemblies, a recycle filter tank assembly, built-in control instruments.

The distillation assembly is designed as a rotary lobe compressor with a temperature sensor, a centrifuge consisting of an evaporator and a condenser separated by a thin wall, a liquid level sensor and a centrifuge speed sensor. The distillation assembly includes an electric motor coupled directly to the compressor by a magnetic coupling and to the centrifuge through a reduction gear. The electric motor has an integral cooling jacket and an electric motor speed sensor.

The fluids pump assembly is a four-tube peristaltic pump, one tube of which is used to pump urine to the distiller, two tubes are utilized to pump the concentrate from the distiller, and the last tube is used to pump the distillate (condensate). The interior of the pump housing is under vacuum.

The vacuum pump is intended for the removal of non-condensable gases and vapor from the distillation assembly and is designed as a four-tube peristaltic pump provided with a cooling jacket that causes the noncondensable gases and vapor to be cooled down.

In the known system, pretreated urine is supplied from the urine intake and storage unit to the circulation loop of the unit for water reclamation from urine, where the urine circulates through a filtering tank which is simultaneously a concentrate tank, until a required degree of water recovery from urine is reached, the circulating urine being delivered to one of the sides of the rotating heat-transfer surface of the centrifuge, where the urine is heated and water is evaporated therefrom in an amount corresponding to the heat input. The urine distillation process is carried out under vacuum. Water vapors are pumped out, pressurized by the compressor thereby increasing their pressure, and delivered to the other side of said rotating heat-transfer surface, where the water vapors are condensed and the condensation heat heats the urine obtained at the opposite side of said surface. The resulting condensate is pumped through a condensate quality monitoring sensor and supplied for subsequent use.

The disadvantages of the known system are as follows: a high power consumption of the vapor compressor, governed by the distiller throughput capacity; a reduction in the

distiller throughput capacity with an increase in the concentration of the solution being evaporated, this leading to a longer time of the system operation and to its greater power consumption; the presence of special peristaltic pumps for pumping urine at the distiller inlet and outlet, which increases the mass and power consumption of the system and decreases the reliability of its operation.

Also known in the art is a multistage distiller for preparing fresh water from sea water, comprising a rotatably mounted vertical hollow rotor, an electric motor, heat-transfer plates made from a metal with a high thermal conductivity and annular partitions arranged alternately in the rotor, annular heat insulation gaskets separating them. The plates, partitions and gaskets constitute distillation stages with evaporation and condensation surfaces and concentrate- and condensate-collecting chambers arranged at the periphery, separated by annular partitions. The distiller is also provided with a preheating heat-exchanger with separate channels for sea water, condensate and concentrate circulation, arranged over the edges of the distillation stages, the channels for sea water circulation being connected at the inlet in parallel with vertical sea water distribution collectors (risers), and at the outlet—with the evaporation surfaces of the distillation stages, whereas the concentrate and condensate channels are connected in parallel at the inlet to the concentrate- and condensate-collecting chambers, respectively, and at the outlet—to the concentrate—and condensate-tanks coupled to means for discharging said fluids.

In the distillation stages (except the first and the last ones) the evaporation surface is the upper side of the preceding stage plate, and the condensation surface is the lower side of the subsequent stage plate; the first distillation stage has no evaporation surface and is provided with an inlet branch pipe for heating vapor, the last stage is connected to a vacuum line for the removal of noncondensable gases and provided with a coil which serves as the condensation surface. The inlet of the coil is connected to the sea water feeding means, and the outlet of the coil is connected to sea-water tanks. [Richard L. Clark and LeRoy A. Bromley, "Saline water conversion by multiple-effect rotating evaporator", Chemical Engineering Progress, vol. 57, No. 1, pp. 64-70].

Vapor is fed to the lower plate, providing heat supply for evaporation. A low pressure (vacuum) is set up at the upper (the coldest) plate to provide the necessary temperature gradient. The liquid to be processed, supplied to the distiller (in the present case, sea water), after heating owing to condensation of vapor from the upper plate at the coil, comes to the preheating heat-exchanger, in which each of the flows is heated to a temperature close to the evaporation temperatures on the plates, and then parallel flows of the liquid being processed is directed to the center of the plates.

Up to 50% of the feed liquid is evaporated as it gradually flows along the plates in the form of a thin film, whereby an intensive heat transfer is ensured. Vapor is condensed on the bottom (lower) surface of the higher-located plates. The condensate and concentrate flow toward the external edge of the plates under the effect of centrifugal forces to the concentrate- and condensate-collecting chambers, respectively, while the partitions separating the chambers preclude mixing of the concentrate and condensate. These latter flow down to the preheating heat-exchanger, providing heating of the feed liquid to be processed. Further, the concentrate and condensate are removed from the distiller.

The presence of the heat-exchanger for preheating the liquid to be processed makes the distiller design more complicated and increases the mass of the distiller.

The known distiller is also disadvantageous in that in the case of its shutdown under zero gravity conditions the liquid being processed will be carried over to the condensate, and this may lead to deterioration of the quality of the processed water.

As the degree of the liquid evaporation is increased to meet space requirements, the total temperature gradient will rise due to an increase of temperature depression; this will add to the power consumption and a decline in the overall efficiency of the distiller.

Furthermore, from RU, A, 2046080, there is known a system for water recovery from urine aboard spacecraft, comprising a urine intake and pretreatment unit, a unit for water reclamation from urine, a reclaimed water sorption/catalytic purification unit, all said units being connected in series. The urine intake and pretreatment unit comprises a means for storage and delivery of pretreatment chemicals and flush water, a gas-liquid separator for separating transport air from urine, a pretreatment chemicals feed indicator, an intermediate tank of separated urine, which is designed as three elastic containers separated from each other, each of said containers being provided with an empty/full sensor and solenoid valves, and a urine feed line. The unit for water reclamation from urine comprises a urine evaporation apparatus provided with a urine circulation loop with a urine heating means, a brine tank connected through a solenoid control valve to the urine circulation loop, a condenser (cooling heat-exchanger), a condensate purge line provided with a condensate intermediate tank with a condensate discharge pump, a line for the removal of humid noncondensable gases, comprising a separator. The reclaimed water sorption/catalytic purification unit is constituted by two columns, one of the columns containing a catalyst and a sorbent arranged in beds and the other containing granular polymeric salt carriers; said unit also comprises a water collection and storage tank, water quality monitoring sensors and solenoid valves.

The urine evaporation unit of the known recovery system is designed as an evaporator provided with an evaporation partition consisting of capillary-porous polymeric semi-permeable membranes, this partition dividing the evaporator into a urine zone through which the liquid flow is passed and an air zone, the air circulating in an independent closed air loop. Evaporation of the urine occurs at atmospheric pressure, whereas making-up with fresh pretreated urine with flush water occurs due to a vacuum generated in the urine loop as the urine is gradually evaporated.

The urine circulation loop comprises a urine circulation pump, a urine electric heater, an air-separating and storing filter, a solenoid valve.

The air circulation loop comprises a condenser, a separator with porous elements, an air blower, and a moisture trap.

The disadvantages of the known system for water recovery from urine are as follows: a low intensity of the evaporation and condensation processes at atmospheric pressure and, consequently, a need in large evaporation and condensation surfaces, this leading to an increase in the mass of equipment; a decrease of the evaporation rate and a deterioration of the condensate quality because of gradual clogging of the capillary-porous membranes and loss of their selective permeability, and, consequently, a reduction in the service life of the evaporator and of the column of the condensate sorption/catalytic purification unit, this leading to an increase of the spare units; absence of the condensation heat recuperation, leading to high power consumption.

Likewise known in the art is a rotary vacuum distiller for water recovery from aqueous solutions, particularly from saline water {U.S. Pat. No. 3,200,050}, which comprises a casing, an electric motor, a hollow rotor rotatably mounted in the casing, heat-transfer plates secured to the rotor, forming a zone of evaporation of the liquid being processed and a zone of condensation, a separating unit which separates the evaporation and condensation zones, devices for distributing the liquid being processed, a circulation loop for the liquid being processed with a means for heating said liquid, a line for feeding the liquid to be processed and a line for discharging condensate, noncondensable gases and concentrate.

The zone of evaporation of the liquid being processed is shaped by the exterior surfaces of inclined heat-transfer plates, and the zone of condensation is formed by the interior surfaces of said plates and by the walls of the rotor.

The separating unit which separates the evaporation and condensation zones is designed as a cylinder with a louver and a compressor installed below said cylinder.

The throughput capacity of the distiller is sufficiently high, but it is not intended for providing a high coefficient of water recovery, and therefore it is not suitable for operating in space, where a high degree of water recovery is required.

Moreover, feeding the liquid to be processed and evaporated to the evaporation surfaces, discharging the concentrate and condensate from the distiller, are feasible only in the presence of gravitation and with a vertical arrangement of the apparatus.

The overall dimensions, mass and power consumption of the distiller do not meet the requirements set for space hardware.

SUMMARY OF THE INVENTION

An object of the present invention is to raise the effectiveness of water recovery from urine aboard the space station.

It is another object of the present invention to reduce the mass and overall dimensions of the urine recovery system.

It is still another object of the invention to decrease the power consumption of the unit for water recovery from urine.

It is yet another object of the invention to reduce the power consumption of the system for water recovery from urine.

These and other objects are accomplished by that according to one aspect the invention consists in that the system for water recovery from urine aboard spacecraft comprises:

- a urine intake and pretreatment unit comprising:
 - a urinal adapted to receive urine forced to be moved by a stream of transport air, having an outlet;
 - a separator for separating the transport air from said urine, having an inlet connected to said outlet of the urinal, and an outlet,
 - a means for storing and feeding pretreatment chemicals, having an outlet connected to said inlet of said separator,
 - a tank for separated urine, connected to said outlet of said separator,
 - a unit for water reclamation from urine arranged to follow the technological process downstream of said urine intake and pretreatment unit, communicated therewith by a urine feed line and comprising:
 - an apparatus for evaporating the separated urine, designed as a rotary vacuum distiller having a rotary drive and

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comprising at least a first stage and a last stage arranged successively and coaxially and having each an evaporation surface and a condensation surface and a condensate collection chamber, communicated with all said condensation surfaces,

a urine circulation loop coupled to said first stage and provided with a heating means,

a urine brine tank connected through a controlled valve to said urine circulation loop,

a condensate circulation loop coupled to said condensate collection chamber and provided with a cooling means,

a line for the removal of noncondensable gases, coupled to the central part of said condensate collection chamber,

a line for discharging condensate, coupled to the peripheral part of said condensate collection chamber,

a unit for purifying said condensate to water grade recovered from urine is produced, having an inlet to which said line for discharging condensate is coupled.

In a preferred embodiment, the unit for purifying condensate comprises a first column with at least two beds arranged lengthwise of the column: a catalyst bed and a sorbent bed, said first column having an outlet, and a second column arranged successively downstream said condensate being purified, said second column being filled with granular polymeric carriers of salts and having an outlet, a first water tank and a second water tank, arranged each at the outlet of said first and second columns, respectively, as well as a first condensate quality monitoring sensor and a second condensate quality monitoring sensor, arranged at the inlet and at the outlet of said first column and having each its own outlet, a tank for off-spec. water, coupled to said outlets of said sensors.

In another preferred embodiment, the recovery system additionally comprises a pump and a filter for removing particulates, installed into said urine feed line.

It is expedient to additionally provide the recovery system with a unit for pumping out said condensate, comprising a condensate intermediate tank and a pump for pumping out said condensate, connected in series, which unit should be installed into said line for discharging condensate upstream of said inlet to said purification unit.

It is desirable that said condensate intermediate tank should comprise a hollow casing, a first piston and a second piston of a different diameter interconnected by a rigid rod and arranged in said casing with a possibility of moving toward said rod, a first leakproof chamber formed by the surface of the first piston of a larger diameter and the opposite wall of said casing, said first leakproof chamber being communicated with said line for discharging condensate, a second leakproof chamber shaped by the surface of said second piston of a smaller diameter and the opposite wall of said casing, said second leakproof chamber being connected to said line for the removal of noncondensable gases, and a third leakproof chamber formed by the surfaces of said first and second pistons, facing each other, said third leakproof chamber communicating with the atmosphere.

Said means for heating said urine circulation loop can be made as an electric heater.

In another embodiment said means for heating said urine circulation loop can be made as a thermoelectric heat pump connected to said condensate circulation loop for the heat input to said urine circulation loop.

It is preferable that said rotary drive of the rotary distiller should be an electric motor provided with a heat exchanger

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having a heated side and a heating side and be coupled with its heated side to said electric motor and with its heating side to said urine circulation loop.

It is expedient that said line for removal of humid non-condensable gases should comprise arranged in series: a receiver made as an elastic container mounted in a rigid casing, the space between the elastic container and the receiver casing accommodating a vacuum pump and an air blower coupled through alternately activated controlled valves, said vacuum pump and air blower being connected in parallel, a condensed moisture separator and a condensate tank.

According to a second aspect of the invention, the system for water recovery from urine aboard spacecraft comprises:

a urine intake and pretreatment unit comprising:

a urinal adapted to receive urine forced to be moved by a stream of transport air, having an outlet;

a separator for separating the transport air from said urine, having an inlet connected to said outlet of the urinal, and an outlet,

a means for storing and feeding pretreatment chemicals, having an outlet connected to said inlet of said separator,

a tank for separated urine, connected to said outlet of said separator,

a unit for water reclamation from urine arranged to follow the technological process downstream of said urine intake and pretreatment unit, communicated therewith by a urine feed line and comprising:

an apparatus for evaporating the separated urine, designed as a rotary vacuum distiller having a rotary drive and comprising at least a first stage and a last stage arranged successively and coaxially and having each an evaporation and condensation surface and a condensate collection chamber, communicated with all said condensation surfaces,

a urine circulation loop coupled to said first stage and provided with a heating means,

a urine brine tank connected through a controlled valve to said urine circulation loop,

a vapor circulation loop for vapor extracted from said last stage of said rotary distiller and delivered to the condensation surface of said first stage, a heat pump made as a vapor compressor being installed into said loop,

a condensate circulation loop coupled to said condensate collection chamber,

a line for the removal of noncondensable gases, coupled to the central part of said condensate collection chamber,

a line for discharging condensate, coupled to the peripheral part of said condensate collection chamber,

a unit for purifying said condensate to water grade recovered from urine, having an inlet to which said line for discharging condensate is coupled.

In the preferred embodiment said compressor has an electric motor provided with a heat exchanger having a heated side and a heating side and being coupled with its heated side to said electric motor and with its heating side to said urine circulation loop.

It is desirable that said rotary drive of the rotary distiller should be an electric motor provided with a heat exchanger having a heated side and a heating side and be coupled with its heated side to said electric motor and with its heating side to said urine circulation loop.

It is also desirable that said recovery system should additionally comprise a cooling means installed in the condensate circulation loop.

Furthermore, it is desirable that said recovery system should additionally comprise a unit for discharging said condensate, comprising a condensate intermediate tank and a pump for pumping out said condensate, connected in series, said unit being installed in said line for discharging condensate upstream of said inlet to said purification unit.

It is desirable that said condensate intermediate tank should comprise a hollow casing, a first piston and a second piston of a different diameter interconnected by a rigid rod and arranged in said casing with a possibility of moving toward said rod, a first leakproof chamber shaped by the surface of the first piston of a larger diameter and the opposite wall of said casing, said first leakproof chamber being communicated with said line for discharging condensate, a second leakproof chamber formed by the surface of said second piston of a smaller diameter and the opposite wall of said casing, said second leakproof chamber being connected to said line for the removal of noncondensable gases, and a third leakproof chamber shaped by the surfaces of said first and second pistons, facing each other, said third leakproof chamber communicating with the atmosphere.

In a preferred embodiment the line for the removal of humid noncondensable gases should comprise arranged in series: a receiver made as an elastic tank mounted in a rigid casing, the space between the elastic tank and the receiver casing accommodating a vacuum pump and an air blower coupled through alternately activated controlled valves, said vacuum pump and air blower being connected in parallel, a condensed moisture separator and a condensate tank.

According to a third aspect of the invention, the rotary vacuum distiller for water recovery from aqueous solutions, preferably from urine aboard spacecraft, comprises:

- a casing;
- a hollow rotor rotatably mounted in said casing,
- a rotary electric motor for said rotor;
- at least two stages, a first stage and a last stage, arranged successively and coaxially in said rotor with the possibility of rotating therewith;
- each of said stages being formed by at least one heat-transfer plate whose one side is an evaporation surface and the opposite side is a condensation surface;
- separation plates whose number corresponds to the number of said stages of the distiller, arranged in said rotor coaxially therewith in succession behind each of said heat-transfer plates;
- condensation zones formed between said condensation surfaces of the heat-transfer plates and separated from said evaporation zones by said separation plates;
- water seals for precluding vapor overflow, disposed in said evaporation zones between said stages of the distiller;
- disks with openings for the removal of noncondensable gases, mounted in said condensation zones coaxially to said rotor and forming with the wall of said rotor water seals for condensate overflow;
- a chamber for collecting condensate and noncondensable gases, disposed downstream of said last stage coaxially therewith and communicated through said water seals of condensate overflow and said openings in said disks with all said condensation zones;
- a pipeline for feeding an aqueous solution to be evaporated to said evaporation zone of said last stage of the distiller;
- channels for overflow of the aqueous solution among said evaporation zones;

means for distributing the aqueous solution being evaporated among said evaporation surfaces of the heat-transfer plates;

a loop for the circulation of the aqueous solution being evaporated between the peripheral part of said evaporation zone of said first stage and the central part of the evaporation surface of the heat-transfer plate of the same zone;

a means for the heat input to said first stage for the evaporation of the aqueous solution;

a means for removing heat from said last stage;

a line for discharging condensate, connected to the peripheral part of said chamber for collecting condensate and noncondensable gases;

a line for the removal of noncondensable gases, connected to the central part of the chamber for collecting condensate and noncondensable gases;

a line for discharging concentrate of said aqueous solution being concentrated, coupled to said loop for the circulation of the aqueous solution being evaporated.

In a preferred embodiment, said means for supplying and removing heat are made as a vapor circulation loop having a first end communicated with said last stage of said distiller behind said separation plate and a second end communicated with the space of the rotor near the condensation surface of the heat-transfer plate of the first stage and the heat pump installed in said loop and made as a vapor compressor, the distiller being provided with an additional means for heat removal, made as a condensate circulation loop coupled to said chamber for collecting condensate and noncondensable gases and provided with a cooling means and a bypass line.

In another preferred embodiment the means for the heat input is made as an electric heater arranged in said loop for the circulation of the aqueous solution being evaporated, and the means for removing heat is made as a condensate circulation loop coupled to said chamber for collecting condensate and noncondensable gases and provided with a cooling means.

In still another preferred embodiment, the means for supplying heat is made as a thermoelectric heat pump arranged in said loop for the circulation of the aqueous solution being evaporated, and the means for removing heat is made as a condensate circulation loop coupled to said chamber for collecting condensate and noncondensable gases and provided with a cooling means, the condensate circulation loop being connected through the heat-transfer surface of said heat pump with the loop for the circulation of the aqueous solution being evaporated.

Furthermore, it is expedient that the rotary vacuum distiller should additionally comprise a central axle rigidly secured with its one end in said casing coaxially thereto from the side of said chamber for collecting condensate and noncondensable gases and having a plurality of longitudinal channels provided with branches and having each a pipe for coupling to a corresponding line,

namely,

said line for feeding the aqueous solution to be evaporated is coupled to the first of said pipes, the branch being disposed in said evaporation zone of the last stage of the distiller and having a delivery means at its end in the peripheral part of this zone,

the outlet line of said loop for the circulation of the aqueous solution being evaporated is coupled to the second said pipe, the branch being disposed in the central part of the evaporation zone of said first stage, and the inlet line of said circulation loop is coupled to the third said pipe, the branch

being disposed in the evaporation zone, provided with at least one discharge tube and having a delivery means at its end in the peripheral part of this zone,

the condensate discharge line is coupled to the fourth said pipe, the branch being disposed in said chamber for collecting condensate and noncondensable gases and having a delivery means at its end in the peripheral part of said zone,

the discharge line of said condensate circulation loop is coupled to the fifth said pipe, the branch being disposed in the central part of said chamber for collecting condensate and noncondensable gases, and the feed line of said condensate circulation loop is coupled to the sixth said pipe, the branch being disposed in the chamber for collecting condensate and noncondensable gases and having a delivery means at its end in the peripheral part of this zone,

the line for the removal of noncondensable gases is connected to the seventh said pipe, the branch being disposed in the central part of the chamber for collecting condensate and noncondensable gases.

It is desirable that said channels for the overflow of the aqueous solution being evaporated should be disposed in said central axle and have branches at the inlet and outlet, disposed in the corresponding evaporation zones, a delivery means being provided at the end of each branch, each branch, starting with the second stage, should be provided with at least one discharge tube directed to the central part of the heat-transfer plate and performing the function of a means for distributing the aqueous solution being evaporated among said evaporation surfaces of the heat-transfer plates and with at least one discharge tube, starting with the second stage, directed to said water seals for precluding vapor overflow.

It is also desirable that said delivery means should be made as an open end of said branch, bent away in a direction counter to the direction of rotation of the rotor.

In a preferred embodiment, said heat-transfer plates and said separation plates are connected pairwise to form a single structural unit, wherein said separation and heat-transfer plates have ribs directed toward each other, said ribs of the separation plates being disposed between said ribs of said heat-transfer plates, and a porous packing being disposed between at least one pair of neighboring ribs.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a general diagrammatic view of the system for water recovery from urine aboard spacecraft according to the invention;

FIG. 2 is a diagrammatic view of the first embodiment of the unit for water reclamation from urine;

FIG. 3 is a diagrammatic view of the second embodiment of the unit for water reclamation from urine;

FIG. 4 is a diagrammatic view of the third embodiment of the unit for water reclamation from urine;

FIG. 5 is a schematic diagram of the rotary multistage vacuum distiller;

FIG. 6 is an enlarged view of portion A in FIG. 5;

FIG. 7 is a diagrammatic view of the condensate intermediate tank of the unit for water reclamation from urine.

BEST EMBODIMENTS OF THE INVENTION

Presented hereinbelow is a detailed description of particular but not limiting embodiments of the invention.

Embodiments of the invention are considered for the case of obtaining water from urine aboard spacecraft, but the

present invention may be successfully used for water recovery from any aqueous solutions, in particular, from other aqueous human waste of the crew.

The system for water recovery from urine comprises the following units connected in series: unit I for urine intake and pretreatment, unit II for water reclamation from urine and unit III for condensate purification, e.g., for condensate sorption/catalytic purification.

Unit I for urine intake and pretreatment comprises a urinal 1, an elastic tank 2 with pretreatment chemicals, an elastic tank 3 with flush water, pretreatment chemicals and a flush water metering device 4, a gas/liquid separator (e.g., a rotary separator) 5 for separating transport air from urine, a pretreatment chemicals feed indicator 6 whose inlet is coupled to the outlet of the pretreatment chemicals and flush water metering device 4 and whose outlet is coupled to the inlet of the gas/liquid separator 5, a transport air fan 7 at the outlet side of which a filter for the removal of harmful contaminants 8 is mounted.

In addition, the unit I for urine intake and pretreatment has an intermediate tank of separated urine, designed as three elastic containers 9, 10, 11, respectively, separated from each other, two of said containers 9 and 10 having the same capacity and the third container 11 having a smaller capacity. Each of said containers is provided with an empty/full sensor 12, 13, 14, respectively, with an inlet solenoid valve 15, 16, 17, respectively, and with an outlet solenoid valve 18, 19, 20, respectively.

The urine intake and pretreatment unit I is connected to the unit II for water reclamation from urine by a urine (liquid to be processed) feed line 21 provided with a urine feed pump 22, a bypass line with a solenoid valve 23 and a urine filter 24.

The unit II for water reclamation from urine, shown in detail in FIG. 2, comprises an apparatus for evaporating the separated urine, which is connected to the urine feed line 21 through inlet solenoid valves 25 and 26 and a safety valve 27, said apparatus being made as a rotary multistage vacuum distiller 28 with a heat-exchanger 29 mounted on its electric motor, a closed urine circulation loop 30 with a urine heating means, connected to the distiller 28, a urine brine tank 31 with a full sensor 32, connected by a brine discharge line 33 through a solenoid valve 34 with the urine circulation loop 30.

In addition, said unit II comprises a closed condensate circulation loop 35 connected to the distiller 28, said circulation loop 35 accommodating a cooling heat-exchanger 36 and two solenoid valves 37 and 38.

The unit II is also provided with a condensate discharge line 39 having a condensate intermediate tank 40 with a condensate pump 41 and a line 42 for pumping out condensate and noncondensable gases with a separator 43.

The line 42 for the removal of humid noncondensable gases has also a first solenoid valve 44, a receiver unit for humid noncondensable gases, a second solenoid valve 45, a check valve 46 and an elastic container 47 with a full sensor 48.

The line 42 for the removal of humid noncondensable gases is connected to its one end to the vacuum distiller 28 and with its other end through a solenoid valve 49 to the condensate discharge line 39. The first solenoid valve 44, the receiver unit for humid noncondensable gases, the second solenoid valve 45, the check valve 46, the separator 43 and the elastic container 47 are connected in series.

The receiver unit for noncondensable gases comprises a receiver 50 made as an elastic container mounted in a rigid

casing, a vacuum pump **51** and an air blower **52** (e.g., a microblower), connected through solenoid valves **53** and **54**, respectively, to the space between the casing and the elastic container of the receiver **50**.

The condensate discharge line **39** additionally comprises a safety check valve **55** and a solenoid valve **56**.

The condensate intermediate tank **40** is coupled from one side to the condensate discharge line between the valves **55** and **56** and from the other side to the line **42** for the removal of humid noncondensable gases.

The urine circulation loop **30** connected to the vacuum distiller **28** is provided with two solenoid valves **57** and **58** and may have three embodiments.

According to a first embodiment (FIG. 2), the urine heating means can be made as an electric heater **59**.

According to a second embodiment (FIG. 3), the system additionally comprises a heat pump made as a vapor compressor **60** whose working space is connected to the distiller **28**. The urine heating means of the urine circulation loop **30** is made as a heat-exchanger **61** arranged on top of the electric motor of the compressor **60**, and the condensate circulation loop **35** is provided with a bypass line **62** with a solenoid valve **63**.

The heat-exchanger **31** of the urine circulation loop **30** is connected in series to the heat-exchanger **29** of the electric motor of the distiller **28**, similarly to the heater **59** (of the first embodiment shown in FIG. 2). The volume of urine in the heat-exchanger **61** is equal to the volume of urine in the heater **59** (FIG. 2), whereby the same degree of urine evaporation is ensured.

According to a third embodiment (FIG. 4), the urine heating means can be made as a thermoelectric heat pump **64**, the latter being connected to the condensate circulation loop **35**.

The condensate intermediate tank **40** is made (FIG. 7) as a hollow casing **65** with two covers **66** and **66**, respectively, and a guide **68**, a large-diameter piston **69** and a small-diameter piston **70** secured on the ends of a rigid rod **71** arranged in the guide **68** movably along the axis of the casing **65**, two annular elastic members **72** and **73** hermetically connected along the inner circumference with the pistons **69** and **70** and along the outer circumference, with the walls of the casing **65**. The pistons **69** and **70** with the annular elastic members **72** and **73** make up three leakproof chambers: a liquid chamber **74**, a vacuum chamber **75** and an intermediate chamber **76**. The liquid chamber **74** is formed between the large-diameter piston **69** and the cover **66** and is connected to the condensate discharge line **39**. The vacuum chamber **75** is formed between the small-diameter piston **70** and the cover **67** and is connected to the line **42** for the removal of humid noncondensable gases. The intermediate chamber **76** is disposed between the pistons **69** and **70**, is provided with two microswitches **77** and **78**, and is communicated with the atmosphere.

The rotary multistage (e.g., three-stage) vacuum distiller **28** (FIGS. 5, 6) comprises a casing **79**, an electric motor **80** rotatably mounted on the casing **79** in bearings **81**, a hollow rotor **82**, heat-transfer plates **83** secured to the rotor **82**, which form evaporation zones **84** of the liquid being processed and condensation zones **85**, separation plates **86** which separate the evaporation zones **84** and the condensation zones **85**, the ribs of said separation plates **86** being received in gaps between the ribs of the heat-transfer plates **83** and porous packings **87**, means for distributing the liquid being processed, the circulation loop **30** for the liquid being processed (particularly urine) with a means for heating the

latter, the feed line **21** for the liquid being processed (the aqueous solution being processed, particularly urine) and the lines **39** and **42** for the removal of condensate and noncondensable gases, respectively.

In addition, the distiller comprises a chamber **88** for collecting condensate and noncondensable gases, the condensate circulation loop **36** and a stationary hollow inlet **89**.

The condensate circulation loop **35** comprises the cooling heat-exchanger **36** and the solenoid valves **37** and **38**, an inlet pipe of the loop **35** being disposed at the periphery of the chamber **88** for collecting condensate and noncondensable gases and made as a Pitot pump **90**, and its outlet pipe being disposed in the central part of the chamber **88** for collecting condensate and noncondensable gases.

The stationary hollow inlet **89** made as a central axle is secured to the casing **79**, is mounted coaxially in the central part of the rotor **82**, and is intended for accommodating a plurality of longitudinal channels provided with branches and having each a pipe for coupling feed and discharge lines.

The stages of the distiller **28** are separated from each other in the evaporation zones **84** by water seals **91** and in the condensation zones **85** by disks **92** with openings **93** for the removal of noncondensable gases, said disks **92** and the wall of the rotor **82** constituting water seals **94** for the condensate overflow.

The inlet of the circulation loop **30** for the liquid being processed (urine) is disposed around the periphery of the evaporation zone **84** of the first stage and is a feed means. The latter is made as a Pitot pump **95** bent away in a direction opposite to the direction of rotation of the rotor **82**. The outlet of the loop **30** is disposed in the central part of the evaporation zone **84** of the first stage of the distiller **28**.

The evaporation zones **84** of all the stages (in the case under consideration, of three stages) are connected successively by overflow channels **96**.

The means for distributing the liquid being processed comprise the overflow channels **96** provided at the inlet and at the outlet with Pitot pumps **97** and discharge tubes **98** whose drain holes are directed to the central parts of the heat-transfer plates and to the water seals **91**.

The outlet of the delivery line **21** for the feed liquid to be processed is provided with a Pitot pump **99** and is disposed around the periphery of the evaporation zone **84** of the last stage.

The inlet of the condensate discharge line **39** is provided with a Pitot pump **100** and is disposed at the periphery of the chamber **88** for collecting condensate and noncondensable gases.

The inlet of the line **42** for the removal of noncondensable gases is disposed in the central part of the chamber **88** for collecting condensate.

The chamber **88** for collecting condensate from the side of the casing **79** is provided with heat insulation **101** to preclude vapor condensation in the space between the rotor **82** and the body **79**.

In the embodiment of the distiller **28**, shown in FIG. 3, the heat input and heat removal means are made as a vapor circulation loop having a first, inlet end **102** (FIG. 5), which is communicated with the last stage of the distiller **28** behind the separation plate **86** of this stage, and a second, outlet end **103** which is communicated with the space of the rotor **82** near the condensation surface of the heat-transfer plate **83** of the first stage. In said loop a heat pump is installed, made as vapor compressor **60** (FIG. 3).

Furthermore, the distiller comprises a mechanical seal **104** intended to preclude vapor leaks from the condensation

zone **85** of the first stage of the distiller **28** into the space between the casing **79** and the rotor **82**, as well as into the chamber **88** for collecting condensate and noncondensable gases, a labyrinth seal **105** for precluding carryover of liquid into the line **42** for the removal of humid noncondensable gases, and a labyrinth seal **106** for precluding carryover of liquid to the inlet **102** of the vapor compressor **60**.

The condensate sorption/catalytic purification unit III (FIG. 1) comprises two columns **107** and **108** arranged in succession, of which the purification column **107** is charged with alternating catalyst and sorbent beds, and the potable water conditioning column **108** is filled with granular polymeric carriers of salts, an elastic container **109** for collecting process water (condensate), an elastic container **110** for storing purified water (condensate) and an elastic container **111** for storing potable water, condensate quality monitoring sensors **112** and **113**, and solenoid valves **114**, **115** and **116**. On lines for collecting process water safety valves **117** and **118** are mounted.

The system of water recovery from urine and the rotary vacuum distiller operate in the following manner.

Urine is transported through a urinal **1** by the stream of transport air created by a fan **7** to a gas/liquid rotary separator **5**, to whose inlet a preset number of doses of pretreatment chemicals with flush water, controlled by a pretreatment chemicals feed indicator **6**, is fed. The transport air separated from the liquid in the gas/liquid rotary separator **5** is discharged through a filter **8** of harmful contaminants to the spacecraft cabin, and a mixture of pretreated urine with flush water comes through a feed valve **17** and one of feed valves **15**, **16** to elastic containers **9**, **11** or **10**, **11** of different capacity, their filling and emptying being controlled by empty/full sensors **12**, **14** and **13**. The containers **9**, **10** have the same capacity (urine being collected alternately in one of these containers and sent to distillation from the other), and container **11** has a smaller capacity equal to the capacity of a urine circulation loop **30** of unit II for water reclamation from urine.

When the containers **9** and **11** or **10** and **11** are full, a cycle of water recovery from urine is initiated by a signal from the corresponding sensors **12** and **14** or **13** and **14**: the valve **17** becomes closed, the feed valves **15** and **16** become switched over (the valve before the filled container closes and the valve before the emptied container opens), the corresponding outlet valve **18** or **19** becomes open, and an instruction is issued for actuating the unit II for water reclamation from urine.

In the case the urine heating means is made as electric heater **59**, the unit II for water reclamation from urine operates in the following manner.

The initial state of the components of the unit II for water reclamation from urine before receiving an instruction to actuate the unit II is as follows:

all the valves are closed;

the condensate circulation loop **35**, including the cooling heat-exchanger **36** and all the condensation zones **85** of the distiller **28** are filled with water;

the urine circulation loop **30**, including the heater **59** and all the evaporation zones **84** of the distiller **28** are filled with urine (with the liquid to be processed). When the unit for water reclamation from urine is switched on for the first time, it is possible to perform self-priming of the loop **30** with urine (with the liquid to be processed);

the inlet **102** and the outlet **103** of the vapor compressor **60** are plugged.

In response to an instruction to actuate the unit for water reclamation from urine, the electric motor **80** of the rotary multistage vacuum distiller **28** is energized. In response to a signal from a revolution counter that the rotor of the distiller **28** has reached a prescribed rotation frequency, the vacuum pump **51** is switched on and the valves **44**, **53** are open. The distiller **28** is evacuated through the line **42** for the removal of noncondensable gases, and when a preset (steady) vacuum value is reached in the unit for collecting noncondensable gases, the valve **53** is closed, the vacuum pump is cut off, the valves **23**, **25**, **57**, **58**, **37**, **38** are open, and the electric heater **59** is energized.

Urine which is under atmospheric pressure, along the urine feed line **21** (the valve **23**, the urine filter **24**, the valve **25**, the safety valve (reducer) **27** and the Pitot pump **99**) comes by gravity to the last stage of the distiller **28** which is under vacuum. The urine overflows along the overflow channels **96** into all the stages of the distiller **28** in succession.

The entry of urine into the distiller **28** is controlled automatically by the safety valve (reducer) **27** as the Pitot pump **99** of the urine feed line **21**, which is directed opposite to the direction of rotation of the rotor **82** and disposed around its periphery, is gradually submerged or exposed (due to evaporation). In all the evaporation zones **84**, at the periphery thereof, rotating rings of liquid are formed, into which the Pitot pumps **97**, stationary with respect to the rotating rotor **82**, of the means for distributing the liquid being processed, and the Pitot pump **95** of the urine circulation loop **30**, are immersed. The discharge tubes **98** of the means for distributing the liquid being processed send the feed liquid to be processed (urine) from the periphery of the evaporation zones **84** to the central parts of the heat-transfer plates **83**, whence, under the effect of centrifugal forces the urine in the form of a thin film flows again to the periphery of the evaporation zones **84**.

The vapor generated in the evaporation zone **84** of the first stage passes through the porous packing **87** to the condensation zone **85**, where it is condensed on the heat-transfer plate **83** of the evaporation zone **84** of the second stage, sprinkled from the opposite side with the liquid being evaporated, which is heated to a saturation temperature and begins to evaporate. The vapor formed in the second stage passes through the porous packing **87** to the condensation zone **85** for heating the liquid in the evaporation zone **84** of the third stage, etc. The vapor formed in the last stage of the distiller **28** is condensed at the face side of the chamber **88** for collecting condensate and noncondensable gases, the condensate from the loop **35**, cooled in the heat-exchanger **36** being fed to the interior side of said chamber **88**.

During the operation, the water seals are filled with condensate, whereby the vapor overflow from one stage to another is precluded, whereas the condensate from all the condensation zones **85** is drained without hindrance from one stage into another and then into the chamber **88** for collecting condensate and noncondensable gases, whence the condensate is transferred by the Pitot pump **100** through the safety valve (external reducer) **55** to the condensate intermediate tank **40**.

Noncondensable gases are removed in succession through the openings **93** in the disks **92** from one condensation zone **85** in which the pressure is high to another condensation zone **85** in which the pressure is lower, then these gases come to the chamber **88** for collecting noncondensable gases and condensate, and are discharged from the distiller along the line **42** for the removal of noncondensable gases. To prevent emergency overflow of the distiller **28** with the

liquid being evaporated or with the condensate, pressure sensors (not shown in FIG. 5) are mounted in the last evaporation stage 84 and in the chamber 88 for collecting condensate and noncondensable gases.

In the first stage, the Pitot pump 95 disposed at the periphery of the rotor 82 pumps the urine being evaporated (the liquid being processed) along the urine circulation loop 30 (the valve 57, the heat-exchanger 29 of the electric motor 80 of the distiller 28, the heater 59, the valve 58) where the urine (the liquid being processed) is heated to a temperature exceeding the temperature of saturation at a given pressure in the distiller 28, and returns the heated urine being evaporated to the heat-transfer plate 83 in the first stage of the distiller 28, where a partial self-evaporation of the urine occurs due to its overheating. As the liquid to be processed is supplied gradually from the first stage for the evaporation in the urine circulation loop 30, the concentration of brine increases. The prescribed final concentration of brine (the degree of water reclamation from the feed liquid) depends on the capacity of the circulation loop 30 and on the quantity of the liquid supplied for the evaporation. The condensate which is formed in all the condensation zones 85 is drained into the chamber 88 for collecting condensate and noncondensable gases, whence it is pumped by the Pitot pump 90 along the condensate circulation loop 35 (the valve 38, the cooling heat-exchanger 36 (cooled with a coolant), the valve 37) and returns to the chamber 88 for collecting condensate and noncondensable gases. The vapor formed in the evaporation zone in the last stage 84 of the distiller 28 is condensed by the cooled condensate. As the condensate gradually comes to the chamber 88 for collecting condensate and noncondensable gases, the Pitot pump 100 supplies the condensate through the safety valve (reducer) 55 to the condensate intermediate tank 40. The condensate intermediate tank 40 operates as follows.

The pressure of air in the intermediate chamber 76 provides a required excess pressure in the liquid chamber 74 with respect to the vacuum chamber 75, said excess being determined by the ratio of the areas of the large-diameter and small-diameter pistons 69 and 70, respectively.

The condensate comes to the liquid chamber 74, when the condensate pressure after the safety valve exceeds the pressure in the chamber 74. The rod 71 with the pistons 69 and 79 then moves toward the microswitch 77 (toward the chamber 74). When the liquid chamber 74 is filled, the piston 69 impacts the actuator (button) of the microswitch 77 which generates a signal for opening the solenoid valve 56 and switching-on the condensate discharge pump 41 which delivers the condensate to the reclaimed water sorption/catalytic purification unit III. As the condensate is discharged from the liquid chamber 74, the rod 71 with the pistons 69, 70 moves in an opposite direction, till it interacts with the actuator (button) of the microswitch 78, in response to whose signal the solenoid valve 56 becomes closed and the condensate discharge pump 41 becomes cut off.

When the sensor 12 (13) generates a signal that the container 10 is empty, the valve 19 (18) opens, the valve 20 closes, and a signal is produced for replacing the evaporated solution (brine) accumulated in the urine circulation loop 30 in the unit II for water reclamation from urine. In response to this signal, the electric heater 59 is de-energized, the valves 23, 25, 57, 58, 37, 38 become closed, the valves 26, 34 become open, and the pump 22 is switched on. The pump 22 displaces the brine from the urine circulation 30 loop (except for the distiller 28) with urine from the container 11 through the valves 20, 26 and 34 into the urine brine tank 31 till a signal is received from the sensor 14 that the container

11 is empty. In response to this signal, the valve 20 is closed, the valve 17 is opened, and a signal is produced to cut off the unit II for water reclamation from urine. In response to this signal, the pump 22 is cut off, the valves 26, 34, 44 become closed, the electric motor 80 of the distiller 28 is disabled, the valves 54, 45 become open, the air microblower 52 becomes switched on; owing to the pressure set up by the air microblower 52 between the elastic container and the casing of the receiver 50 the elastic container contracts, and noncondensable gases together with condensed water vapors are vented therefrom through the valve 45 and check valve 46 into the separator 43, whence the noncondensable gases are discharged into the atmosphere, and the condensate is sent to the elastic container 47. After a prescribed period of time, the valves 54, 45 are closed and the air microblower 52 is cut off. The cycle of water recovery from urine is thus complete. When the sensor 32 indicates that the container 31 is filled with the concentrate, said container is replaced with an empty one. In response to the signal from the sensor 48 that the container 47 is filled with the condensate, the valve 49 is opened, the condensate discharge pump 41 is switched on, and the condensate is fed to the reclaimed water sorption/catalytic purification unit III. In response to the signal from the sensor 48 that the container 47 is emptied, the valve 49 is opened and the condensate purge pump 41 is cut off.

In the case the system is equipped with a heat pump made as vapor compressor 60 whose working space is connected to the distiller 28 (the second embodiment, FIG. 3), and the urine heating means of the urine circulation loop 30 is made as heat-exchanger 61 disposed on top of the electric motor of the compressor 60, the unit II for water reclamation from urine operates as in the system with the heater 59, the only difference being that:

instead of the heater 59, the vapor compressor 60 is switched on and off in response to the same instructions (signals);

in the condensate circulation loop 35 the valves 37, 38 remain closed, whereas the valve 63 is opened and closed instead of them in response to the same instructions. The valves are open only if the temperature of the urine (of the processed liquid) being evaporated rises to the limiting preset value;

through the valve 58 the urine being evaporated leaves the urine circulation loop 30 for sprinkling the heat-exchanger 83 of the first stage of the distiller 28. Heating of the urine in the heat-exchanger 29 of the electric motor of the distiller 28 and in the heat-exchanger 61 of the compressor 60 ensures compensation only for heat losses for reaching the necessary temperature level of the distillation process. Evaporation of the urine (of the liquid being processed) in the first stage takes place owing to the heat of condensation of the vapor formed in the evaporation zone 84 of the last stage, which vapor, after passing through the porous packing 87, is pumped off by the compressor 60 through the inlet 102, is compressed by said compressor, and comes through the outlet 103 to the opposite side of the heat-transfer plate 83 of the condensation zone 85 of the first step of the distiller 28, where said vapor is condensed at higher temperature and pressure values.

In the case the thermoelectric heat pump 64 is used as the urine heating means, the unit II for water reclamation from urine operates as in the embodiment with the heater 59 (the third embodiment, FIG. 4); however, in such a case electric power is supplied to the thermoelectric heat pump 64 (instead of the heater 59), and the condensate is pumped

along the condensate circulation loop **35** through the valve **38**, the heat-exchanger of the cold side of the thermoelectric heat pump **64**, the cooling heat-exchanger **36** (cooled with a coolant), and the valve **37**, and then returns to the chamber **88** for collecting condensate and noncondensable gases of the distiller **28**. In the thermoelectric heat pump **64**, owing to the Peltier effect, part of the heat of condensation of the vapor of the last stage of the distiller **28** is transferred from the condensate circulating through the cold heat-exchanger of the heat pump **64** to the urine (the liquid being processed) circulating through the hot heat-exchanger of the heat pump **64**, the urine becoming thus heated. The resistance (Joule) heat evolved in the thermoelectric heat pump also serves for heating the urine, and the corresponding heat of condensation is abstracted from the circulating condensate in the cooling heat-exchanger **36** which is cooled with a coolant.

The amount of urine in the heat-exchanger of the hot side of the thermoelectric heat pump **64** is equal to the amount of urine in the heater **59**, whereby the same degree of urine evaporation is ensured as in the case of using the heater **59**.

The condensate discharge pump **41** of the unit II for water reclamation from urine the forming condensate is delivered to the flush water tank **3** and is pumped through the condensate quality monitoring sensor **112**, the column **107** for purification from harmful contaminants, the condensate quality monitoring sensor **113**, and the potable water conditioning column **108**. Distilled water is sent to the elastic container **110** for storing purified water, and potable water is fed to the elastic container **111** for storing potable water. In the column **107** sorption/catalytic purification from harmful contaminants is performed on alternating beds of activated carbon with a catalyst and of an anionite with a cationite; in the potable water conditioning column **108** the water purified in the column **107** is subjected to saturation with salts, disinfection, and pretreatment with chemicals.

In response to a signal from the condensate quality monitoring sensor **112** indicating the arrival of contaminated condensate, the valve **114** is closed, and the condensate enters the elastic container **109** for process water, while on receipt of a signal from the condensate quality monitoring sensor **113** that the quality of purified condensate is poor the valve **115** is closed, and the condensate is also fed to the elastic container **109** for process water, whence it can be used as flush water. In order to obtain only distilled water, for the system for water electrolysis the valve **116** is closed.

Hence, the claimed system has made it possible to solve the problem of water recovery from urine in microgravity.

The system for water recovery from urine according to the invention for a space station, based on a high-speed rotary multistage vacuum distiller (the number of revolutions of the rotor being 1,200 to 1,500 r.p.m.) appreciably extends the system potentialities. In the multistage distiller the heat of condensation of the preceding stage is used repeatedly for evaporating the liquid of the next stage. This feature as such reduces consumption of energy on evaporation compared with the theoretically required amount (proceeding from the heat of vaporization) almost by the factor of n , where n is the number of the distiller stages. The overall efficiency of the system in terms of evaporated water is n times higher than in each of the stages. Experimental data have shown that in operation with a three-stage rotary vacuum distiller and an electric heater of the liquid being processed, the specific consumption of energy (with allowance for the power consumption of the drive) amounted to 320 Wh per kg of evaporated water with the throughput capacity of 2.5 to 3 kg/h, this being 2.2 times lower than the theoretical value. With six distillation stages the design value of the specific

energy consumption can be 140 to 160 Wh per kg of evaporated water. However, in the case of water recovery from urine with the required water recovery efficiency not lower than 90%, an increase in the number of stages leads to a growth of the concentration of brine and to a temperature depression in the stages to a greater extent than with a smaller number of the stages. Calculations show that it is hardly expedient to use more than four or five stages in the distiller.

For reducing the power consumption still further, it is suggested to use in the proposed system an external heat pump, for instance, a thermoelectric heat pump (based on Peltier effect) or a vapor compressor instead of an electric heater for the liquid being processed. The design of the distiller and of the system as a whole allow one to use any of the suggested variants.

With the use of a thermoelectric heat pump, the heat of condensation of the last stage of the distiller is transferred to a higher temperature level and heats the urine circulating through the first stage. The thermoelectric pump used in the system according to the invention made it possible to reduce the specific consumption of energy, when operating with the three-stage rotary vacuum distiller, down to 140 Wh per kg of evaporated water.

When a vapor compressor is used as the heat pump, the vapor of the last stage of the distiller is compressed by the compressor and condensed at higher pressure and temperature at the heat-transfer surface of the first stage, transferring the heat of condensation to the urine that sprinkles the opposite side of this surface. In tests of the system with the three-stage rotary vacuum distiller and the vapor compressor, the specific consumption of energy amounted to 60 Wh per kg of evaporated water with the throughput capacity of 2.5 to 3 kg/h. The throughput capacity of the compressor in terms of vapor is smaller approximately by a factor of n , by its degree of compression is n times higher than of that of a similar compressor operating with a single-stage distiller with the same throughput capacity of the distiller in terms of evaporated water. But since the useful work of vapor compression work is small and does not exceed 5 Wh/l, whereas the power of the compressor drive is determined mainly by the mechanical perfection of the design, the overall dimensions, mass and consumption of energy of a compressor featuring the same speed and a low throughput capacity in terms of vapor, apparently, will be smaller.

The high speed of the rotor of the distiller makes it possible to use instead of external peristaltic pumps a velocity head of liquid and, with the help of head means built into the distiller (Pitot pumps), to ensure circulation of the liquid being processed and of the condensate, sprinkling of the heat-transfer surfaces, as well as carryover of the feed liquid into the distiller, overflow of said liquid in the stages, and automatic maintenance of the level of the liquid at the stages.

The high speed of the rotor of the distiller provides a high separation factor, which feature appreciably improves the work of the separation units and the quality of the resulting condensate, as well as intensifies the heat- and mass-transfer processes on the rotating surfaces, this leading to a reduction in the overall dimensions and mass of the distiller.

Supply of the liquid being processed to the last stage of the distiller followed by an overflow of said liquid in the direction of the first stage, with the provision of the liquid circulation through the first stage and the circulation loop, makes it possible to reduce the effect of an increase in the concentration of the liquid being processed on a rise in the

temperature level of the process, on a reduction in the distiller throughput capacity, this leading in the final count to an increase in the efficiency of operation of the system as a whole, including a reduction in energy consumption and upgrading the quality of recovered water.

What is claimed is:

1. A system for water recovery from urine aboard spacecraft, comprising:

a urine intake and pretreatment unit comprising:

a urinal for receiving urine forced to be moved by a stream of transport air, having an outlet,

a separator for separating the transport air from said urine, having an inlet connected to said outlet of the urinal, and an outlet,

a means for storing and feeding pretreatment chemicals, having an outlet connected to said inlet of said separator,

a tank for separated urine, connected to said outlet of said separator,

a unit for water reclamation from urine downstream of said urine intake and pretreatment unit, communicated therewith by a urine feed line and comprising:

a rotary vacuum distiller for distilling the separated urine, having a rotary drive and comprising at least a first stage and a last stage arranged successively and coaxially and having each an evaporation surface and a condensation surface and a condensate collection chamber, communicated with each of said condensation surface,

a urine circulation loop coupled to said first stage and provided with a heating means,

a urine brine tank connected through a controlled valve to said urine circulation loop,

a condensate circulation loop coupled to said condensate collection chamber and provided with a cooling means,

a line for removal of noncondensable gases, coupled to a central part of said condensate collection chamber,

a line for discharging condensate, coupled to a peripheral part of said condensate collection chamber,

a unit for purifying said condensate to water grade recovered from the urine having an inlet to which said line for discharging condensate is coupled.

2. A recovery system according to claim 1, wherein said condensate purification unit comprises a first column with at least two beds arranged lengthwise of the column: a catalyst bed and a sorbent bed, said first column having an outlet, and a second column arranged successively downstream of said condensate purification unit, said second column being filled with granular polymeric carriers of salts and having an outlet, a first water tank and a second water tank, arranged each at the outlet of said first and second columns, respectively, as well as a first condensate quality monitoring sensor and a second condensate quality monitoring sensor, arranged at the inlet and at the outlet of said first column and having each its own outlet, a tank for off-specification water, coupled to said outlets of said sensors.

3. A recovery system according to claim 1, which additionally comprises a pump and a filter of particulates, installed in said urine feed line.

4. A recovery system according to claim 1, which additionally comprises: a unit for discharging said condensate, comprising a condensate intermediate tank and a pump for discharging said condensate, connected in series, said unit being installed into said line for discharging condensate upstream of said inlet to said purification unit.

5. A recovery system according to claim 4, wherein said condensate intermediate tank comprises a hollow casing, a first piston and a second piston of a different diameter interconnected by a rigid rod and arranged in said casing a first leakproof chamber defined by the surface of the first piston of a larger diameter and a opposite wall of said casing, said first leakproof chamber being communicated with said line for discharging condensate, a second leakproof chamber defined by the surface of said second piston of a smaller diameter and the opposite wall of said casing, said second leakproof chamber being connected to said line for the removal of noncondensable gases, and a third leakproof chamber shaped by the surfaces of said first and second pistons, facing each other, said third leakproof chamber communicating with the atmosphere.

6. A recovery system according to claim 1, wherein said means for heating said urine circulation loop is made as an electric heater.

7. A recovery system according to claim 1, wherein said means for heating said urine circulation loop is made as a thermoelectric heat pump connected to said condensate circulation loop for transferring heat to said urine circulation loop.

8. A recovery system according to claim 1, wherein said rotary drive of the rotary distiller is an electric motor provided with a heat exchanger having a heated side and a heating side and coupled with its heated side to said electric motor and with its heating side to said urine circulation loop.

9. A recovery system according to claim 1, wherein the line for the removal of the noncondensable gases comprises arranged in series: a receiver made as an elastic container mounted in a rigid casing, the space between the elastic container and the receiver accommodating a vacuum pump and an air blower coupled through alternately switched-on controlled valves, said vacuum pump and air blower being connected in parallel, a condensed moisture separator and a condensate tank.

10. A system for water recovery from urine aboard spacecraft, comprising:

a urine intake and pretreatment unit comprising:

a urinal for receiving urine forced to be moved by a stream of transport air, having an outlet,

a separator for separating the transport air from said urine, having an inlet connected to said outlet of the urinal, and an outlet,

a means for storing and feeding pretreatment chemicals, having all outlet connected to said inlet of said separator,

a tank for separated urine, connected to said outlet of said separator,

a unit for water reclamation from urine downstream of said urine intake and pretreatment unit, communicated therewith by a urine feed line and comprising:

a rotary vacuum distiller for distilling the separated urine, having a rotary drive and comprising at least a first stage and a last stage arranged successively and coaxially and having each an evaporation surface and a condensation surface and a condensate collection chamber, communicated with each of said condensation surface,

a urine circulation loop coupled to said first stage,

a urine brine tank connected through a controlled valve to said urine circulation loop,

a vapor circulation loop for vapor extracted from said last stage of said rotary vacuum distiller and delivered to

the condensation surface of said first stage, a heat pump made as a vapor compressor being installed into said loop,
 a condensate circulation loop coupled to said condensate collection chamber,
 a line for die removal of noncondensable gases, coupled to a central part of said condensate collection chamber,
 a line for discharging condensate, coupled to a peripheral part of said condensate collection chamber,
 a unit for purifying said condensate to water grade recovered from the urine having an inlet to which said line for discharging condensate is coupled.

11. A recovery system according to claim 10, wherein said compressor has an electric motor provided with a heat exchanger having a heated side and a heating side and being coupled with its heated side to said electric motor and with its heating side to said urine circulation loop.

12. A recovery system according to claim 10, wherein said rotary drive of the rotary vacuum distiller is an electric motor provided with a heat exchanger having a heated side and a heating side and is coupled with its heated side to said electric motor and with its heating side to said urine circulation loop.

13. A recovery system according to claim 12, which additionally comprises a cooling means installed into the condensate circulation loop.

14. A recovery system according to claim 10, which additionally comprises a unit for discharging said condensate, comprising a condensate intermediate tank and a pump for discharging said condensate, connected in series, said unit being installed into said line for discharging condensate upstream of said inlet to said purification unit.

15. A system according to claim 14, wherein said condensate intermediate tank comprises a hollow casing, a first piston and a second piston of a different diameter interconnected by a rigid rod and arranged in said casing a first leakproof chamber shaped by the surface of the first piston of a larger diameter and the opposite wall of said casing, said first leakproof chamber being communicated with said line for discharging condensate, a second leakproof chamber formed by the surface of said second piston of a smaller diameter and the opposite wall of said casing, said second leakproof chamber being connected to said line for the removal of noncondensable gases, and a third leakproof chamber shaped by the surfaces of said first and second pistons, facing each other, said third leakproof chamber communicating with the atmosphere.

16. A recovery system according to claim 10, wherein the line for the removal of the noncondensable gases comprises arranged in series: a receiver made as an elastic container mounted in a rigid casing, the space between the elastic container and the receiver accommodating a vacuum pump and an air blower coupled through alternately activated controlled valves, said vacuum pump and air blower being connected in parallel, a condensed moisture separator and a condensate tank.

17. A rotary vacuum distiller for water recovery from urine aboard spacecraft, comprising:
 a casing,
 a hollow rotor rotatably mounted in said casing,
 a rotary electric motor for said rotor,
 at least two stages, a first stage and a last stage, arranged successively and coaxially in said rotor for rotating therewith,
 each of said stages being formed by at least one heat-transfer plate whose one side is an evaporation surface and the opposite side is a condensation surface,

separation plates whose number corresponds to the number of said stages of the distiller, arranged in said rotor coaxially therewith in succession behind each of said heat-transfer plates,
 condensation zones formed between said condensation surfaces of the heat-transfer plates and separated from evaporation zones by said separation plates,
 water seals for precluding vapor overflow, disposed in said evaporation zones between said stages of the distiller,
 disks with openings for the removal of noncondensable gases, mounted in said condensation zones coaxially to said rotor and forming with the wall of said rotor water seals for condensate overflow,
 a chamber for collecting condensate and noncondensable gases, disposed behind said last stage coaxially therewith and communicated through said water seals of condensate overflow and said openings in said disks with all said condensation zones,
 a pipeline for feeding an aqueous solution to be evaporated to an evaporation zone of said last stage of the distiller,
 channels for overflow of the aqueous solution among said evaporation zones,
 means for distributing the aqueous solution being evaporated among said evaporation surfaces of the heat-transfer plates,
 a loop for the circulation of the aqueous solution being evaporated between a peripheral part of an evaporation zone of said first stage and a central part of the evaporation surface of the heat-transfer plate of the same zone,
 a means for supplying heat to said first stage for the evaporation of the aqueous solution,
 a means for removing heat from said last stage,
 a line for discharging condensate, connected to the peripheral part of said chamber for collecting condensate and noncondensable gases,
 a line for the removal of noncondensable gases, connected to a central part of the chamber for collecting condensate and noncondensable gases,
 a line for discharging concentrate of said aqueous solution being concentrated, coupled to said loop for the circulation of the aqueous solution being evaporated.

18. A rotary vacuum distiller according to claim 17, wherein said means for supplying and removing heat are made as a vapor circulation loop having a first end communicated with said last stage of said distiller behind said separation plate and a second end communicated with said space of the rotor near the condensation surface of said heat-transfer plate of the first stage and the heat pump installed into said loop and made as a vapor compressor, said distiller being provided with an additional means for heat removal, made as a condensate circulation loop coupled to said chamber for collecting condensate and noncondensable gases and provided with a cooling means and a bypass line.

19. A rotary vacuum distiller according to claim 17, wherein said means for supplying heat is made as an electric heater arranged in said loop for the circulation of the aqueous solution being evaporated, and said means for removing heat is made as a condensate circulation loop coupled to said chamber for collecting condensate and noncondensable gases and provided with a cooling means.

20. A rotary vacuum distiller according to claim 17, wherein said means for supplying heat is made as a ther-

moelectric heat pump arranged in said loop for the circulation of the aqueous solution being evaporated, and said means for removing heat is made as a condensate circulation loop coupled to said chamber for collecting condensate and noncondensable gases and provided with a cooling means, the condensate circulation loop being connected through a heat-transfer surface of said heat pump with said loop for the circulation of the aqueous solution being evaporated.

21. A rotary vacuum distiller according to claim **19**, which additionally comprises a central axle rigidly secured with its one end in a casing coaxially thereto from the side of said chamber for collecting condensate and noncondensable gases and having a plurality of longitudinal channels provided with branches and having each a pipe for coupling a corresponding line,

namely,

said line for feeding the aqueous solution to be evaporated is coupled to the first of said pipes, the branch being disposed in said evaporation zone of the last stage of the distiller and having a delivery means in its end at the peripheral part of this zone,

said outlet line of said loop for the circulation of the aqueous solution being evaporated is coupled to the second of said pipes, the branch being disposed in the central part of the evaporation zone of said first stage, and the inlet line of said circulation loop is coupled to the third of said pipes, the branch being disposed in the evaporation zone, provided with at least one discharge tube and having a delivery means in its end at the peripheral part of this zone,

said condensate discharge line is coupled to the fourth of said pipes, the branch being disposed in said chamber for collecting condensate and noncondensable gases and having a delivery means in its end at the peripheral part of said zone,

said outlet line of said condensate circulation loop is coupled to the fifth of said pipes, the branch being disposed in the central part of said chamber for collecting condensate and noncondensable gases, and the inlet line of said condensate circulation loop is coupled to the sixth of said pipes, the branch being disposed in the chamber for collecting condensate and noncondensable gases and having a delivery means in its end at the peripheral part of this zone,

said line for the removal of noncondensable gases is connected to the seventh of said pipes, the branch being disposed in the central part of the chamber for collecting condensate and noncondensable gases.

22. A rotary vacuum distiller according to claim **19**, which additionally comprises a central axle rigidly secured with its one end in a casing coaxially thereto from the side of said chamber for collecting condensate and noncondensable gases and having a plurality of longitudinal channels provided with branches and having each a pipe for coupling a corresponding line,

namely,

said line for feeding the aqueous solution to be evaporated is coupled to the first of said pipes, the branch being disposed in said evaporation zone of the last stage of the distiller and having a delivery means in its end at the peripheral part of this zone,

said outlet line of said loop for the circulation of the aqueous solution being evaporated is coupled to the second of said pipes, the branch being disposed in the central part of the evaporation zone of said first stage, and the inlet line of said circulation loop is coupled to

the third of said pipes, the branch being disposed in the evaporation zone, provided with at least one discharge tube and having a delivery means in its end at the peripheral part of this zone,

said condensate discharge line is coupled to the fourth of said pipes, the branch being disposed in said chamber for collecting condensate and noncondensable gases and having a delivery means in its end at the peripheral part of said zone,

said outlet line of said condensate circulation loop is coupled to the fifth of said pipes, the branch being disposed in the central part of said chamber for collecting condensate and noncondensable gases, and the inlet line of said condensate circulation loop is coupled to the sixth of said pipes, the branch being disposed in the chamber for collecting condensate and noncondensable gases and having a delivery means in its end at the peripheral part of this zone,

said line for the removal of noncondensable gases is connected to the seventh of said pipes, the branch being disposed in the central part of the chamber for collecting condensate and noncondensable gases.

23. A rotary vacuum distiller according to claim **20**, which additionally comprises a central axle rigidly secured with its one end in a casing coaxially thereto from the side of said chamber for collecting condensate and noncondensable gases and having a plurality of longitudinal channels provided with branches and having each a pipe for coupling a corresponding line,

namely,

said line for feeding the aqueous solution to be evaporated is coupled to the first of said pipes, the branch being disposed in said evaporation zone of the last stage of the distiller and having a delivery means in its end at the peripheral part of this zone,

said outlet line of said loop for the circulation of the aqueous solution being evaporated is coupled to the second of said pipes, the branch being disposed in the central part of the evaporation zone of said first stage, and the inlet line of said circulation loop is coupled to the third of said pipes, the branch being disposed in the evaporation zone, provided with at least one discharge tube and having a delivery means in its end at the peripheral part of this zone,

said condensate discharge line is coupled to the fourth of said pipes, the branch being disposed in said chamber for collecting condensate and noncondensable gases and having a delivery means in its end at the peripheral part of said zone,

said outlet line of said condensate circulation loop is coupled to the fifth of said pipes, the branch being disposed in the central part of said chamber for collecting condensate and noncondensable gases, and the inlet line of said condensate circulation loop is coupled to the sixth of said pipes, the branch being disposed in the chamber for collecting condensate and noncondensable gases and having a delivery means in its end at the peripheral part of this zone,

said line for the removal of noncondensable gases is connected to the seventh of said pipes, the branch being disposed in the central part of the chamber for collecting condensate and noncondensable gases.

24. A rotary vacuum distiller according to claim **21**, wherein said channels for the overflow of the aqueous solution being evaporated are disposed in said central axle and have branches at the inlet and outlet, disposed in the

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corresponding evaporation zones, a delivery means being provided in the end of each branch, each branch, starting with the second stage, should be provided with at least one discharge tube directed to the central part of the heat-transfer plate and performing the function of a means for distributing the aqueous solution being evaporated among said evaporation surfaces of the heat-transfer plates and with at least one discharge tube, starting with the second stage, directed to said water seals for precluding vapor overflow.

25. A rotary vacuum distiller according to claim 22, wherein said channels for the overflow of the aqueous solution being evaporated are disposed in said central axle and have branches at the inlet and outlet, disposed in the corresponding evaporation zones, a delivery means being provided in the end of each branch, each branch, starting with the second stage, should be provided with at least one discharge tube directed to the central part of the heat-transfer plate and performing the function of a means for distributing the aqueous solution being evaporated among said evaporation surfaces of the heat-transfer plates and with at least one purge tube, starting with the second stage, directed to said water seals for precluding vapor overflow.

26. A rotary vacuum distiller according to claim 23, wherein said channels for the overflow of the aqueous solution being evaporated are disposed in said central axle and have branches at the inlet and outlet, disposed in the corresponding evaporation zones, a delivery means being provided in the end of each branch, each branch, starting with the second stage, should be provided with at least one

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discharge tube directed to the central part of the heat-transfer plate and performing the function of a means for distributing the aqueous solution being evaporated among said evaporation surfaces of the heat-transfer plates and with at least one discharge tube, starting with the second stage, directed to said water seals for precluding vapor overflow.

27. A rotary vacuum distiller according to claim 21, wherein said delivery means is made as open end of said branch, bent away in a direction counter to the direction of rotation of the rotor.

28. A rotary vacuum distiller according to claim 22, wherein said delivery means is made as open end of said branch, bent away in a direction counter to the direction of rotation of the rotor.

29. A rotary vacuum distiller according to claim 23, wherein said delivery means is made as open end of said branch, bent away in a direction counter to the direction of rotation of the rotor.

30. A rotary vacuum distiller according to claim 17, wherein said heat-transfer plates and said separation plates are connected pairwise to form a single structural unit, wherein said separation and heat-transfer plates have ribs directed toward each other, said ribs of the separation plates being disposed between said ribs of said heat-transfer plates, and a porous packing being disposed between at least one pair of neighboring ribs.

* * * * *



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(12) **United States Patent**
Ellis, Jr.

(10) **Patent No.:** **US 6,409,888 B1**
(45) **Date of Patent:** **Jun. 25, 2002**

(54) **METHOD AND APPARATUS FOR WATER DEGASIFICATION AND DISTILLATION**

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12785

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(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

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(57) **ABSTRACT**

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B01D 19/00; C02F 1/04; C02F 1/78

(52) **U.S. Cl.** **203/10**; 95/241; 203/1;
203/2; 203/39; 203/49; 203/22; 203/DIG. 8;
210/748; 210/760; 210/774

(58) **Field of Search** 203/10, 1, 31,
203/100, 2, 4, 40, 49, 22, 27, DIG. 8, 39;
202/176, 177, 202, 203, 181, 160, 182,
175, 200, 265; 210/748, 760, 774; 95/241,
244

A method and apparatus for water degasification and distillation in an apparatus having a container for a reservoir of water to be degassed and distilled, a relatively small boiler adjoining the container and having a feed water conduit connecting the container and boiler so that a selected water level in the container will fill the boiler to the same level, a coiled tube condenser within the container immersed in the water therein, the condenser coil having a vertically disposed longitudinal axis, a second conduit in the boiler connecting the space above the water level therein to the inlet of the condenser so that steam flows from the boiler to the condenser, an outlet on the condenser extending through a container wall for discharging the condensed steam as degassed distilled water, a heater in the boiler for heating the water therein, a motor driven stirrer axially of the coiled tube condenser for generating a swirling movement of the reservoir water with formation of steam bubbles therein and an ozone generating device in the boiler for purifying the steam. Optionally, an oversized filter is mounted at the outlet of the condenser.

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4 Claims, 4 Drawing Sheets

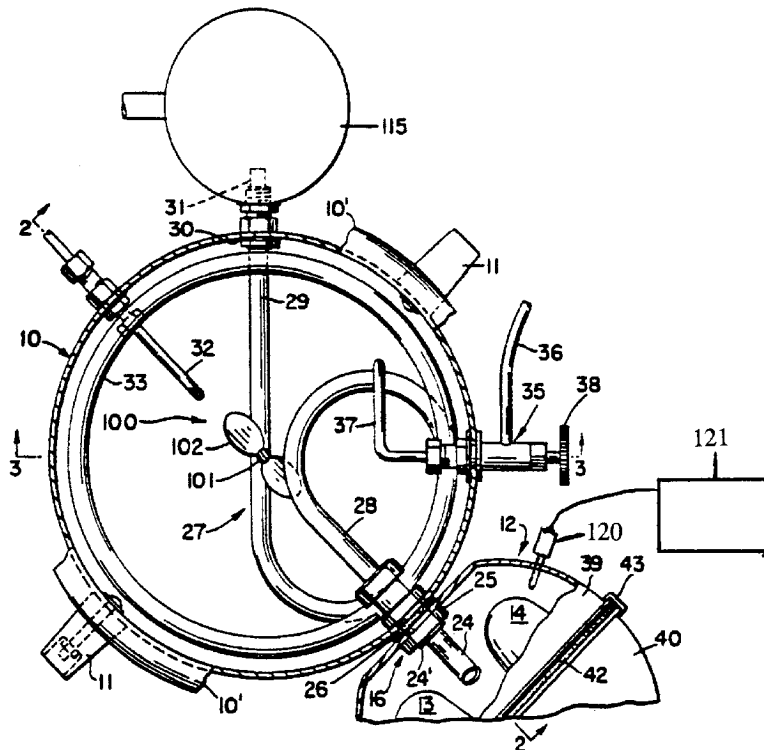


Fig. 1

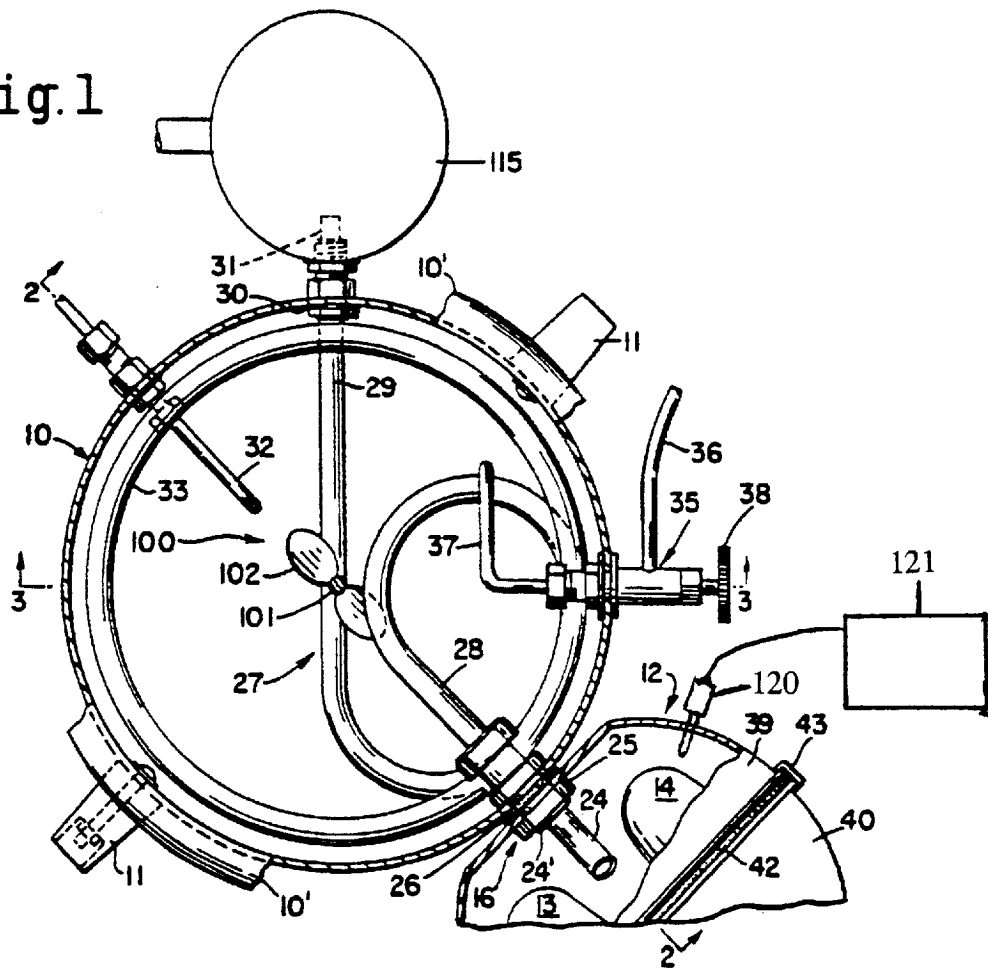


Fig. 2

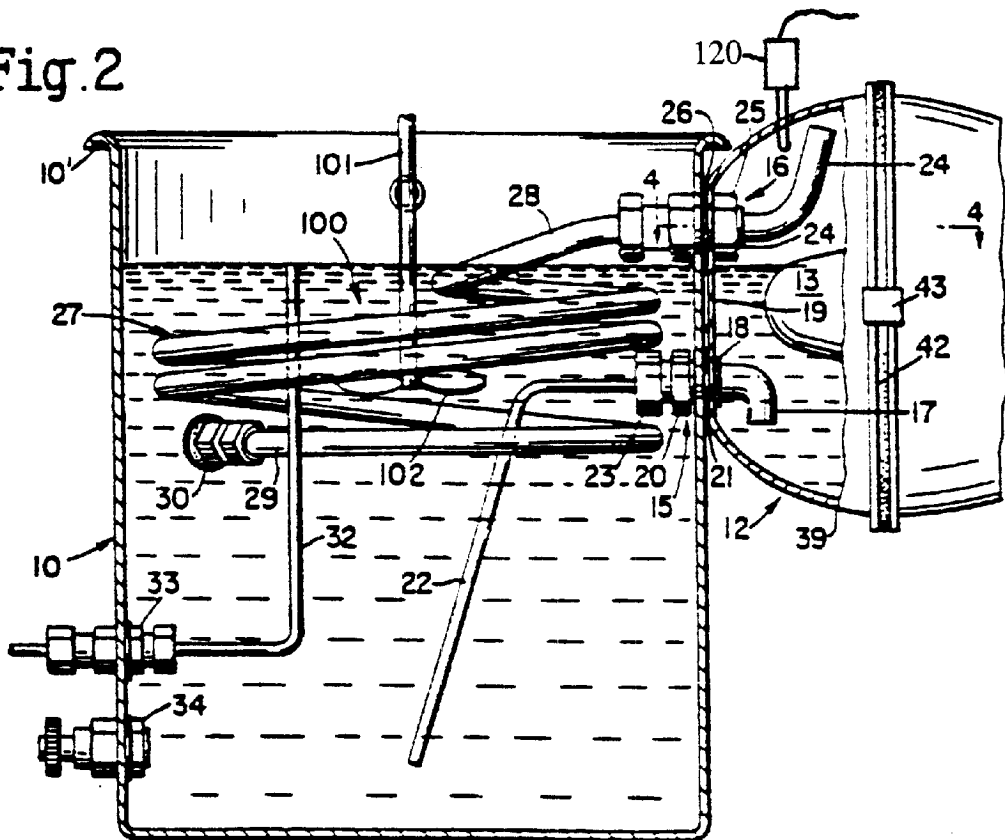


Fig. 3

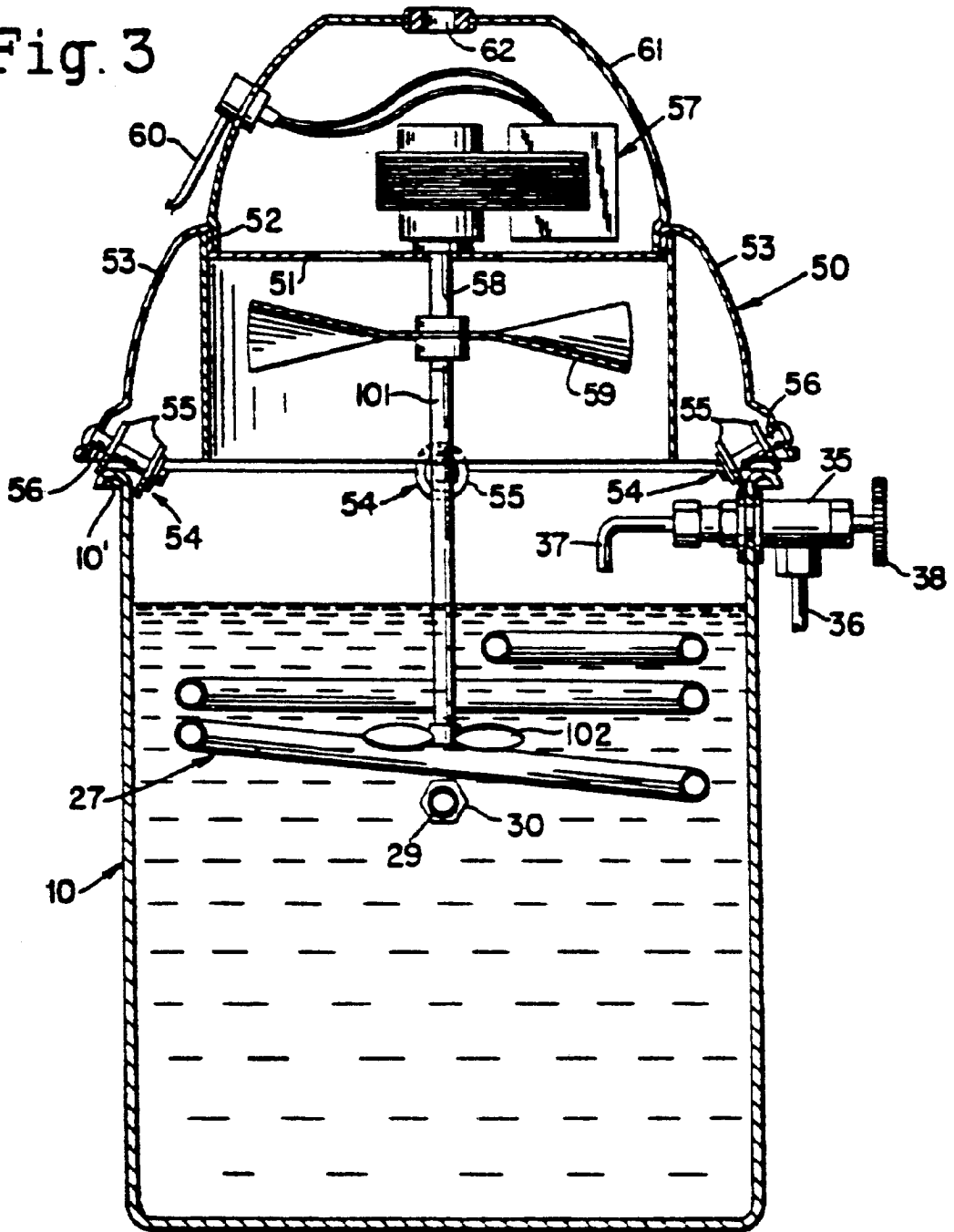


Fig. 4

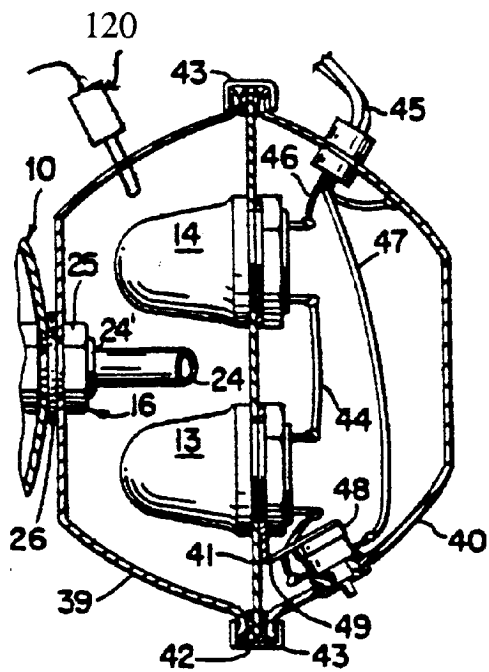


Fig. 5

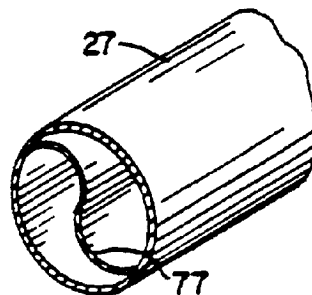
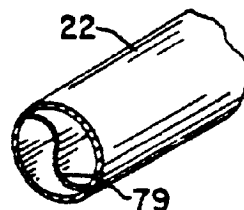


Fig. 6



METHOD AND APPARATUS FOR WATER DEGASIFICATION AND DISTILLATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a distilling apparatus and more specifically to a novel and improved water degasification and distillation apparatus embodying improved means for eliminating and/or neutralizing contaminants in the steam phase prior to condensation.

2. Description of the Related Art

Known water distilling apparatus generally comprise: a closed boiler; means for continuously feeding water to the boiler; means for removing and means for condensing the steam and other vapors evolved in the boiler. As the water in the boiler is being heated to produce steam, any air in the boiler is forced out. In addition, volatilizable chemical components present in the water will boil off and combine with the steam being evolved. Because there is no air in the boiler, the volatile impurities cannot be oxidized. The steam together with the volatilized chemical components will become condensed in the condenser so that the resultant distillate will contain therein the (volatile) chemicals. In instances wherein the raw water exhibits a disagreeable odor such as is produced by sulfur compounds and the like, most of the known to the art distillation apparatus will tend to concentrate the odor compound in the distillate and make the distilled water even more distasteful than the raw water. The inventor hereof has long been concerned with this problem and is the inventor of several patents directed to improved water distillation and degasification systems.

The water distilling apparatus of this invention relates to the apparatus described in Applicant's prior patents U.S. Pat. Nos. 4,420,374, 4,612,090 and 5,203,970, which patents in turn constitute an improvement over the apparatus disclosed in Applicant's earlier patent U.S. Pat. No. 4,339,307. Briefly, the water distilling apparatus described in the above-referenced patents U.S. Pat. Nos. 4,420,374, 4,612,090 and 5,203,970 comprises a very small boiler containing therein an instantaneous heating means and a reservoir for the boiler much larger than the boiler. A condensing coil is immersed within the reservoir so the water in the reservoir functions to cool the condenser. An open connection between reservoir and boiler provides an automatic water supply for the boiler.

The water in the reservoir circulates to and from the boiler, and the boiler heat thus imparted directly to the water in the reservoir together with the heat imparted to the reservoir water from the condenser heats the reservoir water to a temperature that will effectively deaerate the water in the reservoir and boil off any volatilizable constituents present in the water in the reservoir.

The water degasification and distillation apparatus in accordance with these above-referenced patents and in accordance with the invention hereof, comprises in more detail, a relatively large reservoir container adapted to receive the water to be distilled and a small boiler mounted on and to one side of the reservoir. A fluid conduit connects the boiler and the reservoir so that the liquid level in the boiler will be controlled to the liquid level in the reservoir. A vapor outlet in the boiler above the water level thereof is coupled to the condenser coil disposed within the reservoir container and the condensate outlet of the condenser coil extends through the wall of the reservoir container. The condenser coil is positioned so that the liquid in the reservoir will cover a major part or all of the condenser coil. With this arrangement and with the heater(s) in the boiler energized,

the water in the boiler will heat to boiling almost instantaneously and the steam generated in the boiler will be fed out to the condenser. Whenever the steam generated within the boiler exceeds the capacity of the boiler outlet to the condenser to remove the steam from the boiler the steam pressure will force water in the boiler through the fluid conduit back into the reservoir. Then, when the steam pressure is relieved (by outflow of water to the reservoir and of steam to the condenser), water will again flow from the reservoir into the boiler. Pulsation and recirculation of water as just described continues throughout during the operation of the distillation apparatus.

Since hot boiler water is returned to the reservoir through the fluid conduit periodically through the pulsation and since heat from the condenser is continuously added to the water within the reservoir, all water fed to the reservoir increases in temperature. In a word, the reservoir water becomes hot. Desirably, all undesirable volatile material contained in the water fed to the boiler is vaporized prior to entry of the water into the boiler and distillation thereof.

The cold water initially fed to the reservoir (at the top thereof) will normally sink to the bottom of the reservoir while hot water periodically recirculated from the boiler back into the reservoir container (near the bottom) will tend to rise. Thus, the water within the reservoir container tank is in constant movement and is mixing so that desirably all the water of the reservoir is maintained at about the same substantially elevated temperature so as to evolve the undesirable volatilizable components from the reservoir water before the water enters the boiler.

SUMMARY OF THE INVENTION

According to the present invention an ozone generator is placed in the boiler of a distillation or degasification apparatus. When water is forced back into the reservoir, a vacuum is created in the boiler which sucks in air through the condenser. The oxygen in the air is then turned into ozone, a strong oxidizing agent, with the ozone generator. Steam formed in the boiler must pass through the ozone before entering the condenser and therefore any contaminants in the steam are destroyed.

Discussion of the Invention

Ozone is a thermally unstable allotrope of oxygen. It is a powerful oxidizing agent which has seen increased industrial use in bleaching and chemical manufacturing processes requiring strong oxidizing agents. In the laboratory, ozone is usually generated by passing an electric spark through a stream of oxygen. However, ozone may also be prepared by exposing oxygen to ultraviolet light. Because ozone is such a strong oxidizing agent, it is receiving much attention for use in water purification.

The unique design of the degasification and distillation apparatus of this invention results in hot boiler water periodically returning to the reservoir. The flow of water into the reservoir generates a vacuum in the boiler. Air is sucked through the condenser into the boiler to fill the vacuum. By placing an ozone generator in the boiler, the oxygen in the air is oxidized into ozone. When the stream pressure is relieved, water again flows from the reservoir to the boiler. Steam generated in the boiler must now flow through ozone before entering the condenser. The ozone destroys and/or neutralizes any impurities in the water and this results in the production of very pure water. In addition, the oxygen level in the water is increased, improving the taste of the water.

Apparatus of the Invention

In the apparatus of this invention an ozone generator is placed in the boiler. The ozone generator is preferably

placed above the water line where it can interact with the air brought in through the condenser during the periodic pulsation of the water in the boiler. Typically, the ozone generator makes ozone by generating an electric spark. However, the use of an electric spark for generating ozone is not necessary. Any process for generating ozone from air is sufficient for the operation of the invention.

Optionally included in the distillation apparatus of the invention may be a stirrer as taught in U.S. Pat. No. 5,203,970. The stirrer preferably is made part of a fan assembly such as the fan assembly that forms part of the distillation apparatus described in the related patents U.S. Pat. Nos. 4,420,374 and 4,612,890. Conveniently, the stirrer rod can be made an extension of the fan rotor. Advantageously, the fan removes the steam and gases that bubble up from the reservoir water.

Optionally included in the distillation apparatus of this invention may be a deflector insert in the conduit connecting reservoir and boiler and/or in the condenser coil tubing. The deflector(s) generates spin and turbulence in the water passing between reservoir and boiler, and/or causes turbulent fluid flow adjacent the tubular wall of the condenser coil.

Optionally included in the distillation apparatus may be an oversized filter, desirably a charcoal filter, at the delivery end of the condenser.

The above and other advantages of the invention will become more apparent from the following description and accompanying drawings forming part of this Application.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary plan view of one embodiment of the distilling apparatus in accordance with the invention;

FIG. 2 is a cross sectional view of FIG. 1 taken along the line 2—2 thereof;

FIG. 3 is a cross sectional view of FIG. 1 taken along the line 3—3 thereof and illustrates air circulating means carried by the container; and

FIG. 4 is a cross sectional view showing the boiler and a fragmentary portion of the tank taken along the line 4—4 of FIG. 2.

FIG. 5 is a diagrammatic view showing the condenser tube containing a deflector.

FIG. 6 is a diagrammatic view showing the fluid conduit containing a deflector.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and more specifically to FIGS. 1 and 2 it may be seen that the distilling apparatus in accordance with this invention comprises a cylindrical tank reservoir container 10 having a pair of handles 11 secured to the side thereof. A boiler 12 having instantaneous heating elements 13 and 14 therein is affixed to the side of the tank 10 by the fluid connectors 15 and 16. The fluid connector 15 includes an elbow 17 having a shoulder 18 and a threaded shank extending through cooperating openings in the wall 19 of the boiler 12 and the wall of the container 10. A nut 20 engages the shank of the fitting 15 and together with a resilient washer 21 provides a water-tight seal for both the tank 10 and the boiler 12. A water inlet conduit 22 is fixedly coupled to the fitting 15 by means of a nut 23 so that water within reservoir container 10 will automatically feed into the boiler 12 until the water level within boiler 12 corresponds to the reservoir water level inside reservoir container 10. It

will also be observed that the water level is maintained at a level adequate to effect total or at least substantial immersion of the heating elements 13 and 14 in the water of boiler 12.

The steam outlet fitting 16 is of conventional construction and includes an outlet pipe 24, a threaded shank 24' extending through the walls of reservoir container 10 and boiler 12 and secured thereto by a nut 25. A sealing washer 26 is disposed between container and boiler to provide a water-tight connection. In the preferred embodiment of the invention herein illustrated the condenser 27 is in the form of a coiled tube of metal such as stainless steel, copper or the like and has the inlet end portion 28 sealably connected to the fitting 16 within container 10. The outlet 29 of the condenser 27 has a fitting 30 extending through the wall of container 10 and provides the condensate outlet 31. Optionally, but desirably an oversized filter 115 is interposed at condensate outlet 31. As best may be seen in FIG. 1, the coiled condenser tubing generates a cylindrical region 100 at the center of the reservoir container 10. Reservoir container 10 further includes an overflow pipe 32 which is connected to a fitting 33 sealed to the wall of the container 10 and a drain cock 34 for draining water from the container (being useful for cleaning and maintenance). A water inlet valve 35 is at the upper portion of the reservoir container 10 and has an inlet 36, an outlet 37 and a hand-wheel 38 for regulating the water supply in order to maintain an appropriate supply of water to the reservoir container 10.

The boiler 12 is shown more clearly in FIG. 4 and in the preferred embodiment illustrated herein consists of two housing elements 39 and 40. A wall 41 disposed between the housing elements 39 and 40 includes a peripheral seal 42 which is releasably clamped between the outer rims of the housing elements 39 and 40 by clips 43 at the periphery of the boiler 12. This arrangement completely seals the boiler formed by the housing element 39 and the wall 41. The whole boiler can be readily disassembled for cleaning. The heating elements 13 and 14 in the illustrated embodiment are carried by the wall 41 and are connected in series by a lead 44 connecting one terminal of one heater to one terminal of the other heater. The power line 45 has one lead 46 connected to the other terminal of the heater 14 while the second lead 47 is connected through a thermostat 48 to the other terminal of the heater 13. The thermostat is mounted on a bracket 49 in close proximity to the heaters 13. In the event the heater 13 reaches a temperature above the normal operating temperature, the thermostat will operate to open the circuit and de-energize both heaters 13 and 14. It is evident, however, that the heaters 13 and 14 could be arranged for parallel operating or in the alternative a single electric heater may be employed in the boiler provided however it delivers the quantity of heat necessary for operation of the distillation apparatus.

Included in the boiler is the ozone generator 120. Preferably, the ozone generator is inserted into the boiler through a port in housing element 39. As illustrated in FIG. 1, the ozone generator 120 is powered by transformer 121. It is not necessary, however, to have a separate power supply for the ozone generating means. The ozone generator may be powered by the same power supply used to operate heaters 13 and 14.

In the preferred embodiment of the invention herein illustrated a forced air circulation means assists removal of steam and undesirable vapors liberated from the reservoir water within reservoir container 10. The air circulating means which is shown in FIG. 3 comprises an inverted dished cover generally denoted by the numeral 50 over reservoir container 10 which includes a flat upper wall 51

that is perforated or apertured, an upwardly extending peripheral wall **52** and a downwardly curved peripheral wall **53**. The lower peripheral edge of the wall **53** carries three or more diagonally disposed rollers **54** each having spaced discs **55** rotatably carried by a shaft **56**. The discs **55** engage the rolled edge **10'** of the reservoir container **10** and accordingly provide an annular vent between the cover **50** and the top edge of the reservoir container **10**.

The flat apertured wall **51** of the air circulating means supports an electric motor generally denoted by the numeral **57** which powers a shaft **58** extending through the perforated wall **51**. The fan **59** is mounted on shaft **58**. Power is fed to the motor **57** by a cable **60** connected in a conventional manner to the motor. If desired, switch means may be provided for operation of the fan. The fan motor **57** is covered by a vented dome-shaped housing **61** that is securely fitted to the cover **50** and is attached thereto by any suitable means. In the illustrated embodiment of the invention, the dome-shaped housing **61** frictionally engages the peripheral wall **52** of the cover **50**.

In one mode of fan operation, air is drawn into the air circulating means assembly through an opening **62** in the dome-shaped housing **61** and then down through the perforated wall **51** whereupon it is directed downwardly over the reservoir water in reservoir container **10** and thereafter is discharged through the annular opening between the reservoir container **10** and its cover **50**. In the reverse mode of fan operation the fan **59** draws air in through the annular opening between reservoir container **10** and its cover **50** up through perforated wall **51** and opening out through vent **62** in motor housing **61**.

As may be seen in FIG. 3, a stirrer rod **101** extends from an integral connection with motor shaft **58** at the hub of fan **59** preferably but not necessarily axially of the cylindrical reservoir region **100** inside of condenser coil **27** and terminates at the stirrer blades **102** immersed in the reservoir water. The depth of immersion for stirrer blades **102** is not critical, but preferably, they are not deeper than the bottom of coil condenser **27**. In the mode illustrated herein, the stirrer rod was positioned modestly off-center to avoid interference with the outlet bend **29** of condenser coil **27**, see FIGS. 1 and 2.

In the operation of the distillation apparatus of this invention, the reservoir container **10** and boiler **12** are first filled with water to a level at least substantially covering the heating elements **13** and **14** as may be observed most clearly in FIG. 2. It will be observed that when filling reservoir container **10**, water will automatically flow through conduit **22** into the boiler so that ultimately the level of the water in the reservoir container **10** will be the same as the water level in the boiler **12**. When energy is then supplied to the heating elements **13** and **14** they will function to boil the water within the boiler **12**. Oxygen in the air above the water is turned to ozone by ozone generator **120**. Steam generated from heating elements **13** and **14** rises through the ozone and enters inlet **24**. The steam then flows through the condenser coil **27** to be condensed therein. The condensed steam will then discharge through filter **115** as the distillate (liquid) product from the condenser outlet **31**. When first operating the distillation apparatus, it is generally desirable to discard the distillate product until the water inside reservoir container **10** has attained a normal operating temperature which preferably is 180.degree.-190.degree. F. (which is rapidly attained). Heaters **13** and **14** are designed to heat the water within the boiler at a rate faster than the condenser coil **27** can accommodate the steam produced. Accordingly, a head of steam is developed within the boiler **12** and the steam

pressure will force liquid from the boiler back through the conduit **22** into the reservoir container **10** thereby relieving the steam pressure. The flow of the water from the boiler into conduit **22** generates a vacuum in the boiler. The vacuum causes air to be drawn through filter **115** into the condenser outlet **31**, traveling through the condenser and exiting in the boiler via outlet **24** and thereby providing fresh oxygen for the ozone generator **120**. As soon as the steam pressure within the boiler is relieved, water will again flow through the conduit **22** back into the boiler with the result that there will be a periodic reversal of water flow through the conduit **22** and air flow through the condenser **27**. This pulsating action results in a more rapid increase in temperature of the reservoir water within the container **10** by contributing heat over and above the heat imparted to the reservoir water by the action of the condenser coil **27**. It also results in a constant renewing of ozone in the boiler. The temperature of the reservoir water, however, is always below the boiling temperature (of the water in boiler **12**) so that distillate will be condensed in condenser **27**. Preferably the reservoir water should be kept in the range of 180.degree. F. to 190.degree. F. This temperature level will boil off undesirable components from the reservoir water (prior to actual distillation thereof), and also serves to operate condenser **27** adequately. To maintain proper operation of the apparatus, a substantial proportion of the feed water which enters at the inlet **37** ultimately is discharged as overflow through tube **32** and outlet **35**.

As has already been pointed out, a mechanical expedient to facilitate maintenance of a distinct temperature across the condenser coil tubing is illustrated in FIG. 5. Shown there is an enlarged partial cross-section of condenser coil tubing. Inside the tubing is a deflector **77** whose purpose is to generate spiral flow movement of steam and condensate to the tube wall. Also, flow becomes more turbulent thereby helping heat exchange across the tube wall. A like deflector **79** may be provided in the conduit connecting reservoir container **10** and boiler **12** (see FIG. 6). The purpose of deflector **77** is, of course, to create turbulent mixing of the water so as to avoid any temperature stratification either in reservoir container **10** or in boiler **12**.

An additional optional expedient which has been found advantageous in practice of this invention is the provision of a filter, preferably an oversized filter, at the condenser outlet **31**. In the embodiment illustrated herein the oversized filter **115** is a carbon filter.

Filter **115** absorbs any organic materials that are carried over with the condensate. It polishes the condensate, so to speak but also it achieves a superior aeration for the condensate.

As has already been pointed out the distillation apparatus of this invention operates in a pulsating fashion causing water to flow through the connecting conduit **22** back and forth between boiler **12** and reservoir **12**. The same pulsations affect condenser **27**. A pulse of (steam) pressure from boiler **12** passes through the condenser tubing in a forward direction during a steam generation pulse, sending condensate out through filter **115**. Then during the reverse suction pulse, air is drawn into the filter **115**, through the condenser, into the boiler. Thus, the filter **115** acts as much to filter air drawn into the condenser tubing, as it does to filter distillate leaving the condenser tubing.

Manifestly, the pulses are not equal in their effect. Steam is being generated in boiler **12**, then is condensed in condenser coil **27**. The distillate is discharged at the outlet **31** through filter **115**. A net movement outflow movement of

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distilled water through filter **115** results. At the same time, a small net inflow of air into filter **115** and condenser **27** results. The distillate, e.g., at 190.degree.-195.degree. F., is hot enough to heat filter **115** and prevents microbial contamination of the filter. This means that air which enters oversized filter **115** during the suction pulses is retained therein and becomes sterilized by the hot filter before entering condenser **27** and/or becoming absorbed in the distillate. The reason for providing a filter **115** that is oversized is precisely to increase the residence time therein of the inflowing air. Overall, the result is that air heated and sterilized in filter **115** partially aerates the distilled water improving the palatability thereof.

While only certain embodiments of the invention have been illustrated and described herein, it is understood that alterations, changes, and modifications may be made therein without departing from the true scope and spirit thereof.

I claim:

1. A method for producing a distilled water product which comprises:

providing a distillation apparatus comprising a water reservoir container having a water inlet and outlet thereto connected so as to create a reservoir of water therein and a boiler smaller than the reservoir container with an open connection between container and boiler for water flow to or from the boiler, a steam line overhead of the water level in the boiler leading to a condenser immersed in the reservoir, an outlet from

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said condenser to discharge condensate and an ozone generator in said boiler; and

maintaining a predetermined level of reservoir water by introducing feed water into and removing water from said container at a flow rate which maintains a temperature in the range of about 180°-190° F. in the reservoir and heating the water in said boiler to generate steam, the steam passing through ozone generated by said ozone generator and passing into said condenser to be condensed therein by heat exchange against the reservoir water whereby the reservoir water becomes heated and the heated reservoir water becomes devolatilized and deaerated prior to entering said boiler.

2. The method of claim **1** wherein the boiler periodically generates more steam than can be accommodated by the condenser thereby causing a pulsation wherein water is forced to flow out of the boiler back into the reservoir by steam pressure, and the steam pressure pulse is dissipated whereupon water flows back into the boiler from the reservoir, said pulsation also causing periodic flow of condensate out of the condenser and periodic flow of air into said boiler.

3. The method of claim **2** further comprising stirring the water in said reservoir with a mechanical stirrer.

4. The method of claim **3** further comprising providing a filter at the outlet of said condenser.

* * * * *



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(54) **HIGH TEMPERATURE PELTIER EFFECT WATER DISTILLER**

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(58) **Field of Search** 203/10, 100, DIG. 17, 203/DIG. 4; 159/28.6; 202/176, 187, 234, 236, 163; 62/3.2, 3.3; 136/201, 203, 204

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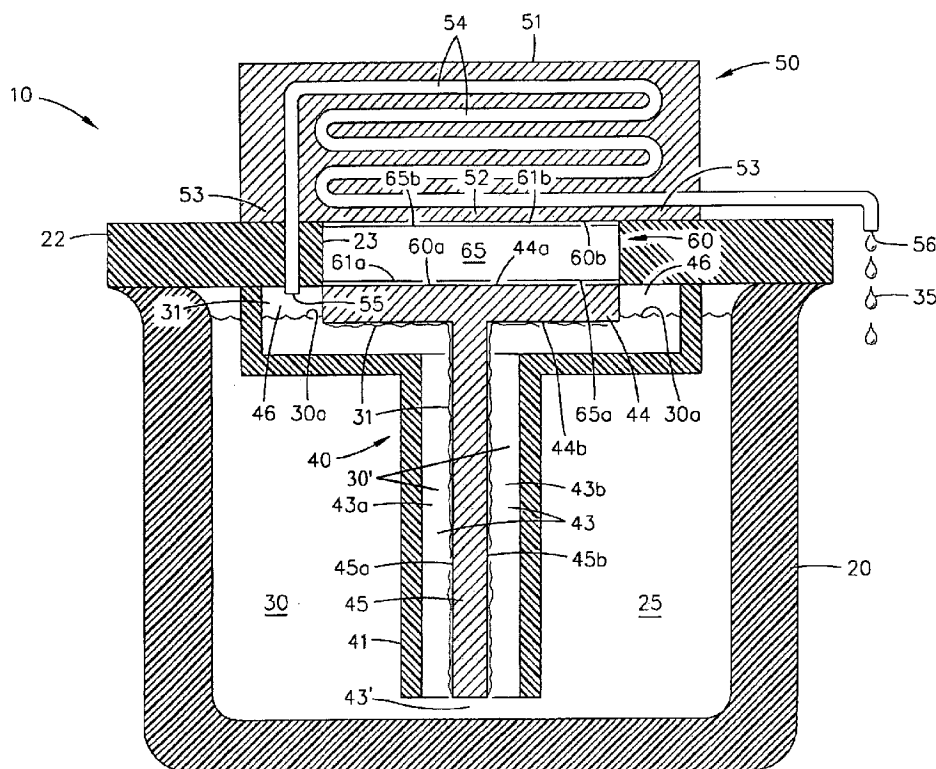
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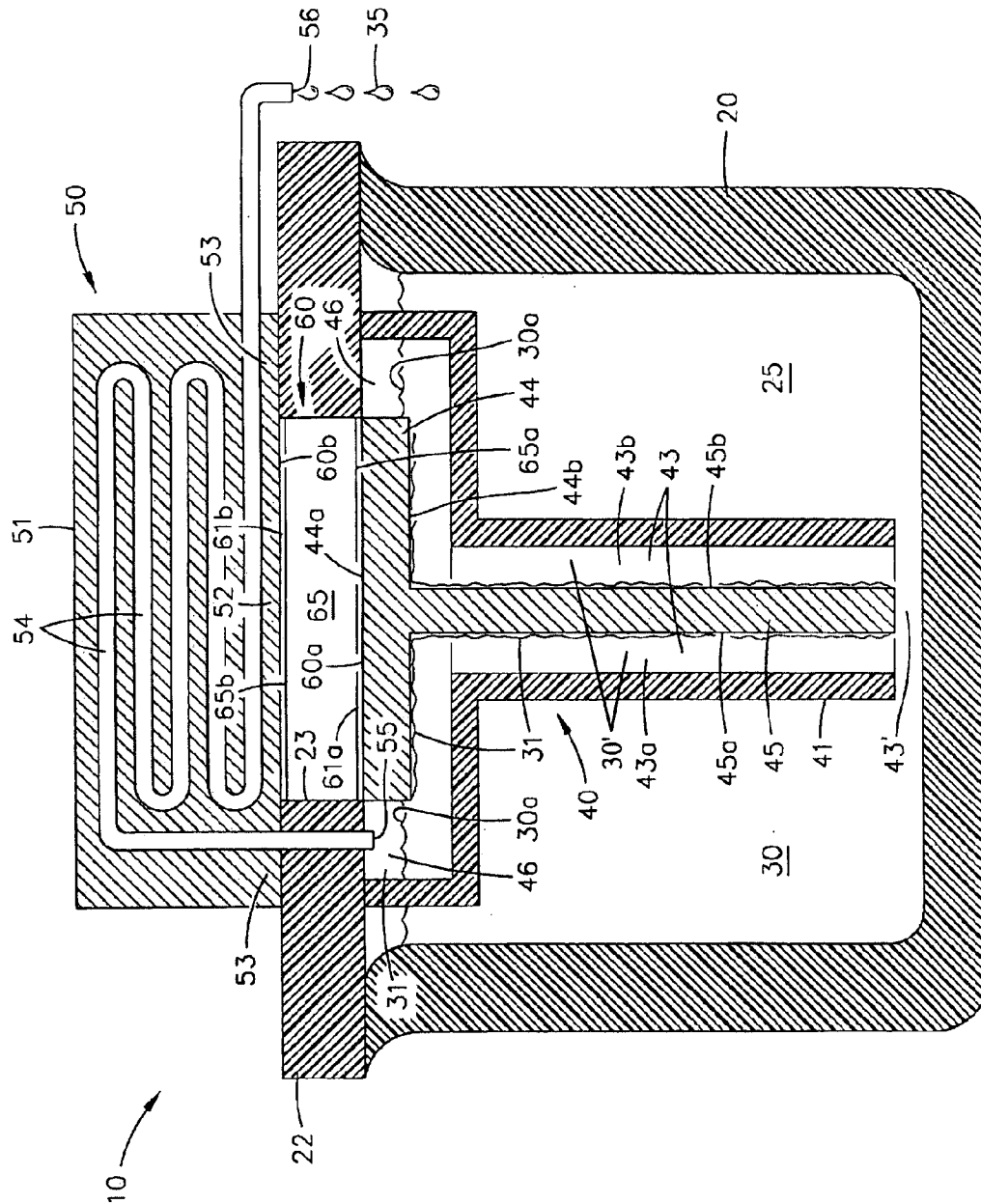
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(57) **ABSTRACT**

An apparatus for and method of distillation uses a high temperature thermoelectric device to heat a liquid, such as water to vapor (steam) and cool the vapor to a purified, distilled liquid. Distillation system has no moving parts, thereby increasing reliability while reducing noise and maintenance. Liquid in a container has a heating section on the container extending into it to boil it into a vapor that is fed to a condenser section disposed on the container adjacent to the heating section. A thermoelectric section provided with a Peltier effect device is interposed between the heating section and condenser section. The Peltier effect device has one side in contiguous contact with the condenser to transfer heat from it and another side is in contiguous contact with the heating section to transfer heat to it to boil the liquid into the vapor and feed the vapor through the condenser that condenses it into distilled liquid.

14 Claims, 1 Drawing Sheet





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HIGH TEMPERATURE PELTIER EFFECT WATER DISTILLER

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention relates to an apparatus for and method of distilling water. More particularly, this invention utilizes a high temperature Peltier effect device to heat water to boil as a vapor and to cool it to distilled water.

Conventional distillers of water such as those designed to distill water in amounts suitable for use in the home have a separate condenser to transfer most or all of the heat along with some steam to the surrounding environment with a fan. This increases the workload on environmental handling systems to remove this heat energy and moisture from environmentally controlled living spaces. Conventional home distillers additionally transfer heat through the walls (including the bottom) of the water reservoir. As water is distilled in these contemporary distillers, precipitates created during the distillation process fall to the bottom of the reservoir. This layer of precipitates decreases the rate of heat transfer to the water and decreases the overall efficiency of these systems. In addition, this layer of precipitates becomes baked onto the bottom of the reservoir and requires expensive efforts and acidic cleansers to remove it.

Reservoirs of the conventional home distillers usually are constructed of relatively expensive stainless steel because of its high thermal conductivity and corrosion resistance. The high thermal conductivity of stainless steel is required because heat is transferred through the walls of the reservoir to the water. Another reason stainless steel is selected for construction of conventional home distillers is that precipitates baked onto the bottom of the reservoir are removed relatively easily. Irrespective of the benefits of stainless steel, it significantly increases the cost of home distillers.

Thus, in accordance with this inventive concept, a need has been recognized in the state of the art for a distillation system using a high temperature thermoelectric device that functions to heat water to its vapor point (steam) and cool the vapor to a distilled water.

SUMMARY OF THE INVENTION

The present invention provides a distillation system and method having a thermoelectric Peltier effect device interposed between and in contact with a heater section extending into a reservoir of water and a condenser section. The water is heated to its vapor point (steam) and cooled to condense to a distilled water by the same Peltier effect device that has no moving parts to provide for increased reliability and reduced noise and maintenance.

An object of the invention is to provide an apparatus for and method of distillation including a high temperature thermoelectric device having a Peltier effect device to first heat water to vapor and then cool the vapor to a distilled water.

Another object of the invention is to provide a distillation apparatus and method having no moving parts, to increase reliability and reduce noise and maintenance.

Another object of the invention is to provide a distillation apparatus and method providing for an increase in efficiency

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by taking the heat energy extracted during condensing and reusing it for heating.

Another object is to provide a distillation apparatus and method evaporating water by flash point vaporization to put heat energy directly in the volume of water instead of wasting it through the walls of a tank and concentrating the heat energy in a small volume of water to reduce the over all requirements for heat energy.

Another object of the invention is to provide a distillation apparatus and method heating only a small volume of water to the boiling point as opposed to conventional systems that heat entire volumes of water to the boiling point for the full duration of the distillation process.

Another object of the invention is to provide a distillation apparatus and method preventing the baking of precipitates onto the walls of the tank to increase reliability and reduce maintenance.

An object of the invention is to provide a highly reliable distillation apparatus and method having no moving parts and fabricated from porcelain, glass, plastics, etc., to reduce production costs as compared to stainless steel.

Another object of the invention is to provide a distillation apparatus and method operable by 110 V power sources as well as safer 12 V or 24 V DC power sources that can be conveniently packaged to be insulated from the effects of high heat and high moisture environments.

These and other objects of the invention will become more readily apparent from the ensuing specification when taken in conjunction with the appended claims.

BRIEF DESCRIPTION OF THE DRAWING

The FIGURE shows a cross-sectional view of a distillation system having a thermoelectric section including a Peltier effect device interposed between a heating section and condenser section in accordance with this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the FIGURE, a distillation system **10** has a container **20** containing a reservoir **25** of water **30**, such as water for distillation into distilled water **35**. Container **20** may be dish-shaped cylinder and made of a variety of materials, such as porcelain, glass, plastic etc., that are capable of holding water **30**, and cover **22** made from a foam-like insulating material covers and extends across container **20** and reservoir **25** to block the transfer of heat. Container **20** may include suitable valves, feeder tubes, and a pump connected to a source (not shown) to replenish water **30** to keep it at or near a predetermined level **30a** of water **30** in reservoir **25**.

Distillation system **10** further includes a heating section **40**, a condenser section **50**, and a thermoelectric section **60**. Thermoelectric section **60** is fitted into a traverse opening **23** in insulating cover **22** so that condenser section **50** and heating section **40** can operatively engage water **30** in container **20** to make distilled water **35**. Heating section **40** is used to boil water **30** from a water state to a gaseous state, or vapor **31**, and condenser section **50** is used to cool and condense the vaporized water **31** to distilled water **35**. Thermoelectric section **60** has heat conductive plates **61a** and **61b** sized to extend across an opening **23** in insulating cover **22** and being in contact with heating section **40** and condenser section **50**, respectively. Thermoelectric section **60** also has a Peltier effect device, hereinafter referred to as PE **65**. PE **65** is disposed between plates **61a** and **61b** to

effect the simultaneous heating and boiling of water **30** to vapor **31** and cooling and condensing of vapor **31** to distilled water **35**.

Heating section **40** includes tubular-shaped wall **41** connected to and extending downwardly from insulating cover **22** to define a percolating chamber **43** having a T-shaped cross-sectional configuration having an open-ended bottom **43'** to receive water **30**. Tubular wall **41** is made from an insulating material to separate and insulate a portion **30'** of water **30** in percolating chamber **43** from the rest of water **30** in container **20**. As water portion **30'** is vaporized, more of water **30** can flow into percolating chamber **43** via open-ended bottom **43'** to replenish water portion **30'**. Optionally, tubular wall **41** and percolating chamber **43** could be eliminated; however, such a modification will increase energy needed to vaporize the increased volume of water **30** and the time required to initiate the distillation process.

Heating section **40** additionally has a flat plate **44** of conductive material, such as metal, that has an inner surface **44a** disposed in contiguous and intimate contact with thermoelectric section **60** via heat conductive plate **61a** to absorb and transmit heat from a hot side **60a** of thermoelectric section **60** to a rod **45**. Rod **45** is connected to and orthogonally extends from flat plate **44** and can be made from the same conductive material as plate **44**. Rod **45** extends into percolating chamber **43** to transmit heat to water portion **30'** at and below level **30a**. Parts of water portion **30'** in portions **43a/43b** of percolating chamber **43** are vaporized, or boiled into vapor **31** by heat conducted through plate **44** along an outer surface **44b** and through rod **45** along rounder outer surface **45a/45b**. The parts of water portion **30'** that are vaporized into vapor **31** are replaced in percolating chamber **43** from water **30**.

Vapor **31** bubbles upward through water portion **30'** and collects in plenum **46**. Plenum **46** includes the regions on both sides of first flat plate **44** and around rod **45** at the top of portions **43a/43b** in percolating chamber **43**.

Condenser section **50** may be fabricated from a block **51** of heat conductive metal material that has portion **52** lying adjacent to and in contiguous contact with a cold side **60b** of thermoelectric section **60**. Other portions **53** of condenser section **50** can extend to lie adjacent insulating cover **22** and be insulated from the heat associated with heated water **30** by heating section **40**. Heat conductive metal block **51** of condenser section **50** can be cast or otherwise suitably machined with at least one serpentine extending traverse passageway **54** from an inlet port **55** communicating with plenum **46** to an outlet port **56** where distilled water **35** may be collected.

Heat conducting plates **61a** and **61b** of thermoelectric section **60** are made from a conductive metal that serves to contain and protect PE **65** from the ambient. Heat conductive plate **61a** also conducts heat and distributes it from PE **65** to surface **44a** of flat plate **44** of heater section **40** and plate **61b** conducts heat from adjacent portion **52** of condenser section **50** to PE **65**. Electrical conductors and control components (not shown) may extend from PE **65** to supply DC power for the duration of the distillation process. PE **65** of thermoelectric section **60** is disposed within plates **61a** and **61b** in such a fashion to be in intimate contact with both heater section **40** and condenser section **50**. PE **65** operates according to the Peltier effect.

The Peltier effect was first discovered in the 19th century and is the liberation of heat at one junction and the absorption of heat at the other junction when a current is passed through a circuit consisting two different metals. However,

the temperature difference obtained with different metals is not high. More recently, semiconductors can be used to produce larger temperature differences across metal-semiconductor junctions of metal and n and p-type semiconductors to produce cold sides (heat absorption) and hot sides (heat liberation) so that a number of such metal-semiconductor junctions contained in PE **65** can be used as an effective source for heating water **30**, such as water to vapor **31** and cooling vapor **31** to distilled water (water) **35**.

A number of commercially available modules for liberating heat to heating section **40** and for absorbing heat from condenser section **50** as per the Peltier effect may be selected by one skilled in the art to which this invention pertains to fabricate PE **65** in thermoelectric section **60**. These include and are not limited to the thermoelectric modules marketed under the trademark ZMAX by Tellurex Corporation 1248 Hastings Street, Traverse City, Mich. 49686; the thermoelectric modules model numbers TED-0606-018 . . . , TED 3030-127 . . . , TED 4040-127 . . . , etc., marketed by TE Distributing INC., 113 Hiltwood Drive, Hendersonville, Tenn. 37075; and the thermoelectric modules marketed by Ferrotec America Corporation, 40 Simon Street, Nashua, N.H. 03060. These modules are capable of heating heating section **40** to about 150 to 200° C. along one surface, or side and provide for a sufficiently lower temperature along another surface, or side to absorb heat from condenser section **50**.

Sufficient numbers of these commercially available thermoelectric modules may be selected and are interconnected and arranged in accordance with manufactures specifications in PE **65** to create hot side **65a** inside and adjacent to hot side **60a** of thermoelectric section with heat conductive plates **61a** in contiguous contact with surface **44a**. The heat of hot side **65a** is conducted to plate **44** and rod **45** via plate **61a** to boil at least part of water portion **30'** into steam-like vapor **31** along surface **45a/45b** of rod **45**. If, as shown in the FIGURE, level **30a** of water **30** in reservoir **25** is raised to place outer surface **44b** of plate **44** in water portion **30'**, then vapor **31** also will form on surface **44a**. Heat is absorbed on cool, or cold side **65b** of PE **65** in contact with heat conductive plate **61b** to cool condenser section **50** via adjacent portion **52** and condense vapor **31** in serpentine passageway **54** into condensed and distilled water **35** that drains from outlet port **56**. This heating and cooling of PE **65** of thermoelectric device **60** occur at the same time during the distillation process and since there are no moving parts, long-term reliability is assured.

In operation, reservoir **25** is filled with liquid, such as water. DC power is coupled to power-up PE **65** of thermoelectric section **60**. Heat energy is transferred from condenser section **50** via adjacent portion **52** to percolating chamber **43** via the high temperature PE **65**, which is in thermal contact with condenser section **50** and flat plate **44** and rod **45**. This heat transfer is accomplished by 1.) absorbing heat in PE **65** on cool, or cold side **65b** that is in contiguous contact with portion **52** of condenser section **50**, 2.) conducting the absorbed heat through PE **65** and plate **44** and rod **45** and reusing it to partially heat water portion **30'**, and 3.) generating heat in PE **65** at hot side **65a** and conducting it to plate **44** and rod **45** to boil water portion **30'** into steam-like vapor **31** along surface **45a/45b** of rod **45** and surface **44a** of plate **44**. Vapor **31** rises and collects in plenum **46** to pass through serpentine passageway **54** due to convection and increased pressure in plenum **46** that is caused by boiling parts of water portion **30'** into vapor **31** in percolating chamber **43**. The heat removed from condenser section **50** cools it via adjacent portion **52** and vapor **31** is

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condensed in serpentine passageway **54** into condensed and distilled water **35** that feeds by gravity through outlet port **56**.

Distillation system **10** of this invention uses high temperature thermoelectric PE **65** to first heat parts of water portion **30'** to a vapor **31** (steam) and then cool vapor **31** to purified distilled water **35**. Distillation system **10** of this invention has no moving parts, thereby increasing reliability and reducing noise and maintenance. Distillation system **10** has increased efficiency by taking the heat energy extracted during condensing and reusing it for vaporization that vaporizes parts of water portion **30'** by flash point vaporization. Concentrating heat energy directly in the volume of water portion **30'** in percolating chamber **43** instead of heating the entire volume of water **30** to its boiling point for the full duration of the distillation process eliminates needless waste of heat that would be lost by transmitting it through the walls of container **20**. In addition, by not boiling water **30** in container **20** baking precipitates onto the inner walls of container **20** is eliminated to reduce maintenance tasks, and relatively expensive stainless steel is not required so that less expensive and more readily available materials such as porcelain, glass, or plastics may be used. Distillation system **10** of this invention is uncomplicated and utilizes commercially available modules in PE **65** to assure high reliability, and can be powered by 12 V or 24 V DC power sources to be safer, have reduced power requirements, and could have power conversion and controls mounted in plug modules isolated from the high heat and high moisture environment where distillation occurs.

Having the teachings of this invention in mind, modifications and alternate embodiments of this invention may be adapted. Distillation system **10** can be in different sizes and configurations and fabricated from a number of different materials chosen to assure long term reliable operation under different operational requirements. Its uncomplicated, compact design, lack of possibly objectionable by-products, and use of commercially available constituents allows its use in confined spaces under adverse conditions.

The disclosed components and their arrangements as disclosed herein all contribute to the novel features of this invention. Distillation system **10** provides a quick and cost-effective way to distill liquid, including water, without introducing unnecessary complications or creating burdensome weight and size constraints. Therefore, distillation system **10**, as disclosed herein is not to be construed as limiting, but rather, is intended to be demonstrative of this inventive concept.

It should be readily understood that many modifications and variations of the present invention are possible within the purview of the claimed invention. It is to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

We claim:

1. A distillation apparatus comprising:

- a container holding water;
- a heating section on said container and extending into said water to boil said water into a vapor;
- a condenser section on said container and adjacent to said heating section to condense said vapor into distilled water;
- a thermoelectric section having a Peltier effect device interposed between said heating section and said condenser section, said Peltier effect device having one side adjacent and in contact with said condenser section to transfer heat therefrom and an other side adjacent to

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and in contact with said heating section to transfer heat thereto to boil said water into said vapor and feed said vapor through said condenser to condense it into said distilled liquid; and

an insulating cover extending across said container and having a traverse opening, said Peltier effect device of said thermoelectric section fitting in said traverse opening to place said one side in contiguous contact with said heating section and said other side in contiguous contact with said condenser section.

2. A distillation apparatus according to claim 2 wherein said heating section has a tubular-shaped insulating wall extending downward into said water to form an open-ended T-shaped percolating chamber to contain a portion of said water therein.

3. A distillation apparatus according to claim 2 wherein said heating section has a heat conductive plate and a rod connected together to extend into said percolating chamber and said water portion.

4. A distillation apparatus according to claim 3 wherein said plate has an inner surface disposed adjacent to and in contact with said Peltier effect device and an outer surface in contact with said water portion in said percolating chamber.

5. A distillation apparatus according to claim 4 wherein said rod orthogonally extends from said plate into said percolating chamber, said vapor forms on the outer surface of said rod and said outer surface of said plate, and said heating section has a plenum collecting said vapor.

6. A distillation apparatus according to claim 5 wherein said condenser section has a passageway serpentinely extending through a block of heat conducting material to receive said vapor at an inlet port and to feed said distilled water therefrom at an outlet port.

7. A distillation apparatus according to claim 6 wherein heat is transferred to said water by absorbing heat in said one side of said Peltier effect device, conducting said absorbed heat through said Peltier effect device and said plate and said rod, reusing said absorbed heat to partially heat said water portion, and generating heat in said Peltier effect device at said other side and conducting said generated heat to said plate and rod to boil parts of said water portion into said vapor along outer surface of said plate and said rod.

8. A method of distilling water comprising the steps of: extending a heating section into liquid in a container; heating said liquid to boil said liquid into a vapor; condensing said vapor into a distilled liquid in a condenser section on said container and adjacent to said heating section;

transferring heat with a Peltier effect device interposed between said heating section and said condenser section, said Peltier effect device having one side adjacent and in contact with said condenser section to transfer heat therefrom and an other side adjacent to and in contact with said heating section to transfer heat thereto to boil said liquid into said vapor and feed said vapor through said condenser to condense it into said distilled liquid;

extending an insulating cover across said container; mounting said Peltier effect device in a traverse opening in said insulating cover; and

placing said one side of said Peltier effect device in contiguous contact with said heating section and said other side of said Peltier effect device in contiguous contact with said condenser section.

9. A method according to claim 8 further comprising the steps of:

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extending a tubular-shaped insulating wall downwardly into said liquid to form an open-ended T-shaped percolating chamber; and

containing a portion of said liquid in said T-shaped percolating chamber.

10. A method according to claim 9 further comprising the step of:

connecting a heat conductive plate and rod of said heating section to extend into said percolating chamber and said liquid portion therein.

11. A method according to claim 10 further comprising the steps of:

placing an inner surface of said plate adjacent to and in contact with said Peltier effect device; and

contacting an outer surface of said plate with said liquid portion in said percolating chamber.

12. A method according to claim 11 further comprising the steps of:

extending said rod orthogonally from said plate into said percolating chamber;

forming said vapor on a surface of said rod and said outer surface of said first plate; and

collecting said vapor in a plenum of said heating section.

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13. A method according to claim 12 further comprising the steps of:

extending a passageway serpentine through a block of heat conducting material of said condenser section;

receiving said vapor at an inlet port of said serpentine extending passageway; and

feeding said distilled liquid from an outlet port of said serpentine extending passageway.

14. A method according to claim 13 wherein said step of transferring heat to said liquid includes the steps of:

absorbing heat in said one side of said Peltier effect device;

conducting said absorbed heat through said Peltier effect device and said first plate and rod;

reusing said absorbed heat to partially heat said liquid portion;

generating heat in said Peltier effect device at said other side;

conducting said generated heat to said plate and rod; and

boiling parts of said liquid portion into said vapor along outer surfaces of said plate and said rod.

* * * * *



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United States Patent [19]

[11] E

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Helmich

[45] Reissued Date of Patent: **Jun. 25, 1996**

[54] HIGH EFFICIENCY WATER DISTILLER

[76] Inventor: **Arthur R. Helmich**, 7823A Camille Dr., Benton, Ark. 72015-9525

[21] Appl. No.: **796,697**

[22] Filed: **Nov. 21, 1991**

Related U.S. Patent Documents

Reissue of:

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Issued: **Jan. 16, 1990**
Appl. No.: **265,587**
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[52] U.S. Cl. **202/176; 137/403; 159/23; 159/DIG. 32; 159/DIG. 41; 165/110; 202/181; 202/185.3; 202/235; 202/254; 203/10; 203/22; 203/100; 203/DIG. 8; 392/401**

[58] Field of Search **202/176, 181, 202/185.3, 197, 235, 254, 206; 203/4, 10, 12, 40, 1, 22, DIG. 8, 100; 392/400-406; 165/110, 111, 113; 159/23, DIG. 32, DIG. 41; 137/403**

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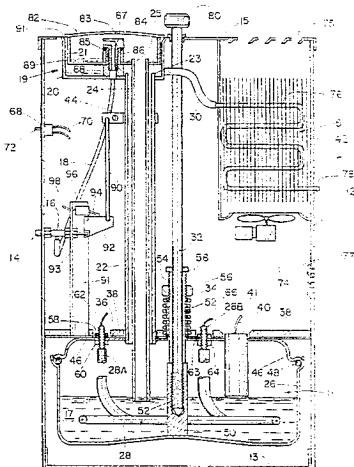
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[57] ABSTRACT

A highly efficient distillation unit is provided for heating water and condensing the generated steam to remove the contaminants from the water. Efficiency is enhanced by providing a compact air cooled fin-and-tube heat exchanger which removes heat from the steam, with a powered blower passing air by the fins. A removable bowl which houses the evaporating water is suspended from a rod biased toward its upper position. Mechanical linkage interconnects the rod and a valve which controls incoming water flow to the bowl. The valve closure member is incrementally moved from an opened position to a closed position as a function of the weight of the water in the heating bowl. A low density electrical heating element is powered with from 40 to 55 watts per square inch of submerged heating element exterior surface. The bowl is configured to have a large surface area of heated water to heater input power, thereby further maximizing efficiency. The unit of the present invention is particularly well suited for home or office use, and may be easily cleaned and economically operated.

21 Claims, 2 Drawing Sheets



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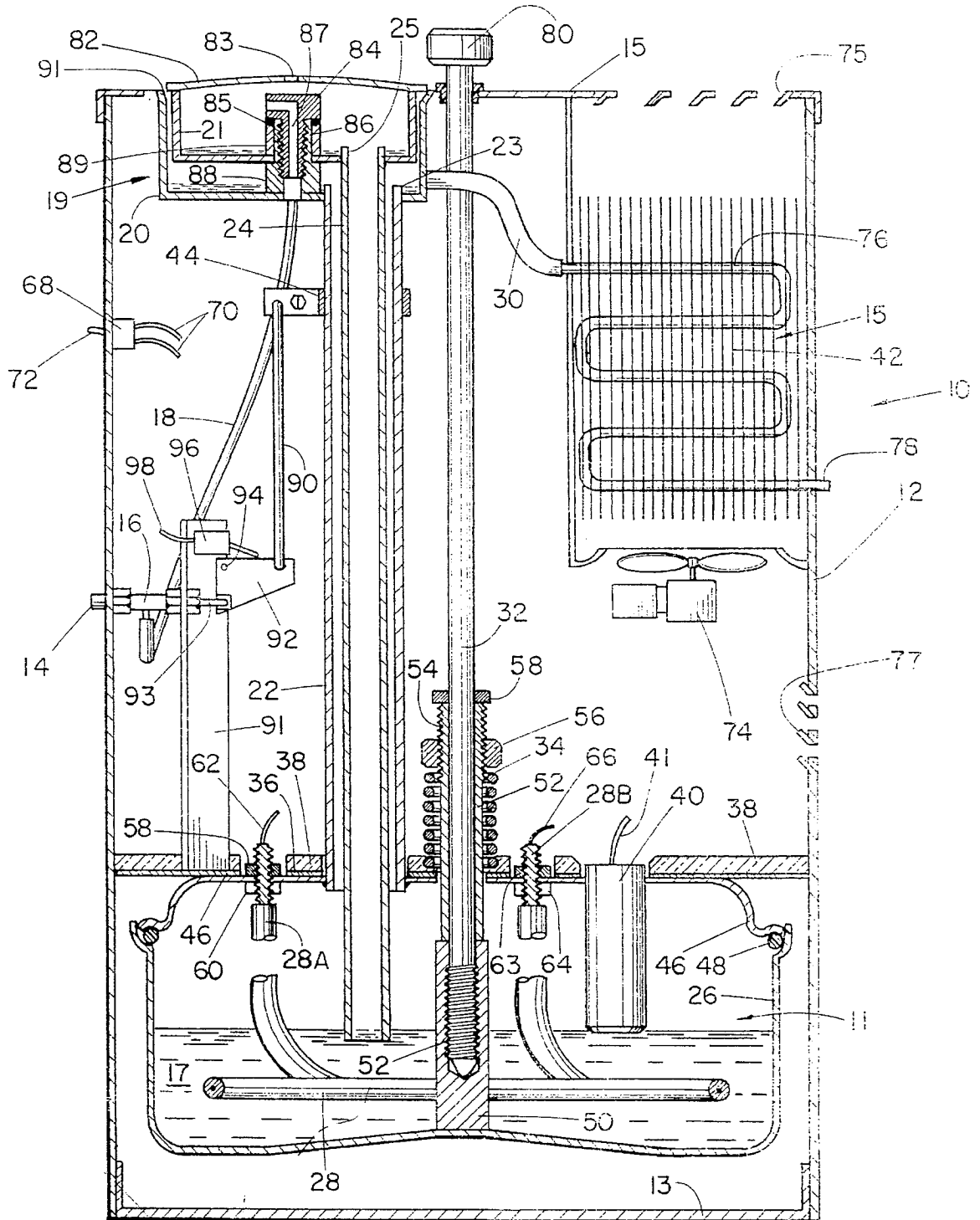


FIG. 1

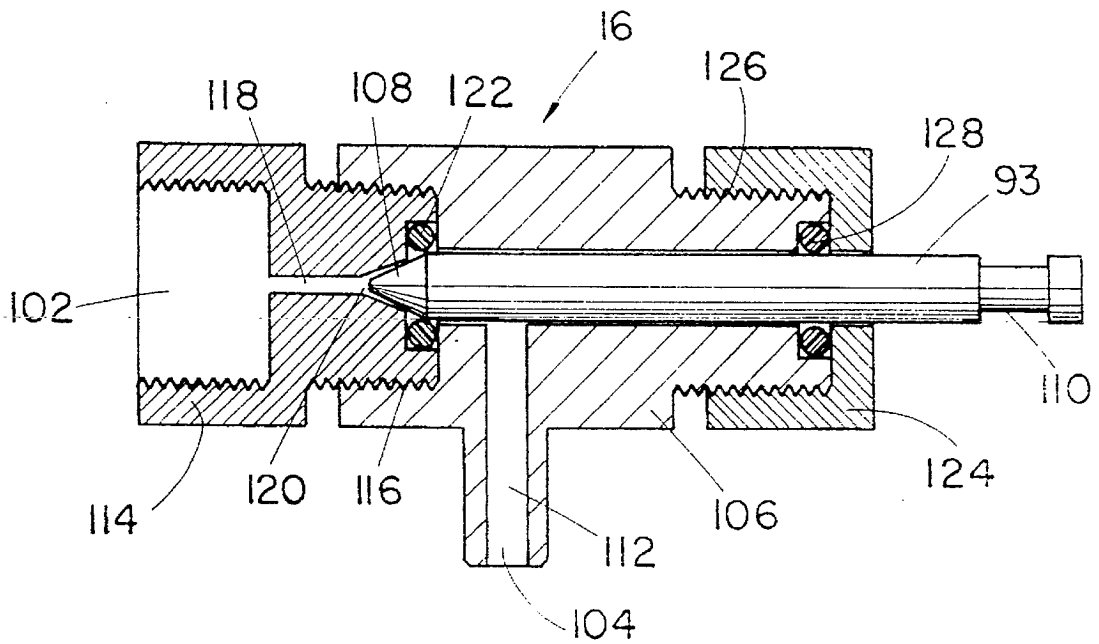


FIG. 2

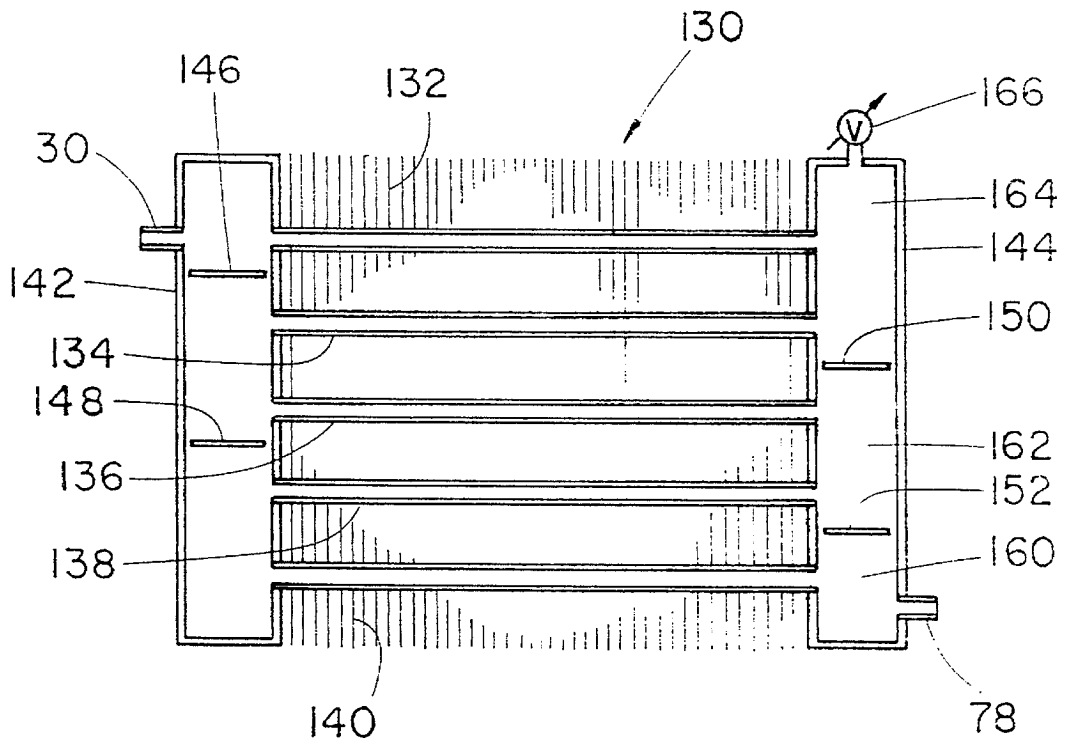


FIG. 3

HIGH EFFICIENCY WATER DISTILLER

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to apparatus for distilling water to remove contaminants and, more particularly, relates to a highly efficient water distiller suitable for home or office use.

2. Description of the Background

Water distillers have been used for decades to purify water. Water distillation provides an effective and highly efficient technique for removing bacteria, chemicals, and toxic organic compounds from contaminated water. In recent years, the public has become more aware of the fact that regular water supplies, including "tap" water supplied by a municipality and local or regional well water, often contains dissolved gases, e.g., sulfur dioxide, and/or other contaminants which are harmful to health. The distillation process heats the water to produce steam, and then condenses the steam to form water free from such contaminants. The contaminants having a vaporization temperature higher than that of water remain in the heating unit of the distiller, while solvents which have a boiling point lower than water may be separated from the steam by venting prior to condensation.

U.S. Pat. No. 771,832 discloses a crude water distiller with a bunsen burner for heating the water. U.S. Pat. No. 3,445,344 discloses a complex distiller with a pump having a rotating inverted open cone. U.S. Pat. No. 3,489,649 discloses a distiller with two separate boiling chambers for achieving double distillation.

U.S. Pat. No. 3,660,246 discloses a distiller with a vertical riser between a distillation chamber and a condensation chamber. The distillate enters an expansion zone and exits through perforations, where it is cooled by a spiral cooling coil. U.S. Pat. No. 3,907,683 discloses a distiller with a constant head reflux condenser to closely regulate the temperature and flow rate of the water from the condenser to the evaporator. U.S. Pat. No. 4,110,170 discloses a condenser which controls the entry of water to the distiller by sensing the temperature of the distillate.

U.S. Pat. No. 3,838,016 teaches a distiller which utilizes spiral condenser coils. A first float is responsive to the water level in the heating unit, and a second float is responsive to the water level in the condensing unit. Each float operates a microswitch, and the signals from each of the floats operates the distiller. U.S. Pat. No. 4,331,514 discloses a distiller with a float valve which regulates the level of water in a boiling chamber. U.S. Pat. No. 4,339,307 discloses a distiller with separate float valves for controlling the water level in a preheat unit and the boiler unit.

An improved water distiller is disclosed in U.S. Pat. No. 4,724,048. This water distiller includes a substantially vertical chimney for passing steam from the heating unit to the condensing unit, and an inner tube axially positioned within the chimney for passing preheated water to the heating unit. In one embodiment, the distiller includes an air-cooled condenser with a blower for removing heat from the condensing steam.

In spite of all the attempts to devise an improved distiller, prior art distillers for home use nevertheless have significant disadvantages which have limited their acceptance. The distillers have generally been considered too costly to operate, since a relatively high wattage is required to produce purified water. Although prior art distiller units advertise that eleven gallons of distilled water per 24 hours is available from a unit operating at 1200 watts, this efficiency is difficult to obtain and more difficult to maintain. Moreover, many lesser priced units cannot even achieve this efficiency.

A further disadvantage of prior art distillers relates to the difficulty with cleaning distillers having floats for sensing water levels and thereby regulating the flow of water to the distiller. Such floats are subject to collecting scale and other debris, and do not maintain the water level in the heating unit of the distiller at a constant value.

The disadvantages of the prior art are overcome by the present invention, and an improved home distiller is hereinafter disclosed which has a high efficiency compared to prior art distillers for producing distilled water.

SUMMARY OF THE INVENTION

A distillation unit of the present invention has several significant advantages compared to prior art units. The distiller preferably utilizes a vertical steam chimney extending upward from the heating bowl, and an internally positioned water chimney for preheating water to the heating bowl. The preheat unit further includes a steam receiving bowl and an interiorly positioned incoming water bowl, which together remove heat from the steam before reaching the condensate unit, and preheat water to the heating bowl. The condensate unit preferably utilizes a parallelepiped fin and tube heat exchanger to minimize space requirements and efficiently remove heat from the steam to form the distillate. The design of the condenser unit further enables undesirable gases to be easily vented from the unit at various stages of the condensation process, without releasing significant amounts of steam and thus decreasing the efficiency.

The heating bowl is preferably suspended from a rod axially movable with respect to the enclosure and biased to its upward position. The heating bowl and rod thus move axially downward to overcome the biasing member in response to increased weight of water in the heating bowl. A valve which regulates the flow of incoming water is incrementally controlled between its open and closed positions as a function of the axial position of the bowl, thus closely regulating the flow of incoming water to the unit. In a preferred embodiment, a mechanical linkage is provided between the rod and a tapered closure member of the valve, such that the axial position of the closure member with respect to its surrounding seat incrementally regulates the flow of incoming water.

Efficiency is further increased by using a low density heating element which receives from 40 to 55 watts of electrical power per square inch of merged heating element surface area. The heating bowl is configured such that the surface area of the water in the heating bowl is high compared to the volume of water in the bowl, thereby reducing heat loss from the bowl. From 0.018 to 0.025 square inches of surface area for the submerged heating element is preferably used per watt of incoming electrical power to the heating element to maintain high efficiency.

It is an object of the present invention to provide a distillation unit with a high efficiency of condensate per electrical power to the heating element.

A feature of the present invention is an improved preheating unit for efficiently removing heat from the steam and preheating water to the heating unit. The distillation apparatus utilizes a low density heating and a fin and tube heat exchanger to improve efficiency. As a further feature of the invention, a valve for controlling incoming water is incrementally regulated between its open and closed positions as a function of the weight of the water in the heating bowl.

An advantage of the present invention is the simplicity yet high efficiency of the unit, thereby making the unit well suited for home or office use. The unit may be easily cleaned and maintained, since a water level float is not used to control incoming water to the unit.

These and further objects, features, and advantages of the present invention will become apparent from the following detailed description, wherein reference is made to the figures in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a pictorial view, partially in cross-section, of a distillation unit according to the present invention;

FIG. 2 is a cross-sectional view of a valve for controlling incoming water to the unit generally shown in FIG. 1; and

FIG. 3 is a cross-sectional view of an alternate embodiment of a condensing unit according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, a suitable embodiment of the distiller unit 10 according to the present invention is shown. The unit as shown in FIG. 1 is well suited for home or office use, and receives contaminated water and produces distilled water at a high efficiency per watt of input power to the unit. Unit 10 comprises an enclosure 12 formed from sheet metal, has planar sides and a base 13 affixed thereto, and a removable cover 15.

Contaminated water, e.g., tap water, flows to the unit via line 14, and the flow rate is incrementally controlled by valve 16, which releases water via line 18 to preheat unit 19. Unit 19 comprises a steam receiving bowl 20 having a substantially planar base and cylindrical sides, and an incoming water bowl 21 positioned within the interior of bowl 20 and having a similarly shaped base and sides.

A substantially vertical chimney 22 extends from the interior cavity between bowls 20 and 21 to the interior of the evaporation unit 11. The upper portion of the chimney 22 forms a lip 23 which projects slightly above (typically less than ¼ inch) the base of bowl 20, so that any condensate in bowl 20 will flow by gravity through line 30 to the condenser unit 15 rather than returning to the evaporation unit 11. Water chimney 20 is axially positioned within the chimney 22, and has a similar upper portion 25 above the base of bowl 21. Lip 25 maintains a low level of water in the bowl 21 (lip 25 is also typically less than ¼ inch above the lower planar surface of bowl 21), and water overflowing lip 25 flows along the interior surface of the chimney 24 to the evaporation unit 11. The lower end of the chimney 24 is below the surface of the water 17 in the evaporation unit 11, so that steam cannot rise through the chimney 24.

A spacer portion 88 integrally formed on connection 86 maintains the lower planar surface of the incoming water bowl 21 a fixed distance above the steam receiving bowl 20. Only a slight gap is provided between the cylindrical sides

of the bowls 20 and 21 to let undesirable gases mixed with the steam (the gases being lighter than the steam) rise upward in this annular gap between the bowls and thus pass out between the upper lips of the bowls 20 and 21. If desired, a small vent port 91 may be provided in the lip of bowl 21 to better allow light gases to vent from bowl 20. Also, a cover 82 is provided over the bowls 20 and 21 to reduce heat loss, but the cover is not sealed to the bowls. A small diameter opening 83 may be provided in the cover to let gases pass out the bowl 21 as water in the bowl is preheated before entering the evaporation unit 11.

Incoming water thus passes via the flexible line 18 to connection 86, which has central passage therein. A nut 84 is threaded to connection 86, so that a sealed flow path is provided between line 18 and flow passage 87 in the nut 84. Passage 87 preferably discharges water into the bowl 21 in a horizontal direction, so that incoming water does not engage cover 82. An O-ring seal 85 seals nut 84 with both connection 86 and riser 89, so that discharged water is prevented from entering bowl 20, while steam is prevented from passing into bowl 21.

Evaporation unit 11 comprises a heating bowl 26 with cylindrical sides and a convex bottom 27 for increased strength. A low density electrical heating coil 28 is provided within the bowl 26. One end 28A of the coil 28 extends through and is secured to the cover 46 of the evaporation unit by nuts 58 and 60, while the other end 28B is similarly affixed to the cover by nuts 63 and 64. Electrical power from lines 62 and 66 thus heats the coil 28, which in turn heats and vaporizes the water 15. Cover 46 is sealed to bowl 26 by O-ring 48. A latching mechanism (not shown) normally secures the bowl 26 to the cover 46, while allowing the bowl to be separated from the cover so that it can easily be removed from the enclosure 12 for cleaning.

A cylindrical rod 32 extends from above the cover 15 to the evaporation unit 11, and is secured by threads 52 to projection 50 weldably fixed to the center of the bowl 26. A spacer 52 is provided along the rod 32 and in engagement with the projection 50, and has threads 54 at its upper ends for receiving nut 56. Collar 58 is affixed to the rod 32, such that the spacer 52 is normally sandwiched between 50 and 58. A coil spring 34 is provided radially outward of the spacer 52, and is sandwiched between the nut 56 and the horizontal intermediate plate 36 secured to the sides of the enclosure 12. An insulation material 38 is provided on top of intermediate plate 36 for reducing the heat loss from the evaporation unit 11. A plurality of circular holes are provided through the intermediate plate 36 and the insulation 38, as shown, for receiving the ends 28A and 28B of the heating coil, a sensor 40 secured to the cover 58, and spacer 52 and rod 32. Sensor 40 generates an electrical shut-off signal transmitted through line 41 to electronics 68 to automatically discontinue power to the heating coil if a temperature of the water in the evaporation unit 11 rises to above a selected limit.

As water evaporates from the bowl 26, the coil spring 34 forces the cover 46 of the evaporation unit toward engagement with the intermediate surface 58. Although FIG. 1 depicts the cover in actual engagement with the intermediate plate 36, it should be understood that the cover and plate are normally slightly separated during operation of the distiller unit. As additional water is fed into the evaporation unit, this further weight of the water in the bowl 26 causes the rod 32 to move downwardly with respect to the enclosure 12, thereby compressing the spring 34. This same downward movement of the rod 32 causes downward movement of the chimneys 22 and 24, and the bowls 20 and 21 respectively affixed thereto.

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Arm 44 is secured to chimney 22, and angle support 91 is affixed to the intermediate plate 36. Rod 90 is connected at one end to arm 44 and at the other end to plate 92. Plate 92 pivots at 94 with respect to support 91. Thus, vertical movement of the rod 32 causes the plunger stem 93 of the valve 16 to move axially inward or outward with respect to the body of the valve 16, thereby incrementally controlling the flow of water to the unit 10. A microswitch 96 is responsive to the movement of the pivot plate 92, and sends a signal via line 98 to the electronics 68 to terminate power to the coil 28 if the plate 92 rotates outside of selected limits. As previously indicated, electronics 68 automatically controls operation of the unit 11, and has one or more switches 72 to manually turn on or off electrical power to the coil 28, or to operate the blower 74. A plurality of wires 70 extend from the electronics 68, and are thus connected to the switch 96, the sensor 40, and the blower 14.

A condenser unit 15 comprises a fin-and-tube heat exchanger, with one or more tubes 76 each connected to a plurality of spaced fins 42. Distillate is thus discharged from the unit through the outlet line 78. The fins 42 of the unit 15 define the general configuration of the condenser, since the tubes 76 pass through the spaced fins. According to the present invention, the fins 42 define a parallelepiped configuration, thereby obtaining the benefits of a highly efficient yet compact condenser. As previously indicated, blower 74 forces air upward through the fins 42, with air incoming to the interior of the unit 12 through slots 77 in one or more sides of the enclosure, and leaving through slot 75 in the cover 15.

The valve depicted in FIG. 1 is shown in greater detail in FIG. 2. The valve 16 includes an inlet 102 in fluid communication with line 14, and an outlet 104 in fluid communication with flexible line 18. The body 106 has an elongate passageway generally filled with a pin-like closure member 93 having an elongate conical sealing surface 108 at one end, and a recess portion 110 at the opposing end adapted for engagement with the pivot plate 92. The body 106 of the valve has an outlet passageway 112 generally perpendicular to the central axis of the closure member 93. Tip 114 is provided with threads 116 for engagement with body 106, and has a central passageway 118 generally aligned with the closure member. A conical-shaped cavity 120 is provided within the tip 114 for receiving the conical sealing surface 108 when the valve is in its fully closed position. An O-ring seal 122 provides fluid tight sealing between the closure member 93 and the tip 114 when the closure member is in the fully closed position as shown. The closure member may incrementally move away from the tip 114, however, and incremental movement of the closure member will closely regulate and incrementally change in a corresponding manner the flow of water through the valve. Thus the flow rate of water through the valve depends upon the incremental axial position of the closure member 93, which in turn depends upon the axial position of the rod 32. Cap 124 is threaded to the body at 126, and has an opening for receiving the end of the closure member, as shown. Seal 128 continually seals between the closure member 93 and the body 106.

The valve 16 as shown in FIG. 2 thus incrementally controls the flow of water to the bowl 21, and thus to the evaporation unit 11. It should be understood that this water flow is at a very slow rate, typically in the range of less than one gallon per hour. The valve 16 thus effectively allows the regulated "dripping" of water to the preheat unit so that no significant temperature fluctuations occur in the water within the bowl 21, thereby increasing efficiency. The valve 16 is thus controlled by the action of the adjustable biasing

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member 34, and the weight of the water in the bowl 26. Regulation of the valve 16 can be effectively controlled by rotating the nut 56.

Normal operation of the unit as shown in FIG. 1 will now be briefly described. Incoming water is controlled by valve 16, which as described above is responsive to the weight of the water in the heating bowl 26. As the level of water in bowl 26 rises, the increased weight compresses spring 24, causing chimney 22 to move downward and moving the stem 93 inward, thereby slowing closing off the flow of incoming water. The result of this action is that water effective "drips" into the bowl 21 and down the chimney 24 and to bowl 26, thereby preventing significant temperature variations of the water in the bowl during normal use of the unit.

Incoming water in bowl 21 will be contained at a relatively low level, e.g., 1/8th of an inch or less, before it passes over the lip 25 and down the inner walls of the chimney 24. The water in bowl 21 will be preheated by steaming bowl 20, and undesirable gases will vaporize and pass out of the hole 83 in the lid 82. Water passing down the chimney 24 will also be further heated as it passes to the bowl 26 by steam in the chimney 22.

The water in bowl 26 is heated by electrical heating element 28, and the formed steam passes up the chimney 22 to bowl 20. While in bowl 20, some of the steam condenses as the water in the bowl 21 is heated, and this condensate flows by line 30 to the condenser unit 15. Lip 23 thus prevents condensate in the bowl 23 from returning to the heating bowl 26, thereby improving efficiency. Also, it should be noted that the side of the bowl 21 is heated by steam in bowl 20. Gases mixed with the steam in bowl 20 are vented, since the upper edges of the bowls 20 and 21 are not in sealing engagement. Alternatively, a small vent passage 91 may be provided in the lip of bowl 21 to ensure that undesirable gases will be easily vented from the bowl 20.

Most of the formed steam will condense in the condenser unit 15 as it passes through the tubes 76. The blower 74 will normally be powered to pass air by the fins 42, thereby cooling the fins and thus the tubes 76. Condensate free from contamination will pass out line 78 to the holding tank (not shown). As explained in further detail below, additional gases may be vented from the condensate unit 15 at various stages along the length of the tubes 76.

In order to clean the unit, the operator may actuate one of the switches 72 to turn off all electrical power to the unit. A side door (not shown) on the closure 12 may be opened to give access to the heating bowl 26. The operator may then rotate knob 80 affixed to the top of rod 32, thereby unthreading the rod from element 50. Bowl 26 may then be unlatched from the cover 46, and easily removed from the unit to clean sediment in the bottom of the bowl. The lid 23 may also be removed, the nut 84 unthreaded from 86, and the bowl 21 and chimney 24 removed by merely lifting these components upwardly. The inside of the bowl 21 and the interior walls of the chimney 24 may include some scale, which can be easily cleaned with a brush. The chimney 22 and bowl 20 may remain fixed to the cover 46, since scale will not appreciably form on these components. The cleaned components may then be reinstalled into the unit, and power returned to the unit to continue distillation process.

The desired level of water in the heating bowl 26 may be effectively controlled by rotating the nut 56 to increase or decrease the biasing force of the spring 34. In general, however, the water level in bowl 26 should be maintained at a relatively low level of 2 inches or less, thereby decreasing

heat loss from the sides of the bowl. If the water level in the bowl were to fall to a level so low that the heating element **28** were not safely submerged, the spring **34** would raise the cover **46** toward the intermediate shelf **36**. This action would trip switch **96**, thereby automatically terminating electrical power to the element **28**. As a further safety precaution, temperature sensor **40** may also be used to terminate power to the unit if its tip is not submerged in water. The fan **74** may be powered only in the summer months, if desired, since the fins **42** may sufficiently cool the tubes **76** during the winter months to caused the desired condensation without forcing air between the fins.

The electrical heating element **28** is a low density heating element which has a large surface area submerged in the water within the bowl **26** per watt of electrical power to the heating element. This low density design ensures that "pockets" of water in the bowl **26** are not overheated to cause agitated "bubbling" of the water, which adversely affect efficiency. Preferably, the heating element causes steam to rise uniformly from the surface of the water. It has been determined that the heating element with approximately 25 square inches of submerged exterior surface should be powered with from 800 to 1450 watts, and preferably from 1000 to 1375 watts of electrical power to maintain the desired efficiency. In other words, the heating element preferably is powered with from 40 to 55 watts per square inch of submerged electrical heating element surface to maintain high efficiency. Stated differently, the surface of the heating element should be in the range of from 0.018 to 0.025 square inches per watt of electrical power. This low density of power to the heating element is a substantial departure from currently available home distillation units, and is a significant contribution to the increased efficiency of the unit.

In addition to maintaining a relatively low level of water in the heating bowl **26** to reduce heat loss, it is also preferably to have a high surface area of water in the heating bowl per unit of electrical power to the evaporator unit **11**. The surface area of the water in the heated bowl is preferably from 1.7 to 2.3 times times the surface area of the submerged electrical heating element. Moreover, the surface area of the bowl in contact with the heated water is preferably less then 2.5 , and preferably in the change of from 1.8 to 2.2, times the surface area of the submerged heating element.

According to the present invention, a distillation unit powered with from 1000 to 1375 watts to the element **28** preferably has approximately 50 square inches of water surface area in the heating bowl. Accordingly, the submerged electrical heating element is powered with from 20 to 27.5 watts per square inch of surface area for the water in the heating bowl. The bowl is thus configured so that from 0.036 to 0.050 square inches of water surface area is provided per watt of power to the electrical heating element.

FIG. 3 depicts an alternate embodiment of a condensation unit generally shown in FIG. 1. A plurality of tubes are arranged in rows and columns, and a header is provided at the end of the tubes for allowing an exchange of fluid between parallel tubes. Thus the condenser unit **130** includes four horizontal tubes **132** each in parallel (literally and in a fluid sense), four similar tubes **134**, four similar tubes **136**, four similar tubes **138**, and four similar tubes **140**. A header assembly **142** is provided at one end of each of the tubes, and a corresponding header assembly **144** is provided at the other end of the tubes. Steam thus enters the header **142** through line **30**, and condensate exits the unit through header **144** and line **78**.

Steam enters the header **142** and passes (to the right as shown in FIG. 3) through one of the four tubes **132** to the

header **144**, and then back to the left through any one of the four tubes **134**. Baffles **146** and **148** in the header **142**, and similar baffles **150** and **152** in the header **144**, thus control the back and forth flow of steam through each of the sets of four tubes. Although substantially all of the steam flows back and forth between the tubes and thus downward through the headers **142** and **144**, each of the baffles may be connected to the side walls of the headers **142** and **144** by spot welding, so that a slight gap allows some fluid communication between different chambers in each header. It should thus be understood that a small amount of steam may pass from chamber **160** in header **144** to chamber **162**, and from chamber **162** to chamber **164**. This minute passage of steam is not desirable, but more importantly allows for the movement of undesirable light gases to move upward in each header unit during the condensation process. These undesirable gases may ultimately escape through the adjustable vent valve **166** at the upper end of one or both of the headers.

The condensation unit as shown in FIG. 3 also has a generally parallelepiped configuration, thereby minimizing space requirements. The use of the headers **142** and **144** at the end of each of the plurality of tubes allows for the intermixing of steam passing through each of the "layers" of tubes and lets steam in the first "row" of the tubes [**130**] **132** intermix within the chamber **164** and pass through the second, third, or fourth row of tubes **134**. This feature desirably allows for the convenient release of gases at various stages in the condensation process by allowing the gases to move upwards in each of the header tubes, then ultimately be released from the condensation unit. The regulatable valve **166** may be closely controlled so that a very small amount of steam ultimately exits the valve **166**, while a relatively large amount of undesirable gases are allowed to exit the condensation unit.

The design of the condensation unit **130** thus effectively allows for the venting of gases at multiple stages along the condensation tubes, although only the expense of one vent valve **166** is necessary. Moreover, this substantially reduces the complexity of operating the unit while maintaining high efficiency and high quality distillate, since multiple vent valves need not be adjusted. Each of the spaced fins **132** shown in FIG. 3 are preferably interconnected with one or more of each of the tubes **132** through **140**, and preferably each of the fins are interconnected with all of the tubes **131** through **140**. The design of the parallelepiped condensation unit as shown in FIG. 3 allows for very efficient condensation of the steam in a minimal amount of space, while also allowing "backflow" of condensation gases through the condensation unit to remove undesirable gases.

The distillation unit of the present invention can produce the same quantity of distilled water during a 24 hour period as other distillation units while operating at substantially less electrical power. While other units strive to obtain 11 gallons of distilled water per 24 hours of operating at 1700 watts, the unit of the present invention is able to obtain approximately 12 gallons of distilled water while operating at 1000 watts. Moreover, if the wattage is increased to approximately 1200 watts, the unit of the present invention can obtain in excess of 14 gallons of distilled water per 24 hours, almost 17 gallons of distilled water in this time period can be obtained for the unit operating at 1375 watts. Moreover, the unit remains easily cleaned and maintained, as previously described.

It should be understood that various modifications to the distillation units described herein may be made without departing from the spirit of the present invention. Preferably

bases are vented from the unit as the water is heated, gases are vented from the steam in the preheat unit, and gases are vented from the steam in the condensation unit. At each of these locations, light gas is preferably vented at a location other than adjacent a high velocity flow path of the steam. Although only one regulatable valve **166** is desired herein for controlling the release of gas from the condensation unit, it should be understood that a similar valve may be provided along the flow path of parts **83** or **91**. The insulation material **38** may be provided, if desired, on the underside of the intermediate plate **32**.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof, and various changes in the design of the apparatus may be made within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. A distillation apparatus for removing contaminants from water, the apparatus comprising:
 - a) an outer enclosure including an incoming water inlet port and a condensed water outlet port;
 - b) a preheat unit including (a) a steam receiving bowl for receiving steam from the evaporator unit, and (b) an incoming water bowl within the steam receiving bowl for removing heat from the steam to preheat water to the evaporator unit;
 - c) a water inlet conduit for passing incoming water from the inlet port to the incoming water bowl;
 - d) a valve for controlling the flow of incoming water through the water inlet conduit;
 - e) an evaporation unit for heating incoming water with contaminants to generate steam, the evaporation unit including (a) a heating bowl disposed within the enclosure for housing the incoming water, (b) an electrical heating element positioned within the heating bowl, and (c) a first cover affixed within the enclosure and over the heating bowl;
 - f) a substantially vertical steam chimney extending from the heating bowl, through the cover, and to the steam receiving bowl;
 - g) a substantially vertical water chimney positioned within the vertical steam chimney for passing water from the incoming water bowl to the heating bowl while removing heat from the steam in the vertical steam chimney to heat the water passing through the water chimney; and
 - h) a condenser unit for cooling the steam to form condensate water, the condenser unit comprising a fin-and-tube heat exchanger including (a) at least one tube in fluid communication at one end with the steam receiving bowl and in fluid communication at the opposite end to the condensed water outlet port for condensing steam to form condensate water, (b) a plurality of spaced fins each thermally connected to at least one tube for transmitting heat from at least one tube to the fins, and (c) a powered blower for blowing air between the fins and thus removing heat from the condenser unit.
2. The distillation apparatus as defined in claim 1, further comprising:
 - a) a vent port from the steam receiving bowl for venting gases from the steam before the steam is passed to the condenser unit.
3. The distillation apparatus as defined in claim 1, wherein the incoming water bowl has a lower substantially planar surface, and has an overflow port to the vertical water

chimney less than $\frac{1}{4}$ inch above the lower substantially planar surface for maintaining a low level of water in the incoming water bowl.

4. The distillation apparatus as defined in claim 1, wherein the steam receiving bowl has an outlet vertically above the tube for the condenser unit such that condensate formed in the steam receiving bowl will drain to the condenser unit.

5. The distillation apparatus as defined in claim 1, wherein the at least one tube comprises a plurality of tubes for passing steam in parallel, and wherein the condenser unit further comprises a plurality of headers spaced along the plurality of tubes for intermixing steam passing within the plurality of tubes and a vent port between the plurality of headers for venting gases from the steam passing through the plurality of tubes.

6. The distillation apparatus as defined in claim 1, wherein the outer enclosure further includes a second cover having an air outlet port, sidewalls having an air inlet port vertically below the cover, and wherein the powered blower is positioned below the plurality of fins.

7. The distillation apparatus as defined in claim 6, wherein the condenser unit has a parallelepiped configuration.

8. The distillation apparatus as defined in claim 1, wherein;

the vertical steam chimney is movable within the outer enclosure; and

the valve is responsive to movement of the vertical steam chimney.

9. A distillation apparatus for removing contaminants from water, the apparatus comprising:

an outer enclosure having an incoming water inlet port and a condensed water outlet port;

evaporation means for heating incoming water to generate steam, the evaporation means including a heating bowl disposed to the enclosure for housing incoming water, heating means positioned within the heating bowl, and a cover within the enclosure and over the heating bowl;

a condenser unit for cooling the steam to form condensate water;

a rod axially movable within the enclosure and removably interconnected with the heating bowl, such that the heating bowl and interconnected rod move axially within the enclosure;

biasing means for biasing the rod and heating bowl axially toward an upper position; and

valve means for controlling the flow of incoming water to the heating bowl, the valve means including a closure member incrementally positionable between a fully opened position and a fully closed position and movably responsive to the axial position of the rod, such that the weight of water in the heating bowl moves the rod toward a downward position overcoming the biasing means and incrementally closing the valve means.

10. The distillation apparatus as defined in claim 9, further comprising:

a mechanical linking means for interconnecting the valve closure member and the rod; and

the valve means including an annular seat for sealing engagement with the closure member; and

the closure member having a conical-shaped tip for fitting radially within and being axially movable with respect to the annular seat.

11. The distillation apparatus as defined in claim 9, wherein the heating bowl is suspended in the enclosure from the axially movable rod.

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12. The distillation apparatus as defined in claim 11, wherein the heating bowl has a substantially vertical central axis, and wherein the rod is coaxial with the central axis of the heating bowl.

13. The distillation apparatus as defined in claim 9, 5 wherein

the rod is threadably interconnected to the heating bowl; and

the rod passes through the cover over the heating bowl. 10

14. The distillation apparatus as defined in claim 10, further comprising:

a trip switch responsive to the linking means for terminating power to the heating means.

15. The distillation apparatus as defined in claim 10, further comprising:

a preheat unit including (a) a steam receiving bowl for receiving steam from the evaporation means, and (b) incoming water bowl within the steam receiving bowl for removing heat from the steam to preheat the water to the evaporation means. 20

16. The distillation apparatus as defined in claim 9, wherein the heating means comprises an electrical heating element positioned within the heating bowl and having a surface area submerged under water in the heating bowl in a range of from 0.018 to 0.025 square inches per watt of electrical power to the heating element. 25

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17. The distillation apparatus as defined in claim 16, wherein the heating bowl is configured such that the surface area of the water in the heating bowl is from 0.036 to 0.050 square inches per watt of power to the electrical heating element.

18. The distillation apparatus as defined in claim 16, wherein the heating bowl has a generally cylindrical configuration, and the surface area of the heating bowl in contact with the heated water is less than about 2.5 times the surface area of the electrical heating element submerged under water.

19. The distillation apparatus as defined in claim 9, wherein the heating bowl is configured such that the surface area of water in the heating bowl is maintained in the range of from 1.7 to 2.3 times the surface area of the [submerged] heating means submerged in the water in the heating bowl.

20. The distillation apparatus as defined in claim 1, wherein the heating bowl is configured such that the surface area of water in the heating bowl is maintained in the range of from 1.7 to 2.3 times the surface area of the heating element submerged in the water in the heating bowl.

21. The distillation apparatus as defined in claim 1, wherein the heating bowl has a surface area in contact with water less than about 2.5 times the surface area of the heating element submerged in the water in the heating bowl.

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