Dec. 6, 1966 K. D. BROWN 3,290,229

APPARATUS FOR DIRECT CONTACT CONDENSATION OF VAPORS

Original Filed Jan. 25, 1962 6 Sheets-Sheet 1

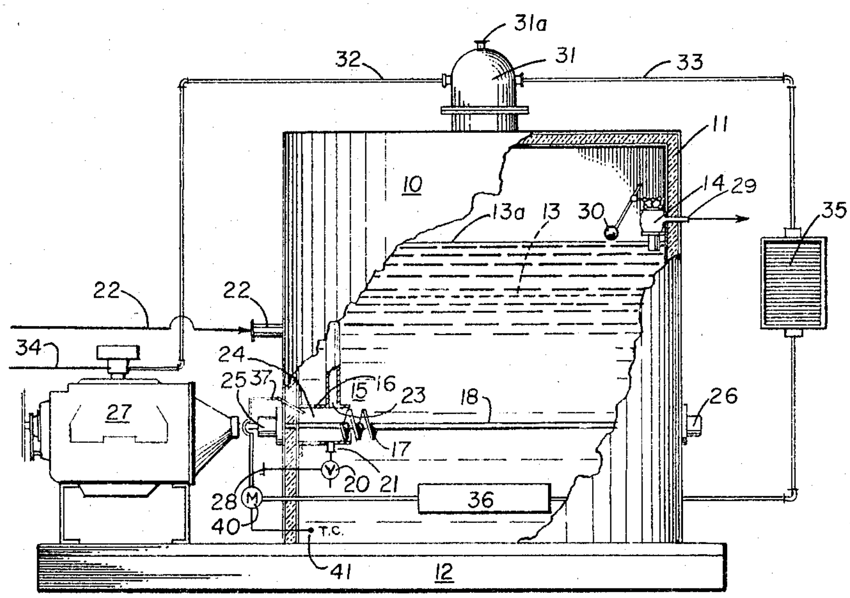

Fig 1

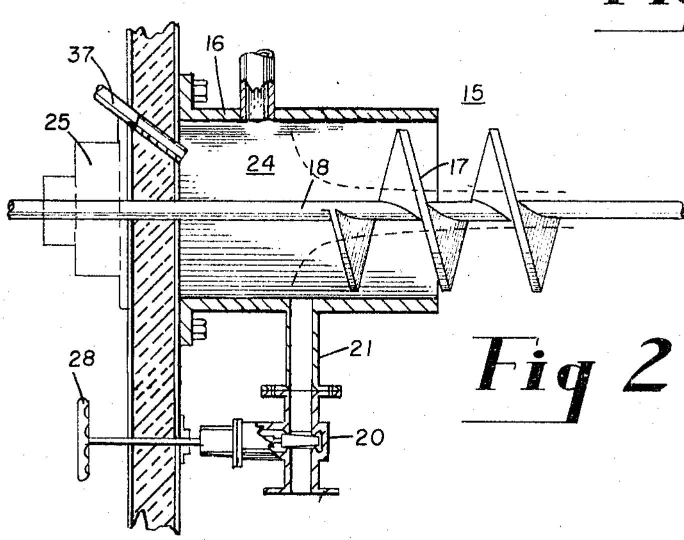

Fig 2

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APPARATUS FOR DIRECT CONTACT CONDENSATION OF VAPORS

Original Filed Jan. 25, 1962 6 Sheets-Sheet 2

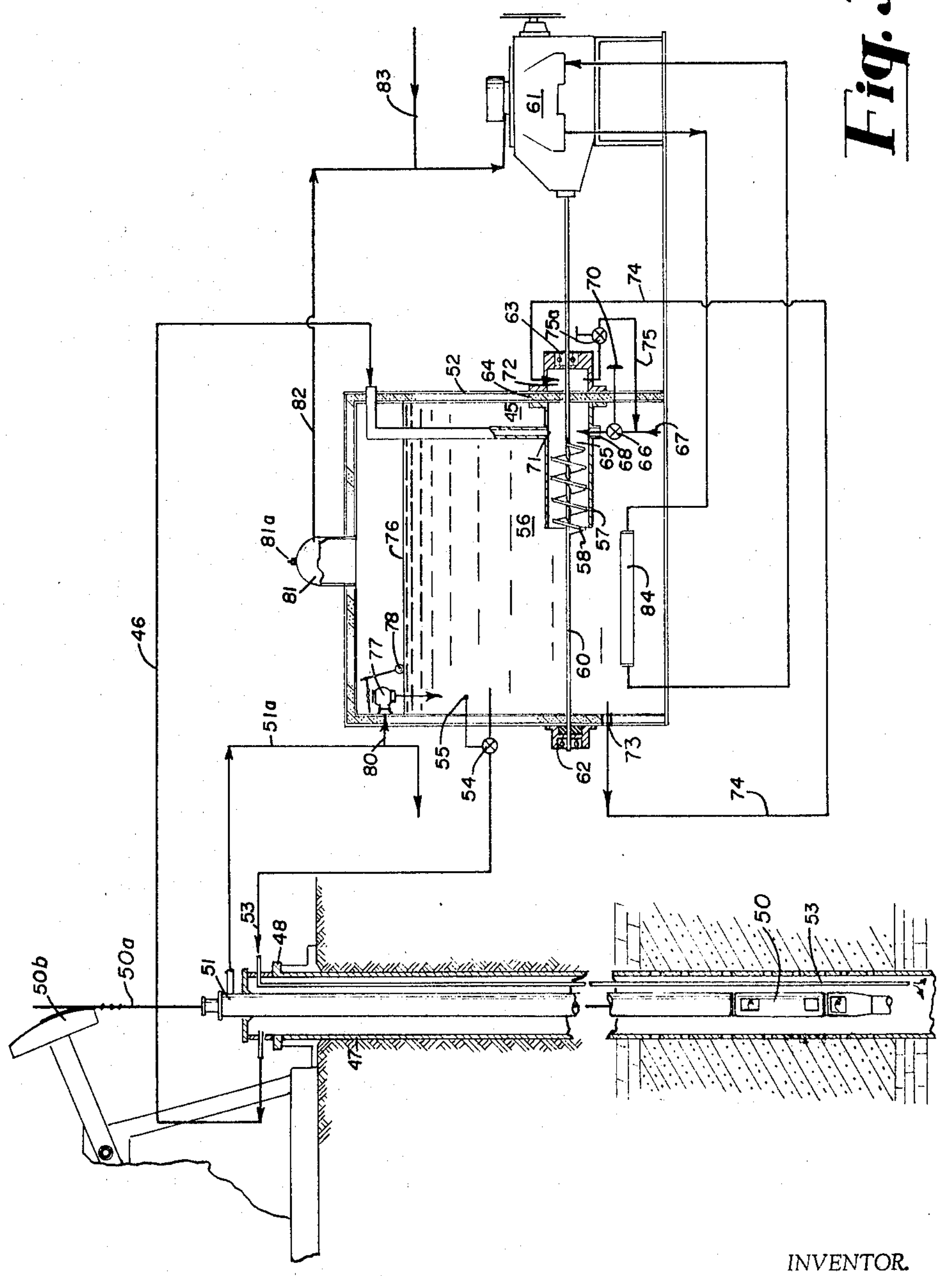

Fig. 3

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APPARATUS FOR DIRECT CONTACT CONDENSATION OF VAPORS

Original Filed Jan. 25, 1962 6 Sheets-Sheet 3

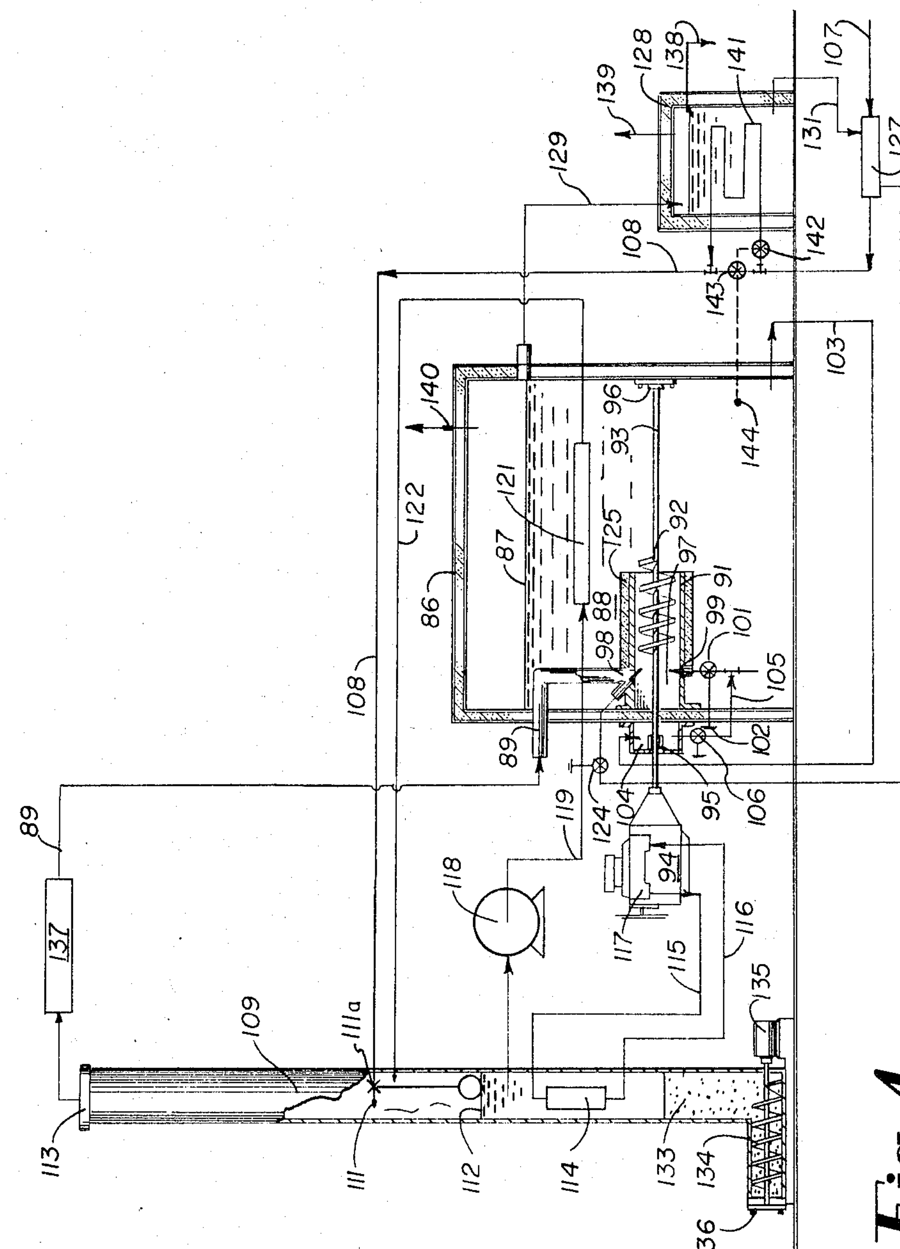

Fig. 4

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APPARATUS FOR DIRECT CONTACT CONDENSATION OF VAPORS

Original Filed Jan. 25, 1962 6 Sheets-Sheet 4

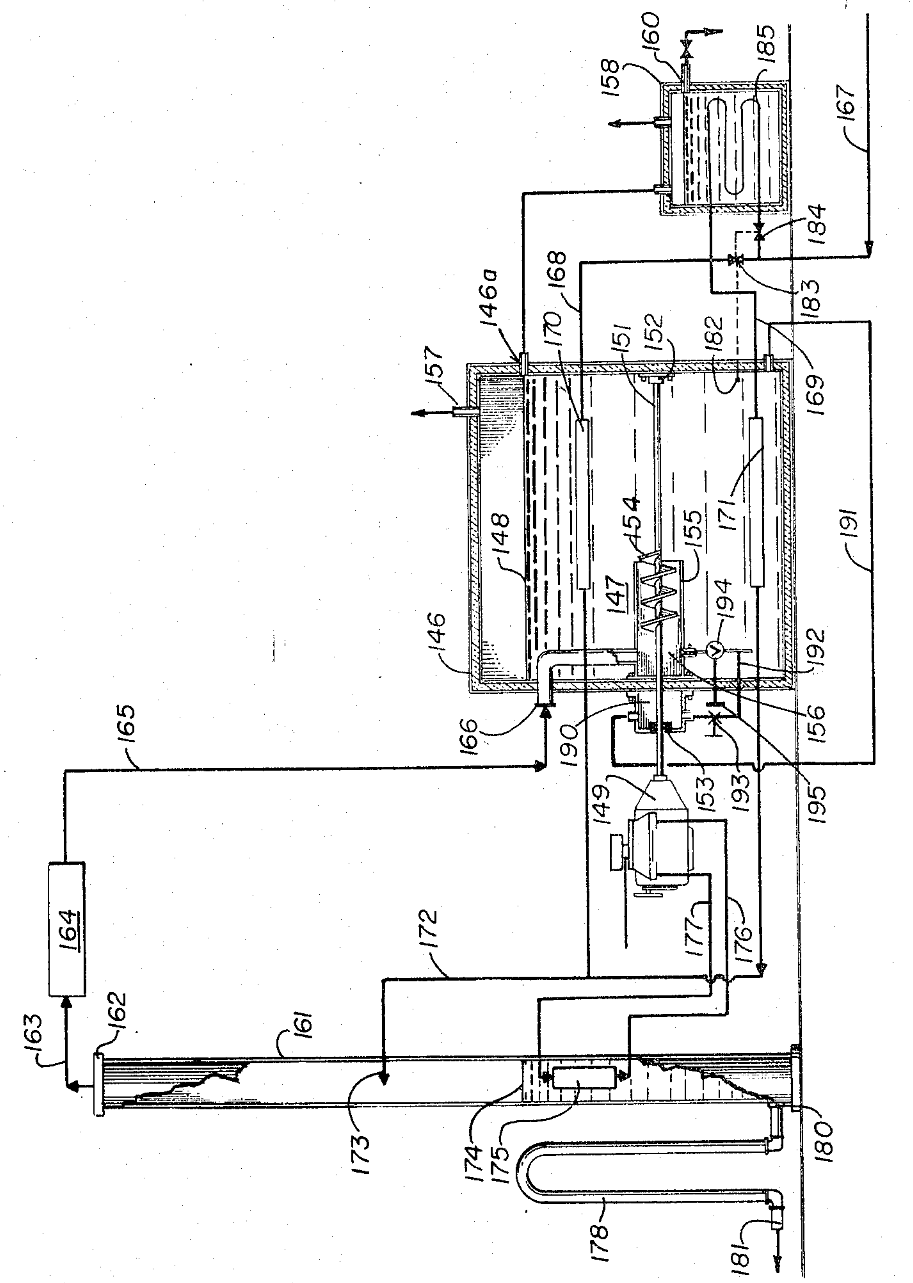

Fig. 5

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APPARATUS FOR DIRECT CONTACT CONDENSATION OF VAPORS

Original Filed Jan. 25, 1962 6 Sheets-Sheet 5

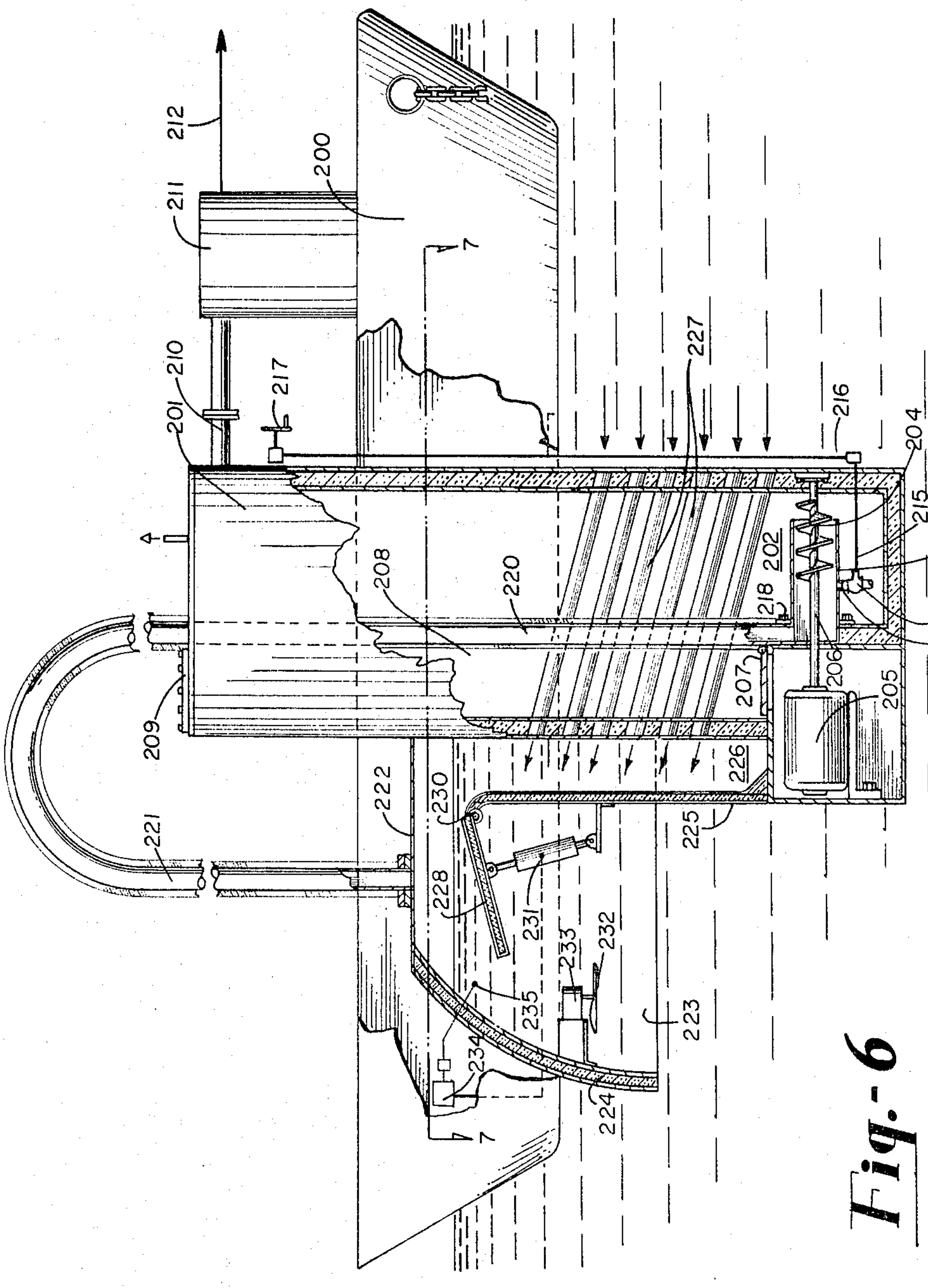

Fig.-6

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APPARATUS FOR DIRECT CONTACT CONDENSATION OF VAPORS

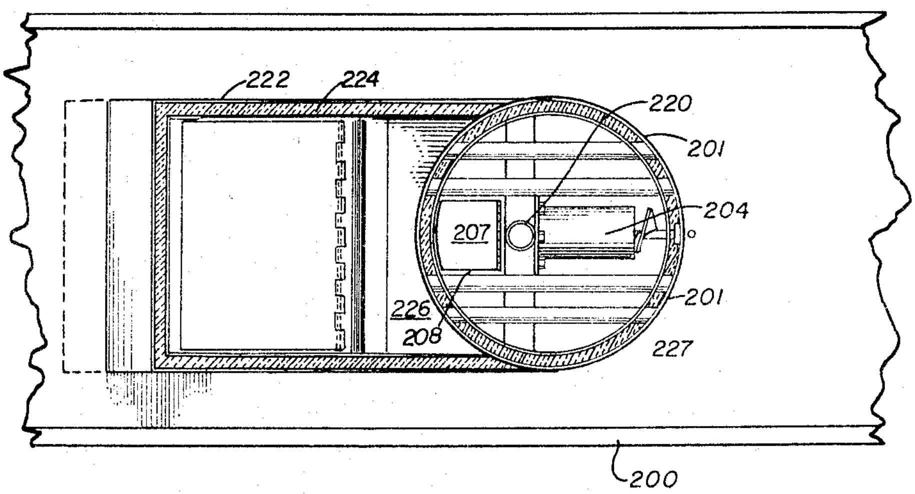

Fig. 7

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United States Patent Office

3,290,229
Patented Dec. 6, 1966

3,290,229

APPARATUS FOR DIRECT CONTACT CONDENSATION OF VAPORS

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Original application Jan. 25, 1962, Ser. No. 168,675, now Patent No. 3,204,861, dated Sept. 7, 1965. Divided and this application Dec. 14, 1964, Ser. No. 418,112
11 Claims. (Cl. 202—177)

This application is a division of my copending application Serial No. 168,675, filed January 25, 1962.

This invention relates to vacuum pumps and to systems employing such pumps and particularly to an improved pump and control system for pumping large volumes of gas and for facilitating the purification of liquid and the like.

Many industrial processes require large volumes of gas to be pumped continuously and various types of pumps and blowers have been proposed or employed for this purpose. Certain of these applications require that relatively low pressures be maintained and conventional expansible chamber, displacement and centrifugal pumps have not proved entirely satisfactory for these applications. By way of example, it has been proposed to maintain relatively low pressures in oil wells to facilitate the production of oil but conventional equipment has proved to be uneconomical and difficult to maintain in operation for this purpose. Another application of vacuum pumps occurs in the separation of water and material dissolved or suspended therein. Here it has been found difficult to maintain the required low pressures while removing large volumes of water vapor.

It is an object of this invention to provide an improved apparatus for maintaining low pressures in oil wells and the like and for facilitating the production of volatile constituents therefrom.

It is another object of this invention to provide an improved apparatus for effecting the evaporative separation of water and solids mixed or dissolved therein.

It is a further object of this invention to provide an improved evaporation and condensing apparatus for purifying liquids.

It is a still further object of this invention to provide an improved apparatus for effecting the evaporative purification of water on a large scale.

Briefly, in carrying out the objects of this invention in one embodiment thereof, a vacuum pump is provided which comprises a tank containing a body of liquid in which is immersed a pump having a rotor of the screw or helical type arranged in a cylinder or shroud closed at one end and opening into the tank at the other. The pump is provided with a gas inlet and a liquid inlet adjacent its closed end, the liquid inlet being arranged to admit liquid from the tank. The pump during operation produces a vortex in the shroud and the vortex is controlled by adjusting the liquid inlet opening. It has been found that by proper adjustment of the rate of recirculation of the liquid a highly effective pumping action is secured which is capable of maintaining a high vacuum (low gas intake pressure) when the liquid intake supply is regulated and will pump a high volume of gas. The pump operates effectively as a vacuum pump and will maintain a vacuum in an oil well where it maintains a continuous and steady pressure and greatly facilitates the production of oil and of volatile constituents. In another embodiment of the invention the pump is employed in combination with an evaporative purifying system for water and provides an efficient evaporative system for desalting sea water.

The features of novelty which characterize this invention are set forth in the claims annexed to and forming a part of this specification. The invention itself, however, both as to its organization and method of operation will be better understood upon reference to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is an elevation view partly in section to show the interior illustrating a vacuum pump used in systems embodying the invention;

FIG. 2 is an enlarged sectional view of the shroud and rotor of the pump of FIG. 1;

FIG. 3 is a somewhat diagrammatic view partly in section illustrating an oil well heating system embodying the invention;

FIG. 4 is a view similar to that of FIG. 2 illustrating a water purifying system embodying the invention;

FIG. 5 is another view similar to FIG. 3 illustrating a water desalting system embodying the invention;

FIG. 6 is an elevation view partly in section illustrating a boat provided with a sea water desalting system embodying the invention; and

FIG. 7 is a sectional view taken along the line 7—7 of FIG. 6.

Referring now to the drawings, the vacuum pump shown in FIG. 1 includes a generally cylindrical closed tank **10** having its walls insulated as indicated at **11** and mounted on a supporting base **12**. The tank is arranged to be filled with a liquid such as water to a predetermined level indicated at **13** and with a condensed petroleum liquid to a level **13***a* maintained by operation of a float valve **14** in a manner to be described below. In the lower portion of the tank and mounted on the left-hand wall as shown there is provided a pump **15** comprising a cylindrical sleeve or shroud **16** and a screw or helical rotor **17** mounted on a horizontal shaft **18** for rotation partly within the shroud. The diameter of the rotor is enough smaller than the internal diameter of the sleeve **16** to leave a substantial annular clearance space. The left end of the shroud adjacent the tank wall is closed while the right end opens into the tank. The rotor **17** extends a short distance into the shroud, the major portion of the screw lying outside the shroud.

Liquid is circulated from the tank through the pump **15** under control of a valve **20** for varying the water admitted to the shroud through an inlet **21** in the bottom wall thereof. Gas or vapor from a supply line **22**, which may, for example, be connected to an oil well (not shown) is admitted to the pump through a vapor inlet **23** in the top wall thereof. Both the liquid inlet **21** and the gas inlet **23** communicate with the pump **15** within a chamber **24** formed between the closed end of the shroud and the rotor **17**. The shaft is journaled in bearings **25** and **26** and is driven by a suitable prime mover illustrated as an internal combustion engine **27**.

When the rotor **17** is driven at a suitable speed, say 900 revolutions per minute, gas is drawn into the pump through the inlet **23** and a vortex forms about the shaft **18** decreasing in diameter toward the right as indicated by dotted lines in FIG. 2. The water or other liquid is forced outwardly by centrifugal force and forms an effective seal around the rotor. Condensible vapors are liquefied in the vortex and in the water in the tank, noncondensibles being released into and rising through the main body of liquid in the tank. In order to secure effective and efficient operation of the pump it is necessary to adjust the liquid return through the inlet port **21** to secure its optimum setting for the conditions of operation. In the illustration the valve **20** is of the gate type and is controlled manually by a wheel **28**. When the optimum valve setting has been attained, large volumes of gas are drawn into the pump and condensed.

The pump at this setting is capable of maintaining a relatively high vacuum while pumping large volumes of gas.

The rapid condensation of vapor by operation of the rotor **17** raises the level **13***a* of the petroleum liquid in the tank and a float **30** which operates the valve **14** rises and opens the valve to discharge liquid until the level is restored. The discharged liquid is supplied to a production line or pipe **29** for use or transportation.

When the pump is operated to pump a petroleum gas well, for example, the heavier hydrocarbons are condensed in the liquid in the tank while the lighter hydrocarbons, non-condensible under the conditions of operation of the pump, are collected in the tank above the level of liquid therein. These gases rise into a dome **31** and are removed through pipes **32** and **33** or through a suitable pop off valve **31***a*. The pipe **32** may be employed to supply gas to the engine **27** to supplement or replace the usual fuel supply through a supply line **34**. The line **33** is employed to supply cooling gas to the pump; this gas passes through a heat transfer unit **35**, cooled by air or other suitable fluid, and is then returned to the pump through a heat exchanger **36** in the liquid in the lower portion of the tank and thence through a nozzle **37** into the chamber **24**. The operation of this heat transfer arrangement may be controlled by a valve **40** actuated automatically in response to the temperature of the liquid in the tank as determined by a temperature sensing element **41** located therein.

In this application of the vacuum pump it is desirable to maintain a relatively low temperature of the water in the tank and it is for this reason that the rotor **17** is confined only at the entrance of the shroud. As will be pointed out below, the enclosure of a substantial length of the rotor in the shroud results in the generation of a very substantial quantity of heat which is desirable for many applications of the invention. The cooler temperatures realized in the pump of FIG. 1 facilitate the condensation of the heavier hydrocarbons and the return of cooled gas through the line **33** further effects cooling of the liquid.

The diameter of the rotor determines the size of the vortex formed during the operation of the pump. For a given shaft speed the larger the diameter of rotor the larger the vortex and the greater the peripheral speed of of the turns of the helix. The volumetric capacity of the pump is determined by the speed of the shaft and the length of pitch of the helix. It will thus be apparent that a wide range of design is available. The spacing of the rotor from the shroud or cylinder wall may also be varied within a relatively wide range dependent upon the application for which the pump is intended. In all cases the control of the admission of liquid to the pump cylinder is relatively critical and is adjusted to effect the optimum performance in each application and condition of operation.

For many applications of the pump of this invention it is desired to generate substantial quantities of heat, and FIG. 3 illustrates a system wherein such heat is employed to facilitate the production of relatively viscous petroleum. In this embodiment a pump assembly indicated generally at **45** and which is similar to that shown in FIG. 1 is connected by a vacuum or suction line **46** to remove gas from a well casing **47**, the suction line being connected in communication with the interior of the casing through a well head fitting **48**. Liquid petroleum is removed from the well by operation of a pump **50** connected by a sucker rod **50***a* to be driven by a horsehead **50***b*; the pump receives liquid from the formation and delivers it to a production stream or tube **51**.

In order to heat the well fluids in the well, high temperature liquid is supplied from the tank **52** of the pump assembly **45** through a line **53** under control of an automatic valve **54** having a temperature sensing element **55** immersed in the liquid in the tank. The line **53** extends downwardly into the well between the casing and the tubing **51** so that the hot liquid flows downwardly alongside the production tube and heats the liquid petroleum flowing upwardly therethrough; the hot liquid thus flows down into the well and over the producing surface of the formation where it counteracts the refrigerating effect of the liquid vaporized under the low pressure; the liquid then flows upwardly with the well fluids through the tube **51**. The vacuum pipe **46** maintains the well at low pressure during the operation of the pump **45** and greatly facilitates the production of the well fluids. The pump **45** maintains a steady suction line pressure and has been found very effective in increasing the rate of production from petroleum formations which have been relatively low rate producers.

The pump assembly **45** includes a pump **56** comprising a sleeve or shroud **57** and a helical rotor **58** mounted on a shaft **60** for rotation in the shroud by operation of an internal combustion engine **61**. The shaft **60** is journaled in bearings **62** and **63** and the rotor **58** is positioned within the sleeve **57** substantially throughout its length, the rotor diameter being smaller than the internal diameter of the sleeve and providing an appreciable spacing therebetween. The shroud is closed at its right-hand end by a plate **64** and a suction chamber **65** is formed between the end plate and the rotor **58**. This arrangement which provides a longer portion of the rotor in the shroud results in the generation of larger amounts of heat in the liquid which is thereby maintained by higher temperatures than in the embodiment of FIG. 1.

Liquid is admitted to the pump under control of a valve **66** which controls a passage from valve inlet **67** in the tank to a pump intake port **68**. The valve has been illustrated as manually controlled by a hand wheel **70**. Gas or vapor from the well flows through the suction line **46** to a vapor inlet or port **71** entering the chamber **65**. It will be noted that both intake ports **68** and **71** enter the chamber **65** behind the last turn or blade of the rotor **58**; this arrangement of the rotor and ports assures effective operation of the pump.

The bearing **63** adjacent the suction side of the pump is sealed by liquid circulated from the tank through a compartment **72** in the bearing assembly and thence to the pump intake. For this purpose liquid is drawn from an outlet **73** in the side of the tank through a pipe **74** to the compartment **72** and thence to the chamber **65** under control of a valve **75***a* through a conduit **75** opening adjacent the inlet of the valve **66**. This prevents leakage of air into the suction side of the pump through the bearing **63**.

In this application the liquid in the tank **52** is petroleum and other well fluids and is maintained at a level **76** by operation of a float valve **77** actuated by a float **78**; whenever the liquid level falls sufficiently the float opens the valve and admits petroleum from the production line indicated at **51***a* through a connection **80**.

Volatile petroleum components collect above the level of the liquid in the tank and fill a dome **81**; these gases are removed from the dome through a line **82** and are supplied as fuel for the engine **61**, excess gases being removed by a pop off valve **81***a*. Fuel gas may also be supplied through a second source indicated as a supply line **83**.

Additional heat may be supplied to the liquid in the tank **52** from the hot exhaust gases of the engine or from its cylinder jacket cooling system; by way of example, a heat exchange device **84** has been shown immersed in the liquid in the tank and connected to receive the hot fluid from the engine **61** and to return the fluid to the engine after it has been cooled by this heat exchanger.

The valve **54** is controlled to open and admit hot liquid to the well casing when the temperature as sensed by the element **55** is above a predetermined value. The system thus operates to maintain a low pressure in the well formation and simultaneously supply hot well fluid or other liquid to heat the viscous petroleum fluids and facilitate their production from the formation and their flow through the production pipes under operation of the pump **50**.

The system of this invention including the vacuum pump may be employed effectively for purifying liquids such as muddy river water and sewage and a system for this purpose is diagrammatically illustrated in FIG. 4. The vacuum pump is essentially the same as that disclosed in connection with FIG. 3 and comprises an insulated closed tank **86** within which liquid is maintained to a level indicated at **87** and having a rotary pump assembly **88** submerged in the body of liquid for drawing gas or vapor through a suction line **89**. The pump includes a cylindrical sleeve or shroud **91** and a helical rotor **92** mounted on a shaft **93** driven by an internal combustion engine **94**. The shaft is mounted in bearings **95** and **96** in essentially the same manner as the shaft of FIG. 3.

The sleeve **91** is closed at its left-hand end as illustrated which provides an intake chamber **97** between the left end of the rotor and the wall of the tank. The suction line **89** opens into the chamber **97** at a port **98** to the rear of the rotor **92** and liquid from the tank is admitted to the sleeve through an intake port **99** under control of a valve **101** provided with a hand wheel **102** similar to that employed in the embodiments previously described. The rotor **92** has a diameter substantially less than that of the sleeve **91** and operates in the same manner as the rotor **58** of the embodiment of FIG. 3 to produce a vortex about the rotor resulting in a high vacuum together with the generation of heat within the liquid in the tank and condensation of vapors passing therethrough.

The bearing **95** is provided with a liquid seal similar to that of the bearing **63** in FIG. 3, liquid being circulated from the body of liquid in the tank **86** through a line **103** to a sealed chamber **104** and thence to the inlet of the valve **101** through a connection **105** controlled by a hand valve **106**. This sealing arrangement prevents the admission of air to the inlet chamber of the pump through the bearing assembly.

Liquid to be treated, which may for example be river water or sewage, is admitted to the system from a supply through a connection **107** and passes through a pipe **108** to an upright tower **109** which it enters at a nozzle **111** under control of a float valve **111*a***, the nozzle being positioned above the surface of liquid in the tower indicated at **112**. The tower **109** is of sufficient height to prevent withdrawal of liquid by the suction pressure in the line **89** which is connected in communication with the tank through a head fixture **113**.

Heat is supplied to the liquid within the tower **109** through a heat exchanger **114** connected to receive heat transfer liquid through line **115** from jacket **117** of the engine **94** and to return the liquid through line **116**. In addition, liquid is withdrawn from the tower **109** by operation of a pump **118** which discharges the liquid through a pipe **119** to a heat exchanger **121** and returns it to the tower **109** through a pipe **122**. The liquid to be treated which is supplied from the line **107** may also be heated as it passes through a heat exchanger **127** which receives fresh water or other purified liquid from a collecting tank **128**. The collecting tank is connected to receive hot fresh water from the tank **86** through a line **129** and to supply liquid to the heat exchanger **127** through a connection **131** and thence to the pump inlet **98** through a line **132**. The admission of water from the line **132** to the pump chamber **97** is controlled by a hand valve **124**. The water cooled by heat exchange with the incoming water in the line **107** is substantially cooler than the water in the tank **86** and facilitates the production of lower pressures at the pump inlet. The production of lower pressures is further facilitated by insulating the pump shroud or casing **91** as indicated at **125** thereby further reducing the rise of temperature of the water in the shroud.

It will thus be apparent that the liquid to be treated which is supplied to the tower **109** after being heated and on being discharged into the tower a substantial portion of this liquid will flash into vapor and be withdrawn through the line **89** by operation of the pump, the vapor thereby being separated from the foreign matter carried into the tower. The concentrated liquid then falls to the body of liquid within the tower and further portions are further evaporated from the surface **112**, the concentrated foreign matter collecting in the bottom portion of the tower as indicated at **133**. After a substantial accumulation of the foreign matter **133**, the system is stopped, whereupon the accumulated matter may be removed by a helical screw **134** driven by an electric motor **135** and thereby discharged through a valved plate structure **136** which is open to allow the material to be driven therethrough when it is to be removed from the tower.

In order to assure a minimum passage of liquid particles through the line **89**, a separator or scrubber **137** may be provided. This scrubber may include heating apparatus (not shown) to vaporize any such particles and remove any substances carried thereby. It will be understood that the provision of the unit **137** will not be necessary in many installations and is merely a refinement to assure removal of the last vestige of foreign matter from the vapor stream.

The vapor removed from the liquid within the tower **109** is thus supplied to the pump **88** and is condensed by operation of the pump and added to the liquid within the tank, which then rises above the level **87** and flows into the auxiliary tank **128**, from which it is removed through a pure water supply line **138**. The tank **128** is preferably open to the atmosphere through a connection **139**. The tank **86** is also open to the atmosphere through a connection **140**.

A further temperature control is provided for the liquid flowing from the line **107** to the supply line **108** and comprises a heat exchange coil **141** arranged in the tank **128** in heat exchange with the purified water therein together with a normally closed valve **142** and a normally open valve **143**. The valves **142** and **143** are controlled in accordance with the temperature of the water within the tank **86** as determined by a sensing element **144**; when the temperature falls below a predetermined value, the valve **143** is closed and the valve **142** opened so that the water from the line **107** is circulated through the tank **128** and picks up heat from the water therein.

During the operation of the system illustrated in FIG. 4, large volumes of vapor are removed from the tower **109** and condensed and the system provides a highly efficient and rugged arrangement for purifying water containing solids. It will be understood that the operation of the pump **88** produces very substantial amounts of heat and relatively high temperatures of the water contained in the tank **86**.

The system of this invention may also be employed for the purification of water containing foreign matter in solution and, for example, may be used for desalting brackish water or sea water to produce pure water for domestic use or the like. A system for this purpose is illustrated in FIG. 5. In this system a vacuum pump of the closed tank type similar to that described in connection with the previous embodiments is employed. As illustrated, the vacuum pump of this system comprises a closed tank **146** having a rotary pump **147** mounted therein below the normal level of liquid indicated at **148**. The pump **147** is driven by an internal combustion engine **149** having a shaft **151** mounted in bearings **152** and **153** and on which the helical rotor indicated at **154** is mounted. The rotor **154** rotates within a housing or shroud **155** which has an internal diameter substantially greater than that of the rotor and provides an inlet chamber 156 between the left-hand end of the housing and the left-hand end of the casing as shown.

During the operation of the system fresh or purified water collects in the tank 146 and is discharged through an overflow or outlet 146*a*, the tank being at atmospheric pressure as indicated by an outlet pipe 157. The overflowing fresh water collects in an accumulator or auxiliary tank 158 and is discharged therefrom for use through an overflow connection 160.

The pump system as just described is connected to evaporate water from an evaporating chamber comprising an upright tower 161 the outlet of which is connected to a closed header 162 as indicated at 163 and conducts the vaporized water through a steam separator 164 and outlet conduit 165 to an inlet or suction connection 166 of the pump 147. The suction line 166 is connected to the pump 147 in communication with the chamber 156 as in the arrangements of the pumps previously described.

Salt water to be purified is admitted to the system through a supply line 167 and normally flows through conduits 168 and 169 through parallel heat exchangers 170 and 171 to a line 172 connected to supply salt water to the towed 161. The inlet line 172 terminates in a nozzle or head 173 within the tower 161 and delivers the liquid into the zone above the normal liquid level in the tower at 174. The nozzle 173 sprays the salt water into the tower where a portion of it is flashed immediately into vapor, the remainder falling to the body of liquid at the bottom of the tower; the tower is heated by a heat exchanger 175 connected in the liquid cooling system of the internal combustion engine 149 by lines 176 and 177; this cooling system is similar to that of FIG. 4 and circulates a suitable liquid heated by the engine block or exhaust gases or both. The tower 161 is maintained under a vacuum or low pressure by operation of the pump 147 and the withdrawn water vapor admitted to the pump is condensed by operation of the pump and added to the water within the tank 146. Any air or other non-condensible gases passing through the system may be removed through the outlet 157.

The tower 161 is made sufficiently tall that the suction pressure created by the pump 147 cannot draw liquid from the body of liquid within the tower into the exhaust line 163. The height to which water can be raised by operation of a vacuum is dependent upon the atmospheric pressure since it is the difference between atmospheric pressure and pressure in the pump which determines the pressure difference tending to force the liquid water upwardly through the tower 161. It is necessary to remove the concentrated solution or salt water from the tank and for this purpose an inverted-U or siphon 178 is provided which is connected to the bottom of the tower 161 at 180 and to a discharge line at its other end as indicated at 181. The height of the inverted-U 178 is made sufficient to prevent the drawing of air into the system from the loop during operation of the pump at its lowest suction pressure, the siphon provides the overflow for excess liquid within the body in the tower 161 and thus maintains the normal level 174 of the liquid in the tower. The loop 178 thus provides an overflow for the tank while at the same time preventing the breaking of the vacuum pressure within the tower 161. The steam separator 164 is provided in the line 163 in order to retain particles of water which may reach the line 163 and allow them to evaporate before proceeding into the suction line 165.

During the operation of the system, should the temperature of the water within the tank 146 fall below a preselected value, a temperature sensing element 182 will cause operation of a pair of valves 183 and 184 to close the direct communication between the inlet 167 and the lines 168 and 169 and to open communication between the line 167 and a heat transfer coil 185 within the tank 158. Upon this change in the circuits the salt water to be treated

passes through the coil 185 in the tank 158 and is heated by the water in this tank before proceeding through the heat exchangers 170 and 171 in the tank 146.

The system as illustrated also includes the sealing chamber for the bearing 153 as indicated at 190, this chamber being filled with water circulated from the tank 146 by operation of a supply line 191 connected to the lower portion of the tank 146 and conducting the liquid through the chamber 190 to a connection 192 under control of a hand valve 193. This circulated water is supplied to the intake side of a valve 193 which controls the recirculation of water from the tank 146 through the pump 147 in the same manner as the liquid intakes of the pumps described above.

During operation of the system the valve 194 is adjusted by a hand control indicated as a wheel 193 so that optimum conditions are realized. Under these conditions of operation low pressure is achieved in the suction line 166 and large amounts of heat are liberated into the water within the tank 146. This heat is available to heat the supply water and facilitate the flashing of the salt water into steam within the tower 161. Under optimum conditions the vortex formed by the helical rotor 154 acts effectively to withdraw and condense the steam passing through the inlet conduit 166, the steam not condensed within the shroud 155 being condensed shortly after emerging from the shroud at the right end of the pump.

The system as illustrated in FIG. 5 makes it possible to provide effective pumping and evaporation of water from sea water and the like without requiring that moving parts of the system be located in the salt water and subject to the heavy corrosion resulting therefrom. In the present installation it will be noted that the pump and its bearings are all located where they are subject only to wetting by the fresh water produced by operation of the system.

The system of this invention may also be employed for installation on a ship or other vessel such as a barge anchored offshore, and in FIGS. 6 and 7 a system of this type is illustrated. As shown in these figures a floating barge or other vessel 200 is provided with a cylindrical insulated tank 201 mounted to extend a substantial distance into the water below the vessel. In the lower portions of the tank there is arranged a pump 202 of the same general construction as the pumps previously described and which comprises a cylindrical sleeve or shroud 203 within which is mounted a helical rotor 204 driven by an electric motor 205 by rotation of a shaft 206 mounted in suitable bearings in the walls of the tank structure. In the arrangement illustrated the motor 205 is located in an offset portion or housing formed at one side of the tank.

Access to the compartment in which the motor 205 is located may be had through a door 207 hinged at the bottom end of a vertical passage 208 within the tank and which is closed at the top by a plate 209 bolted to the top cover of the tank. The tank 201 is arranged to hold a body of water filling the tank to the level of an overflow conduit 210 from which freshwater flows to a reservoir 211 and may be distributed through a suitable outlet indicated diagrammatically by the arrow 212. Water is recirculated through the pump shroud 203 from an inlet 213 under control of a valve 214 connected by operating rods 215 and 216 to a hand wheel 217 on the deck of the vessel. The vapor intake of the pump 202 which is indicated at 218 is connected through a suction line 220 and an inverted-U 221 to an inverted dome or bell 222 mounted on the vessel and having an open end 223 a substantial distance below the level of the sea. The side walls of the bell 222 are insulated as indicated at 224 in order to prevent undue cooling by the sea water or air surrounding the valve. A vertical wall 225 is mounted above the casing of the motor 205 and extends upward parallel to the wall of the tank 201 and in spaced relationship thereto to form a vertical chamber 226. The wall 225 is heat-insulated as indicated.

A multiplicity of parallel tubes **227** extend through the tank **201** and are open at both ends. These tubes slope upwardly as shown and, because of the heating of the sea water within the tubes by heat exchange with the hot water within the tank produced by operation of the pump **202**, the sea water rises and enters the area **226** and flows upwardly and over the upper end of the wall **225** onto a sloping wall **228** which is hinged to the top of the wall **225** at **230**. The slope of the wall **228** is arranged to be adjusted by operation of a suitable mechanism such as a hydraulic actuator indicated at **231**. Under some conditions of operation the flow of sea water through the tubes **227** may be produced by movement of the vessel **200** through the water or by anchoring the vessel in a moving stream.

It will now be apparent that during the operation of the pump low pressure is maintained within the bell **222** which constitutes the evaporating chamber of the system and the heated water will vaporize, the vapor being drawn into the pump and condensed. The tube **221** is thermally insulated and is made sufficiently high to prevent the drawing of liquid through the tube, the height of this loop being of the order of thirty-five feet for this purpose. The water within the bell **22** is cooled on being vaporized and flows toward the left-hand side as viewed in FIG. 6 and thence downwardly, the circulating being facilitated further by operation of a propeller **232** driven by a suitable motor **233**. The slope of the wall **228** may be controlled automatically by a motor device **234** arranged to actuate the hydraulic operator **231** when the temperature within the left end of the bell as sensed by a sensing element **235** falls below a predetermined value. The slope of the wall **228** is decreased when the temperature falls so that the heated water may accumulate more readily in the upper portion of the bell.

During the operation of the system as illustrated, the propeller **232** has been provided in order to effect a positive flow of the water within the bell downwardly and out the bottom thereof. It will be understood, however, that there is a natural thermal flow due to the rising effect of the heated water within the chamber **226** and its movement over and down along the wall **228** as it is cooled and thence downwardly and out the bottom of the bell.

During the operation of the system as illustrated the sea water is drawn continuously through the tubes **227** and a portion of it is vaporized within the bell; the remainder is then returned to the sea. This provides an automatic arrangement for disposing of the concentrated solution produced by operation of the system and continuous operation and production of large amounts of fresh or distilled water is effectively accomplished by the system.

All of the systems as described above employ the cylindrical shroud and helical rotor of applicant's invention. As has been mentioned above, the effect of this rotor may be varied by changing the portion of the rotor which is within the shroud, and greater cooling is accomplished by having a smaller portion of the rotor within the shroud so that the cooling effect of vapor drawn through the pump and expanded may be utilized and so that there is a minimum heating due to the compression or vortex forming characteristics of the helical rotor within the shroud. The adjustment of the valve for controlling the recirculation of water through the pump has been found to be critical, as mentioned above, and for this reason the adjustment is made in accordance with the particular conditions of operation for each application and condition of operation at the time. Furthermore, the spacing between the helical rotor and the shroud is also selected to secure optimum conditions for any one application of the invention.

To further facilitate an understanding of the invention and by way of example and not by way of limitation, one

pump embodying the invention was constructed which had the followng dimensions:

	Inches
Internal diameter of shroud **16**	25
Length of shroud **16**	27½
Diameter of shaft **18** (for length of rotor and through chamber **24**)	3 7/16
Distance from bottom of tank to shroud	17½
Diameter of rotor helix	24
Pitch of rotor helix (2 turns), each turn	5
Length of chamber **24** between wall and first rotor turn	12¾
Diameter of gas inlet **23**	10
Diameter of liquid inlet **21**	12
Gate valve **20**	12

The pump was mounted in a tank four feet five inches wide, six feet ten inches long and nine feet high filled with water to a height of seven feet and thus containing opproximately 1300 gallons. The rotor was driven by a diesel engine at approximately 800 r.p.m. When the gas inlet supply conduit was closed the pump maintained a vacuum of 24 inches of mercury and the temperature of the water was observed to rise from 48° F. to 86° F. in eighteen minutes.

While the invention has been described in connection with specific constructions of the pumping unit and systems, various other applications and modifications will occur to those skilled in the art. Therefore it is not desired that the invention be limited to the specific constructions illustrated and described and it is intended by the appended claims to cover all modifications which fall within the spirit and scope of the invention.

I claim:

1. A liquid evaporation system comprising means providing an evaporating chamber, a tank for containing a body of liquid substantially free of impurities means including a combined liquid and vapor pump arranged in said tank and having a liquid inlet and a vapor inlet for circulating liquid in said tank and for withdrawing and condensing vapor from said chamber, means for driving said pump, flow control means for adjusting the flow of liquid through said pump, means for removing liquid from said tank, means for supplying liquid for evaporation to said chamber, means utilizing heat resulting from the operation of said pump for heating the liquid in said chamber, and means for removing concentrate from said chamber.

2. A liquid evaporation system as set forth in claim **1** wherein said pump comprises a substantially cylindrical casing closed at one end and open at its other end, in communication with said tank and a helical rotor mounted in said casing for rotation on an axis lying longitudinally of said casing, the periphery of said rotor being spaced from the inner wall of said casing and said rotor being spaced from the closed end of said casing to provide an intake zone, said chamber being connected in communication with said zone through said vapor inlet to conduct vapor thereto and said flow control means admitting liquid from said tank to said zone through said liquid inlet.

3. A liquid evaporation system as set forth in claim **2** including means providing thermal insulation for the walls of said casing about said rotor, means for utilizing liquid to be evaporated for cooling liquid substantially free of impurities and admitting it to said zone to lower the temperature of the liquid circulated through said pump.

4. A liquid evaporation system as set forth in claim **1** including a heat exchanger positioned to lie below the surface of the liquid in said tank, and pump means for circulating liquid from said chamber through said heat exchanger and back to said chamber for heating the liquid in said chamber.

5. A liquid evaporation system as set forth in claim 1 including a storage tank for receiving purified liquid from said first mentioned tank, a heat exchange conduit in said storage tank, and selectively operable means for circulating the liquid to be evaporated to said chamber directly or alternatively through said heat exchanger.

6. A liquid evaporation system as set forth in claim 5 including means dependent upon the temperature of the liquid in said closed tank for actuating said selectively operable means.

7. An apparatus for removing salt from sea water or the like comprising a tank for containing fresh water, means providing an evaporating chamber, means including a combined liquid and vapor pump arranged in said tank below the level of water therein and having a liquid inlet and a vapor inlet for circulating water therein and for withdrawing and condensing water vapor from said chamber, and means including heat exchange conduits passing through said tank for conducting sea water continuously into said chamber and for heating such water to facilitate the evaporation thereof.

8. An apparatus for removing salt from sea water or the like as set forth in claim 7 wherein the lower portion of said tank is arranged to be submerged and said evaporating chamber comprises an inverted vessel arranged to be submerged whereby heated sea water discharged from said conduits flows into said chamber and thence out the bottom thereof while a portion thereof is evaporated in said chamber.

9. An apparatus for removing salt from sea water or the like as set forth in claim 8 including an adjustable horizontally hinged downwardly inclined baffle plate in said chamber for directing the downward movement of water therethrough.

10. An apparatus for removing salt from sea water or the like as set forth in claim 8 wherein said conduits slope upwardly toward said chamber whereby flow of sea water into said chamber is facilitated by the heating thereof in said conduits.

11. An apparatus for removing salt from sea water or the like as set forth in claim 8 wherein said means for withdrawing vapor from said chamber comprises an upwardly extending inverted-U pipe of sufficient height to prevent the lifting of liquid water from said chamber to said tank.

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