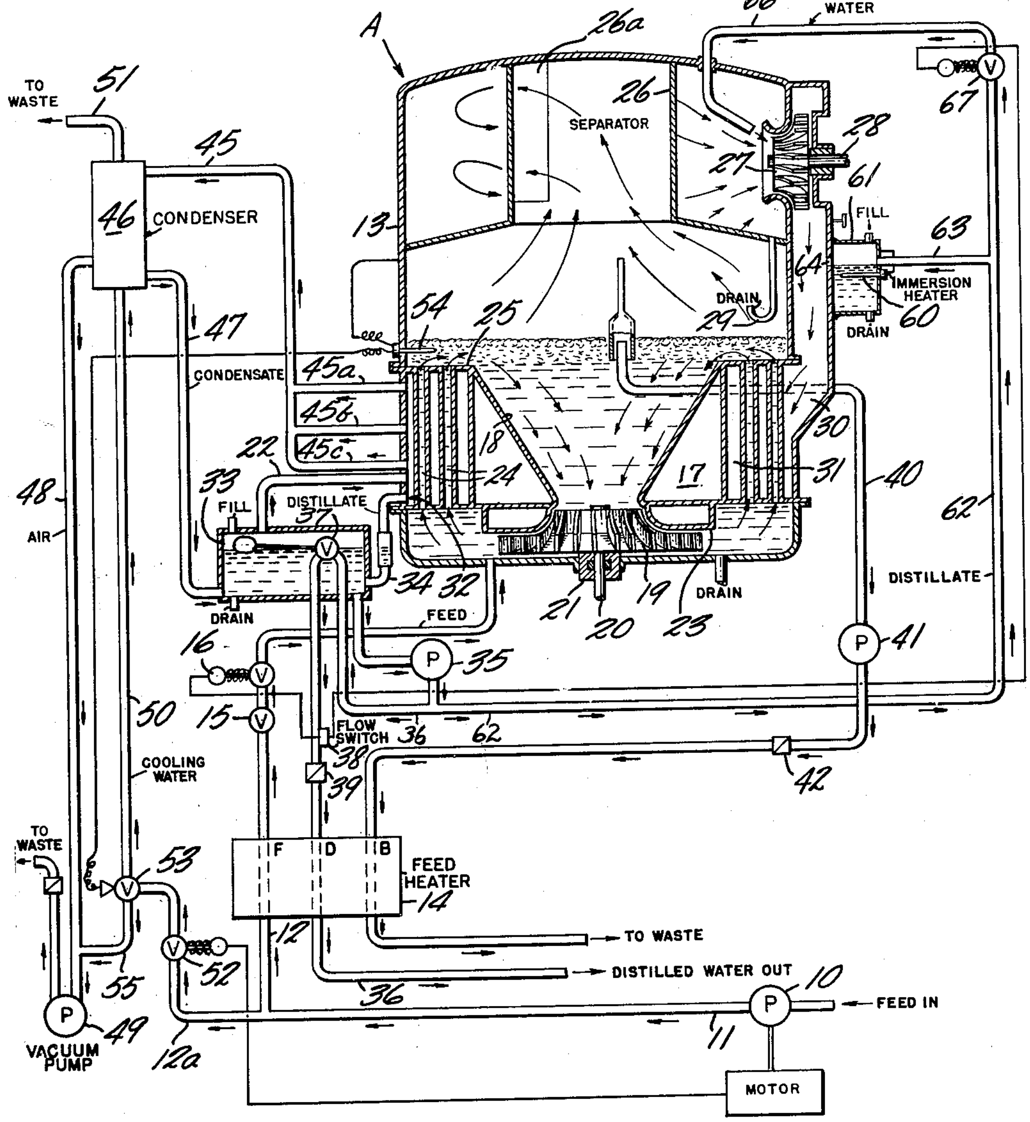
June 29, 1965 J. E. POTTHARST, JR 3,192,130

FORCED CIRCULATION EVAPORATOR

Filed Feb. 8, 1960 3 Sheets-Sheet 1

FIG. 1.



INVENTOR.
JOHN E. POTTHARST, JR.

BY Brumbaugh, Free, Graves & Donohue

his ATTORNEYS.

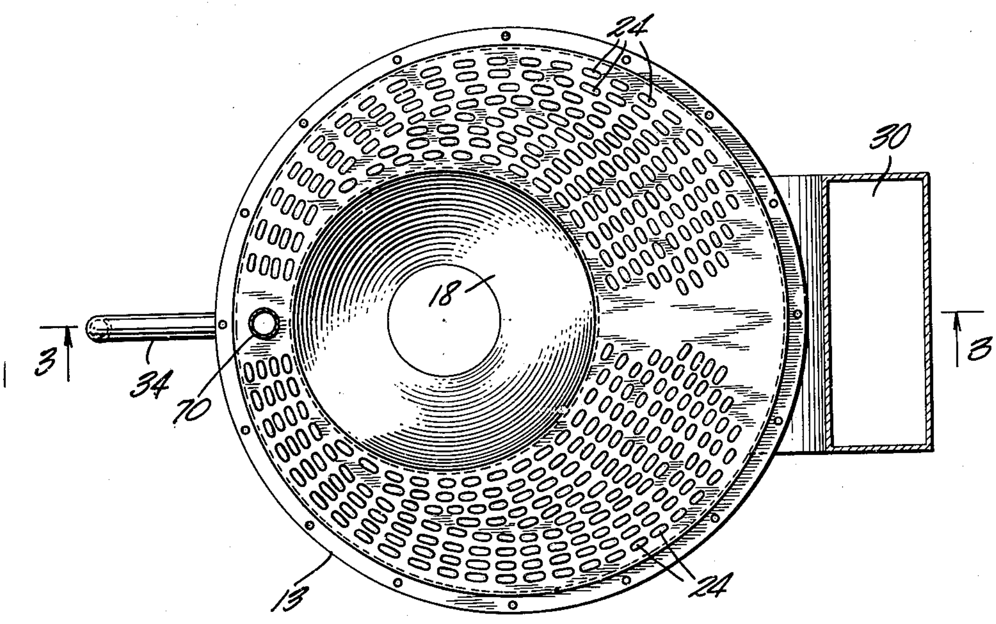


FIG. 2.

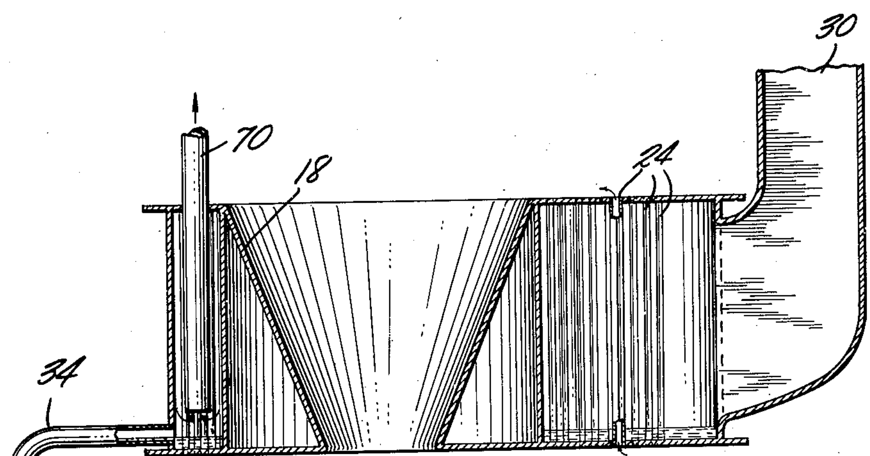


FIG. 3.

INVENTOR.
JOHN E. POTTHARST, JR.

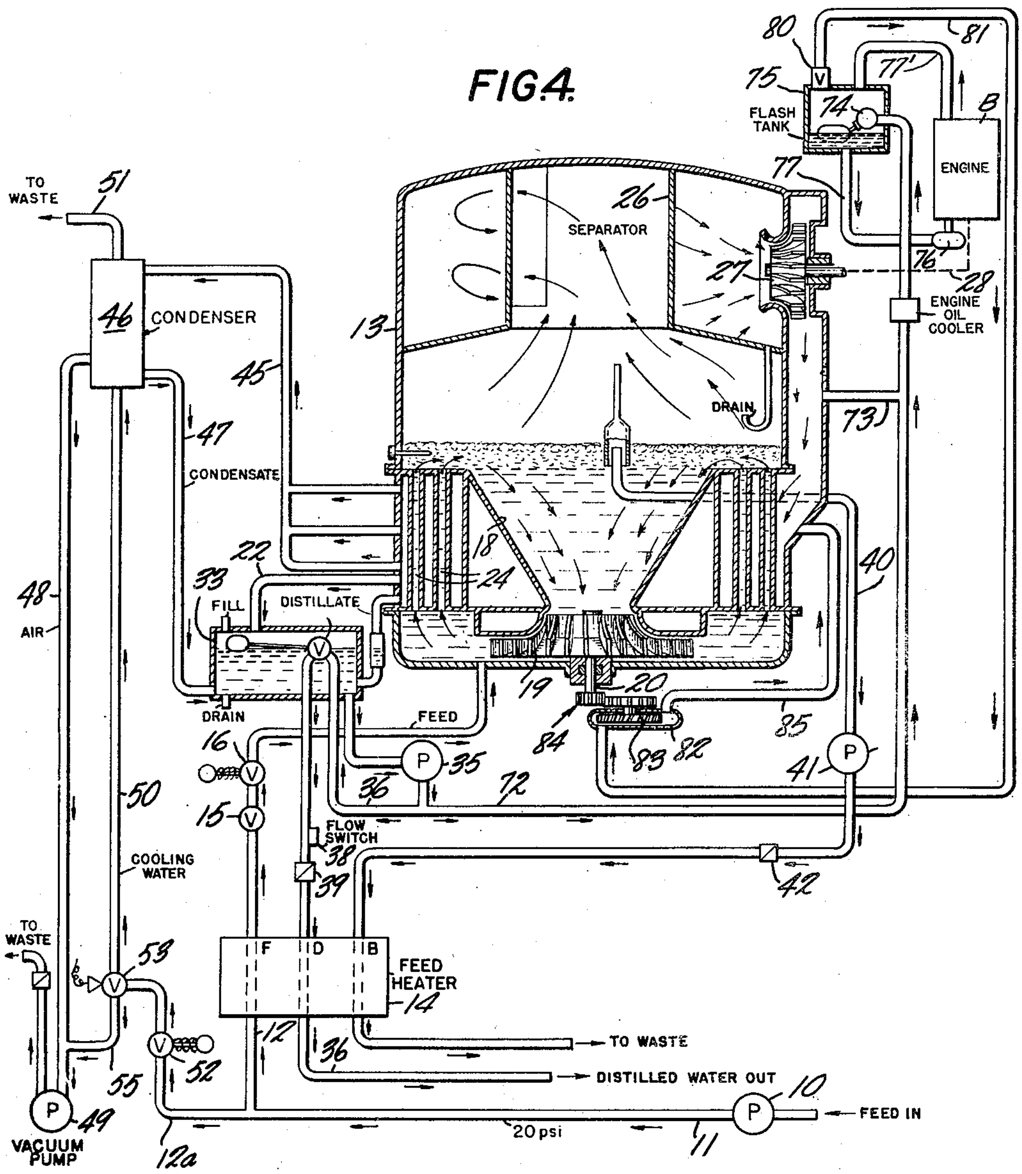
BY
Brumbaugh, Free, Graves & Donohue
his ATTORNEYS.

June 29, 1965 J. E. POTTHARST, JR 3,192,130

FORCED CIRCULATION EVAPORATOR

Filed Feb. 8, 1960 3 Sheets-Sheet 3

FIG.4.



INVENTOR.
JOHN E. POTTHARST, JR.

BY

Brumbaugh, Free, Graves & Donohue

his ATTORNEYS.

United States Patent Office

3,192,130
Patented June 29, 1965

3,192,130
FORCED CIRCULATION EVAPORATOR

John E. Pottharst, Jr., New Orleans, La.
(408 Northline, Metairie, La.)

Filed Feb. 8, 1960, Ser. No. 7,374
5 Claims. (Cl. 202—160)

This invention relates to improvements in apparatus for evolving vapor from a liquid, and in particular, relates to a novel apparatus in which a continuous circulation of liquid is maintained within a vaporization chamber.

The principal object of the present invention is to provide a compact, low cost apparatus of novel design in which the liquid to be vaporized is circulated through a plurality of heat-exchange passages with a minimum expenditure of energy.

In the apparatus of the present invention, the lower end of a reservoir for the liquid to be vaporized serves as an axial intake for a rotary circulator accommodated in the lower region of the vaporization chamber. The circulator causes the liquid from which vapor is to be evolved to circulate in a substantially toroidal pattern, first downwardly through a central reservoir and then outwardly to the inlet ends of an array of heat-exchange passages which surround the reservoir and then upwardly through the heat-exchange passages to the vapor region of the vaporization chamber. The vapor evolved from the liquid is withdrawn upon discharge of the liquid from the outlet ends of the heat-exchange passages, and the liquid which remains unvaporized is returned to the upper inlet end of the liquid reservoir to continue the circulatory pattern. The design and arrangement of the circulator and its housing provides for maximum saving in space and materials and minimum expenditure of energy.

Other objects and features of the present invention include a novel control system for the evaporator, a novel vapor chest in which the vapor is condensed in heat-exchange relationship with the liquid to be vaporized, novel means for supplying auxiliary heat to the vapor evolving apparatus, a novel means for driving the circulator and a novel means for withdrawing condensed vapor and non-condensible gases from the system.

For a complete understanding of the present invention, reference may be made to the detailed description which follows, and to the accompanying drawings, in which:

FIGURE 1 is a view of the distillation apparatus of the present invention in which part of the apparatus is shown in cross-sectional elevation, and part is shown schematically;

FIGURE 2 is a cross-sectional plan view of a slightly modified form of the apparatus shown in FIGURE 1;

FIGURE 3 is a cross-sectional elevation taken on the line 3—3 of FIGURE 2, looking in the direction of the arrows; and

FIGURE 4 is a view of still another form of the apparatus of the present invention in which part of the apparatus is shown in cross-sectional elevation and part is shown schematically.

Referring to the embodiment of the present invention shown in FIGURE 1 of the drawings, sea water or other liquid solution to be distilled, hereinafter frequently referred to as feed water, is supplied by a pump **10** through conduits **11** and **12** to the housing **13** of a distillation unit A. Before being admitted to the distillation unit, the feed water is preheated within a compound heat exchanger **14** in which the feed water is brought into out-of-contact heat exchange relationship with both the distillate manufactured by the unit A and the undistilled concentrated liquid or "blow-down" discharged as waste therefrom.

The housing **13** contains a vaporization chamber within which the feed water is vaporized. Before being admitted into the vaporization chamber, the feed water passes through a manually operated valve **15** and an automatically operated valve **16**. The feed water is supplied at a rate sufficient to maintain the liquid at a predetermined level.

The lower region of the vaporization chamber contains a liquid reservoir or downtake which is defined by a funnel-shaped wall **18** surrounded by a void **17**. The lower end of the funnel-shaped wall **18** communicates with the center of a blade-carrying rotor or circulator **19** which is mounted at the bottom of the vaporization chamber for rotation about a vertical axis. The rotor **19** is driven by a suitable drive means (not shown in FIGURE 1) through a shaft **20** which extends through a seal **21** accommodated in the bottom wall of the housing **13**.

The rotor **19** operates to maintain a continuous circulation of the feed water in a toroidal path of flow within the vaporization chamber. More specifically, the lower end of the funnel-shaped wall **18** forms an axial intake for the rotor so that a downward flow of the liquid is maintained within the reservoir. An annular wall **23** spaced above the bottom wall of the housing **13** cooperates with the said bottom wall to form a radial discharge passage for the liquid circulated by the rotor. The wall **23** is generally parallel to the bottom wall of the housing at its outer periphery, but curves upwardly toward the intake opening at its inner periphery. The circulator moves the liquid downwardly through the reservoir or downtake, then outwardly into a pressure-diffusing volute beneath the tubular passages **24** which changes the velocity head into a pressure head and upwardly through the tubular passages **24** which are arranged in annular array around the funnel-shaped wall **18**. As the solution to be distilled flows upwardly through the vertical tubes **24**, it is brought into out-of-contact heat-exchange relationship with a fluid at higher temperature, thereby raising the temperature of the liquid in contact with the heat-exchange surfaces above the boiling point established by the pressure within the upper vapor region of the vaporization chamber. Thus, as soon as the liquid emerges from the upper ends of the tubes **24**, some of the liquid flashes into vapor. The unvaporized liquid flows across the heat-exchange surface **25** to the liquid reservoir or downtake and the vapor evolved from the liquid flows upwardly and thence outwardly through a moisture separating wall **26** accommodated in the upper vapor region of the vaporization chamber. This flow of vapor is facilitated by a compressor blower **27** accommodated within the housing **13** but outside the separator wall **26**. The blower is driven by an engine located outside of the housing **13** through a shaft **28**.

The separator wall **26** is well known in the art and may take various forms, such as a perforated wall having baffles **26a** interposed in the passages thereof. Moisture formed on the inside surface of the wall **26** falls back into the lower liquid region of the vaporization chamber. Moisture formed on the outside surface of the separator wall flows downwardly and then outwardly along the sloped surface of the base of the wall **26** and returns to the vaporization chamber through the drain pipe **29**.

The compressor-blower discharges the compressed vapor downwardly through a duct **30** to a calandria chamber or vapor chest **31** which surrounds the tubes **24**. The compressed vapor is condensed while in out-of-contact heat-exchange relationship with the liquid in the tubes **24**, thereby transferring its latent heat to the liquid to be distilled. The higher the compression of the vapor, the greater is the amount of heat transferred to the liquid to be distilled. It is possible to carry on the distillation operation, once the operation is initiated, by only the energy expended in driving the compressor-blower 27, as described more fully in connection with the embodiment shown in FIGURE 4.

The distillate is withdrawn from the calandria 31 through a discharge port 32 and conducted to a tank 33 by a conduit 34. The tank 33 holds a quantity of distillate which is useful particularly during starting of the apparatus. Vapor evolved in the tank 33 during operation flows back into the vapor chest through the conduit 22. The discharge port 32 is preferably located opposite the discharge end of the duct 30 which admits the vapor to the vapor chest, so that the vapor travels through the chest in either of two curved paths equal in length.

The distillate accumulated in the tank 33 is pumped therefrom by a pump 35 through a conduit 36, causing most of the distillate to pass through a float controlled valve 37 within the tank 33, a flow switch 38, a one-way valve 39 and the feed heater 14 before being conducted to a storage tank. The remainder of the liquid discharged by the pump 35 flows through the conduit 62, as will be described below. The valve 37 operates to maintain a certain level of distillate in the tank 33. As the level of the liquid falls, the float closes the valve, decreasing or stopping entirely the flow through the conduit 36.

The concentrated liquid is drawn off from the bottom of the vaporization chamber through a conduit 40 by a "blow-down" pump 41. The concentrated liquid passes through a one-way valve 42 and then through the feed water heater 14 wherein it is brought into heat-exchange relationship with the feed water.

A vent conduit 45 having inlets 45*a*, 45*b* and 45*c* at different levels is provided to remove the air and any other non-condensible gases from the vapor chest 31. This air mixed with steam is 100% saturated. Consequently, a certain amount of steam vapor is removed with the air. However, this steam vapor is in a large part recovered within the condenser 46 and returned to the tank 33 via the conduit 47.

The non-condensible gases are removed from the condenser 46 through the conduit 48 by a water-cooled vacuum pump 49. The cooling water for the condenser is supplied from the intake conduit 11 through conduits 12*a* and 50. This coolant is discharged as waste from the condenser via the conduit 51. The supply of coolant to the condenser is controlled by a solenoid-actuated on-off valve 52 interposed in the conduit 12*a* and an automatic valve 53 controlled by a thermostat 54 within the vaporization chamber. The valve 52 is solenoid-operated and is opened as soon as the motor which drives the pump 10 is started. The valve 53 controls the flow of coolant to the condenser 46 through the conduit 50 and the flow of coolant to the pump 49 through the conduit 55 in a manner to be described.

The auxiliary heat required by the system while it is in operation or for starting is supplied by electric immersion heaters 60 accommodated within a tank 61 adjacent the duct 30. Distillate is supplied to the tank 61 by the pump 35 through the series-connected conduits 62 and 63. Vapor evolved within the tank 61 by the heat supplied by the immersion heaters is introduced into the duct 30 through a connecting port 64. The immersion heaters are automatically controlled by the thermostat 54 so that they will supply the necessary heat for initiating the operation of the apparatus as well as during the operation of the apparatus as additional heat is required.

It has been found advantageous to supply desuperheating distillate to the intake of the compressor 27 to prevent the compressed steam from becoming superheated. If superheated vapor is supplied to the vapor chest 31, an excessive amount of heat will be supplied to the liquid within the vaporization chamber. As a result, the interior of the tubes 24 will scale if sea water is the liquid from which vapor is evolved. In addition, saturated vapor condenses more readily in the vapor chest and the work of compressing the vapor is somewhat less when it is prevented from becoming superheated.

The desuperheating distillate is supplied to the intake of the compressor blower 27 through a conduit 66 which communicates with the discharge side of the distillate pump 35 through the conduit 62. A solenoid-controlled valve 67 interposed in the conduit 66 is opened under the control of the flow switch 38 when the apparatus is functioning to manufacture distillate in a sufficient quantity.

In starting up the apparatus, the reservoir 18 is filled and the manually controlled valve 15 in the conduit 12 is opened. However, the automatically controlled valve 16 is closed preventing the supply of feed water to the reservoir. Also, the valve 67 in the conduit 66 is closed during starting. The immersion heaters 60 heat the liquid within the tank 61, thereby supplying vapor to the vapor chest 31. As the vapor is condensed within the vapor chest it gives up heat to the liquid within the tubes 24 to evolve vapor within the vapor region of the vaporization chamber. This vapor is compressed by the compressor blower 27 and introduced into the vapor chest 31 through the duct 30. The liquid within the tank 61 is replenished from the tank 33 during this initial operation. This, in turn, reduces the level of the liquid within the tank 33 so that the valve 37 closes the conduit 36. As the manufacture of distillate increases and the level of the liquid within the tank 33 rises, the float-controlled valve 37 will gradually open permitting distillate to flow through the conduit 36. When this flow increases to about one-third of the unit's rated capacity, the flow switch 38 is actuated opening the solenoid-controlled valves 16 and 67, the former admitting additional feed water to the vaporization chamber, and the latter supplying desuperheating water to the compressor intake.

When equilibrium is established and the apparatus is operated at rated capacity, it is preferred to maintain a relatively low pressure within the vapor region of the vaporization chamber, thereby establishing a low boiling point for the liquid to be distilled. With proper control of pressure wtihin the vaporization chamber, the velocity of the continuously circulated feed water within the vaporization chamber and the control of the concentration, scaling within the tubes 24 can be eliminated when distilling sea water. For a more detailed explanation of the process for the elimination of scaling within the tubes 24, reference should be made to my copending application Serial No. 23,751, filed April 21, 1950, (now abandoned), as a continuation-in-part of my application Serial No. 726,362, filed April 4, 1958 (now abandoned).

The rotary circulator 19, as explained above, maintains a continuous toroidal circulation pattern within the liquid region within the vaporization chamber. This circulation pattern affords a relatively short hydraulic circuit necessitating the expenditure of a minimum of horsepower to maintain the continuous flow. Furthermore, part of the hydraulic circuit itself, that is, the bottom wall of the housing 13 and the spaced-apart wall 23 serve as the housing for the circulator, thereby simplifying the design of the evaporator and effecting savings in both space and material.

In flowing from the liquid reservoir through the heat-exchange tubes and back to the liquid reservoir, the liquid travels in a closed path, or that is to say, through a full 360° circuit. Since the pumping friction or circulating heat for non-linear flow is greater than in linear flow and the dissipation of energy increases with the total number of degrees through which the liquid must turn, the design and arrangement of the rotary circulators is especially significant. More specifically the axial intake centrifugal circulator imparts 90° or one-fourth of the total turn to the liquid while at the same time providing the shortest possible flow path for the liquid. In addition, in making the bottom of the vaporization chamber a modified centrifugal pump volute, the total length of the hydraulic path is held to a minimum, thereby contributing to the efficiency of the circulatory system, an advantage over and above the compactness, low cost and simplicity which are inherent in the design.

To maintain a constant temperature and pressure within the vaporization chamber, it is necessary to compensate for variations in the temperature of the feed water introduced into the vaporization chamber. When colder feed water is introduced, it is necessary to supply auxiliary heat by the immersion heaters **60** which operate under the control of the thermostat **54**. When warmer feed water is introduced, there is a problem of disposing of excess heat even though the immersion heaters are inoperative. This disposal of heat in the system under consideration is accomplished by increasing the rate of withdrawal of vapor from the vapor chest **31** through the conduit **45**, by increasing the quantity of coolant flowing through the vacuum pump **49** or by increasing the flow of coolant through the vent condenser. As will be described below, in this system it is accomplished by increasing the flow of coolant through the vacuum pump until it is at maximum and then by increasing the flow of coolant to the vent condenser.

Essentially, the purpose of the vacuum pump **49** is to remove air and non-condensible gases, and for this purpose any suitable pump can be used. The vacuum pump is preferably a water ring type cooled by feed water supplied to the pump via the conduit **55**. A characteristic of this type of pump is that at a constant low pressure below atmospheric pressure, it has a high air-handling capacity at low cooling water temperatures, conversely, with increasing coolant temperatures the air-handling capacity of the pump decreases to a point at which its operation at the constant low pressure becomes somewhat erratic. This is the result of the temperature of the coolant approaching or reaching the boiling point established by the low pressure. When the coolant reaches the temperature of vaporization (that is, at the low established pressure), the pump **49** can no longer pump air as steam fills the pumping spaces. Too much coolant fills the pumping spaces. Therefore, the vent condenser **46** is used to protect the vacuum pump from excess steam reaching it after the pump is already supplied with a maximum supply of coolant. The condensate manufactured in the vent condenser, of course, is salvaged and, as explained above, delivered to the tank **33**.

The withdrawal of increased vapor from the vapor chest **31** to remove excess heat in the manner described above has the advantage of providing a high rate of flow therethrough, thereby affording the best possible flushing out of air and non-condensible gases. This not only helps maintain constant temperature and pressure within the vaporization chamber, but contributes to the efficiency of the apparatus.

Thus, control of the high vacuum (low pressure) vapor compression distillation system of the present invention is achieved by the regulation of the coolant supplied to the vacuum pump **49** and the coolant supplied to the vent condenser **46** by the control valve **53**. At low feed water temperatures, the vapor educted from the vapor chest **31** is held to the minimum required by reducing or cutting off the flow of coolant to the vent condenser via the conduit **50** and by throttling the flow of coolant to the vacuum pump **49** only to the minimum necessary to provide the necessary water seal for the pump. At higher feed water temperatures, in order to maintain constant evaporating temperature and pressure, it is necessary to dissipate some of the usable heat. Initially, this is accomplished by increasing the flow of the coolant to the pump **49** under the control of the temperature-responsive valve **53**. However, this can be increased only until the maximum water allowable through the pump is reached, i.e., a point is reached at which further increase of coolant to the pump **49** results in reduced pump capacity and increased horsepower consumption. The control valve **53** also limits the flow to the pump **49** to the maximum allowable. At still higher feed water temperatures, there is no further increase in the supply of coolant to the pump (i.e., once the maximum rate of flow has been established), but the control valve **53** begins to increase the flow of coolant to the condenser **46** through the conduit **50**, thereby to condense vapor in the condenser more rapidly to dissipate heat.

It is apparent that this control system provides automatic regulation of the coolant supplied to both the pump **49** and the condenser **46** under the control of the temperature-responsive control valve **53** in order to maintain heat balance conditions throughout the full range of feed water temperatures encountered, and at the same time provides means for eliminating the air and non-condensible gases from the system.

The solenoid-actuated valve **52** interposed in the conduit **12*a*** remains open while the motor which drives the pump **10** is in operation. In smaller apparatus it is feasible to drive the pumps **10**, **35** and **41** from the same motor.

The wall **18** which defines the reservoir is shown in FIGURE 1 as centrally located with respect to the array of tubes **24** and the vapor chest **31**. A modified form of the vapor chest is shown in FIGURES 2 and 3 of the drawings. In this embodiment, the reservoir is offset from the center of the housing **13** in the direction of the discharge port **32** and away from the discharge of the conduit **30**. This construction provides two separate passages for the compressed vapor, one around each side of the central reservoir, in which the cross-sectional area gradually diminishes between the vapor inlet (that is, the discharge from the duct **30**) and the condensate outlet **32** (that is, the inlet to the distillate conduit **34**). This arrangement has the advantage of maintaining a flow of condensate through the vapor chest at relatively constant velocity, flushing ahead and sweeping out the non-condensible gases toward the inlet to a vapor vent **70** which communicates with a vapor condenser similar to the condenser **46** described above. Adequate venting of the non-condensible gases and a high, relatively constant vapor velocity results in a higher and more even transfer of heat to the solution to be distilled within the tubes **24**.

In the embodiment of the invention illustrated in FIGURE 4 of the drawings, the auxiliary heat for the system is obtained from the coolant for the engine B which drives the compressor-blower **27** through the drive shaft **28**. The coolant for the engine B is supplied to the cooling system through a conduit **72** which communicates with the discharge side of the distillate pump **35**. This coolant is stored within a flash tank **75** and is circulated through the engine parts by a pump **76**. After cooling the engine, the heated liquid is returned to the flash tank **75** through a conduit **77′**. The coolant is replenished to maintain a predetermined liquid level in the flash tank **75** by the float valve **74** in the conduit **72**.

The vapor evolved from the liquid within the flash tank can be utilized either to drive the rotary circulator **19** or to supply auxiliary heat to the system, or for both. Toward this end, as the vapor pressure builds up within the flash tank **75**, it is relieved by the valve **80** and passes through a conduit **81** to the turbine housing **82**. The steam serves as the impelling fluid to drive a turbine rotor **83** which is connected through a gear transmission system **84** to the drive shaft **20** of the rotary circulator **19**. The steam emerges from the turbine housing through a discharge conduit and is introduced into the duct **30** by the conduit **85**.

In this embodiment, distillate is supplied from the conduit **72** to the duct **30** by the connecting conduit **73**. As explained above, this distillate is introduced to prevent the compressed vapor from becoming superheated.

The invention has been described in preferred forms and by way of example only, and obviously many variations and modifications may be made therein without departing from the spirit thereof. The invention, therefore, is not to be limited to any particular form or embodiment, except insofar as such limitations are set forth in the appended claims.

I claim:

1. A distillation apparatus comprising a housing defining a vaporization chamber therein, said vaporization chamber including an upper vapor region and a lower liquid region, means defining a downtake passage in the liquid region of the vaporization chamber, a plurality of liquid passages defined by heat exchange surfaces surrounding the downtake passage, means circulating the liquid downwardly through the downtake passage and upwardly through passages defined by the heat exchange surfaces, a vapor chest surrounding the downtake passage and in communication with the heat exchange surfaces defining the liquid passages, a duct for introducing the evolved vapor into the vapor chest, whereby the vapor travels around the downtake passage in either direction, and a port for withdrawing the condensate from the vapor chest, said port being located substantially diametrically opposite the discharge end of the duct which introduces the vapor into the vapor chest, the downtake passage being offset from the center of the housing toward the port which removes the distillate from the vapor chest and away from the discharge end of the duct which introduces vapor into the vapor chest, and having walls which together with the walls of the housing, define the vapor chest to have an effective vertical cross-sectional area which gradually diminishes on both sides of the downtake passage from said duct to said port whereby the effective cross-sectional area of both of the passages through the vapor chest around the downtake passage gradually diminishes.

2. A distillation system comprising a housing defining a vaporization chamber therein within which vapor is evolved from a liquid to be distilled, means for compressing the vapor to elevate its temperature, a vapor chest in heat-exchange relationship with the liquid to be distilled within the vaporization chamber, passage means establishing communication between the compressing means and the vapor chest for introducing the compressed vapor evolved within the vaporization chamber into the vapor chest, pump means in communication with the vapor chest for withdrawing uncondensed gases and vapor therefrom, said pump means including means for varying the pumping capacity of the pump means to thereby vary the amount of uncondensed gases and vapors withdrawn by the pump means which in turn regulates the rate of heat supplied to the liquid to be distilled by the compressed vapor, and control means connected to said means for varying the pumping capacity and automatically operable in response to the rate of heat transfer between the compressed vapor and the liquid to be vaporized to control said means for varying the pumping capacity to regulate the rate of withdrawal of uncondensed gases from the vapor chest by said pump to maintain heat balance equilibrium.

3. A distillation system comprising a housing defining a vaporization chamber therein within which vapor is evolved from a liquid to be distilled, a vapor chest in heat-exchange relationship with the liquid to be distilled within the vaporization chamber, passage means establishing communication between the vaporization chamber and the vapor chest for introducing the vapor evolved within the vaporization chamber into the vapor chest, a vacuum pump in communication with the vapor chest for withdrawing uncondensed vapor and non-condensible gases therefrom, the output of said vacuum pump influencing the rate of withdrawal of vapor from the vapor chest and the dissipation of heat, a condenser in heat-exchange relationship with the vapor and non-condensible gases withdrawn from the vapor chest to condense the vapor, the rate of condensation in said condenser influencing the rate of withdrawal of vapor from the vapor chest and the dissipation of heat by the vapor within the vapor chest to the liquid to be distilled, passage means communicating with the condenser and with the vacuum pump for supplying coolant thereto, the output of said vacuum pump being related to the supply of coolant thereto, temperature-sensitive means communicating with the vaporization chamber, and valve means controlled by said temperature-sensitive means to control both the rate of supply of coolant to the vacuum pump and the rate of supply of coolant to the condenser, whereby the control of the supply of coolant to the vacuum pump and the condenser helps maintain the heat balance in equilibrium.

4. An apparatus for evolving vapor from a liquid comprising a housing defining a vaporization chamber therein, said vaporization chamber including a lower liquid region and an upper vapor region, means defining a downtake passage in the liquid region of the vaporization chamber for the liquid to be vaporized, a plurality of heat exchange passages surrounding the downtake passage in the liquid region of the vaporization chamber, a driven, axial-intake, centrifugal-discharge circulator mounted for rotation on a vertical axis beneath the discharge end of the downtake passage, said circulator including means rotatably carried therewith to deflect the liquid circulated thereby downwardly and outwardly to provide a low-friction path of flow for the liquid, means cooperating with the circulator and connecting with the lower end of the downtake passage and then extending downwardly and outwardly in closely spaced relationship to the circulator so as to define an axial intake, centrifugal discharge flow passage through the circulator between the discharge end of the downtake passage and the lower ends of the heat exchange passages, said flow passage providing a short, low friction flow to the liquid between the downtake passage and the heat exchange passages, a vapor chest surrounding the downtake passage in heat-exchange relation with the liquid within said heat exchange passages, the vapor being condensed within the vapor chest while in heat-exchange relation with the liquid passing through the heat exchange passages, a duct for conducting vapor from the vapor region of the vaporization chamber to the vapor chest, a port for discharging condensate from the vapor chest on the side of the housing opposite the side that the vapor is introduced by the duct, the vapor traveling around the down-take in both directions in passing from the duct to the port, the downtake being offset from the center of the housing toward the port and having walls, which together with the walls of the housing define the vapor chest to be of gradually diminishing cross-sectional area between the duct and the port.

5. An apparatus for evolving vapor from a liquid comprising a housing defining a vaporization chamber therein, said vaporization chamber including a lower liquid region and an upper vapor region, a funnel-shaped downtake passage within the liquid region of the vaporization chamber, said funnel-shaped downtake passage being offset from the center of the vaporization chamber, a plurality of vertically disposed heat exchange passages within the liquid region of the vaporization chamber surrounding the funnel-shaped downtake passage, the space within the vaporization chamber around the heat exchange passages and the downtake passage defining a vapor chest, an axial-intake, centrifugal-discharge circulator mounted for rotation on a vertical axis at the bottom of the housing beneath the lower discharge end of the funnel-shaped downtake passage, means carried by the rotor and defining a plurality of passages which curve downwardly from the lower end of said funnel-shaped downtake passage and then outwardly, such that the circulator itself gradually deflects the liquid first in a downward direction from the lower discharge end of the funnel-shaped downtake passage, and then in an outward direction, means defining an annular space surrounding the circulator and

establishing communication between the discharge of the circulator and the lower inlet ends of the heat exchange passages, a stationary surface having a downwardly and outwardly curved wall closely spaced above the circulator and defining at its inner end the axial intake for the circulator and at its outer end the centrifugal discharge passage for the circulator, the axial-intake passage defined by said stationary wall being connected with and forming a continuation of the downtake passage and the outer portion of said stationary wall cooperating with the circulator to form a low friction path of flow to the lower region of the annular space surrounding the circulator, the fluid discharged by the circulator flowing outwardly and upwardly toward the heat exchange passages, the circulator imparting continuous circulation to the liquid in the liquid region of the vaporization chamber in a torroidal fashion upwardly through the heat exchange passages, then inwardly toward the wider upper end of the funnel-shaped downtake passage and then downwardly along the funnel-shaped wall of the downtake passage toward the smaller, lower discharge end of the downtake passage and then into the axial intake of the circulator, thereby providing a short, low-friction path of flow to the liquid, and means for compressing the vapor evolved in the vapor region of the vaporization chamber, means for discharging the compressed vapor into the vapor chest on the side of the vaporization chamber more remote from the location of the funnel-shaped downtake passage, the vapor being in large part condensed within the vapor chest in out-of-contact heat exchange relationship with the liquid in the heat exchange

passages, and a discharge port for withdrawing condensate from the vapor chest on the side of the vaporization chamber substantially opposite the side that the compressed vapor is introduced, whereby the compressed vapor flows through the vapor chest in two paths around the funnel-shaped downtake passage toward the discharge port at which the condensate is removed, said two paths being of diminishing vertical cross-sectional area.

References Cited by the Examiner

UNITED STATES PATENTS

1,213,596	1/17	Baufre	202—75 X
1,670,743	5/28	Schneible	202—160
2,055,385	9/36	Noack.	
2,487,884	11/49	Lunt	202—75
2,515,013	7/50	Kruhmin	202—75
2,537,259	1/51	Cleaver et al.	202—75 X
2,589,406	3/52	Latham	202—75
2,619,453	11/52	Andersen	202—75
2,863,501	12/58	Farnsworth	202—75 X

FOREIGN PATENTS

469,231	7/37	Great Britain.
56,668	6/36	Norway.

NORMAN YUDKOFF, *Primary Examiner.*

GEORGE D. MITCHELL, ALPHONSO D. SULLIVAN, RICHARD D. NEVIUS, *Examiners.*