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(54) PRODUCING FRESH WATER FROM AIR RAISED TO HIGH HUMIDITY BY EXPOSURE TO WATER VAPOR FROM CONTAMINATED SOURCES OF WATER

(71) I, CURZON DOBELL of Nassau, Bahamas, a British subject, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method and apparatus for the production of potable or fresh water and more particularly to the abstraction of said potable water from humid air in a three stage cycle or apparatus.

It is well known that in certain areas of the world there is a shortage of fresh water, and particularly potable water because of the geographical nature of the area or due to the fact that certain areas although they have a sufficient water supply up to the present time now require more fresh water because of population and industrial expansion.

Some common methods of abstracting fresh water from sea water or brackish water have been directed toward such abstraction by freezing or electrolysis, but these methods require large quantities of expensive power, and the capital cost and maintenance costs involved in the use of the necessary apparatus are high.

According to the present invention there is provided a method of producing potable water from an external source of a continuously supplied stream of partially saturated atmospheric air, comprising continuously passing the said stream of air through a first stage to decrease its relative water saturation value by increasing its temperature whereby the air becomes less saturated, passing the less saturated air through a second stage where it is exposed to a source of water vapour to raise the the relative water saturation value whereby the air becomes saturated, decreasing the relative saturation value of the saturated air by passing same into a third stage to simultaneously decrease its temperature and increase its pressure whereby potable water is condensed out of said saturated air stream, and passing the air into the atmosphere after the water in the air has been extracted therefrom.

By virtue of the present invention, a stream of partially saturated air is put in a condition in a first stage, where it can absorb more moisture, it then passes to a second stage where it is exposed to a source of water vapour, which can be made from sea water or brackish water from wells or any other source of polluted water unfit for human consumption or industrial requirements, and in a third stage the temperature is reduced to lower the saturation point, and the pressure is increased over that in the first stage, for the same purpose, to cause condensation of pure water which is drained off to a suitable reservoir. Further according to the present invention there is provided an apparatus for producing portable water from an external source of a continuously supplied stream of partially saturated atmospheric air, comprising a first stage chamber having an inlet and outlet for receiving and passing said stream of air therethrough and heating means operatively connected with said first chamber for raising the saturation point of the air stream passing through said chamber; a second stage chamber having an outlet and being in communication with said first stage chamber outlet and means in said second stage chamber for adding moisture to said air stream up to the raised saturation point; a third stage chamber to receive the saturated air stream therefrom and cooling means operatively connected with the third stage chamber for reducing the saturation point of the saturated air stream passing through and out of said third stage chamber to condense water out of said air stream; and means to produce a predetermined pressure differential of increase between the pressure of the air stream in the first stage chamber and the pressure in the third stage chamber.

The flow of the required volume of air through the three stages can be accomplished by making the whole apparatus rotatable so that a wind scoop for the intake of air always faces the wind and an exhaust from the apparatus always faces away from the wind, or by using a chimney effect, or by the use of a pressure fan between the second and third stages or by a combination of the rotatable apparatus and/or chimney effect as described, and/or the use of pressure fan means as described plus an automatic cut in of the pressure fan means when the air flow created by the combination is insufficient.

In one embodiment of the present invention, a method of producing potable or fresh water in a three stage process comprises passing a stream of atmospheric air which contains a large quantity of water vapor through a first stage wherein the temperature of the air is increased so that the saturation point of the air increases as a result of which a given volume of air will be able to absorb a greater quantity of water, in the form of vapor and hence it can carry more water vapor therein. After the temperature of the air stream is increased it is exposed to a source of moisture in a second stage, the moisture being absorbed by the air, until the saturation point is reached. Thereafter, this stream of air is passed to a third stage wherein the air temperature is lowered to cool the saturated air, and to condense the water vapor in the air and thus produce fresh or potable water.

The method and apparatus of the present invention can be used for producing fresh water particularly in areas with a fairly high relative humidity wherein the humid air contains a large quantity of water vapor which can be abstracted with far less energy than it takes to separate water from the salt in sea water.

Fresh water may be produced in a three stage process using predetermined differentials in temperature and pressure by passing the stream of air through the first stage and increasing its temperature while decreasing its pressure so as to increase the amount of water vapor that can be absorbed by the stream, passing it through a second stage and increasing the actual water vapor carried in the air stream by exposing it to additional water vapor and thereafter passing it to a third stage wherein the temperature of the air is decreased and the pressure is increased so as to condense the water vapor in the air stream.

The apparatus of the present invention may comprise three stages in the form of two concentric cylinders vertically disposed to provide a chimney effect to move increased quantities of air containing water vapor therethrough and wherein the air stream moves upwardly in the first and downwardly in the third stage. The first stage is provided with means for increasing the temperature of the air flowing therethrough which means may include fin members, and the entire surface of the first stage preferably is painted a dull black to absorb solar heat. The third stage preferably is insulated therefrom and exposed surfaces may be painted a shiny white to minimize heat absorption in the third stage. The provision of the means for heating the air in the first stage will cause the incoming air to rise. The second stage is provided with means for increasing the water vapor content of the air flowing threrethrough. The third stage is provided with cooling means which will cause the air stream to move downwardly or sink thereby creating a normal draft through the three stage apparatus irrespective of the wind velocity. Such apparatus having concentric vertically disposed cylindrical members forming a first stage, a second stage, and a third stage, may be provided with means for permitting it to rotate on a swivel base whereby the air intake to the first stage is pointed into the wind and the exhaust from the third stage is pointed away from the wind.

The first stage may be provided with auxiliary heater means so as to increase the temperature of air in the first stage when the solar temperature differential falls below a predetermined level, and auxiliary fan means may be disposed in the third stage to move the air and increase its pressure therein when the wind velocity falls below a predetermined level.

The cross sectional area of the first stage may be smaller than that of the third stage so as to provide reduced pressure in the first stage and increased pressure in the third stage.

The air in the first stage may be heated by solar energy and the air stream may be cooled in the third stage to squeeze the water vapor out of the air without the use or operation of a fan between the first and third stages and without the use of auxiliary heater means when the solar temperature is above a predetermined level and the wind velocity is above a predetermined level, so that the only energy required is for running the cooling water and condensate pumps for removing condensate extracted from the air stream.

The apparatus may have a structure which permits it to float in the water or to be utilized on land, as desired.

The apparatus preferably comprises a first stage consisting of an air inlet duct and means for utilizing solar energy to heat the air passing through the first stage, and a second stage including a reservoir and wick means therein for containing water to charge the air stream with the maximum amount of water vapor it is capable of absorbing. The pressure may be reduced in the first stage by the Venturi method and/or by use of a pressure fan placed between the second stage and a third stage with a restricted outlet. The temperature of the air is reduced in the third stage and the pressure is increased in the third stage in order to condense out in the third stage by cooling and pressure the water vapor contained in the flowing stream of air.

The apparatus may be of compact arrangement and be made out of light gauge sheet metal with a structure that enables it to be placed on land at one time to be utilized to produce fresh water, and to be floated in sea sea water at another time with the first and second stages disposed above the sea level, and the third stage disposed below the sea level to provide a temperature differential between the first stage and the third stage.

The apparatus may consist of three stages having substantially a ring or loop configuration with the first and second stages consisting of a relatively wide rectangular horizontal air flow duct of shallow depth, which thereafter is curved or looped downwardly and reverses its direction providing another horizontally extending section, and which duct thereafter loops or curves upwardly and terminates in a short forwardly extending horizontal outlet portion. The second stage is provided with means for adding water vapor to the air stream, and a pressure fan at the downstream side of the second stage. The third stage is provided with cooling coil means so as to decrease the temperature of the saturated air flowing through the third stage in order to condense out and remove the saturated water vapor from the air stream, which cooling coil means may be provided with a connection for supplying heated water to the second stage so that the humidity of the air flowing through the first stage can be decreased in order to increase the efficiency of the fresh water production.

The apparatus may thus consist of a looped duct having first, second and third stages therein with structural means for floating the duct in water or using it interchangeably on land in order to produce fresh water from a stream of humid air flowing therethrough.

In one form of the apparatus consisting of a looped duct with fan means disposed between the second stage and the third stage thereof and a cooling coil in the third stage, water may be pumped therethrough to cool the saturated air and squeeze out of it the water vapor therein, and the condensate from the air stream may be collected in the bottom of the third stage and be pumped to a small storage tank disposed in the apparatus at a higher level. The apparatus is preferably also provided with rudder means and flotation means thereon so that the air inlet to the first stage is always pointing into the wind, so that when the wind velocity is above approximately ten miles an hour, there is no need to run the fan means between the second and third stages and the only energy required in the apparatus is to run the small cooling water and condensate pumps.

In another form of the apparatus of the present invention with a looped configuration the first stage is provided with baffle means for utilizing solar energy to increase the temperature of the air flowing through the first stage, a reservoir and wick plate means are disposed in the second stage through which the stream of air passes so the air will absorb water and increase its water vapor content, the third stage is in communication with the first and second stages and receives the saturated and humid air stream therefrom with fan means disposed between the second and third stages with a restricted inlet to reduce the pressure in the first and second stages and increase the pressure in the third stage, and cooling means are provided in the third stage so that the decrease in the temperature and increase in pressure of the air stream as it flows through the third stage permits the water vapor carried in the air stream to condense out into fresh water.

The wick plate means in the second stage may be removed and cooling the tubes or coil in the third stage may be effected by disposing the first and second stages above the ground level to increase the incoming air stream temperature, and disposing the third stage below the ground or otherwise insulating it to provide some degree of cooling plus increasing the pressure in the third stage by the fan so that some pure water can be produced by the third stage alone.

Other features and advantages of the present invention will be readily apparent from the following detailed description of three preferred embodiments thereof when considered in connection with the accompanying drawings, in which:

FIGURE 1 is a wide view of an apparatus embodying the present invention;

FIGURE 2 is a front end view of the apparatus shown in FIGURE 1, viewed from the left of Figure 1;

FIGURE 3 is a side elevational view of another apparatus embodying the invention;

FIGURE 4 is a horizontal section of the apparatus taken along line 4—4 of FIGURE 3; and

FIGURE 5 is a side view of still another apparatus embodying the present invention.

Referring to the drawings and firstly to Figures 1 and 2, the reference numeral 10 generally designates an apparatus or structure for the production of fresh water from a relatively humid stream of air which contains a large quantity of water vapor passed through the structure to a three-stage operation. The structure 10 is substantially rectangular in shape as best illustrated in FIGURE 2 and is provided with a frame made of vertical legs or members 11 spaced laterally and longitudinally of each other to which horizontal or transversely extending members 12 and 13 are secured by any suitable means such as brazing or by bolts to form a rigid structure. Although the drawings illustrate only two sets of vertical members 11 and two sets of transverse members 12 and 13, it is apparent that if desired more structural members can be provided.

An air flow duct generally designated 14 through which the air stream of atmospheric air flows consists of an upper elongated flat horizontally extending section 15, a downwardly curved section 16, a lower straight horizontal section 17, and an upwardly curved discharge section 18. The air duct 14 comprises a generally looped configuration with the section 16 curved backwardly upon itself, and the discharge section 18 curved backwardly with respect to the straight section 17. The discharge section 18 is disposed just below the upper section 15 of the duct and extends inwardly curved section 16, a lower straight overlaps the backwardly curved portion 18 as best shown in FIGURE 1. The inlet end 19 of the duct 14 is slightly enlarged when compared with the upper section 15 of the duct which comprises a shallow box approximately three inches deep and six feet wide. The bottom of upper section 15 of the duct includes a reservoir 20 adapted to contain approximately one-half to one inch of sea water, or contaminated water, which saturates a plurality of spaced vertical wick plates or members 22 disposed adjacent the discharge end of the upper section 15. It should be noted that any overflow of water in reservoir 20 will spill over the end or lip 31 of inlet end 19 and duct 14. The wick plates 22 extend across the air passage formed by the upper section 15 and are generally of a braided cotton material so that water from the reservoir 20 will completely saturate them. They can be secured within the upper section 15 by any suitable means. The upper section 15 is curved or bent upwardly as indicated at 23 adjacent the discharge end so that any of the water in the reservoir 20 will not overflow into the curved section 16 of the air duct.

The first stage of the apparatus is generally indicated at 24 and consists of the portion of the upper section 15 from the inlet end 19 to a point 15a disposed along section 15. The second stage of the apparatus extends from 15a and includes curved section 16 to a point approximately adjacent a fan 25 located at the discharge end of the curved section 16. The duct 14 progressively has its cross section reduced or narrowed from the wide shallow box configuration of section 15 with a cross section of approximately one and a half square feet to an intermediate cross section at curved section 16 of approximately one square foot until finally it is reduced to its smallest cross section beyond the fan 25 in the horizontal section 17 of the duct. The horizontal section 17 constitutes the third stage of the apparatus.

The first and second stages respectively adjacent the upper section 15 and beyond point 15a of the duct 14 are provided with a plurality of vertical transversely extending elongated baffle plates 30 secured thereto and painted black, as is the upper section 15, so that a relatively large black surface area is exposed to the sun for heating the air. Heat can also be supplied to the first stage by conventional means with an oil or gas heater so as to increase the temperature of the stream of humid air flowing through the first stage of the device.

In the first stage the temperature of the air stream through the apparatus is increased and the pressure may also be decreased. Both changes increase the saturation point of the air so that it can carry more water vapor. Actually the increase of temperature is far more beneficial. Increasing the temperature requires only a small amount of the energy which would be required to increase the saturation point to the same level by decreasing the pressure. It is not necessary to have both increase in temperature and decrease in pressure.

After the first stage where the air is put in a condition where it can absorb more moisture, it then passes to the second stage where it is exposed to a source of moisture which can be sea water or brackish water from wells or any other source of polluted water unfit for human consumption or industrial requirements. Exposing the air to an additional source of moisture is done by using wick plates 22 in which the moisture can rise by capillary action where it intercepts the air flow, or by the use of fog nozzles directed against the air flow in a closed chamber. In either case provision can be made that no drippage from the wick plates or condensation from the fog nozzles is carried into the third stage to contaminate the product water. This can be done by a drip pan in the second stage draining in the opposite direction of the air flow.

In the third stage the air can be cooled in several ways such as by circulating the contaminated water through cooling coils if the temperature of this water is 10°F. or more below the temperature of the air stream, or by circulating the product water through cooling coils if it is 10° F. or more below the temperature of the air stream, or by mechanical refrigeration by circulating condensed Freon (Registered Trade Mark) gas through cooling coils just as in a room air conditioner, and discharging the absorber heat to the outside air.

The third stage is provided with a cooling coil having parallel passes 32 and 33 in communication with a condensate pump 34 for passing cooling water through horizontal section 17 of the third stage of the air duct 14 to reduce the temperature of the air flowing therethrough in order to condense from the saturated air the water vapor therein to produce fresh water. The two passes 32 and 33 of the cooling coil discharge into a relatively large diameter tube 35 closed at both ends and in communication with a pipe connection 36 for supplying feed water to the reservoir 20 in section 15 of the first stage of the apparatus. The utilization of the cooling water from the two cooling coil passes increases the temperature of the feed water before it is supplied to the reservoir 20 and thus increases the efficiency of the device. The cooling water passed through the cooling coils 32 and 33 can be from a source such as a well, or sea water as illustrated in FIGURE 1.

In the embodiment illustrated in FIGURE 1, the device is provided with stabilizers 38 in the form of sealed ballast members or tubes, as best shown in FIGURE 2, connected to opposite sides of the structural members 11 so that the device will float in sea water. The level of the sea water will be as indicated at 39 in FIGURE 1 with the sea level being disposed at approximately one-half the height of the device. When the device is floated in the sea, the lower half of the section 16 and 18 and the horizontal section 17 are completely submerged in the sea water, as illustrated, to properly cool the third stage of the operation and decrease the temperature of the air flowing therethrough. When this device is used on land, the bottom of members 11 may be disposed on the ground or, if desired, the lower portion of the device can be insulated and placed below ground level so that the apparatus is half underground and analogous to its disposition in sea water.

A condensate extraction trough or channel 40 extends below the cooling coils 32 and 33 and below the lower end of the horizontal section 17 so that condensate from around the outside of the walls thereof will fall to the bottom thereof and into the trough or channel 40. A condensate pipe 41 communicates with the trough 40 and with the suction of a condensate pump 42 secured by any suitable means to the lower side of the upper section 15. The condensate pump 42 is provided with a discharge line 43 for passing the purified water into a storage tank 44 secured to the structural members 11. The tank 44 extends transversely of the structure between the sealed ballast members or tubes 38.

A vertical fixed fin or rudder 45 is secured by any suitable means to the upper surface of the curved section 16 and anchor connection means 46 are secured to the bottom of the discharge section 18 so that an anchor can be attached to the device. The rudder 45 permits the device to head into the wind in boat fashion so that the inlet end 19 for receiving the incoming air is constantly facing into the wind. An outlet 46 at the discharge end of the duct section 18 is disposed in a direction facing opposite the direction of the inlet end 19 and is therefore constantly facing away from the wind.

The differential in pressure between the first stage and the third stage is accomplished by making the cross-sectional area of the first stage larger than the cross-sectional area of the third stage so that the velocity of a given volume of air through the first stage will be lower than through the third stage, which will produce a higher pressure in the first stage than in the third stage. By reducing the air intake and exhaust openings the use of a fan located between the first and third stages will also reduce pressure in the first stage and increase it in the third stage.

In operation, for producing fresh water from a stream of air having a fairly high relative humidity, the air enters the inlet 19, when the device is floated in sea water, as shown in FIGURE 1, and passes or flows through the upper section 15. The sea water flows into the reservoir 20 through the pipe line 36 from the cooling coils 32 and 33. The water in the reservoir 20 rises by capillary action up through the wick plates 22 and the air stream intercepts and passes through the braided cotton members to charge the air with the maximum amount of water it is capable of absorbing. The duct and baffle plates 30 which are painted black and exposed to solar radiation heat and increase the temperature of the air stream flowing through the upper section 15 forming the first stage of the device. The provision of the fan 25 supported on spider means adjacent the inlet of horizontal section 17 of the third stage causes a pressure differential between the first stage and the third stage with the first stage having a reduced pressure and the third stage having an increase in pressure.

In the first stage the temperature of the air stream is increased and the pressure is reduced. The saturation point of the air stream increases so that a given volume of air will absorb a greater quantity of water in the form of invisible vapor. Thereafter, the air stream has the amount of water vapor carried in it increased by passing it to the second stage wherein it is exposed to a source of moisture.

In the third stage the air stream has its pressure increased and its temperature reduced so that the dew point of the air stream is decreased and the water vapor carried in the air stream begins to condense or deposit out as a liquid with the water particles or droplets falling to the bottom of the horizontal section 17 and being caught in the condensate channel 40 after which they are pumped by the condensate pump 42 through lines 41 and 43 into the fresh water storage tank 44.

In warm climates with a fairly high relative humidity, it has been found the air contains a large quantity of water vapor which can be abstracted with less energy than is required to extract fresh water from sea water. At 70° F.

temperature and 70% relative humidity, one cubic mile of air contains 26 million gallons of water. Thus some pure water can be produced by the third stage alone, i.e., by condensing the water out of the air pressure and cooling and using a fan when necessary to maintain the air flow. If a source of salt or brackish water is available, the efficiency can be greatly increased by adding to this pressure and cooling stage a first stage in which the incoming air is raised in temperature and a second stage in which the air stream is exposed to the salt or brackish water. This increases the amount of water vapor in the air which is condensed out in the third stage by cooling and pressure.

When the wind is 10 miles an hour or more, there is no need to run the fan and the only energy required is to run the small cooling water and condensate pumps. When the wind velocity is below 10 miles an hour, the fan is automatically turned on to continue the same flow of air through the machine.

It has been found by calculations that with the sun shining, an air temperature of 80° F., 70% relative humidity, cooling water temperature at 75° F., and a wind velocity of 10 M.P.H., this pressure and cooling stage alone will produce 2.5 gallons of water per hour with an energy consumption of 0.3 k.w.h. If the wind velocity falls below 10 M.P.H., the fan cuts in using an additional 0.03 k.w.h. At two cents per k.w.h., the energy, including the fan, would be $0.48 (forty-eight cents) per 1,000 gallons of water.

Although forming no part of this invention, it would also be possible to produce water by this device in areas far removed from any source of salt or brackish water. In this case the wick plates and the cooling tubes would be removed. The first stage would be exposed above ground to heat the incoming air and the third stage would be set below ground or otherwise insulated to provide some degree of cooling, plus pressure by the fan.

FIGURES 3 and 4 illustrate a modification of the apparatus for carrying out the method of the present invention. This embodiment comprises a structure 50 having an outer cylindrical member 51 within which is disposed an inner cylindrical member 52. The cylindrical member 51 is closed off at the top and bottom and is provided with an air inlet duct 53 in the lower end thereof through which a relatively humid stream of air is passed. The inner cylindrical member 52 is open at the upper end and is provided with a curved or bent section 54 adjacent its lower end extending through the wall of the cylindrical member 51 so as to form a discharge opening 55 for the apparatus. Cylindrical member 52 is concentrically disposed within the cylindrical member 51 so that an annular passage 56 is provided around the cylindrical member 52. It is thus apparent that the cylindrical members 51 and 52 form concentric cylinders standing vertically to provide a chimney effect to move increased quantities of air through the structure. A plurality of annular heating fins 57 are secured by any suitable means to the outer surface of the cylindrical member 51 to absorb solar heat. A cylindrical casing 58 made of transparent plastic material is secured by any suitable means over the heating fins 57 to reduce solar heat loss due to wind. The heating fins 57 are painted black to absorb more heat and as can be clearly seen in Fig. 3 are stacked in a vertical arrangement around the cylindrical member 51.

The bottom 59 of the cylindrical member 51 is mounted by any suitable means on a bearing 60 which in turn is mounted on a fixed pedestal 61 so that the entire structure can freely rotate or swing around the base 61. A rudder 62 is secured to the upper end of the cylindrical member 51 and extends through the plastic casing 58 so that the inlet duct 53 is pointed into the wind and the discharge opening 55 which is disposed opposite the inlet duct 53, is pointed away from the wind.

An annular liquid reservoir 63 is secured to the outer surface of the inner cylindrical member 52 adjacent the upper portion thereof and in the annular passage 56. Water is supplied to the reservoir 63 by inlet tubing 64 extending through the cylindrical member 51 and the plastic casing 58. The tubing 64 is made of flexible material and is of such a length that it will not interfere with the rotation or swiveling of the structure. Wick plates 65 of braided cotton or other wicking material are disposed in the reservoir 63 and extend across the upper portion of the annular passage 56 so that the incoming stream of air flowing through the structure is exposed to a source of water to charge the air with the maximum amount of water it is capable of absorbing.

The first stage of the structure comprises the portion of annular passage 56 below and up to reservoir 63. The portion of the annular passage 56 adjacent and above reservoir 63 and passage 66 adjacent the upper portion of the cylindrical member 52, and extending down to a pressure fan 67 comprises the second stage of the structure. Fan 67 is secured by a spider member 68 within the cylindrical member 52.

The first stage is also provided with an auxiliary oil, gas or electric heater 70 disposed adjacent the inlet duct, 53 which can be operated by automatic means if desired when the solar temperature differential falls below a predetermined level.

The third stage of the structure comprises the portion of cylindrical member 52 disposed below the fan 67. The third stage is provided with a cooling coil 71 having coolant inlet and outlet lines 72 and 73 respectively. The lines 72 and 73 are made of flexible material and are of sufficient length so as to permit the entire structure to rotate or swivel about the base 61 without causing any damage to the lines 72 and 73. A condensate trough 75 is disposed in the bottom of the duct section 54 and is provided with a condensate discharge line 76 connected thereto by any suitable means, in communication with a storage tank, not shown.

Cooling water entering line 72 and flowing into the cooling coil 71 can be connected to a source of contaminated or brackish water or can be connected to the fresh water storage tank, not shown. The supply of water to the reservoir 63 through the tubing 64 can be from any moisture source such as sea water or other contaminated or brackish water.

In operation, a stream of relatively humid air containing a large quantity of water vapor passes through the inlet duct 53 into the first stage of the structure and thereafter flows upwardly through the annular passage 56, changes direction, and flows downwardly through the cylindrical member 52. The increase of temperature in the air flowing through the first stage and through the annular passage 56 provides a natural updraft since warm air rises. As the body or stream of air passes through the second stage, wick plates 65, and is exposed to a source of water the air is charged with the maximum amount of water it is capable of absorbing.

The clear plastic casing 58 prevents any solar heat loss due to wind while the heating fins 57, which are painted black, absorb a maximum amount of solar radiation to heat the air stream. So long as there is a sufficient wind and the sun is not completely obscured and a supply of brackish or otherwise polluted water is available, the structure when rotatable will produce potable water with the use of a very small pump to circulate the feed and cooling water.

The pressure fan 67 between the second and third stages can be actuated by a switch if desired to cut in the fan whenever the wind drops below a certain speed or it can be run continuously for a higher production. The oil or gas heater 70 disposed in the inlet duct 53 can cut in whenever the temperature drops below a certain value or it can be used continuously if desired to supplement the solar heat. To provide a 24-hour production of water the heater would operate during the hours of darkness or heavy clouds and the fan would operate when the wind velocity drops below approximately 8 to 10 miles an hour. If desired the structure can operate in regions far removed from any source of coolant water by using standard refrigeration equipment to provide the differential in temperature between the first and third stages, and the use of a fan to produce the required volume of air flow. The efficiency would then depend entirely on the relative humidity of the air.

The air stream flows into the passage 66 of the cylindrical member 52 and thereafter downwardly therein. The heating of the air in the first stage of the structure and the decrease of the temperature by the cooling coil 71 in the third stage will cause the air to rise and sink in the outer and inner cylindrical members, respectively, thereby creating a normal draft in the structure irrespective of wind velocity.

Thus the structure of the invention embodied in Figs. 3 and 4 provides a three stage device for carrying out the method of the present invention in the form of parallel cylinders which stand vertically to provide a natural chimney effect to promote the air circulation therethrough and the production of fresh water.

Another modification of the present invention shown in Fig. 5, embodies the same three stage principle for producing fresh water, as already described except it operates entirely on purchased energy to heat the air in the first stage and reduce the temperature in the third stage, and includes a blower fan to maintain constant circulation. In this arrangement no use is made of solar heat or wind velocity. While this would cost more to operate, a larger production of pure water can be accomplished with a much smaller machine.

In this embodiment, a casing 80 is provided having a first stage with an air inlet 82 and an electric heater 84 therein. The air outlet 86 from the first stage communicates with a second stage provided with a spray header 88 having a plurality of spray nozzles for spraying water droplets across the path of flow of the air stream. A drip conduit 89 is provided for draining excess water from the second stage. A pressure fan 90 is disposed in a chamber downstream of the second stage, and adjacent the inlet end of a third stage in the casing.

A cooling coil 91 is disposed in the third stage, having an inlet pipe 92 and outlet pipe 93 connected thereto. A pump 94 is disposed in inlet pipe 82 for supplying coolant to the coil, while the outlet pipe 93 is connected to the spray header 88 to supply the heated water to the second stage. If desired, the cooling coil can be a refrigeration unit, in which case the water in inlet pipe 92 can go directly to the spray header 88. A pipe 99 provides an alternate direct source of supply of sea water to the spray header 88. A valve 100 is disposed in line 93 to shut off flow therethrough.

The spray nozzles in spray header 88 are of a special commercial type called fog nozzles which produce a very fine mist composed of pure water vapor and very fine droplets. Where fog nozzles are used instead of wick plates the fog should be directed back against the inflowing air stream so that the air can pick up the vapor and the droplets have time to fall to a pan at the base before the air reaches the third stage. Any contamination in the water does not pass to the vapor but it does to the droplets so that it is important that the droplets do not enter the third stage. Baffle plates 101 insure that the droplets do not enter the third stage.

A throttle valve 95 of the butterfly type is disposed adjacent the outlet from the third stage and can be controlled to give a predetermined pressure differential. Product water is removed through pipe line 96 in the third stage to a storage tank 97. Thus, with this embodiment the first stage can be utilized to heat air and reduce the pressure therein, while the third stage can be utilized to cool the air and increase the pressure of air vapor to abstract product water.

WHAT I CLAIM IS:—

1. A method of producing potable water from an external source of a continuously supplied stream of partially saturated atmospheric air, comprising continuously passing the said stream of air through a first stage to decrease its relative water saturation value by increasing its temperature whereby the air becomes less saturated, passing the less saturated air through a second stage where it is exposed to a source of water-vapour to raise the relative water saturation value whereby the air becomes saturated, decreasing the relative saturation value of the saturated air by passing same into a third stage to simultaneously decrease its temperature and increase its pressure whereby potable water is condensed out of said saturated air stream, and passing the air into the atmosphere after the water in the air has been extracted therefrom.

2. A method according to claim 1, wherein a decrease in the relative water saturation value is achieved in the first stage partly by decreasing the pressure of the air stream therein.

3. A method according to Claim 1 or Claim 2, wherein the relative water saturation value is decreased in the first stage by increasing the temperature of the air stream by means of an external heating source.

4. A method according to Claim 3, wherein the external heating source includes solar energy.

5. A method according to Claim 3 or Claim 4, wherein the external heating source comprises the consumption of a conventional fuel.

6. A method according to any one of the preceding claims, wherein the relative water saturation value is increased in the second stage by adding water vapour from an external source of non-potable water.

7. A method according to any one of the preceding claims, wherein the relative water saturation value is reduced in the third stage by flowing coolant in heat exchange relationship with the saturated air stream.

8. A method according to any one of Claims 1 to 6, wherein the relative water saturation value is reduced in the third stage by submersing the third stage in a body of material having a temperature less than the temperature of the saturated air stream in the second stage.

9. A method according to Claim 7, wherein the relative water saturation value is reduced in the third stage by cooling said air stream with an external source of non-potable water.

10. A method according to Claim 7 or Claim 9, wherein the relative water saturation value is reduced in the third stage by circulation of at least a portion of the condensate collected from the third stage.

11. A method according to any one of Claims 1 to 6, wherein cooling is carried out in the third stage by conventional refrigeration.

12. A method according to Claim 9 or Claim 11, wherein the cooling water after passing in heat exchange relationship with the air stream in the third stage, is used to provide the source of additional water vapour.

13. A method according to any one of the preceding claims, wherein the stream of air passes through the three stages as a function of the natural velocity of the air.

14. A method according to any one of the preceding claims, wherein the temperature changes in the stream of air in said first stage and in said third stage provide a chimney or draft effect to create air flow through the three stages irrespective of the velocity of the air stream entering the first stage.

15. A method according to Claim 13 or Claim 14, wherein the air flow through the three stages is selectively supplemented or supplanted by the creation of a forced draft of the air stream.

16. An apparatus for producing according to any one of the preceding claims potable water from an external source of a continuously supplied stream of partially saturated atmospheric air, comprising a first stage chamber having an inlet and outlet for receiving and passing said stream of air therethrough and heating means operatively connected with said first chamber for raising the saturation point of the air stream passing through said chamber; a second stage chamber having an outlet and being in communication with said first stage chamber outlet and means in said second stage chamber for adding moisture to said air stream up to the raised saturation point; a third stage chamber to receive the saturated air stream therefrom and cooling means operatively connected with the third stage chamber for reducing the saturation point of the saturated air stream passing through and out of said third stage chamber to condense water out of said air stream; and means to produce a predetermined pressure differential of increase between the pressure of the air stream in the first stage chamber and the pressure in the third stage chamber.

17. Apparatus as claimed in Claim 16, wherein the crosssectional area of the first stage chamber is larger by a predetermined value than the cross-sectional area of the third stage chamber.

18. Apparatus as claimed in Claim 16 or Claim 17, wherein the auxiliary pressure differential producing means is disposed between said first and third stage chambers and comprises means to create a forced draft from said first stage chamber through said second and third stage chambers.

19. Apparatus as claimed in any one of claims 16 to 18, wherein the heating means comprise solar energy heat absorbing and transmitting surfaces.

20. Apparatus as claimed in Claim 19, wherein auxiliary heating means activated by a conventional fuel is provided in the first stage chamber for supplementing or supplanting the solar heating means for raising the temperature of said air stream.

21. Apparatus as claimed in any one of claims 16 to 20, wherein the cooling means comprises a cooling coil assembly associated with said third stage chamber and a pump to circulate a cooling liquid therethrough.

22. Apparatus as claimed in Claim 21, wherein said cooling liquid is a conventional refrigerant, non-potable water or a portion of the water condensed in the third stage chamber.

23. Apparatus as claimed in Claim 16, including material surrounding said third stage chamber and having a temperature lower than the temperature of the air stream entering said third stage chamber, to assist in reducing the saturation point of the air stream.

24. Apparatus as claimed in any one of Claims 16 to 23, rotatably positioned in a supporting surface, and including means to face the inlet of the first stage chamber constantly into the wind.

25. Apparatus as claimed in any one of Claims 16 to 24, wherein said moisture adding means comprises wick members in said second stage chamber, said wick members having one end immersed in non-potable water or a portion of the condensate from the third stage chamber and extending across the path of flow of said air stream from said first stage chamber.

26. Apparatus as claimed in any one of Claims 16 to 24, wherein the moisture adding means comprises fog forming spray elements positioned in said second stage chamber to direct the fog against the flow of said air stream toward said second stage chamber, said spray elements being supplied with non-potable water or a portion of said third stage chamber condensate by conventional pump means.

27. Apparatus as claimed in Claim 16, wherein said first stage chamber comprises an elongated, horizontally disposed air conveying section with inlet and outlet ends, the section having a substantially greater horizontal width than depth with an enlarged inlet end; solar heat absorbing and transmitting means secured to the upper portion of said horizontal section; said second stage chamber comprises a horizontal section of the same configuration as the first section and a downwardly curved section of rectangular cross-section connected at its inlet end to the outlet end of said first horizontal section, a plurality of wick members disposed vertically across the air flow path at the inlet end, the lower ends of said wicks being immersed in a source of water, the second chamber communicating at its outlet end with the inlet end of said third stage chamber which comprises a substantially horizontally positioned and extending duct section of rectangular cross-section and having as an outlet therefrom an upwardly curved duct section with its outlet end facing in a direction opposite to that of the inlet end of said first duct section and disposed vertically adjacent and below first duct section; cooling coil means disposed in the horizontal portion of said third chamber section to condense out of the air stream water vapour carried therein; a fresh water storage tank; means for passing water condensed from said third duct section to said storage tank; said three duct sections, said storage tank and cooling coil means being supported by a frame to which is secured floation and ballast means of sufficient dimension and size to float said frame and apparatus partially immersed in a body of water, said frame having a rudder means for causing the inlet end of said first duct section to point into the wind, and means for rotatably anchoring said framework and apparatus to the bottom of the body of water.

28. Apparatus as claimed in Claim 27, wherein fan means are disposed in said first curved section adjacent the outlet end thereof to decrease pressure in said first and second sections and increase pressure in said third section.

29. Apparatus as claimed in Claim 27 or Claim 28, wherein the bottom surface of the inlet ends of said first and second surface of the inlet ends of said first and second sections are inclined upwardly so as to form a shallow tank, said cooling coil means including a pump to draw water from the body of water in which said apparatus floats and pass said water through said cooling coil and into said tank, and the lower ends of said wicks are immersed in said tank.

30. Apparatus as claimed in Claim 27, wherein the bottom surface of the inlet end of said second section is upwardly inclined, a transverse opening is formed in said bottom surface just forward of said inclined surface, a casing open at both ends encompases said opening and extends downwardly into and below the surface of the body of water, and the lower ends of said wicks extend through the casing into the body of water.

31. Apparatus as claimed in Claim 27, wherein the bottom surface of the inlet ends of said first and second sections are inclined upwardly to form a shallow tank, misting or fog nozzles are positioned across said second

section adjacent the inlet end in lieu of said wicks, and said nozzles are connected to said cooling coil means which passes cooling water from the coils to said nozzles.

32. Apparatus as claimed in any one of Claims 27 to 31, wherein auxiliary heating means fired by gas or oil are positioned in the inlet end of said first section.

33. Apparatus as claimed in Claim 16, wherein said first stage chamber comprises an annular duct having an outer surface formed by a first elongated, certically disposed cylinder having closed top and bottom ends and an inner surface formed by a second vertically disposed cylinder axially positioned within said first cylinder and an air inlet conduit extending outwardly from the bottom of said annular duct through the wall of the first cylinder; solar heat absorbing and transmitting means secured to the outer wall of said first cylinder and covered by a cylindrical transparent casing; said second stage chamber comprises the upper portion of said annular duct and the upper portion of the duct formed by the inner wall of the upper portion of said second cylinder which is open at the upper end thereof and which upper end is spaced from the closed top of the first cylinder, and moisture adding means annularly positioned around the upper portion of said second cylinder in said annular ducts; said third stage chamber comprises the lower portion of said duct formed within said second cylinder and the duct formed by a curved tubular element connected to the lower end of said second cylinder with the outward end of said element extending through the lower wall of the first cylinder in a direction opposite to that of the inlet conduit of said first cylinder and disposed diametrically thereto, cooling coil means disposed in the lower portion of said second cylinder to condense out of the air stream water vapour carried therein; means for collecting and passing water condensed from said third chamber to a storage tank separated from said apparatus, and said first cylinder being supported at its base by a rotatable element and having rudder means mounted on the upper portion for causing the inlet conduit of said first duct section to point into the wind.

34. Apparatus as claimed in Claim 33, wherein said moisture adding means comprises an annular reservoir positioned on the upper portion of the second cylinder and wick members, said wick members having one end immersed in the non-potable water or a portion of the condensate from the third stage chamber in the reservoir and extending across the path of flow of said stream to the inner wall of the first cylinder.

35. Apparatus as claimed in Claim 33 or Claim 34, wherein fan means are disposed in said cylinder adjacent the upper end thereof to decrease pressure in said first and second sections and increase pressure in said third section.

36. Apparatus as claimed in any one of Claims 33 to 35, wherein auxiliary heating means fired by gas or oil are positioned in the inlet end of said first section.

37. Apparatus as claimed in Claim 16, wherein said first stage chamber comprises an elongated, horizontally disposed air conveying section with an enlarged inlet end and a tapering outlet end; heating means positioned between the inlet and outlet ends; said second stage chamber comprises an elongated horizontally disposed section of cross-section equal to the outlet end of said first section and connected at its inlet end to the outlet end of said first horizontal section, and misting or fog forming nozzles positioned within said second chamber, the second section communicating at its outlet end with the inlet end of said third stage chamber which comprises a horizontally positioned and extending duct portion of similar cross-section and having in its outlet portion an air flow throttling device, a blower fan positioned adjacent the inlet end of said third section to draw air through said apparatus and in concert with said throttling device to provide air pressure differential between the first and third sections; cooling coil means disposed in the horizontal portion of said third chamber section to condense out of the air stream water vapour carried therein and to provide a source of water from said nozzles; and means for passing water condensed from said third duct section to a storage tank.

38. Apparatus for producing potable water from an external source of a continuously supplied stream of partially saturated atmospheric air, substantially as hereinbefore described with reference to Figures 1 and 2, or Figures 3 and 4, or Figure 5 of the accompanying drawings.

39. A method according to Claim 1 for producing potable water, substantially as hereinbefore described.

40. Potable water, whenever produced by the method claimed in any one of Claims 1 to 15 and 39, or by means of the apparatus claimed in any one of Claims 16 to 38.

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3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

Fig. 1

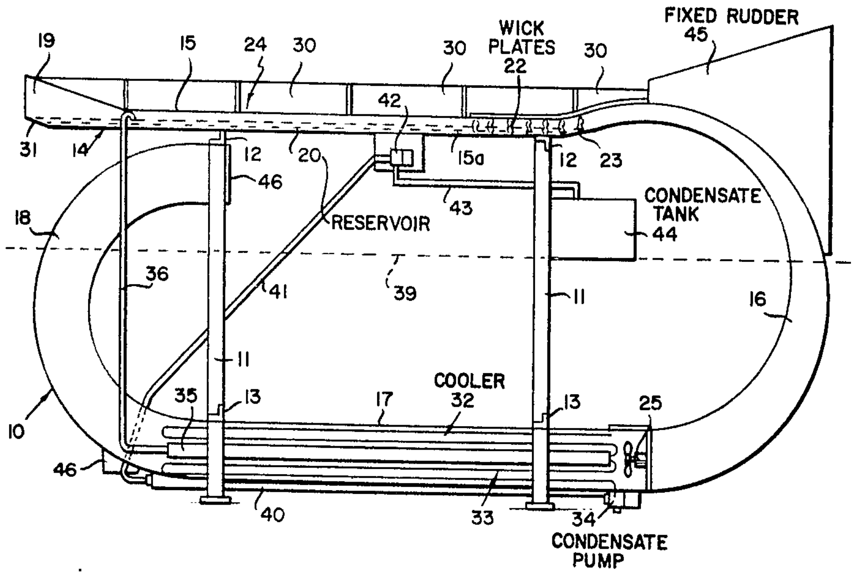
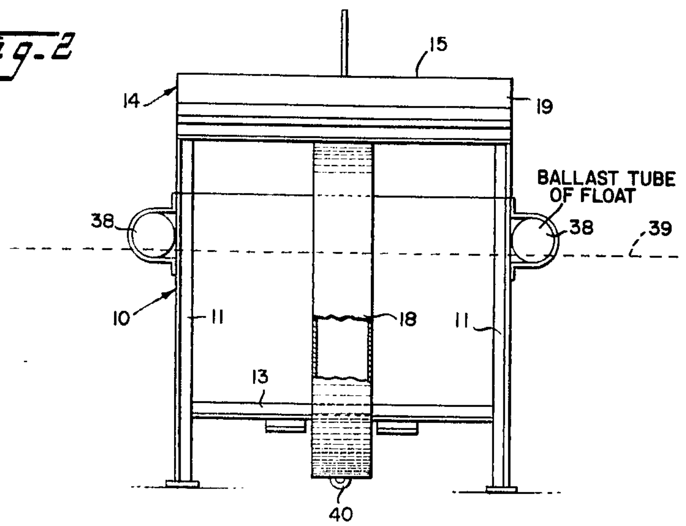


Fig. 2



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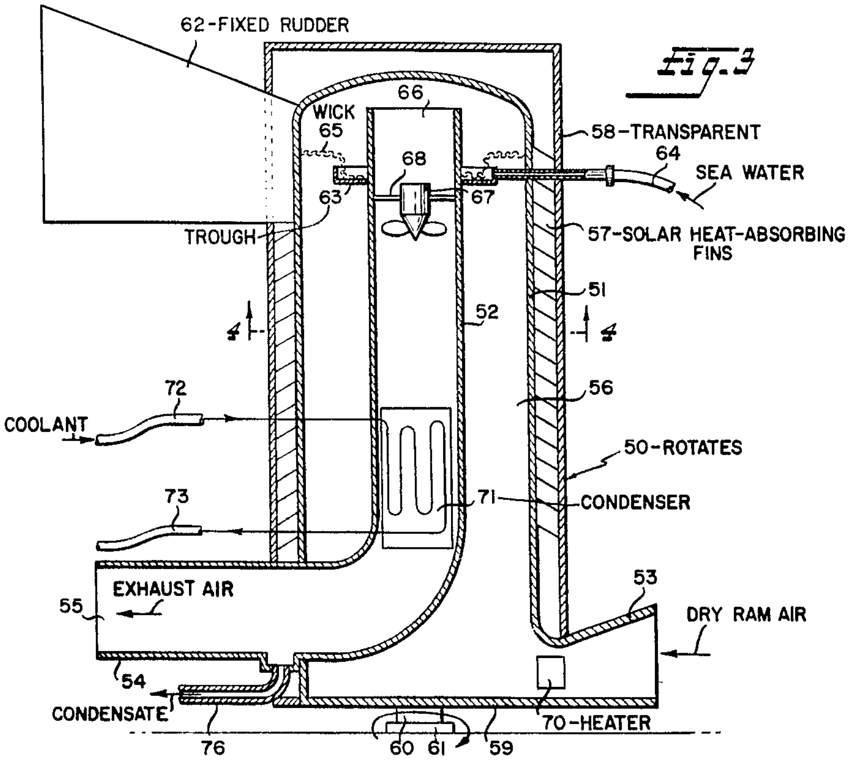

Fig. 3

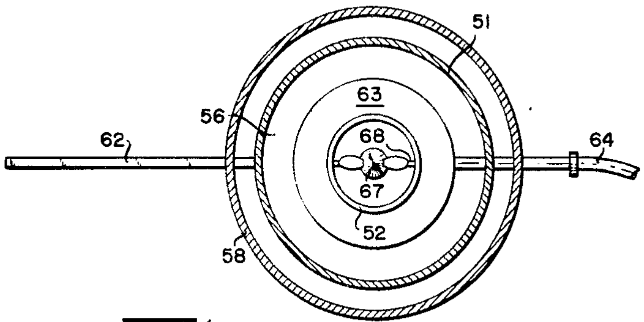

Fig. 4

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Sheet 3

Fig. 5