MULTIPLE EFFECT STILL WITH THERMO-COMPRESSION OF VAPORS

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This invention relates to improvements in stills and methods of distillation or concentration.

For simplicity, the invention will be explained with reference to a still for purifying sea water.

The major object of the invention is to provide for repeated re-use of heat to enhance the efficiency. More particularly, I propose to conduct evaporation at a succession of pressure and temperature levels, repeatedly returning heat from a lower heat level to a higher heat level so that the same heat will be re-used in the cycle of evaporation. By the present invention I seek to increase the heat efficiency of a three effect still more than fifty percent as compared with devices previously known for this purpose.

It is a further object of the invention to provide a still which is useful for military purposes in that it is exceptionally compact and self-contained, radiates a minimum of heat such as might affect infra red detecting apparatus; and one which avoids the venting of any visible jet of steam such as might be detectable visually.

While the device has been referred to as a still, it is obviously also effective as an evaporator or a concentrator, and is therefore useful for a variety of purposes other than that specifically described by way of exemplification. Other objects and uses of the invention will be apparent to those skilled in the art upon study of the following disclosure.

In the drawings:

Fig. 1 is a view illustrating diagrammatically in perspective an apparatus embodying the invention, portions of the apparatus being broken away to expose in section the interior construction.

Fig. 2 is a view in transverse section through one of the calandrias or stills and through certain other associated parts.

Fig. 3 is a fragmentary cross section through a portion of the third effect calandria.

Like parts are identified by the same reference characters throughout the several views.

The entire apparatus is so compact as to be readily portable. In one self-contained unit it includes the furnace or boiler 8 with a boiler feed tank or hot well 16 and a steam jet compressor 7 operated by steam carried to it from the boiler through pipe 8. There are also several sets of heat exchangers performing different functions as will hereinafter be described. The steam jet compressor 7 maintains the desired sequence of vapor pressures in the successive sets of apparatus, while the desired movement of liquid is controlled by pumps and traps.

Sea water lifted by pump 9 through the sea water inlet pipe 10 is delivered from the pump through pipe 11 through the tubes of a condenser 12. This condenser is a heat exchanger comprising a jacket 13 with headers near its ends connected by tubes 14 through which the sea water passes. The water leaves the condenser 12 through pipe 15 which is equipped with a spring loaded valve 16 through which a part of the sea water may be returned through pipe 17 to the sea.

For maximum efficiency of operation some of the returned sea water may be recirculated through pipe 18 back to the inlet 10. It may also, if desired, be passed through the radiator 19 through which air may be drawn by fan 20 for cooling purposes. A thermostatic valve at 21 may be provided to pass the recirculated water to maintain the temperature of water admitted to the condenser substantially constant. The condenser may be then designed to handle the hottest water which will ever be required to be used in the apparatus, and the water actually used may be maintained at the temperature for which the condenser was designed, thus making for maximum efficiency. This temperature control and recirculation is, however, an optional feature.

The loading valve 18 causes a portion of the sea water pumped through the condenser to pass upwardly from pipe 15 through pipe 23 to a heater 25. The sea water will already have acquired some heat in the condenser 12. The heater 23 is a heat exchanging device similar in design to the condenser having a jacket 26 provided adjacent its ends with headers connected by pipes 27 through which the sea water passes. The jacket space of the heater 25 communicates freely with the jacket space of the condenser 12 so that the same vapors may circulate through both jackets, as will hereinafter be explained.

In passing through the jacket of the heater 25, the sea water will be heated to approximately the temperature of the vapors in the heater. The warmed sea water will leave the heater through pipe 28, going to the bottom of a heater 33, preferably of the type provided for a plurality of passes of the sea water through the heating fluids therein. From the top of the heater 30 the sea water is returned through pipe 31 to the bottom of another similar heater 32. (See Fig. 2.)

From heater 32, the sea water is delivered
through pipe 35 into the first effect still A, construction of which is best illustrated in Fig. 2.

There is a jacket 36 which provides a sea water reservoir 37 in which the water admitted through pipe 38 is maintained at a constant level by a float valve. Above this there is a vapor collecting dome at 39. In referring to a dome I use the word generally to indicate any vapor collecting chamber or passage.

The jacket surrounds the upper end of a calandria casing 40 having a header 41. To the space below the header leads a large pipe 42 opening downwardly from the sea water space 37 of jacket 36. From the header numerous pipes 43 lead upwardly and open through the top of the calandria casing 40. Hot vapor and gases supplied to the interior of the calandria casing by means hereinafter to be described, evaporate water from the sea water which is exposed to the heat in the pipes 43. The sea water has already been heated above its atmospheric boiling point in its passage through the condenser and the several heaters already described, and a substantial part of the water admitted by the float valve will flash into steam immediately upon entering the jacket. Another part of its water content is readily condensed in the calandria, and the vapor escapes through the upper ends of the tubes 43 into the vapor dome 39.

Evaporation may be extremely rapid, with the result that most or all of the liquid in the tubes 43 will be in rapidly upward circulation and will be carried out of the top of the tubes. A canopy 44 catches such liquid and returns it downwardly over the outside of the casing and back into the pool of sea water collected in the well at 37. The vapor, freed from the majority of its entrained water, passes through a foraminous plate 45, which so distributes the flow as to preclude any high velocity, localized current from entraining and lifting water.

From the dome the vapor may pass tangentially into a separator 47 within the cylindrical interior of which the vapor whirls to rid itself centrifugally of entrained water. The foraminous wall at 48 has an offset margin at 49 to skim off the water which is thrown to the outside of the whirling mass of vapor and the water is thereupon delivered back through the drainage pipe 50 into the calandria jacket. The wall 48 may be reformed adjacent its openings, as shown in Fig. 2, to facilitate return to the vapor space of vapors and gases which have passed with the water behind the wall.

The sea water has now received first step concentration and will hereinafter be called brine. It is necessary to trace the movement both of the brine and the vapors removed therefrom into the successive effects B and C.

The brine which remains in the reservoir 37 leaves the reservoir through pipe 50 and enters the corrugated vertical riser of the second effect B through a float controlled valve, the pipe 50 corresponding to pipe 35 in Fig. 2. Since the pressure is lower in still B than in still A, some of the water of the brine will flash into vapor immediately upon entering the reservoir of still B.

Meantime the vapor, having passed from the separator through its axial outlet pipe 52 into the upper jacket space of the heater 32 (Fig. 1 and Fig. 2). The vapors pass downwardly through the heater 32, giving off heat to the sea water which has already been partially heated and is traversing the pipes 53 of heater 32 in the manner previously described.

Some of the vapor will be condensed in the heater 32 by delivery of heat through the walls of the pipes to the incoming sea water therein. The condensate and the vapor will be forced by pressure differentials established as hereinafter explained, to pass outwardly from the bottom of heater 32 through pipe 55 into the vapor space of the calandria 40 of still B.

In all respects previously described, the second still B is identical with the first. Its calandria casing 40 houses tubes 43 exactly as shown in Fig. 2. These tubes contain the partially concentrated brine delivered into the reservoir of its jacket 36 through the pipe 50 from the first effect.

Surrounding the tubes of the second effect calandria is the condensate and vapor admitted to the casing 40 from the heater 32. The condensate and vapor will now give off heat to the brine in the tubes for further evaporation in the second still to further concentrate the brine and to release additional vapor into the dome at the top of the second effect B.

Freed of gaseous entrained brine in the manner previously described, the vapor from the second effect B will pass through pipe 56 into the jacket space of heater 30 about the tubes through which the sea water is passively entrained to the first effect. Passing downwardly through the jacket of heater 30 the vapors, and such further condensate as may be condensed in the heater 30, are delivered through the pipe 57 to the jacket space within the casing 48 of the calandria of the third effect. The further concentrated brine in the reservoir of the second effect B is delivered through pipe 58 to the jacket 38 of the third effect C where the float valve 59 maintains at constant level the brine in the reservoir 37. In the third effect C the brine is brought to maximum concentration (so far as the present disclosure is concerned) by flash at the reduced pressure and by further evaporation in the tubes 43 and the extremely concentrated brine is removed at a predetermined rate through pipe 60 and discharged to waste by a pump 61.

Obviously, the rate at which the pump is operated will determine not merely the rate at which brine is withdrawn from the third effect C, but also the rate at which brine is withdrawn from the second and first effects B and A, and the calandria jackets. The brine is delivered to the first effect A, all of these devices being maintained at constant level by float valves which make them interdependent so that a reduction of level in the third effect C will be communicated to the preceding effects.

Meantime the final extraction of vapor from the concentrated brine passes from the third effect C to its separator 47 and through the axial outlet pipe 62 thereof into a duct 63 which leads to the inter-communicating jackets 26 and 13 of the heater 25 and condenser 12 respectively. The vapor will first give up its heat to the slightly warmed sea water in the tubes of the heater 25, and will thereupon give up heat to the coldest sea water in the tubes of the condenser 12.

Condensate has formed in the casing 40 of the calandria of the first effect A. Such condensate leaves the first effect pipe 54 and the drain valve trap 65 and is led thence through pipe 66 into the heater 32 where it joins the liquid as has been condensed in the heater from the vapors formed in the first effect still. A substantial part of the hot condensate may flash steam in the vapor space of the heater due to the considerably reduced pressure in the heat-
er. Some of the vapor thus produced will be recondensed in the heater by giving off heat to the sea water admitting the heater tubes. All condensate, vapor, and gas passes as previously described, through pipe 55 into the casing of the second effect calandria. Here again, the condensate is removed through a pipe 64 and a drain valve or trap 65 from which another pipe 66, identified with that previously described, leads into the jacket space of the heater 30 where further flash evaporation and recondensation occur.

Thus, through the pipe 61 from the jacket space of heater 30, all of the condensate and vapor formed in the first two effects and in the heaters 32 and 33, passes into the jacket space in the calandria 40 of the third effect still C. A similar discharge pipe 64 leads through a similar drain valve or float valve trap 65.

From the trap 65 it is possible to deliver the condensate upwardly into the condenser 12, but because the condensate is at its boiling point vapor lock is apt to occur, and I prefer, therefore, not to elevate the hot liquid. Accordingly, pipe 68 is led from trap 65 to a condensate cooler 80 from the top of which a pipe 81 leads vapor upwardly into condenser 12. Condensate accumulated in the condenser flows back to the jacket of the condenser cooler 80 through pipe 82. From the bottom of condenser cooler 80 pipe 69 leads to a pump 70 which discharges the distilled condensate through a flow indicator 71 and discharge pipe 72 to the point of use. The flow indicator 71 may be made to offer sufficient resistance to flow to assure the by-passing through pipe 73 of sufficient quantities of distilled water to supply the hot water in the feed water tank 8 for the boiler 5, subject to the control of float valve 74 therein.

In the cooler the condensate is rapidly cooled by a coil 93 of any desired capacity, which is supplied with the coldest water available. This may conveniently be done by connecting the coil as a by-pass across the pump 8 which circulates the hot water through the apparatus.

In every such operation there are certain un-condensable gases to be disposed of. In the assumed illustration these uncondensable gases consist primarily of air dissolved in the sea water. I dispose of these, and in addition, create the pressure differentials required for the operation of the device, by means of the steam jet compressor 7. This compressor has an inlet pipe 76 leading from the inter-communicating jacks 26 and 13 of heater 22 and condenser 12 respectively, as clearly shown in Fig. 2. The steam jet developed by the compressor 7 not only produces a pressure slightly above atmospheric in the first effect calandria, but also draws a considerable vacuum in the jackets 76 and 13. This extract from these jackets all remaining vapor and gas, whether condensable or non-condensable. This vapor and gas is delivered with the steam at the same pressure and temperature into the steam space of the first effect calandria. Being at the same pressure and temperature as the steam, the vapors and gases thus delivered into this steam space give off their heat to the water or partially concentrated brine in the tubes 43 of the first effect calandria.

Since the final effect is operated at subatmospheric pressures, it is necessary to use some sort of a pump for venting non-condensable gases. In order to vent such gases, it is also necessary to withdraw substantial quantities of vapor, much of the heat energy of which could not be salvaged if it were discharged with the non-condensable gases at this point of the system.

In actual practice, the amount of steam required to vent the non-condensable gases may be of the order of 10% of all the steam required to operate the entire apparatus. Hence very considerable savings are effected by using the steam jet compressor which returns not only the steam used therein but also the non-condensable gases and the relatively high volume of vapor contained therewith in the calandria where the vapor may be reused to deliver off its heat to the heated fluid in the first effect. The amount of vapor so returned has heat energy usable in the first effect which more than justifies the amount of energy used in the compressor. Use of the salvaged heat successively in the second and third effects brings about further substantial economies.

It is necessary to vent the non-condensable gases from all effects is thus accomplished in one operation as an incident to these other advantages. In the heating fluid space of the first effect the non-condensable gases are at superatmospheric pressure and, the steam and vapor being substantially all condensed on its path through the heating fluid space, the non-condensable gases reach the point of discharge with very little steam or vapor mixed therewith.

Near the top of the first effect calandria is a baffle 76 which need not be duplicated in the other effects. This baffle causes gases to follow a path upon which condensable gases have a chance to condense. As the uncondensable gases rise above the baffle they are vented at 77 through a condenser coil 78 which encloses the upper end of jacket 40 in the path of the canopy 44. This assists in reducing the temperature of the gases, and the cooled gases and such condensate may be moving therewith move through pipe 78 to a float valve trap 80 from which a pipe 81 returns the condensate to the jacket of heater 32 while a pipe 82 leads the remaining gases to the hot well or feed water tank 8. This tank is vented at 83. In it a final condensation of any remaining condensable gas is achieved while the air or other gas absolutely non-condensable escapes to the atmosphere. Meanwhile any heat remaining in the non-condensable gas has been imparted to the feed water and the gas which escapes is virtually cooled to atmospheric temperature and is invisible.

It is not essential to vent the air through the hot well if a more efficient vapor vent condenser is employed, as indicated at 85. This condenser contains a coil 89 (Fig. 2) which is exposed in condenser 95 to the sea water passing through pipe 35 toward the first still. Condensation is carried by the same trap shown at 80. It is not necessary that both of these condensing arrangements be used. Either may be dispensed with. However, if condenser 95 is omitted, it is desirable that the gases be vented below water level in the hot well so that no remaining plume of steam will betray the presence of the apparatus when it is used for military purposes.

The steam compressor furnishes the pressure differential which assures the efficient and effective operation of the device as described. While the exact figures will vary in different installations, I may state by way of example, that the steam pressure at the boiler may be of the order of 275 pounds. The steam pressure in the first effect calandria steam space may be 1/2
7 pound to 1 pound gauge, while the condenser jacket and heater 25 may be at a sub-atmospheric pressure maintained to a vacuum equivalent to that produced by 20 inches of mercury. This vacuum in the condenser 12 and the heater 25 is likewise communicated into the third effect dome. The effect of this amount of vacuum in the third effect dome acts to produce a somewhat lesser degree of vacuum in the second effect dome and the third effect calandria amounting, in the assumed case, to approximately 14 inches of vacuum (35). This in turn corresponds to a vacuum in the first effect dome and the second effect calandria of approximately 9 inches (Hg). It is because of the progressive reduction of pressure in the successive stills that vapor may be successively evaporated in the successive stills at progressively lower temperatures, the heat meantime having been delivered up to the incoming sea water to raise it to the point where it will evaporate at the maximum pressure existing in the first effect.

Fig. 3 illustrates how non-condensable gases may be discharged from the tops of the vapor spaces of the second and third effect calandrias. In this instance the gases are vented through a small duct 84 and vent fitting 85 into the vapor space 84 which, as above explained, is at lower pressure. The non-condensable gases from the calandria vapor space of the second effect can either be vented into the vapor space in the dome of the second effect or into the vapor space of the dome of the third effect. In any event, all non-condensable gases from the second and third effects will ultimately be passed back through the compressor to the first effect, from which they will be discharged at super-atmospheric pressure. In the meantime all water vapor which has not been condensed in the condenser will be recompressed and used again with the boiler steam. The heat of such vapor, as well as the heat of the non-condensable gases, is saved either in the brine of the first effect or in the boiler feed water.

With the device set up as described, a given weight of boiler steam will evaporate a nearly equal quantity of water from the brine in the first effect. The vapor from the first effect will, in turn, evaporate a nearly equal weight of water from the brine in the second effect, while the vapor from the second effect will evaporate a nearly equal quantity of water from the brine in the third effect. If the quantities were all exactly normal, one pound of boiler steam would thus evaporate three pounds of water in the successive effects.

By operating with a steam pressure not too high above atmospheric in the first calandria, and by maintaining a vacuum in the condenser which is not too great, and at the same time by generating boiler steam at high pressure for use in the steam jet compressor, I am able to compress and use in the first calandria more than half of the vapor delivered to the condenser. This reuses more than 50% of the quantity of heat originally delivered by the boiler and results in a very high heat efficiency. In practice my three effect evaporator has yielded more than four pounds of distilled water per pound of steam used.

This high efficiency results in part from the fact that heat is passed from low heat levels back to high heat levels. This is done in the first effect by passing part of the heat in the vapor in the condenser back to the first calandria by compressing it from a vacuum in the condenser to super-atmospheric pressure in the first calandria. Similarly in the successive effects, I reuse the heat in each stage by operating at progressively decreasing pressures.

While no motors have been shown to operate the various pumps, it will be understood that any source of power may be used. If steam engines are employed, operated from boiler 8, the used steam may be vented through the hot well 6. Likewise, if internal combustion engines are used, the heat developed in the jackets of such engines may be delivered to the hot water through the jackets of the water of the hot well. In any case, whether the water in the hot well is heated by the gases vented thereto through pipe 22, or whether the water in the hot well is heated by some extraneous means not constituting any part of the present invention, I may desire to use the heat of the water in the hot well to assist the functioning of the stills.

One convenient way of doing this is to return such water through pipe 87 subject to the control of any desired type of valve (such as that shown at 89) to the inlet pipe 55 which leads into the heating space of the calandria of the second effect B. The water in the hot well is distilled water and, upon being thus returned, it will commingle with other distilled water to heat the concentrates in the second still B, ultimately returning to the condensate cooler and being pumped from the condensate cooler by means of pipe 69 and pump 70.

Reference has already been made to the effect of the steam jet pump in establishing super-atmospheric pressure in the heating space of the calandria of the first effect and a sub-atmospheric pressure in the condenser jacket. Condensation in the condenser, as well as the continuous withdrawal of condensate from such jacket by means of pipe 69 and pump 70, assists in maintaining this pressure differential which is relied upon to maintain the flow of condensate from the several heaters 32 and 30 and the several stills A, B and C to the condenser or condensate cooler.

I claim:

1. An evaporator comprising the combination with a calandria of a heating fluid passage and a heated fluid passage, and means for collecting vapor from the last mentioned passage, of a boiler for developing steam pressure and provided with a hot well, a steam jet pump having its outlet connected to the heating fluid passage of the calandria and having an inlet connected to said boiler and a second inlet communicating with said vapor collecting means, means for condensing a portion of such vapor between the vapor collecting means and the second inlet of said pump, said pump being adapted to re-compress uncondensed vapor and deliver it to the heating fluid passage of said calandria, and means for admitting from the heating fluid passage of said calandria gases remaining uncondensed therein, said venting means extending into the hot well below the level of the water therein.

2. In a device of the character described, the combination with a boiler for developing steam pressure and a steam jet pump having one inlet connected with the boiler and having a second inlet for fluid to be pumped and having an outlet, of a series of at least three evaporators each comprising a calandria having a first passage for heating fluid and a second passage for a fluid to be heated, each evaporator includ-
ing a means for collecting vapor from the fluid in the second mentioned passage, a pipe leading from the pump outlet to the first passage of the first calandria, means connecting the respective first passages of the calandrias of the respective evaporators in series, means connecting the second passages of the respective calandrias of successive evaporators in series for the delivery of unevaporated liquid sequentially from one to another, means for withdrawing from the respective vapor evaporated from such liquid and delivering it to the respective first passages of successive evaporators, means for discharging concentrated liquid from the second passage of the calandria of the last evaporator of the series, condensing means comprising a heat exchanger having a fluid passage adapted to receive vapor and gases from both passages of a final evaporator of said series and having a second fluid passage adapted to receive a heat absorbing liquid, means for delivering liquid from the second condenser passage to the second passage of the calandria of the first evaporator of said series, and a connection from the first passage of the condenser to the second inlet of said pump whereby vapors uncondensed in said condenser are re-compressed in said pump by steam from said boiler and delivered to the first passage in the calandria of the first evaporator, said pump establishing progressively reduced pressures between the vapor in successive evaporators whereby fluid which has caused evaporation in the calandria of one evaporator may again cause evaporation in the calandria of each subsequent evaporator.

3. The device of claim 2 in which the first passage of the calandria of the first evaporator is provided with means for venting uncondensed gas maintained therein under compression by said pump.

4. The device of claim 2 in which the first passage of the calandria of the first evaporator is provided with a vent means and said boiler is provided with a hot well for its water supply with which said vent means communicates below water level.

5. The device of claim 2 in which at least one of said evaporators is provided with a pre-heater comprising a heat exchanger having a passage communicating with the vapor space of said evaporator to receive vapor therefrom and having another passage connected in series with the second passage of the calandria of the first evaporator as an inlet thereto.

6. In a device of the character described, the combination with a steam boiler and a pump having a first inlet connected with the boiler and provided with a second inlet and an outlet, of first, second and third evaporators each comprising a calandria having a heating fluid passage and a passage for liquid to be heated and a vapor dome, means for delivering liquid to be heated to the respective calandria passages of successive evaporators, said means including a pipe leading to the first evaporator and having in series a plurality of pre-heater conduits, means for delivering heating fluid from the calandria of the first evaporator, along with vapor from the vapor dome of the first evaporator into the heating fluid passage of the calandria of the second evaporator, said means including a pipe leading to the first evaporator, and means including a conduit in heat exchange relation to a pre-heater conduit portion of the liquid pipe leading to the first evaporator, conduit means also in heat exchange relation to said pipe and connected for the delivery of fluid from the heating fluid passage of the calandria of the second evaporator and from the vapor dome of the second evaporator to the heating fluid passage of the third evaporator, a condenser also in heat exchange relation to a portion of said pipe and comprising a passage leading from the vapor dome of the third evaporator and communicating with the heating fluid passage of the calandria of the third evaporator to receive vapor and condensate produced in said third evaporator and received by said third evaporator from the preceding evaporator, means for withdrawing the condensate from the condenser, and a vapor connection from the condenser to the second inlet of said pump whereby vapors uncondensed in said condenser are returned by said pump under compression to the heating passage of the calandria of the first evaporator.

7. The device of claim 6 in which the heating passage of the calandria of the first evaporator is provided with a vent.

8. The device of claim 6 in which the boiler is provided with a hot well and the heating passage of the calandria of the first evaporator is provided with a vent having a connection to said hot well below the level of the boiler therein.

9. The device of claim 6 in which the hot well is provided with means for maintaining water therein from said condensate withdrawal means, and with a pipe leading from said hot well to the heating fluid passage of the calandria of one of said evaporators, the heating fluid passage of one of said evaporators being vented into said hot well.

10. A still assembly comprising the combination with a series of stills having liquid passages, heating vapor passages and vapor collecting domes communicating with the liquid passages, of means connecting the dome of each still with the heating fluid passage of a subsequent still, said last mentioned means including a condenser for condensing vapor received from such dome, means providing a further connection through the same condenser from the heating fluid passage of each still to the heating fluid passage of the subsequent still for delivering condensate from the heating passage along with condensate from the dome of each still to the heating fluid passage of the subsequent still, means connecting the liquid passages of the several stills, means for circulating liquid through the several stills and withdrawing concentrate from the last still of the series, and means for maintaining progressively reducing pressure upon the liquid passages of the respective stills, said means comprising a condenser with which the dome and heating fluid passage of the last still communicates, a steam jet compressor having a vapor inlet communicating with the condenser to receive uncondensed gases therefrom, and a connection from said compressor to the heating passage of the first still, said compressor having a steam jet connection whereby steam, vapor, and compressed uncondensed gases are delivered to the heating fluid passage of the first still at super-atmospheric pressure, said passage of the first still having a vent for such gases, and the dome of the last still being maintained at sub-atmospheric pressure.

11. A still assembly comprising a plurality of stills and heat exchanger in series, each still comprising a heating fluid space, a heated fluid space, and a vapor space, and each heat exchanger comprising a heating fluid space and a heated fluid space, means connecting both the vapor space...
and the heating fluid space of a first still of said series to the heating fluid space of the heat exchanger, means for connecting the heating fluid space of the said heat exchanger to the heating fluid space of the next successive still of the series, whereby both the condensate and vapor and uncondensed heating fluid from the first still are led through the heat exchanger to the heating fluid space of the second still, and means for delivering fluid to be heated to the heated fluid space of the first still through the heated fluid space of said heat exchanger.

12. The assembly of claim 11, further including a conduit connected from the heated fluid space of the first still to the heated fluid space of the second still and a return connection for uncondensible gases from a final still of said series, the means for delivering heating fluid to the first still of the series comprising a jet pump for employing the energy of heating fluid so delivered to recompense the uncondensible gases returned by said connection, the heating fluid space of the first still being provided with a vent for such uncondensible gases.

13. A still assembly comprising a series of stills including at least a first and a second still, each still including a heating fluid space, a heated fluid space and a vapor space; a heat exchanger between the first and second stills having a heated fluid space, said exchanger also having a heating fluid space operatively connected between the heating fluid space of the first and second stills, a separate connection from the vapor space of the first still to the heating fluid space of said exchanger, and a connection for delivering fluid from the heated fluid space of the first still to the heated fluid space of the second; and means for delivering heating fluid to the heating fluid space of the first still of the series and for removing condensate from the heating fluid space of the last still of the series, said last means including a jet pump having an inlet connection from the vapor space and the heating fluid space of the last still of the series, whereby to maintain a pressure differential between the successive stills and recompense vapor removed from the last still for delivery to the first still, said first still having a vent opening from its heating fluid space for discharge of uncondensible gases.

14. In a multiple effect evaporator, each effect comprising a heating fluid passage, a heated fluid passage and a vapor space, the combination with a source of steam under pressure, of a steam operable compressor having a steam inlet, a vapor and gas inlet, and means for discharging steam, vapor and gas into the heating fluid space of the first effect, means for venting non-condensible gases from the heating fluid space of the first effect, an operative transfer connection from the heating fluid space and the vapor space of respective effects to the heating fluid space of the last mentioned effect and provided with an outlet in operative connection with the vapor and gas inlet of said compressor, said compressor comprising means for re-compressing the vapor and non-condensible gas from the last effect and delivering such vapor and gas under pressure to the heating fluid space of the first effect whence such gas is vented.

15. The device of claim 14, in which the connections aforesaid from respective effects to successive effects include heat exchange means, and a make-up conduit connected in sequence through said heat exchange means and leading to the heated fluid space of the first effect.

16. The combination with a steam jet compressor having a steam inlet and a second inlet for gases and vapors to be compressed, and an outlet for steam, vapor and gas, of a series of evaporators each comprising a heat exchanger having a heating fluid passage and a heated fluid passage, each of said evaporators having a vapor and gas outlet from its heated fluid passage and an outlet from its heating fluid passage, a connection from the respective outlets of a first evaporator of said series to the heating fluid passage of another evaporator and the heating fluid space of said heat exchanger a connection from the respective outlets of the last mentioned evaporator to the second inlet of said compressor for the delivery to the compressor of uncondensible vapors and uncondensible gases, and means operatively connecting the compressor outlet with the heated fluid space of said first evaporator whereby uncondensible gases from the heated fluid passages of the several evaporators are returned to the heating fluid passage of said first evaporator, said compressor establishing a pressure differential through the evaporators of said series and through the heating fluid passage of said first evaporator being at super-atmospheric pressure and having a vent for the discharge of non-condensible gases accumulated from the passages of the said evaporators.

17. In a multiple effect evaporator, each effect comprising a heating fluid space, a heated fluid space and vapor space, the combination with means connecting the heated fluid spaces of the several effects in sequence for the delivery of heated fluid successively through the several effects, means for venting the heating fluid space of the first effect, means for connecting the heating fluid space and the vapor spaces of respective effects to the heating fluid spaces of successive effects, a compressor having a steam, vapor and gas outlet to the heating fluid space of the first effect and having a steam inlet for the operation of the compressor and an inlet for vapor and gas in operative connection with the vapor space and the heating fluid space of the last of said successive effects, said compressor comprising means for operating the several effects at successively reduced pressures, the heating fluid space of the first effect being at super-atmospheric pressures and the heating fluid space of the last of said successive effects being at sub-atmospheric pressures, said compressor also comprising means for returning non-condensible gases from the several effects to the heating fluid space of the first effect from which such gases are vented by the pressure differential between the heating fluid space of the first effect and the atmosphere.

18. In combination, a series of evaporators each including a passage for heating fluid and a passage for heated fluid, conduit means connecting the heated fluid passages of the several evaporators in series, means including heat exchangers for conducting both heating fluid and vapor from respective evaporators to the heating fluid spaces of successive evaporators, said means being adapted to carry non-condensible gases from the heated fluid passages of the respective evaporators to the last successive evaporator aforesaid, means for conducting fluid to be heated through the several heat exchangers sequentially to the heated fluid passage of the first evaporator of the series, means for delivering non-
The device of claim 18, in which the means for delivering vapor and non-condensable gases comprises a steam jet compressor arranged to deliver steam from its jet with recompressed vapors and gases to the heating fluid passage of said first evaporator.

20. A method of evaporation which comprises the establishment of pressure differential between successive stills, passing distilland from respective stills to successive stills at successively lower pressure, concurrently passing both heating fluid and extracted vapor from respective stills into operative heat transmitting relation to distilland in such successive stills to effect further evaporation from the distilland at the reduced pressure in such successive stills, collecting vapors and uncondensed gases from the last of such successive stills, condensing vapors so collected, recompressing uncondensed vapors and uncondensable gases from all of said stills and delivering the recompressed vapors and gases into operative heat exchange relationship to the distilland in a still previous to such last still, and venting the uncondensable gases from said previous still.

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REFERENCES CITED

The following references are of record in the file of this patent:


Chemical Industry, vol. 43, No. 12, page 302, 1924.

Chemical and Metallurgical Engineering, vol. 28, 1923, pages 25 to 31, 73 to 78.