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METHOD FOR TRANSFER OF LIQUID IN MULTIPLE-EFFECT
REFRIGERATION PROCESSES AND APPARATUS THEREFOR

Filed Dec. 15, 1961

2 Sheets-Sheet 1

Fig. 1

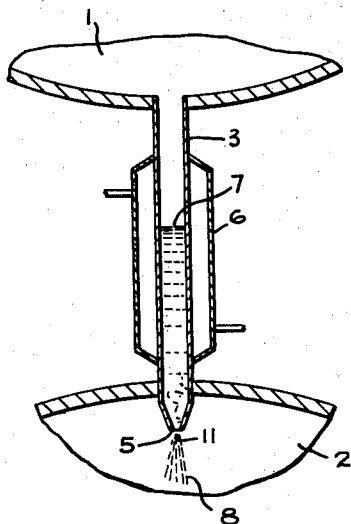


Fig. 2

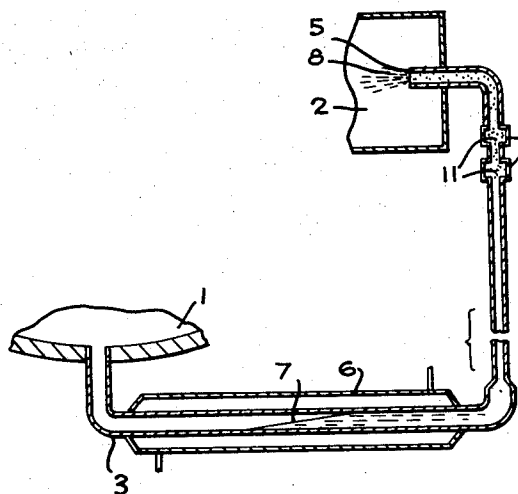
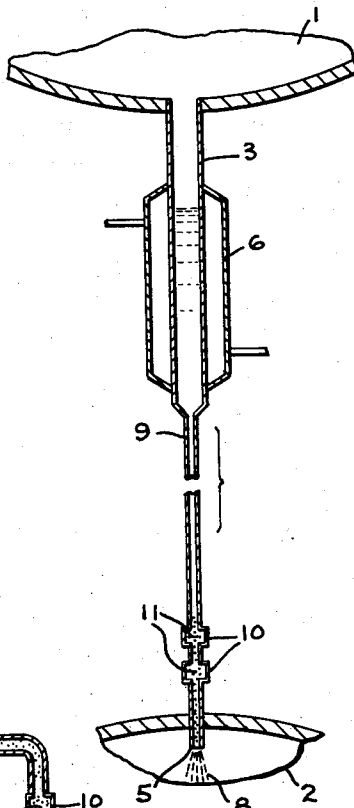


Fig. 3

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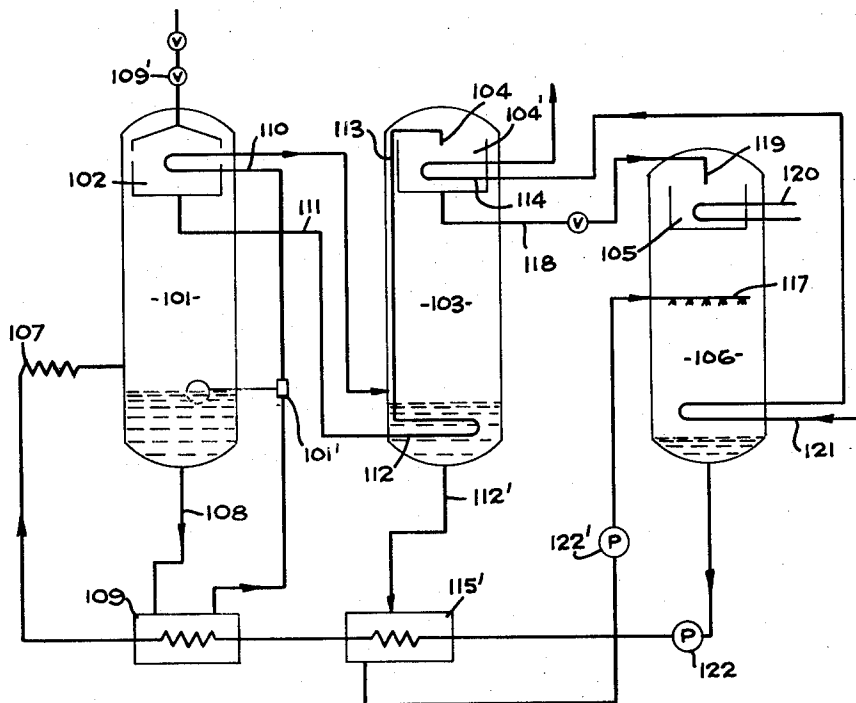


Fig. 4

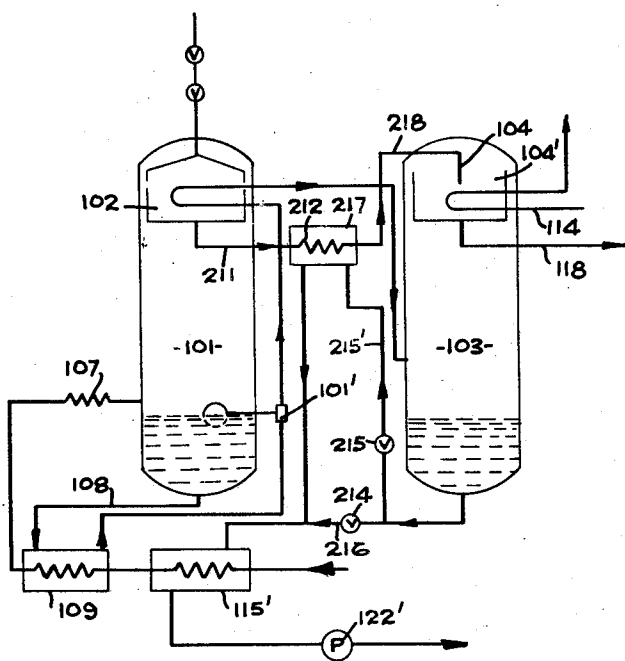


Fig. 5

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METHOD FOR TRANSFER OF LIQUID IN MULTIPLE-EFFECT REFRIGERATION PROCESSES AND APPARATUS THEREFOR

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20 Claims. (Cl. 62-101)

This invention relates to methods and apparatus for the removal of volatile liquids from zones in which such liquids accumulate at their bubble point if a mixture of volatile liquids, or boiling point if the liquid is composed of a single volatile component, in contact with its vapor. The liquid is withdrawn into a second zone in which the pressure is materially lower than in the first zone, so that the liquid entering the second zone undergoes flash vaporization. The liquid passes from zone one to zone two through a vapor trap in which the withdrawn liquid is employed to create a liquid seal in the conduit between the first and second zones and which thus permits of the establishment of different pressures in the two zones.

A particularly useful application of my invention is the removal of a liquid from a still or condenser in which liquid accumulates in contact with its vapor and is to be withdrawn from the zone of accumulation. A good example of the application of my invention is in refrigeration systems, where the liquid refrigerant is allowed to flow into an accumulating zone. It is then withdrawn into a zone of lower pressure where the liquid partially flashes to vapor. In order to maintain the required pressure differential between the first and second zone, it is desirable to minimize and ideally prevent the withdrawal of vapor along with liquid from the first zone.

Conventional methods for accomplishing this objective are by the use of a float valve or by the use of a temperature controller which indirectly follows the accumulation of liquid. These methods all require moving parts, such as valves and bearings. An alternative method of controlling the removal of liquid is in the use of a tube of restricted cross-sectional area, conventionally but not scientifically termed "capillary," or through an orifice which has a capacity somewhat larger than the full flow of the liquid to be withdrawn from the zone of accumulation. Such devices allow all the liquid to flow along with some of the vapor, the orifice or other restriction being sufficient to maintain the desired pressure difference. The vapor loss through such a capillary or orifice is not very great, especially when the pressure in the zone from which the liquid and vapor are discharged is low, and in some cases this is tolerable. However, there are cases in which such an expedient is not tolerable.

It is an object of my invention to accomplish the withdrawal of liquid through a discharge conduit without necessitating moving parts, such as valves, without any substantial loss of vapor along with liquid, so as to minimize and, in practical effect, to eliminate transfer of vapor from the first zone to the second zone.

In carrying out the process of my invention, I provide a discharge conduit between the two zones. This may be an orifice, for example, one having the ratio of orifice length to diameter known as a sharp-edged orifice, or one having a larger ratio of orifice length to cross-section. It may be an elongated pipe whose cross-section is made relatively small and of a length to give the required rates of liquid flow at the temperature differentials to be described hereinafter.

I cool the liquid prior to its reaching the discharge end of the conduit and entering the second zone. The degree of cooling of the liquid is such that its temperature

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prior to its discharge from the orifice or pipe into the lower pressure zone is such as to produce a vapor pressure somewhat below the vapor pressure of the liquid in the first zone and sufficient to establish the desired rate of flow through the discharge end. The liquid discharges into the second zone in the form of a jet. The fluid in a region between the inlet and the discharge end of the pipe or orifice will be in the liquid phase, and at a pressure at least equal to the vapor pressure corresponding to its temperature. This region is ahead of the discharge end and occupies a substantial length of the conduit, including also a portion of the cooling zone. A liquid body is maintained between the inlet to the cooling zone and the discharge orifice or pipe end, and vapor communication is maintained between the surface of this liquid body and the vapor in the first zone. I provide a cooling zone between the first zone and said discharge conduit. With the level of the liquid positioned within the cooling zone, the cooling is insufficient to condense all of the vapor available to enter the cooling zone, and a liquid level is maintained in the cooling zone in contact with its vapor if the rate of flow through the conduit permits.

In the preferred embodiment of my invention, the rate of accumulation of the liquid in the cooling zone and the rate of discharge of liquid from the end of the conduit are correlated by the temperature of the liquid being discharged so that the level of the liquid in the cooling zone wets only a portion of the surface subject to heat exchange with the cooling medium. Under such conditions, the discharge conduit may be termed a full-flow conduit, and the rate of flow of liquid through the discharge conduit may be termed full-flow conditions.

While I do not wish to be bound by any theory as to why my novel vapor trap operates to maintain a liquid level between the two zones, I believe that the following is the reason for its successful operation:

In the process of my invention, as the liquid flows through the discharge conduit, the pressure falls until it reaches its vapor pressure at the temperature to which it has been cooled before discharge, and if bubbles are nucleated, incipient vaporization occurs. Beyond this point, which I call the vaporization point, as the liquid proceeds, it vaporizes and its temperature falls substantially along its vapor pressure curve until it reaches the pressure existing in the second zone and reaches the resultant equilibrium temperature. Most of this pressure drop from its vapor pressure at the vaporization point to the pressure in the second zone typically takes place after it leaves the conduit as a jet of fluid.

To distinguish the jet in my invention from a free liquid jet where the pressure on the liquid along the liquid jet is in excess of the boiling point of the liquid in the jet throughout its path, I designate the jet of my process a free-boiling jet.

The pressure at the vaporization point is the vapor pressure of the liquid, and this is determined by its temperature. The mass flow rate from the vaporization point through the discharge end of the conduit is the same as the mass flow rate of the fluid moving from the liquid-vapor interface towards the vaporization point. This depends on the pressure difference between the pressure on the liquid at the entrance to the conduit and the pressure at the vaporization point. Unless modified in substantial effect by gravity heads, this difference is substantially the difference between the pressure in zone one and the vapor pressure of the liquid at the vaporization point. When the liquid in zone one is in substantial equilibrium with its vapor in zone one, this difference is substantially the difference in vapor pressure of the liquid in zone one and the vapor pressure of the liquid at the vaporization point in contact with its vapor

at such point. Thus, the rate at which the liquid discharges into the second zone varies with the difference between the pressure on the liquid at the inlet to the conduit and the aforesaid pressure at the vaporization point. Therefore, as the temperature of the liquid at the vaporization point increases, the discharge rate decreases, and as the temperature decreases, the discharge rate increases.

The cooling zone contains a vapor zone in communication with the vapor space in zone one, and the temperature of the liquid and vapor at the upper liquid-vapor interface is at the condensing temperature of the vapor, i.e., the temperature in the first zone. The temperature at the end of the cooling zone will depend on the area of the cooler in contact with the liquid and the mass rate of movement of the liquid through the cooler. This mass rate is the same as the mass rate of discharge into the second zone, which, as stated above, depends on the temperature to which the liquid has been cooled prior to such discharge.

In my process, when the liquid surface is within the cooling zone in contact with the vapor in the cooling zone, the cooling rate, as stated above, is made insufficient to condense all of the vapor available to enter the cooling zone. The area of the cooling conduit covered by the liquid, i.e., the wetted area, will remain constant if the volumetric and therefore the mass rate of accumulation of liquid in the conduit produced by the inflow of liquid and partial condensation of the vapor equals the volumetric rate of movement of liquid toward the vaporization point. For any condition, the wetted area increases if the rate of accumulation becomes greater than the discharge rate from the cooling zone and decreases if the rate of accumulation becomes smaller than the rate of discharge.

If the wetted area increases due to a rise in the level of liquid in the cooling zone, more cooling will take place, and the temperature of the liquid at the vaporization point becomes lower. The difference in pressure of the liquid at the liquid level and at the vaporization point is greater, and thus the rate of outflow increases. Conversely, a decrease in the wetted area causes an increase in the temperature of the liquid at the vaporization point, with a consequent decrease in pressure difference, resulting in a decrease in the outflow rate.

As the rate of accumulation of liquid in the cooling zone changes, the wetted area and the outflow rate automatically adjust themselves and reach a new equilibrium position for the wetted area where the rate of discharge of the liquid again equals the rate of accumulation of liquid. Thus, there will always be liquid in the cooler. However, if the rate of accumulation falls to too low a value, the level of liquid in the cooling zone may be so close to the discharge end of the cooler that lack of nucleation at the vaporization point or other accidental variations in flow may cause a discharge of some vapor with the fluid. This stimulates nucleation and causes normal conditions to be re-established.

The effective, i.e., practical, throttling range of the vapor trap thus may be somewhat less than the theoretical range. However, this range may be made sufficiently large by proper choice of the cooling conduit geometry and constitution, temperature of the coolant employed, and the geometry of the discharge conduit.

In order to aid in establishing the operating conditions, I find it helpful that the flow through the discharge conduit be under turbulent flow conditions. This is particularly so where the flow rates are low and the vapor pressure low. To aid in attaining this condition, I provide a turbulence-inducing zone and preferably a plurality of turbulence-inducing zones at a multiple of places adjacent the discharge end of the discharge conduit, such as enlargements of the cross-sectional area of the conduit.

In my process, if equilibrium between liquid and vapor can be maintained at the pressures and temperatures

in the discharge conduit and in the boiling jet, the vaporization point is substantially at the discharge end of the orifice 5 in FIG. 1 or the end 5 of discharge conduit 9 in FIG. 2. This condition occurs except at extremely low rates of flow equivalent to velocity below "critical" velocity of the fluid. By "critical velocity" I mean the linear velocity of the fluid in the discharge conduit 9 of FIG. 2, or orifice 5 of FIG. 1 at its narrowest cross-section, which velocity is the velocity of "unaffected flow."

In my process, when nucleation occurs at the vaporization point, the fluid flow rate through the smallest cross-section is approximately at a "critical velocity."

The meaning of these terms is well understood by those skilled in this art. For purposes of illustration and description of said terms, see Handbook of Engineering Fundamentals, by Eschbach, 2nd edition, published by Wiley & Sons, 1961, pages 8-36 to 8-40.

I prefer to locate said smallest cross-section in a zone adjacent the discharge end of the conduit. Under such conditions, the vaporization point is substantially at this zone of narrowest cross-section.

The above considerations assume equilibrium conditions which are ideal for nucleation of bubbles. Under usual and practical conditions, this occurs adjacent or at said point of narrowest cross-section, when said critical velocity is attained. Unless provisions for nucleation are made, the vaporization point may not be attained, even though the required temperature and pressure are present. In such case, the vaporization point, instead of being at the said smallest cross-section, is at some point upstream therefrom. By use of my zones of turbulence to provide nucleation, I position the vaporization point at the desired locality, preferably adjacent the discharge end.

While my invention is applicable to any liquid system for discharge of liquid from a zone where it is in contact with its vapor, as in a condenser or still, into a lower pressure zone, it is particularly adapted to refrigeration systems. I have found it particularly useful in a multiple-effect absorption refrigeration system, wherein it may be employed to drain the first-effect condenser into the second-effect condenser, or other zone of lower pressure, in which case it is desirable to have a system which will not permit passage of vapor from one zone into the next zone.

This invention will be further described by reference to the drawings, in which:

FIGS. 1-3 are schematic showings which illustrate the principles of my invention; and

FIGS. 4 and 5 are flow sheets showing the application of my invention to a two-effect refrigeration system.

In FIG. 1, 1 is the zone in which a liquid, at its boiling point, if it be a single component liquid, or at its bubble point, if it be a multiple component liquid, accumulates in the presence of its vapor. The liquid level may be in zone 1 or descend into a cooler conduit 3, wherein it is cooled by coolant passing through the cooler 6. In my process, the level 7 is in the conduit 3, so that the wetted area in 3 is only a part of the cooling surface. The liquid discharges through an orifice 5 as a boiling jet 8 into a zone 2, which is at a lower pressure than zone 1. The discharge orifice 5 may be smaller or equal to the diameter of the pipe 3.

FIG. 2 is similar to FIG. 1, but the discharge orifice is in the form of an elongated conduit 9. This conduit may be and preferably is of restricted cross-section, i.e., one in which the length of the conduit is many times its diameter or width. The conduit 9, for example, may be of the same cross-section as conduit 3 of cooler 6, or may be of smaller cross-section; and the pipe end 5 may be of the cross-section of the conduit 9 or smaller cross-section. The liquid begins to boil at vaporization point 11, which ideally is at the discharge end of orifice 5 of FIG. 1 and end 5 of FIG. 2.

If, however, because of practical considerations, nucleation fails to occur at the ideal point, the vaporization point will move upstream into the discharge conduit or orifice. I minimize this result by locating nucleation inducing zones adjacent the discharge end, so that if the vaporization point starts upstream from the discharge end, it will not move upstream beyond these zones of nucleation.

In both FIG. 1 and FIG. 2, the temperature to which the liquid in the cooler is cooled is determined by the heat transfer in the cooling zone 6, and the outflow rate is dependent on the algebraic sum of the liquid head and the pressure difference between the pressure in 1 and the vapor pressure of the liquid at the vaporization point. For purposes of illustration, assume this point to occur at 11 in FIG. 2 and adjacent the outlet from orifice 5 in FIG. 1.

Whenever the liquid level in zone 1 falls so that vapor and liquid enter the cooler 6, I may, by adjusting the temperature of the fluid at the vaporization point, control the volumetric discharge rate through the conduit 9. I may make this rate substantially equal to the volumetric rate of accumulation of liquid in cooler 3. In this manner, liquid level 7 will be maintained in cooler 6 above conduit 9.

The temperature at the top 7 of the column of liquid is the same as the temperature of liquid and vapor in zone 1. The temperature of the liquid at the vaporization point 11 is made to be sufficiently lower, by suitable arrangement of cooling surfaces and coolant temperature, so as to establish the required vapor pressure, for example, at point 11 in conduit 9.

In both the forms of FIG. 1 and FIG. 2, the discharge rate through the discharge passage depends on the pressure differential (plus liquid head) occurring between 1 and 11.

The temperature of the liquid at the vaporization point in the discharge orifice 5 or in the conduit 9 may vary over rather wide limits, resulting from a variation of the wetted area of the cooler, decreasing as the area increases and increasing as the area decreases. Thus, as the level 7 in 3 tends to rise as the rate of accumulation of fluid in the cooler increases, the wetted area, i.e., the area covered by the liquid in 3, tends to increase, and the temperature at 11 tends to decrease. Thus, the pressure differential tends to increase, and this causes a tendency for the rate of flow to increase. The levels will become stabilized at some level when the mass rate of discharge through the orifice 5 or conduit 9 becomes equal to the rate of accumulation of liquid in the conduit 3 of cooler 6.

If the rate of accumulation falls to lower values, the level falls to lower values, the temperature of the liquid at the vaporization point increases, and the pressure difference decreases, resulting in the reduction in the rate of discharge through the orifice or conduit. If, because of a temporary upset in the conditions in zone 1, the liquid level in the cooler approaches orifice 5 or conduit 9, the temperature of the liquid approaches the temperature in zone 1, and the pressure difference between zone 1 and the vapor pressure of the liquid at the orifice or conduit 9 diminishes to a low value, and substantially the entire area of the cooler is full of vapor. Since, however, the vapors are being cooled, some of the vapors will be condensed so that the rate of accumulation of liquid in the conduit 3 is somewhat greater than the rate of inflow of liquid from zone 1 into conduit 3, and the liquid level may be maintained at a point above the outlet 5 at least temporarily, until the initial conditions in zone 1 are re-established and the liquid level is again inside the cooler.

The system, by proper choice of the cross-sectional area and length of the cooler 3, and coolant temperature and flow characteristic of conduit 9 of FIG. 1 or orifice 5 of FIG. 2, will permit of an establishment of the level of

liquid in 3 for a given condition of inflow of liquid from 1 into 3 and maintain such a liquid level over a wide range of rates of liquid flow into 3.

In the form of FIG. 3, the cooler 3 is substantially horizontal, but is elongated and arranged so it will establish a liquid level as at 7. Due to the vapor velocity in the condensing tube, the liquid is swept toward the end of the vapor zone and banks up in the tube.

Under some conditions, the liquid stream exiting from the discharge end may be superheated. This militates against the establishment of liquid-vapor equilibria in the discharge conduit. I have found that I may reduce the effect of such superheat to a large extent by introducing zones of turbulence in the conduit ahead of the discharge end in order to nucleate bubbles. Thus, I may cause variations in linear velocity, for example, by reducing the linear velocity of the stream and then accelerating the stream to increase its velocity, by providing enlargements in the cross-sectional area of the conduit, preferably at a plurality of spaced points, as illustrated at 10 in FIGS. 2 and 3. This variation in flow introduces zones of turbulence in the conduit and aids in nucleation of bubbles and in establishment of the desired pressure at the vaporization point. By positioning these zones of enlarged cross-section at a point in advance of and adjacent to the desired position of the vaporization point, the nucleation of bubbles and establishment of the desired pressure at the vaporization point may be obtained. By employing multiple points of turbulence, multiple points of nucleation may be obtained.

The process and apparatus of my invention find practical utility in multiple-effect systems, particularly a multiple-effect refrigeration system, employing an absorption stage to establish the pressure at which the refrigerant is evaporated to give the desired refrigeration. Such systems employing the improvements of my invention are illustrated in the flow sheet of FIG. 4.

The absorbing liquid which contains the refrigerant, which, for example, may be a solution of salt in water, preferably lithium bromide in water solution, is heated in heating zone 107 to the boiling point and introduced into a separating zone 101, where the unvaporized concentrated lithium bromide solution is separated from the water vapor. The pressure in the separating zone may be any suitable pressure, but is conveniently somewhat above ambient pressure, e.g., atmospheric pressure. The water vapor is passed to a condensation zone 102. The concentrated solution, at the boiling point, is passed via line 108 and cooled by heat exchange in 109, in indirect heat exchange with the relatively cooler, dilute lithium bromide solution passing to the heating zone 107. The concentrated solution is thus cooled to a lower temperature and passed via coil 110 in indirect heat exchange in condenser 102 with the water vapor separated in the aforementioned separating zone 101. The water condensate accumulates in the aforementioned condensation zone 102, at the pressure in the separating zone 101. Uncondensed gases accumulating in 101 are discharged to ambient pressure through valve 109'.

The improvement of my invention provides for the removal of water from the condensation zone 102 without any substantial removal of water vapor from the condensation zone 102 or separation zone 101.

As an illustration of my invention, the water condensate is passed through pipe 111 and through the cooling coil 112, immersed in the pool of cooler lithium bromide solution in the evaporation zone 103. The temperature of the liquid bath and of the vapor in space 103 are substantially constant throughout the length of the pipe 112, and thus the coolant is at the same temperature at the inlet to pipe 112 and outlet of the pipe 113. Exiting from 104, the free boiling jet is discharged into the second condensation zone 104', operating at the lower pressure of zone 103. This is preferably at a low

sub-atmospheric pressure. As an example, it may be of the order of 0.1 of an atmosphere.

The partially cooled concentrate, after heat exchange in 109 and in condenser 102, passes from coil 110 into the separation zone 103, under the control of the float valve 101'. The partially concentrated lithium bromide from 101 passes through 110 and partially flashes in 110 to the low pressure in 103. The unvaporized concentrated solution accumulates in 103. The water vapor thus produced is commingled with vapor from 104 and condensed in 104' by heat exchange with cooling liquid passing through coil 114.

The commingled water condensate then passes from 104' through line 118 and is introduced via pipe 119 into refrigeration evaporator 105, operating at a still lower temperature and pressure. The liquid exiting from 119 passes in heat exchange with fluid in 120, for example, water, which is to be cooled in the refrigeration process, and the liquid is vaporized.

The concentrated solution in 103 is passed via line 112' and heat exchanger 115', where it is cooled, and then by pump 122' into 106 via 117. The water vapor from 105 is absorbed in 106 in the concentrated lithium bromide solution introduced via 117 and cooled by cooling liquid passed through 121 in series with coil 114. The vapor pressure of the absorbent liquid in the absorber 106 establishes the pressure in the refrigerator evaporation zone 105. Thus, depending on the temperature of the cooling water, and therefore the temperature of the absorbing liquid, the pressure may be of the order of a few millimeters of mercury absolute pressure and sufficient to establish the desired temperature of the water in contact with the coils 120. The diluted lithium bromide solution is pumped by pump 122 through heat exchangers 115' and 109 to the heater 107.

In order to impart additional flexibility to the system, I may modify the system according to FIG. 4 by employing the systems of FIGS. 2 or 3 in the flow sheet illustrated in FIG. 5. For this purpose, the input to 122' may be by-passed in part or in whole by means of valves 214 and 215 and lines 215' and 216 to pass in heat exchange in cooler 217 with the fluid passing in line 211, to be passed through 217 directly to 104 instead of through cooler 112 as in FIG. 4. Valves 214 and 215 control the amount of fluid passing from 103 in exchange with the water in 212, and thus control the temperature of the water at the vaporization point in line 218, to establish the desired flow rate out of 104 to maintain a liquid level between 102 and 104 to act as a vapor trap, as described above.

The system involves the vaporization of the salt solution to produce a partially concentrated salt solution by heating the solution in 107 to its boiling point at an elevated temperature and pressure. The hot, unvaporized fraction is separated from its vapor at such pressure in 101, and the vapor is condensed in 102 at the above pressure by heat exchange with the unvaporized fraction passing through 110, which has first been cooled by heat exchange in 109, with the liquid passing from 108. The condensate thus produced and the partially cooled, unvaporized fraction are flashed in a second evaporation stage 103 at a lower pressure, and the resultant vapor is condensed by a cooling medium passing in 114, and the further concentrated salt solution is separated in 103 from the water vapor. The second condensate is introduced into a third evaporation zone 105 at a still lower pressure, where it is passed in heat exchange with fluid to be cooled, passing through 120, and the condensate is evaporated. The generated vapors are absorbed in the concentrated cooled liquid salt solution removed from 103, to establish the low pressure in the third evaporation stage.

By employing the liquid accumulating in 103 as the cooling medium for the liquid withdrawn from 102, the liquid flowing through the vapor traps described above will be in a constant temperature thermal bath of lower tem-

perature. Thus, the coolant is at the same temperature throughout the cooling zone. In the system of FIG. 5, a temperature gradient is established between the inlet and outlet of the cooler 217.

The pipe systems 112 and 113 forms the vapor trap described above in which 112 is the cooling zone similar to 6 of FIGS. 1 and 2, and 113 and 218 are similar to the conduit 9. The schematic drawings of FIGS. 4 and 5 are not intended to be descriptive of the geometry of the system but merely are process flow diagrams. A vaporizing point is established in 113 of FIG. 4, and in the conduit 218 of FIG. 5, aided by providing zones of nucleation by means of turbulent zones such as the enlargements 10 in conduit 9. The temperature, and therefore the vapor pressure of the liquid at the vaporizing point, will be established by the cooling zone. This is designed to establish a liquid level in the system 113 and 112 and the conduit 218 of FIG. 5, so that there is a liquid seal between the inlet to 211 and the outlet at 104. The rate of discharge of the fluid from 104 and the liquid levels will adjust themselves as explained above, to maintain a liquid level between the high and low pressure zones.

The vapor in 101 and 102 enters the cooling zone, and the vapor space extends from the liquid level in the cooling zone into the condenser 102. The temperatures of the vapor and the water at the liquid-vapor interface are both at the condensation temperature of the water at the pressure in 102. As liquid accumulates in 112 or 217 and flows towards 104, the temperature of the liquid drops, due to cooling in the cooler, and at some point in lines 112 and 113 or 212 and conduit 218 the temperature falls to a temperature where the vapor pressure of the liquid is equal to the pressure on the liquid. Vaporization occurs at this point, particularly if nucleation of bubbles has occurred. The liquid has reached the vaporization point. The rate of flow of the liquid is thus controlled by adjusting the cooling of the liquid so that the vapor pressure at the vaporization point is correlated with the rate of accumulation of liquid in the conduit system, so as to maintain liquid in the conduit system and a seal between the staged pressure zones 101 and 103.

While I have described particular embodiments of my invention for the purpose of illustration, it should be understood that various modifications and adaptations thereof may be made, within the spirit of the invention, as set forth in the appended claims.

I claim:

1. A process for refrigeration of fluid, which comprises:

(A) heating an aqueous salt solution to its vaporization point at a relatively elevated temperature, to produce a partially concentrated salt solution and water vapor at a relatively elevated pressure;

(B) separating said vapor from said partially concentrated salt solution in a separating zone at said pressure;

(C) withdrawing and cooling said partially concentrated salt solution;

(D) passing said cooled, partially concentrated salt solution in heat exchange with said water vapor, and condensing said water vapor in a condensation zone, and separating water condensate and uncondensed vapor in said condensation zone at a relatively elevated pressure;

(E) introducing said partially concentrated salt solution into a zone of lower pressure than in said separating zone and

(a) separating water vapor from further concentrated salt solution in said second zone referred to in (E) above, and forming further concentrated salt solution;

(F) passing water condensate and water vapor from said condensation zone into a cooling zone and flowing said water condensate from said cooling zone through a discharge passageway to a condensate vaporizing zone.

- (a) which condensate vaporizing zone is maintained at a substantially lower pressure than in said condensation zone referred to in (D) above;
- (G) maintaining a vapor space in contact with liquid water condensate in said cooling zone and cooling said water condensate passing through said cooling zone to a lower temperature than in said condensation zone referred to in (D) above; and
- (a) thus maintaining the cooled liquid water condensate in said cooling zone at a pressure above the vapor pressure of said liquid in said zone, and thus maintaining a liquid body in said cooling zone;
- (b) passing the cooled water condensate from said cooling zone through said discharge passageway into the condensate vaporizing zone referred to in (F) above and maintained at a pressure substantially less than the pressure in said first-mentioned condensation zone referred to in (D) above; and
- (c) reducing the pressure in the passage of the water condensate through said discharge passageway substantially to the vapor pressure of said cooled liquid water condensate; and
- (d) vaporizing the said liquid water condensate at a vaporization point in said passageway, referred to in (F) above, between said condensation zone, referred to in (D) above, and said condensate vaporizing zone referred to in (F) above, and discharging liquid water condensate and vapor from said discharge passageway into said condensate vaporizing zone; and
- (e) thus maintaining a liquid body between the said condensation zone specified in (D) above and said condensate vaporizing zone specified in (F) above;
- (f) commingling the water vapor from said condensate vaporizing zone specified in (F) above and from said zone of lower pressure specified in (E) and (E-a) above; and
- (H) condensing said commingled vapors referred to in (G-f) above and removing the condensate thus formed; and
- (I) introducing the said last-named condensate into an evaporation zone maintained at a pressure lower than in said zone of lower pressure specified in (E) above, and passing the water condensate in indirect heat exchange with a fluid to be refrigerated, and vaporizing the said last-named condensate to form water vapor at said lower pressure; and
- (J) cooling the further concentrated salt solution specified in (E-a) above, and contacting said vapor specified in (I) above in an absorption zone with the further concentrated salt solution, and absorbing said vapor in said salt solution to form a diluted salt solution, to maintain said pressure in said absorption zone and in said evaporation zone specified in (I) above at said lower pressure; and
- (K) passing said diluted salt solution and heating the same, as specified in (A) above, in cycles of operation.
2. In the process of claim 1, in which said discharge passageway referred to in (F) of claim 1 is an orifice.
3. In the process of claim 1, in which said discharge passageway referred to in (F) of claim 1 is an elongated passageway of restricted cross-section.
4. In the process of claim 3, nucleating bubbles in the passageway referred to in (F) of claim 1 and establishing the vapor pressure referred to in (G-c) of claim 1 at the vaporization point referred to in (G-d) of claim 1.
5. In the process of claim 4, wherein said bubbles are nucleated at a plurality of spaced points along said passageway referred to in (F) of claim 1.
6. In the process of claim 1, in which the passage of the water condensate and water vapor through the pas-

sageway referred to in (F) of claim 1 is in turbulent flow adjacent to said vaporization point referred to in (G-d) of claim 1.

7. In the process of claim 6, in which the discharge passageway is an elongated passageway of restricted cross-section, and the liquid in said passageway referred to in (F) of claim 1 is in turbulent flow adjacent to said vaporization point referred to in (G-d) of claim 1.

8. In the process of claim 6, in which the passageway referred to in (F) of claim 1 is an elongated passageway of restricted cross-section, and flowing said water condensate referred to in (G-b) of claim 1 through the elongated passageway and decelerating the linear velocity and then accelerating the linear velocity of said liquid flow, in a region adjacent said vaporization point referred to in (G-d) of claim 1.

9. In the process of claim 6, in which said liquid flow through said passageway referred to in (F) of claim 1 is in turbulent flow at a plurality of spaced points adjacent to said vaporization point referred to in (G-d) of claim 1.

10. In the process of claim 9, in which the linear velocity of said condensate flowing through the elongated passageway referred to in (F) of claim 1 is decelerated and accelerated at a plurality of spaced regions spaced apart along said passageway.

11. In the process of claim 1, in which said water condensate passing to said discharge passageway referred to in (F) of claim 1, through the cooling zone referred to in (F) of claim 1, is in heat exchange with the further concentrated salt solution in said separating zone referred to in (E) of claim 1, which further concentrated salt solution is maintained at a temperature lower than the temperature of the condensate passing through said cooling zone to said discharge passageway, thereby cooling said condensate flowing to the discharge passageway to a temperature to establish said vapor pressure referred to in (G-c) of said claim 1.

12. In the process of claim 2, in which said water condensate passing to said discharge passageway referred to in (F) of claim 1, through the cooling zone referred to in (F) of claim 1, is in heat exchange with the further concentrated salt solution in said separating zone referred to in (E-a) of claim 1, which further concentrated salt solution is maintained at a temperature lower than the temperature of the condensate passing through said cooling zone to said discharge passageway, thereby cooling said condensate flowing to the discharge passageway to a temperature to establish said vapor pressure referred to in (G-c) of said claim 1.

13. In the process of claim 3, in which said water condensate passing to said discharge passageway referred to in (F) of claim 1, through the cooling zone referred to in (F) of claim 1, is in heat exchange with the further concentrated salt solution in said separating zone referred to in (E-a) of claim 1, which further concentrated salt solution is maintained at a temperature lower than the temperature of the condensate passing through said cooling zone to said discharge passageway, thereby cooling said condensate flowing to the discharge passageway to a temperature to establish said vapor pressure referred to in (G-c) of said claim 1.

14. In the process of claim 4, in which said water condensate passing to said discharge passageway referred to in (F) of claim 1, through the cooling zone referred to in (F) of claim 1, is in heat exchange with the further concentrated salt solution in said separating zone referred to in (E-a) of claim 1, which further concentrated salt solution is maintained at a temperature lower than the temperature of the condensate passing through said cooling zone to said discharge passageway, thereby cooling said condensate flowing to the discharge passageway to a temperature to establish said vapor pressure referred to in (G-c) of said claim 1.

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15. In the process of claim 5, in which said water condensate passing to said discharge passageway referred to in (F) of claim 1, through the cooling zone referred to in (F) of claim 1, is in heat exchange with the further concentrated salt solution in said separating zone referred to in (E-a) of claim 1, which further concentrated salt solution is maintained at a temperature lower than the temperature of the condensate passing through said cooling zone to said discharge passageway, thereby cooling said condensate flowing to the discharge passageway to a temperature to establish said vapor pressure referred to in (G-c) of said claim 1.

16. In the process of claim 6, in which said water condensate passing to said discharge passageway referred to in (F) of claim 1, through the cooling zone referred to in (F) of claim 1, is in heat exchange with the further concentrated salt solution in said separating zone referred to in (E-a) of claim 1, which further concentrated salt solution is maintained at a temperature lower than the temperature of the condensate passing through said cooling zone to said discharge passageway, thereby cooling said condensate flowing to the discharge passageway to a temperature to establish said vapor pressure referred to in (G-c) of said claim 1.

17. In the process of claim 7, in which said water condensate passing to said discharge passageway referred to in (F) of claim 1, through the cooling zone referred to in (F) of claim 1, is in heat exchange with the further concentrated salt solution in said separating zone referred to in (E-a) of claim 1, which further concentrated salt solution is maintained at a temperature lower than the temperature of the condensate passing through said cooling zone to said discharge passageway, thereby cooling said condensate flowing to the discharge passageway to a temperature to establish said vapor pressure referred to in (G-c) of said claim 1.

18. In the process of claim 8, in which said water condensate passing to said discharge passageway referred to in (F) of claim 1, through the cooling zone referred to in (F) of claim 1, is in heat exchange with the further

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concentrated salt solution in said separating zone referred to in (E-a) of claim 1, which further concentrated salt solution is maintained at a temperature lower than the temperature of the condensate passing through said cooling zone to said discharge passageway, thereby cooling said condensate flowing to the discharge passageway to a temperature to establish said vapor pressure referred to in (G-c) of said claim 1.

19. In the process of claim 9, in which said water condensate passing to said discharge passageway referred to in (F) of claim 1, through the cooling zone referred to in (F) of claim 1, is in heat exchange with the further concentrated salt solution in said separating zone referred to in (E-a) of claim 1, which further concentrated salt solution is maintained at a temperature lower than the temperature of the condensate passing through said cooling zone to said discharge passageway, thereby cooling said condensate flowing to the discharge passageway to a temperature to establish said vapor pressure referred to in (G-c) of said claim 1.

20. In the process of claim 10, in which said water condensate passing to said discharge passageway referred to in (F) of claim 1, through the cooling zone referred to in (F) of claim 1, is in heat exchange with the further concentrated salt solution in said separating zone referred to in (E-a) of claim 1, which further concentrated salt solution is maintained at a temperature lower than the temperature of the condensate passing through said cooling zone to said discharge passageway, thereby cooling said condensate flowing to the discharge passageway to a temperature to establish said vapor pressure referred to in (G-c) of said claim 1.

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