May 14, 1946. R. M. BUFFINGTON 2,400,138

REFRIGERATION

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Fig. 1.

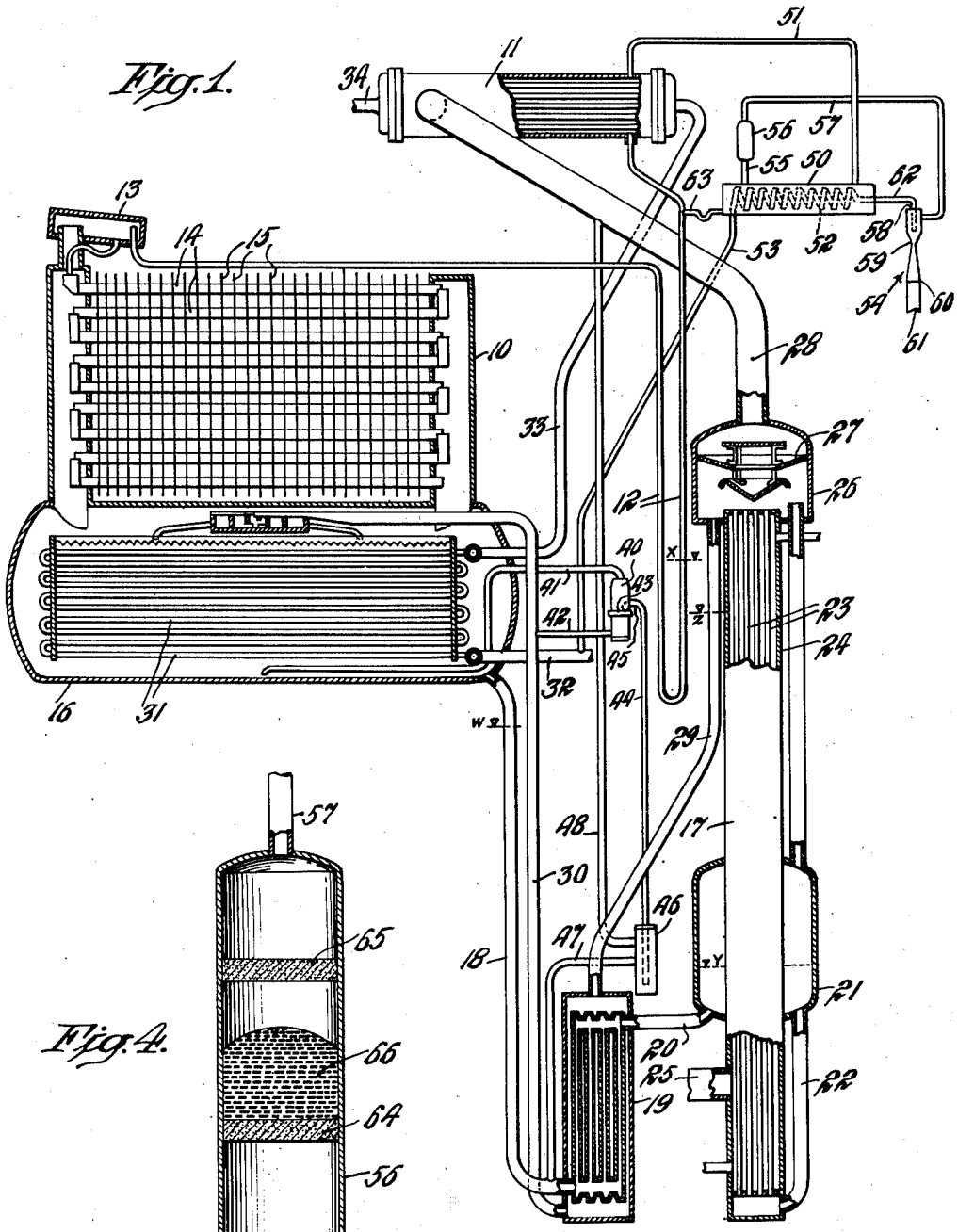


Fig. 4.

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Fig. 2.

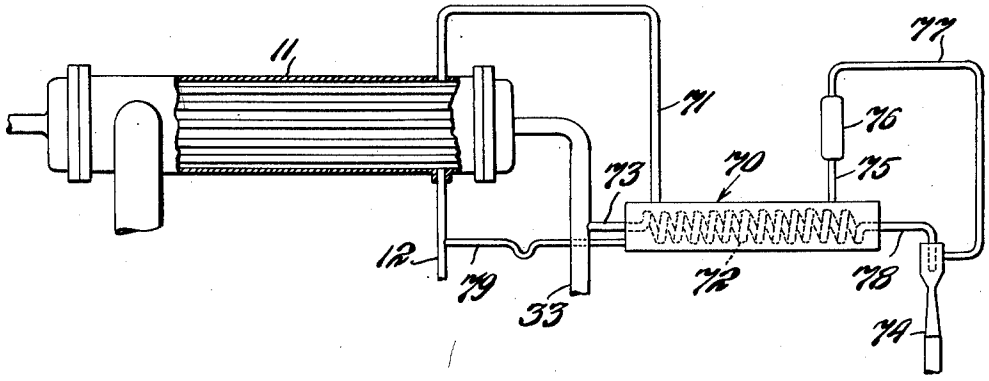
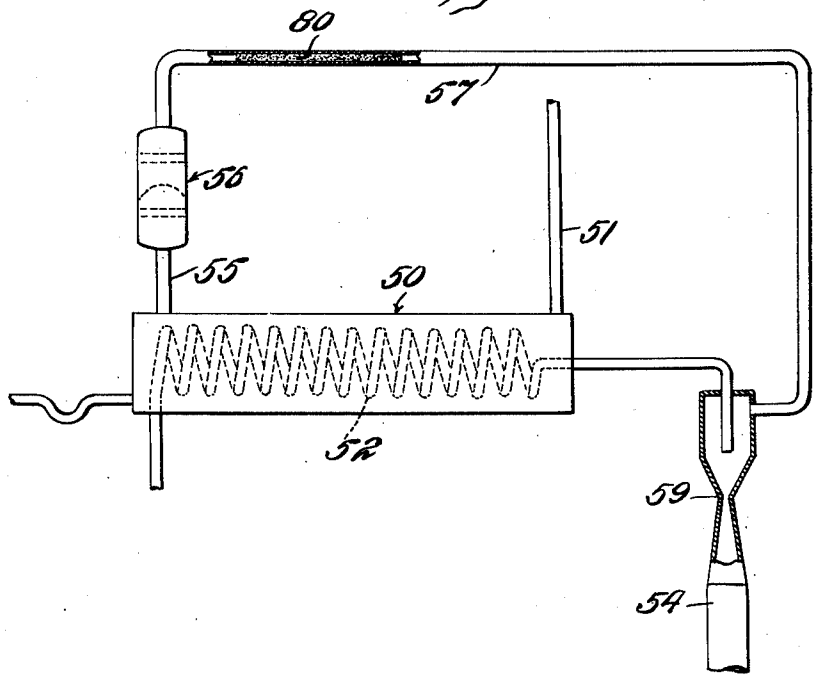


Fig. 3.



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UNITED STATES PATENT OFFICE

2,400,138

REFRIGERATION

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Application May 24, 1944, Serial No. 537,104

20 Claims. (Cl. 62—119)

The present invention relates to a method of and apparatus for purging non-condensible gases from absorption refrigeration systems and is an improvement in the method and apparatus illustrated and described in an application for United States Letters Patent of John G. Reid, Jr., filed concurrently herewith.

While the method and apparatus of the present invention may be used in other absorption refrigeration systems, it is particularly adapted for use in a system of the type illustrated and described in the United States Letters Patent to Albert R. Thomas et al. No. 2,292,503, entitled "Refrigeration." The absorption refrigeration system illustrated in the Thomas et al. patent operates in a partial vacuum and utilizes water as a refrigerant and a saline solution as an absorbent. In such a refrigeration system non-condensible gases may accumulate in the various elements of the system which must be purged periodically.

In the application for United States Letters Patent of John G. Reid, Jr., referred to above, it is proposed to circulate cooling water through a condenser and water-operated aspirator successively to condense refrigerant water vapor in the condenser and produce a pressure in the aspirator corresponding to the vapor pressure of the cooling water flowing therethrough. When no non-condensible gases are present in the condenser, the temperature and vapor pressure of the cooling water flowing through the aspirator will be slightly less than the condensing temperature and pressure in the condenser. A check valve between the condenser and aspirator reduces the pressure at which media will flow from the condenser to the aspirator to a value below the pressure produced by the aspirator so that during normal operation no refrigerant vapor will flow to the aspirator. However, upon the occurrence of non-condensible gases in the condenser less heat will be transferred to the cooling water and the temperature of the cooling water leaving the condenser will be reduced so that the aspirator will produce a pressure below the pressure in the condenser less the pressure drop due to the check valve. The non-condensible gases then will flow from the condenser to the aspirator and will be entrained and discharged with the water exhausting from the aspirator. The Reid method and apparatus, therefore, is operative to withdraw non-condensible gases from the system without withdrawing any pure refrigerant vapor; but Reid proposes to reduce the pressure at which media will flow to the aspirator to a value only slightly below the pressure in the condenser. Under these conditions of operation the ratio of the volume of non-condensible gases to the volume of refrigerant vapor contained therein is of the order of 1 to 26 so that 26 units of refrigerant vapor will be withdrawn with each unit of non-condensible gas.

The principal object of the present invention is to materially reduce the amount of refrigerant vapor withdrawn with the non-condensible gases by the aspirator.

Another object of the invention is to segregate the non-condensible gases in the condenser and cool them to the temperature of the cooling water entering the condenser to reduce the partial pressure and volume of refrigerant vapor in the non-condensible gases.

Another object is to flow the cooling water through an auxiliary condenser in a direction countercurrent to the direction of flow of the refrigerant vapor therein to segregate non-condensible gases at the cold end of the condenser at a substantial partial pressure by reducing the partial pressure of the refrigerant vapor mixed therewith to the vapor pressure of the cooling water entering the condenser.

Another object is to prevent the flow of gases from the condenser to the aspirator until the aspirator produces a substantial pressure drop therebetween.

Another object is to provide an apparatus for withdrawing non-condensible gases which is rendered operative only when the gases are present in the condenser at a substantial partial pressure.

Another object is to provide a loaded check valve in the connecting means between the condenser and aspirator to produce a pressure drop of the desired value.

Still another object of the invention is to provide a mercury check valve in combination with a packing in the connection between the condenser and aspirator to provide a positive seal in the connection and restrict the flow of media therebetween.

These and other objects will become more apparent from the following description and drawings in which like reference characters denote like parts throughout the several views. It is to be expressly understood, however, that the drawings are for the purpose of illustration only and not a definition of the limits of the invention, reference being had for this purpose to the appended claims. In the drawings:

Fig. 1 is a diagrammatic view of an absorption refrigeration system incorporating the novel features of the present invention and showing the

auxiliary condenser arranged for counter-current flow to reduce the vapor pressure and volume of refrigerant vapor in the non-condensible gases.

Fig. 2 is a diagrammatic view of a purging means of modified construction showing the auxiliary condenser arranged for parallel flow with a loaded check valve for producing a substantial pressure drop between the condenser and aspirator to reduce the partial pressure of the refrigerant vapor in the condenser,

Fig. 3 is a view similar to Fig. 2 showing another purging means of modified construction comprising a check valve and packing arranged in series to provide a substantial pressure drop between the auxiliary condenser and aspirator, and

Fig. 4 is a sectional view of the loaded check valve for sealing the refrigeration system from the atmosphere and producing a pressure drop between the auxiliary condenser and aspirator.

In accordance with the method of the present invention cooling water is circulated successively through a condenser connected to the refrigeration system and a water-operated aspirator connected to the condenser. The cooling water condenses refrigerant vapor in the condenser and produces a pressure in the aspirator corresponding to the vapor pressure of the water flowing therethrough. Preferably, the condenser is a small auxiliary unit connected to the main condenser of the system and adapted to operate at a pressure and temperature equal to or slightly lower than the pressure and temperature in the main condenser to insure flow of refrigerant vapor and non-condensible gases thereto.

The improvement in the method of the present invention comprises reducing the partial pressure of the refrigerant vapor and increasing the partial pressure of the non-condensing gases of the mixture withdrawn by the aspirator. As the relative volumes of refrigerant vapor and non-condensible gases in the mixture are proportional to their partial pressures less refrigerant vapor will be withdrawn with the gases. As an example, if the total pressure in the condenser is 55.1 mm. Hg abs., the partial pressure of the refrigerant water vapor is 53.1 mm. Hg and the partial pressure of the non-condensible gases is 2 mm. Hg then 26.5 times as much water vapor as non-condensible gases will be removed by the aspirator. If, on the other hand, the partial pressure of the water vapor is reduced to 18.7 mm. Hg and the partial pressure of the non-condensible gases is increased to 36.4 mm. Hg, approximately twice as much non-condensible gases as water vapor will be removed.

In accordance with the present method, the partial pressure of the refrigerant water vapor is reduced by cooling the mixture of refrigerant vapor and non-condensible gases. To this end, the cooling water may be circulated through the auxiliary condenser in a direction countercurrent to the direction of flow of the refrigerant vapor entering the condenser. The relatively warm refrigerant vapor entering the auxiliary condenser is first subjected to the relatively warm cooling water leaving the condenser and then flows toward the colder end of the condenser. When no non-condensible gases are present, the refrigerant vapors are condensed by the transfer of their latent heat to the cooling water. If any non-condensible gases are present in the refrigerant vapor they will continue to flow toward the cold end of the condenser where they accumulate and blanket off that portion of the condenser which they cover. As the non-condensible gases transmit only sensible heat their temperature is quickly reduced to the temperature of the cooling water entering the condenser. Thus, the countercurrent flow condenser operates to segregate the non-condensible gases and reduce their temperature to the temperature of the water entering the condenser. At the lower temperature the partial pressure of the refrigerant vapor will be reduced to the vapor pressure of the cooling water entering the condenser and the difference between the partial pressure of the refrigerant vapor and the condensing pressure will constitute the partial pressure of the non-condensible gases.

As the non-condensible gases continue to accumulate in the condenser they progressively blanket off more of the cooling surface of the condenser so that less surface area is available for condensing refrigerant. Since the rate of heat transfer falls off as the area of effective cooling surface is reduced, the temperature of the cooling water gradually decreases as the amount of non-condensible gases increases. As the temperature of the cooling water flowing through the aspirator decreases it will progressively decrease the pressure therein until a pressure is reached at which the non-condensible gases in the condenser will flow to the aspirator. Where a counter-current flow condenser is used the pressure at which the non-condensible gases are withdrawn is not critical as they may be purged at any pressure below the condensing pressure. Preferably, however, the flow of gases from the condenser to the aspirator is prevented until a substantial quantity of non-condensible gases is segregated and temporarily stored in the condenser before pumping starts. The pressure at which the removal of gases is initiated, however, should be of such a value as to prevent the gases from backing up into the main condenser.

When the cooling water is circulated through the auxiliary condenser in a direction parallel to the flow of refrigerant vapor therethrough the non-condensible gases are segregated and cooled to reduce the partial pressure of the refrigerant vapor therein by providing a resistance between the condenser and aspirator which produces a substantial pressure drop therebetween. Preferably the resistance is so constructed and arranged so as to provide a seal for positively preventing the flow of any media therethrough until a predetermined pressure drop is produced by the aspirator but the present invention is intended to include any resistance, which either positively stops or merely restricts the flow of the gases. Refrigerant vapor entering the condenser will be condensed in the usual manner until non-condensible gases occur which blanket off the surface of the condenser which they cover. As the non-condensible gases continue to accumulate in the condenser, the temperature of the cooling water is progressively reduced. However, due to the resistance in the path of flow between the auxiliary condenser and aspirator the latter will not start to pump until a substantial quantity of the gases are present in the condenser. If the resistance produces a pressure drop of such a value as to prevent the initiation of a pumping operation until the auxiliary condenser is completely filled with non-condensible gases a maximum volume of the gases and a minimum volume of refrigerant vapor will be present therein. However upon a slight change in operating conditions, such as less heat transfer in the condenser due to the

accumulation of scale or slime therein, or an increase in the pressure produced by the aspirator due to an obstruction therein, the gases will not be withdrawn from the condenser and will back up into the main condenser. The resistance, therefore, should have a value above the theoretical minimum value and should be such as to reduce the parital pressure and volume of refrigerant vapor in the condenser to the lowest possible degree consistent with the removal of the gases under all conditions of operation which may be reasonably expected. Thus, the resistance in the path of flow between the condenser and aspirator operates to segregate and cool the non-condensible gases and thereby reduce the partial pressure of the refrigerant vapor so as to substantially decrease the amount of refrigerant withdrawn with the gases. When sufficient surface area of the auxiliary condenser is blanketed by the non-condensible gases the aspirator will produce a pressure lower than the pressure in the condenser less the pressure drop due to the resistance to withdraw the gases from the condenser.

Referring to the drawings a preferred apparatus for carrying out the steps of the method is shown in Fig. 1 as applied to a two-pressure absorption refrigeration system similar to that illustrated and described in the Thomas et al. patent, referred to above. In a system of this type liquid refrigerant such as, for example, water is introduced into the upper part of an evaporator or cooling element 10 from a condenser 11 through a path of flow including a U-shaped tube 12 and flash chamber 13. The liquid refrigerant evaporates in the evaporator 10 with consequent absorption of heat from the ambient such as a stream of air flowing over the exterior surface of the tubes 14 and fins 15 of the evaporator. The refrigerant vapor formed in the evaporator 10 flows to an absorber 16 in which the vapor is absorbed into a liquid absorbent such as, for example, a solution of lithium chloride, lithium bromide or the like.

The absorption liquid enriched with refrigerant is conducted from the absorber 16 to a generator 17 in a path of flow including conduit 18, liquid heat exchanger 19, conduit 20, vessel 21, and conduit 22. Within the generator 17, a plurality of riser tubes 23 are enclosed within a shell 24 forming a chamber to which steam is supplied through a conduit 25 from a suitable source of supply. The heating of the riser tubes 23 by the steam causes refrigerant vapor to be expelled from the absorption solution and the expelled vapor is effective to raise the absorption liquid by gas or vapor-lift action.

The expelled vapor passes from the upper ends of the riser tubes 23 into a vapor separating chamber 26 having suitable baffles 27 therein and thence flows through a conduit 28 to the condenser 11 in which the vapor is liquefied. The liquid refrigerant formed in the condenser 11 flows by gravity into the U-shaped tube 12 to the upper part of the evaporator 10 as explained above to complete the refrigeration cycle.

The raised absorption liquid from which refrigerant vapor has been expelled is conducted from the upper part of the generator 17 to the absorber 16 to absorb refrigerant vapor, this liquid being conducted to the absorber in a path of flow including a conduit 29, liquid heat exchanger 19, and conduit 30. The heat liberated by the absorption of refrigerant vapor in the absorber 16 is taken up by a cooling medium such as, for example, water which flows upwardly through vertically disposed banks of pipes 31 in the absorber. The cooling water is introduced into the lower end of the banks of pipes through a conduit 32 and is discharged from the upper end of the banks of pipes through a conduit 33. The conduit 33 is connected to the condenser 11 so that the cooling water also may be utilized to effect cooling of the condenser. The cooling water is discharged from the condenser 11 through a conduit 34.

The system operates in a partial vacuum with generator 17 and condenser 11 operating at one pressure and evaporator 10 and absorber 16 operating at a lower pressure. The pressure differential between the high and low pressure sides of the system is maintained by liquid columns in the up-leg of the U-shaped tube 12 between the condenser 11 and the evaporator 10 and in the conduits 18 and 30 connecting the absorber 16 and heat exchanger 19. The liquid level in the U-shaped tube 12 is indicated by the reference character x; the liquid levels in the conduit 18 and vessel 21 connected thereto through the heat exchanger 19 are indicated by the reference characters w and y; and the liquid level in the conduit 29 connected to the conduit 30 through the heat exchanger 19 is indicated by the reference character z.

During operation of the refrigeration system non-condensible gases may accumulate in the various elements thereof. These non-condensible gases are probably formed by the chemical action of the fluids with the metallic parts of the system. Any non-condensible gases occurring in the generator 17 are swept into the condenser 11 with the refrigerant vapor flowing thereto at high velocity. The gases in the condenser 11 normally tend to accumulate adjacent its outlet end from which they are purged. The non-condensible gases in the evaporator 10 are swept into the absorber 16 by the refrigerant as it flows into the absorber at high velocity. The gases then accumulate in a layer at the bottom and center of the absorber 16 where turbulence is at a minimum. Thus, the non-condensible gases accumulate adjacent the outlet from the condenser 11 and at the bottom and center of the absorber 16 and blanket off that portion of the condenser or absorber which they cover.

In the embodiment of the invention illustrated in Fig. 1 of the drawings, the non-condensible gases are transferred continuously from the absorber 16 to the condenser 11 by means of a vessel 40 which draws the gases from the bottom of the absorber into the top thereof through a conduit 41. A portion of the absorption liquid flowing to the upper part of the absorber 16 through the conduit 30 is diverted to the bottom of the vessel 40 through a conduit 42. Preferably an apertured septum plate 43 is positioned intermediate the ends of the vessel 40 to provide a measuring orifice for controlling the amount of absorption liquid flowing therethrough. Thus, the diverted absorption liquid is brought into intimate contact with the non-condensible gases drawn into the top of the vessel 40 through the conduit 41. A vertical tube 44, which may be referred to as a fall tube pump, has a curved upper end 45 connected to the vessel 40 above the septum plate 43 with its lower end extending into a separating chamber 46. A conduit 47 is connected to the separating chamber 46 at a point above the lower end of the vertical tube 44 and the opposite end of the conduit is connected to

the conduit 18 leading to the heat exchanger 19. A second conduit 48 is connected to the separating chamber 46 at a point above the conduit 47 and the upper end of the second conduit is connected to the conduit 28 between the generator 17 and condenser 11.

Absorption liquid flows into the bottom of the vessel 40 and upwardly through the orifice in the septum plate 43 and into the upper bent end 45 of the fall tube 44 until the liquid siphons into the fall tube. At the end of a siphoning operation small quantities of non-condensible gases in the upper part of the vessel 40 enter the upper bent end 45 of the fall tube 44 and become trapped between successive bodies or slugs of the absorption liquid. The internal diameter of the fall tube 44 is such that gas and liquid cannot pass each other while flowing therethrough and the column of absorption liquid and non-condensible gases maintains the pressure differential between the high pressure and low pressure sides of the system. The non-condensible gases are discharged from the lower end of the fall tube 44 and bubble upwardly through the absorption liquid in the separating chamber 46 which acts to strip any refrigerant vapor therefrom and the gases escape through the conduits 48 and 28 to the condenser 11. The absorption liquid in the separating chamber 46 escapes through the conduit 47 to the conduit 18 of the main circuit of the refrigeration system. Thus, the non-condensible gases in the low pressure side of the system are transferred continuously to the condenser 11 where they accumulate adjacent the outlet end thereof.

In accordance with the present invention an automatic purging apparatus is provided for receiving, segregating, cooling and temporarily storing the gases and withdrawing the gases from the system only when they are present at a substantial partial pressure. The purging apparatus may be used in conjunction with any suitable condenser but preferably a small auxiliary condenser 50 is provided which is connected to the main condenser 11 adjacent its outlet by means of a conduit 51. While the auxiliary condenser 50 may take other forms it is herein illustrated as a horizontal cylindrical shell forming a closed chamber and having a water cooled coil 52 therein. In the preferred embodiment of the invention illustrated in Fig. 1 the auxiliary condenser 50 is arranged for counter-current flow to segregate and temporarily store the non-condensible gases at the cold end of the condenser and reduce the partial pressure of the refrigerant vapor in the gases to the vapor pressure of the cooling water entering the condenser. While cooling water at any suitable temperature may be used, it is preferable to supply the auxiliary condenser 50 with the coldest water available, to reduce the partial pressure of the refrigerant vapor to a minimum. For this purpose the end of the cooling coil 52 at the opposite end of the condenser 50 from the inlet conduit 51 for refrigerant vapor is connected to the water main 32 by means of a conduit 53. Thus, the cooling water will flow through the cooling coil 52 in a direction toward the right as viewed in Fig. 1 and countercurrent to the direction of flow of refrigerant vapor and non-condensible gases.

The auxiliary condenser 50 is connected to a water-operated aspirator 54 in a path of flow including a conduit 55, check valve 56 and conduit 57. The aspirator 54 has an inlet port 58, a restricted throat 59 intermediate its end and an outlet port 60 to which a discharge tube 61 is connected. The conduit 55 is connected to the outlet or left-hand end of the auxiliary condenser 50 as viewed in Fig. 1 and the conduit 57 is connected to the restricted throat portion 59 of the aspirator 54. The outlet end of the cooling coil 52 is connected to the inlet 58 to the aspirator 54 by means of the conduit 62. Thus, cooling water flows from the water main 32 through the conduit 53, cooling coil 52 of the auxiliary condenser 50, conduit 62, and restricted throat 59 of the aspirator 54, successively.

The media entering the auxiliary condenser 50 will first contact the relatively warm end of the cooling coil 52 and will flow through the condenser toward the left as viewed in Fig. 1 to meet progressively colder sections of the cooling coil. When no non-condensible gases are present the latent heat will be transmitted from the refrigerant vapor to the cooling water flowing through the cooling coil 52 to condense the vapor and the arrangement is such that the temperature of the cooling water leaving the condenser will be only slightly lower than the temperature of the refrigerant vapor entering the condenser. A conduit 63 connects the bottom of the cold end of the auxiliary condenser 50 to the U-tube 12 to drain condensate from the condenser and preferably the conduit is so constructed and arranged as to provide a liquid trap therebetween. Any non-condensible gases entering the auxiliary condenser 50 will flow toward the left-hand end thereof where they will be subjected to cooling water at the lowest available temperature. As the sensible heat of the non-condensible gases will be quickly transferred to the cooling water the temperature of the gases accumulated in the auxiliary condenser 50 will be reduced to substantially the same temperature as the water entering the condenser. Refrigerant vapor then will be present in the non-condensible gases at a partial pressure corresponding to the vapor pressure of the cooling water entering the auxiliary condenser. As the vapor pressure of the water entering the auxiliary condenser 50 is considerably below the condensing pressure therein the partial pressure of the non-condensible gases will have materially increased. As the relative volumes of refrigerant vapor and non-condensible gases correspond to their partial pressures the ratio of refrigerant vapor to non-condensible gases at the cold end of the auxiliary condenser 50 will be reduced to a minimum.

With the form of purging apparatus illustrated in Fig. 1 the pressure in the aspirator 54 at which the non-condensible gases are withdrawn is not critical as the gases are segregated and cooled at one end of the condenser to reduce the amount of refrigerant vapor therein simultaneously with the condensing of refrigerant vapor in the remainder of the condenser. The pressure at which the non-condensible gases are withdrawn should be sufficiently below the pressure in the auxiliary condenser to prevent withdrawal of pure refrigerant vapor therefrom and sufficiently above the vapor pressure of the cooling water entering the auxiliary condenser to insure removal of the gases under any conditions of operation which reasonably may be expected to occur. To control the pressure at which the gases are withdrawn the check valve 56 is loaded to provide a pressure drop between the auxiliary condenser 50 and water-operated aspirator 54 of a predetermined value.

The loaded check valve 56 may be of any suit-

able type for permitting the flow of non-condensible gases from the auxiliary condenser 50 to the aspirator 54 while preventing the flow of atmospheric air to the condenser. The check valve 56 as herein described and illustrated in detail in Fig. 4 comprises a cylindrical vessel having spaced septum plates 64 and 65 of a porous ceramic material extending thereacross with a body of liquid 66 such as mercury covering the lower plate 64. Such a check valve is illustrated and described in detail in the prior copending application for United States Letters Patent of Charles Alfred Roswell, Serial No. 481,729, filed April 3, 1943, entitled "Valve." The check valve 56 positively seals the refrigeration system from the aspirator 54 and is loaded to produce the desired pressure drop between the auxiliary condenser 50 and aspirator 54 by initially providing a head or column of mercury on the plate 64 of a predetermined height corresponding to the pressure drop. The initial loading of the check valve 56 will vary for particular operating conditions to produce a pressure drop of a desired value. One form of the invention having now been described in detail the mode of operation of the apparatus is explained as follows.

During normal operation of the refrigeration system steam will be supplied to the generator 17 through the conduit 25 which will vaporize refrigerant vapor in the tubes 23. The vaporized refrigerant will rise through the separating chamber 26 and conduit 28 into the main condenser 11 and some refrigerant vapor will flow from the latter to the auxiliary condenser 50 through the conduit 51, the vapor being condensed to a liquid simultaneously in both condensers. The liquid refrigerant will flow from the outlets of the condensers 11 and 50 through the U-shaped tube 12 and flash chamber 13 into the evaporator 10 where the liquid refrigerant will be evaporated to produce refrigeration. Refrigerant vapor in the evaporator 10 will flow to the absorber 16 and will be absorbed in absorption solution therein. The dilute absorption solution will flow continuously from the absorber 16 through the conduit 18, heat exchanger 19, conduit 20, chamber 21, and conduit 22 back to the base of the generator 17. Simultaneously, the concentrated absorption solution in the separating chamber 26 will flow through the conduit 29, heat exchanger 19, and conduit 30 back to the absorber 16.

During the operation of the refrigeration system any non-condensible gases occurring in the generator 17 will be carried into the main condenser 11 with the refrigerant vapor and then will flow from the main condenser to the auxiliary condenser 50 through the conduit 51. Simultaneously, any non-condensible gases occurring in the evaporator 10 will be swept into the absorber 16 by the refrigerant vapor and will accumulate in the bottom and center of the absorber where turbulence is at a minimum. During operation of the refrigeration system the non-condensible gases at the bottom and center of the absorber 16 will be continuously withdrawn therefrom and transferred to the main condenser 11 by means of the vessel 40 and fall tube pump 44. Thus the non-condensible gases occurring in the various parts of the system will be continuously transferred to the main condenser 11 and will flow from the main condenser to the auxiliary condenser 50 through the conduit 51.

Also, during operation of the refrigeration system cooling water will flow from the water main 32 through the conduit 53 to the cooling coil 52 in the auxiliary condenser 50 and will flow from the cooling coil to the inlet port 58 of the water-operated aspirator 54 successively. Due to the flow of the cooling water through the aspirator 54 a partial vacuum will be created at the throat 59 of a value depending upon the vapor pressure of the water. In other words, the water in the aspirator 54 will vaporize when a predetermined low pressure is reached and the pressure at which the water vaporizes is dependent upon its temperature. During normal operation with no non-condensible gases present in the auxiliary condenser 50 heat will be transferred from the refrigerant vapor to the cooling water to increase its temperature to a value only slightly less than the condensing temperature. With water at this relatively high temperature the aspirator 54 will not produce a pressure below the condensing pressure less the pressure drop due to the loaded check valve 56 so that media will not flow from the auxiliary condenser 50 to the aspirator 54.

When non-condensible gases occur in the system they will be drawn into the auxiliary condenser 50 and will flow from its warm end towards its cold end where they gradually accumulate. As the gases are non-condensible only sensible heat will be transferred through the coil 52 to the cooling water. As a result the non-condensible gases will be segregated and cooled to the temperature of the water entering the auxiliary condenser 50. At this low temperature the vapor pressure of the refrigerant or, in other words, water vapor will be reduced to the vapor pressure of the inlet cooling water whereby to substantially increase the partial pressure of the non-condensible gases. As the relative volumes of refrigerant vapor and non-condensible gases will correspond with their respective partial pressures the amount of non-condensible gases in the mixture will have materially increased.

As the non-condensible gases gradually accumulate in the auxiliary condenser 50 they will blanket off the portion of the cooling coil 52 which they cover to gradually and progressively reduce the temperature of the circulating water supplied to the aspirator 54. At the lower temperatures of the cooling water, the aspirator 54 will progressively lower the pressure at the throat 59. The non-condensible gases will continue to accumulate in the auxiliary condenser 50, until the aspirator 54 produces a pressure lower than the condensing pressure less the pressure drop due to the loaded check valve 56 at which time the non-condensible gases will flow from the auxiliary condenser to the aspirator and be discharged with the water exhausting therefrom.

The purging of the non-condensible gases from the auxiliary condenser 50 will continue so long as the temperature of the water flowing through the aspirator 54 is sufficiently low so as to cause media to flow from the condenser to the aspirator. However, as the non-condensible gases are purged they are replaced by refrigerant vapor. Due to the transfer of the latent heat of the refrigerant vapor to the cooling water in the cooling coil 52 the temperature of the cooling water will increase which, in turn, will increase the vapor pressure of the water flowing through the aspirator 54. At the higher vapor pressure the water flowing through the aspirator 54 cannot reduce the pressure at the throat 59 to a value below the pressure occurring in the auxiliary condenser less the pressure drop due to the loaded check valve 56. As a result the aspirator 54 is operative auto-

matically to withdraw non-condensible gases having a substantial partial pressure equal to or only slightly less than the difference between the condensing pressure and the vapor pressure of the cooling water entering the condenser.

As an example the following operating conditions for a particular unit are given as illustrative, Case I indicating the conditions when no non-condensible gases are present in the auxiliary condenser, Case II indicates the conditions when the auxiliary condenser is filled with non-condensible gases and Case III indicates a preferred arrangement in the which the check valve is loaded to produce a pressure drop of 15 mm. Hg. Abs. and assuming that a sufficient quantity of non-condensible gases is present in the condenser to reduce the temperature of the cooling water leaving the condenser to 90° F.

Case I

A. Auxiliary condenser:		
1. Cooling water inlet temperature	°F.	70
2. Cooling water outlet temperature	°F.	103
3. Condensing temperature	°F.	104
4. Condensing pressure (at 104° F.)	mm.HgAbs.	55.1
5. Partial pressure of refrigerant vapor	mm.Hg.	55.1
6. Partial pressure of non-condensible gases	do.	0
B. Aspirator:		
1. Water inlet temperature	°F.	103
2. Pressure (vapor pressure of water at 103° F.)	mm.Hg.	53.67
C. Check valve:		
1. Pressure drop due to loaded check valve	mm.Hg.	30
D. Purging pressure:		
1. Condenser pressure less pressure drop	mm.HgAbs.	25.1

Case II

A. Auxiliary condenser:		
1. Cooling water inlet temperature	°F.	70
2. Cooling water outlet temperature	°F.	70
3. Condenser temperature	°F.	70
4. Condenser pressure	mm.HgAbs.	55.1
5. Partial pressure of refrigerant vapor (vapor pressure at 70° F.)	mm.Hg.	18.7
6. Partial pressure of non-condensible gases	do.	36.4
B. Aspirator:		
1. Water inlet temperature	°F.	70
2. Pressure (vapor pressure of water at 70°)	mm.Hg.	18.7
C. Check valve:		
1. Pressure drop due to loaded check valve	do.	30
D. Purging pressure:		
1. Condensing pressure less pressure drop	mm.HgAbs.	25.1

Case III

A. Auxiliary condenser:		
1. Cooling water inlet temperature	°F.	70
2. Cooling water outlet temperature	°F.	90
3. Condensing temperature	°F.	104
4. Condensing pressure (at 104° F.)	mm.HgAbs.	55.1
5. Partial pressure of refrigerant vapor	do.	18.7
6. Partial pressure of non-condensible gases	do.	36.4
B. Aspirator:		
1. Water inlet temperature	°F.	90
2. Pressure (vapor pressure of water at 90° F.)	mm.Hg.	35.5
C. Check valve:		
1. Pressure drop due to loaded check valve	mm.HgAbs.	15
D. Purging pressure:		
1. Condenser pressure less pressure drop	do.	40.1

It will be noted by reference to Cases II and III that the ratio of the partial pressure of the non-condensible gases to the refrigerant vapor is approximately 2 to 1 so that two units of the non-condensible gases will be withdrawn for each unit of refrigerant vapor during a purging operation.

In Fig. 2 a purging apparatus of modified construction is illustrated in which the cooling water and refrigerant vapor have parallel or concurrent flow through the auxiliary condenser. The auxiliary condenser **70** is generally similar to the auxiliary condenser **50** previously described and is connected to the main condenser **11** by means of the conduit **71**. The cooling coil **72** in the condenser **70** is connected to the water line **33** extending between the absorber **16** and condenser **11** by means of a conduit **73**. It will be observed that the conduits **71** and **73** are connected to the same end of the auxiliary condenser **70** so that both cooling water and refrigerant vapor are supplied thereto for parallel or concurrent flow therethrough. The opposite end of the auxiliary condenser **70** is connected to the aspirator **74** in a path of flow including the conduit **75**, check valve **76**, and conduit **77**. The outlet end of the cooling coil **72** is connected to the inlet port of the aspirator **74** by a conduit **78** and condensate drains from the auxiliary condenser **70** to the U-tube **12** through a conduit **79**. In this arrangement the pressure at which the media flows from the auxiliary condenser **70** to the aspirator **74** is critical and the check valve **76** should be loaded to produce a substantial pressure drop of a value only slightly less than the difference between the condensing pressure and the vapor pressure of the water entering the condenser, whereby to cool the non-condensible gases to a temperature as close as possible to the temperature of the cooling water entering the condenser to increase the partial pressure of the gases. Theoretically, the gases may be cooled to the temperature of the cooling water entering the condenser **70** but practically due to the necessity of a temperature gradient to cause heat to flow and the formation of scale and slime in the condenser **70** and aspirator **74** the gases only can be cooled to a temperature above the theoretical temperature at which the removal of gases will be assured for any operating condition which may occur.

Refrigerant vapor entering the auxiliary condenser **70** is condensed by the transfer of its latent heat to the water flowing through the cooling coil **72**. The transfer of heat to the cooling water increases its temperature to a value only slightly less than the condensing temperature. When non-condensible gases enter the auxiliary condenser **70** they accumulate adjacent the warm end and blanket off that portion of the cooling coil which they cover. The non-condensible gases, however, will have substantially the same temperature as the water entering the aspirator instead of the lower temperature of the cooling water entering the auxiliary condenser as in the preferred arrangement illustrated in Fig. 1. Due to the blanketing of the portion of the condenser covered by the non-condensible gases the amount of heat transferred to the cooling water is decreased to progressively decrease the temperature of the water flowing through the aspirator **74**. The non-condensible gases will continue to accumulate in the auxiliary condenser and as they blanket off the portion of the condenser which they cover their temperature gradually decreases. The non-condensible gases are thus accumulated and segregated in the auxiliary condenser to decrease the partial pressure of refrigerant vapor and increase the partial pressure of the non-condensible gases.

As the temperature of the water flowing through the aspirator **74** decreases the pressure produced by the aspirator progressively decreases until it reaches a value below the pressure in the condenser **70** less the pressure drop due to the loaded check valve **76** at which time the non-condensible gases will flow from the auxiliary condenser to the aspirator and be discharged

with the water exhausting therefrom. Thus, it will be observed that the construction illustrated in Fig. 2 is operative to automatically exhaust the non-condensible gases from a parallel flow condenser only when they are present at a substantial partial pressure in the auxiliary condenser 70, to materially reduce the amount of refrigerant vapor removed with the gases.

Another modified construction of purging apparatus is illustrated in Fig. 3 in which a check valve and a packing in the conduit between the auxiliary condenser and aspirator cooperate to produce the desired pressure drop therebetween. The arrangement of the auxiliary condenser 50 and aspirator 54 is substantially identical with that illustrated in Fig. 1. The main condenser 11 is connected to the auxiliary condenser 50 by a conduit 51; the auxiliary condenser is connected to the throat 59 of the aspirator 54 in a path of flow including the conduit 55, check valve 56 and conduit 57; and the cooling coil 52 is connected between the water main 32 and aspirator 54 to flow the cooling water in a direction countercurrent to the direction of flow of refrigerant vapor. In this form of construction, however, the check valve 56 seals the refrigeration system from the aspirator but provides only a nominal pressure drop of a few mm. Hg and the pressure drop between the auxiliary condenser 50 and aspirator 54 is produced by the combination of the check valve and a packing 80 of asbestos, or the like, in the conduit 57. The packing 80 and check valve 56 cooperate to produce a pressure drop between the auxiliary condenser 50 and aspirator 54 of a suitable value, whereby to cause the non-condensible gases to be temporarily stored and cooled to the temperature of the cooling water entering the condenser before they are withdrawn. The apparatus illustrated in Fig. 3 operates in substantially the same manner as the preferred form of construction illustrated in Fig. 1 to reduce the partial pressure of the refrigerant vapor and materially increase the partial pressure of the non-condensible gases before the mixture is withdrawn from the system.

It will now be observed from the foregoing specification that the present invention provides for materially reducing the amount of refrigerant vapor withdrawn with the non-condensible gases during a purging operation. It will also be observed that the present invention provides for segregating and cooling the non-condensible gases to substantially the same temperature as the circulating water entering the auxiliary condenser to reduce the partial pressure and volume of refrigerant vapor in the gases. It will still further be observed that the present invention provides for restricting the flow between the auxiliary condenser and aspirator by means of a loaded check valve or the like to produce a pressure drop of the desired value.

While three different constructions of purging apparatus are herein illustrated and described, it will be understood that other changes may be made in the steps of the method and the form and construction of the apparatus without departing from the spirit or scope of the invention. It will also be understood that the present invention is particularly useful with refrigeration systems using water as both a refrigerant and a cooling medium and that if other refrigerants are used they must have vapor characteristics similar to water or a different cooling medium must be used having vapor characteristics similar to those of the refrigerant. Therefore, without limiting myself in this respect, I claim:

1. The method of purging non-condensible gases from an absorption refrigeration system operating in a partial vacuum and having a condenser and fluid operated aspirator connected to the condenser which comprises condensing refrigerant vapor in the condenser, segregating any non-condensible gases occurring in the condenser, cooling the gases to a temperature substantially below the condensing temperature to reduce the partial pressure and proportional amount of refrigerant vapor in the gases, flowing a fluid through the aspirator to produce a pressure therein corresponding to the vapor pressure of the fluid flowing therethrough, and varying the vapor pressure of the fluid flowing through the aspirator above and below the pressure at which media will flow from the condenser to the aspirator in accordance with the amount of non-condensible gases in the condenser.

2. The method of purging non-condensible gases from an absorption refrigeration system operating in a partial vacuum and having a condenser and water-operated aspirator connected to the condenser which comprises condensing refrigerant vapor in the condenser, segregating any non-condensible gases occurring in the condenser, cooling the gases to substantially the temperature of the cooling water entering the condenser to reduce the partial pressure and proportional amount of refrigerant vapor in the gases, flowing water through the aspirator to produce a pressure corresponding to the vapor pressure of the water flowing therethrough, and varying the vapor pressure of the water above and below the pressure at which media will flow from the condenser to the aspirator in accordance with the amount of non-condensible gases in the condenser.

3. The method of purging non-condensible gases from an absorption refrigeration system operating in a partial vacuum and having a condenser and water-operated aspirator connected to the condenser which comprises flowing cooling water through the condenser and aspirator successively to condense refrigerant vapor in the condenser and produce a pressure in the aspirator substantially equal to the vapor pressure of the water flowing therethrough, cooling any non-condensible gases in the condenser to substantially the same temperature as the temperature of the cooling water entering the condenser to reduce the partial pressure and proportional amount of refrigerant vapor in the gases, and automatically decreasing the temperature of the water supplied to the aspirator in response to the presence of non-condensible gases in the condenser to decrease the pressure produced by the aspirator below the pressure at which media will flow from the condenser to the aspirator to withdraw the gases

4. The method of purging non-condensible gases from an absorption refrigeration system operating in a partial vacuum and having a main condenser, an auxiliary condenser connected to the main condenser and a water-operated aspirator connected to the auxiliary condenser which comprises flowing cooling water through the auxiliary condenser in a direction counter-current to the direction of flow of the refrigerant vapor therein to condense the refrigerant vapor, operating the auxiliary condenser at a slightly lower pressure than the main condenser to cause media

to flow to the auxiliary condenser and segregate any non-condensible gases at the end where the cooling water enters the condenser, said cooling water cooling the non-condensible gases to substantially the same temperature as the temperature and vapor pressure of the cooling water entering the condenser to reduce the amount of refrigerant vapor therein, and flowing water through the aspirator to withdraw non-condensible gases from the auxiliary condenser.

5. The method of purging non-condensible gases from an absorption refrigeration system operating in a partial vacuum and having a condenser and water-operated aspirator connected to the condenser which comprises flowing cooling water through the condenser in a direction countercurrent to the direction of flow of refrigerant vapor therethrough to condense refrigerant vapor therein and segregate non-condensible gases at the end where the cooling water enters the condenser, said cooling water cooling the non-condensible gases to substantially the same temperature as the temperature of the water entering the condenser, directing the cooling water from the condenser through the aspirator to produce a pressure therein corresponding to the vapor pressure of the cooling water, resisting the flow of media between the condenser and aspirator to produce a pressure drop therebetween, and varying the vapor pressure of the water supplied to the aspirator in accordance with the presence or absence of non-condensible gases in the condenser to vary the pressure produced by the aspirator to values below and above the pressure at which media will flow from the condenser to the aspirator.

6. The method of purging non-condensible gases from an absorption refrigeration system operating in a partial vacuum and having a condenser and water-operated aspirator connected to the condenser which comprises transferring non-condensible gases from the various elements of the system to the condenser, flowing cooling water through the condenser in a direction countercurrent to the direction of flow of refrigerant vapor therethrough to condense the refrigerant vapor therein and segregate non-condensible gases at the end where the cooling water enters the condenser, said cooling water cooling the gases to the temperature of the cooling water entering the condenser, passing the cooling water from the condenser through the aspirator to produce a pressure therein corresponding to the vapor pressure of the water flowing therethrough, resisting the flow of media between the condenser and aspirator to produce a pressure drop therebetween, and automatically decreasing the vapor pressure of the water supplied to the aspirator in response to the amount of non-condensible gases in the condenser until the pressure produced by the aspirator is less than the pressure at which media will flow from the condenser to the aspirator.

7. The method of purging non-condensible gases from an absorption refrigeration system operating in a partial vacuum and having a condenser and water-operated aspirator connected to the condenser which comprises flowing cooling water through the condenser in a direction countercurrent to the direction of flow of refrigerant vapor therethrough to condense refrigerant vapor therein and segregate non-condensible gases at the end where the cooling water enters the condenser, resisting the flow of media between the condenser and aspirator to produce a pressure drop therebetween, supplying water to the aspirator at such a temperature that its vapor pressure is above the pressure in the condenser less the pressure drop due to the resistance so that no refrigerant vapor will flow from the condenser to the aspirator, and decreasing the temperature and vapor pressure of the water supplied to the aspirator in accordance with the amount of non-condensible gases in the condenser until the aspirator produces a pressure below the pressure in the condenser less the pressure drop due to the resistance whereby to withdraw the gases from the condenser.

8. The method of purging non-condensible gases from an absorption refrigeration system operating in a partial vacuum and having an auxiliary condenser and water operated aspirator connected to the main condenser which comprises flowing cooling water through the auxiliary condenser and aspirator successively to condense refrigerant vapor in the condenser and create a partial vacuum in the aspirator corresponding to the vapor pressure of the water flowing therethrough, and resisting the flow of media between the auxiliary condenser and aspirator to produce a substantial pressure drop therebetween, and thereby reduce the temperature and vapor pressure of the cooling water at which the aspirator will operate to withdraw media from the auxiliary condenser whereby to progressively cool the gases as they accumulate in the condenser.

9. The method of purging non-condensible gases from an absorption refrigeration system operating in a partial vacuum and having an auxiliary condenser and water-operated aspirator connected to the main condenser which comprises flowing cooling water through the auxiliary condenser and aspirator successively to condense refrigerant vapor in the auxiliary condenser and produce a pressure in the aspirator corresponding to the vapor pressure of the water, the vapor pressure of the water in the aspirator varying from a maximum to a minimum depending upon the amount of non-condensible gases in the auxiliary condenser, and resisting the flow of media between the condenser and aspirator to produce a substantial pressure drop and reduce the pressure at which the aspirator will operate to withdraw gases from the condenser to a minimum.

10. The method of purging non-condensible gases from an absorption refrigeration system operating in a partial vacuum and having a condenser and water-operated aspirator connected to the condenser which comprises flowing cooling water through the condenser in the same direction as the refrigerant vapor and non-condensible gases, flowing the cooling water through the condenser and aspirator successively to condense refrigerant vapor in the condenser and produce a pressure in the aspirator substantially the same as the vapor pressure of the water, the temperature of the water in the aspirator varying from a value above the condenser inlet temperature to a value slightly below the condensing temperature depending upon the amount of non-condensible gases in the condenser, and resisting the flow of media between the condenser and aspirator to produce a pressure drop therebetween only slightly less than the difference between the total pressure and partial pressure of refrigerant vapor in the condenser when the latter is filled with non-condensible gases whereby the aspirator is operative automatically to withdraw the gases

with a minimum amount of refrigerant vapor therein.

11. In a two pressure absorption refrigeration system of the type which operates in a partial vacuum and in which non-condensible gases may accumulate, a generator, a condenser, an evaporator, an absorber, means connecting the elements for circulation of refrigeration and absorbent therethrough while maintaining the pressure differential, an auxiliary condenser connected to said system, a water-operated aspirator connected to said auxiliary condenser, means for supplying water for flow through the auxiliary condenser and aspirator successively, and means in the connection between the auxiliary condenser and aspirator to produce a substantial pressure drop therebetween.

12. In a two pressure absorption refrigeration system of the type which operates in a partial vacuum and utilizes water as a refrigerant, a fall tube pump for transferring non-condensible gases from the low pressure side to the high pressure side of the system while maintaining the pressure differential therebetween, a condenser connected to the high pressure side of said system, a water-operated aspirator connected to said condenser, means for flowing cooling water through the condenser and aspirator successively to condense refrigerant vapor in the condenser and produce a pressure in the aspirator corresponding to the vapor pressure of the cooling water flowing therethrough, the temperature and vapor pressure of the cooling water in the aspirator decreasing proportionately to the amount of non-condensible gases present in the condenser, and means between the condenser and aspirator to substantially reduce the pressure at which media will flow from the condenser to the aspirator whereby the aspirator operates to withdraw non-condensible gases from all parts of the system and the last named means operates to reduce the amount of refrigerant withdrawn with the gases.

13. In an absorption refrigeration system of the type which operates in a partial vacuum and in which non-condensible gases may accumulate, a generator, a condenser, an evaporator, an absorber, means interconnecting the elements for the circulation of a refrigerant and absorbent, an auxiliary condenser connected to said system, a water-operated aspirator connected to said auxiliary condenser, means for flowing water through the auxiliary condenser and aspirator successively, and a check valve between the auxiliary condenser and aspirator for permitting the flow of non-condensible gases to the aspirator while preventing the flow of atmospheric air into the system, said check valve being loaded to produce a substantial pressure drop in the connection between the auxiliary condenser and aspirator.

14. In an absorption refrigeration system of the type which operates in a partial vacuum and in which non-condensible gases may accumulate, a condenser connected to said system, a water-operated aspirator connected to said condenser, conduits providing a path of flow for cooling water through the condenser and aspirator successively, said conduits being connected to the condenser to cause the cooling water to flow therethrough in a direction countercurrent to the direction of flow of refrigerant vapor therein to segregate and cool any non-condensible gases to the temperature of the water entering the condenser, and means between the condenser and aspirator to produce a pressure drop greater than the difference between the pressure in the condenser and the pressure produced by the aspirator when no non-condensible gases are present in the condenser.

15. In an absorption refrigeration system of the type which operates in a partial vacuum and utilizes water as a refrigerant, a generator, a condenser, an evaporator, an absorber, means interconnecting the elements to provide a closed circuit for the circulation of a refrigerant and absorbent, an auxiliary condenser connected to said system, a water-operated aspirator connected to said auxiliary condenser, conduits providing a path of flow for cooling water through the auxiliary condenser and aspirator successively, said conduits being connected to the auxiliary condenser to cause the cooling water to flow therethrough in a direction countercurrent to the direction of flow of refrigerant vapor therein to segregate and cool any non-condensible gases to the temperature of the water entering the auxiliary condenser, and means between the auxiliary condenser and aspirator to produce a substantial pressure drop therebetween.

16. In an absorption refrigeration system of the type which operates in a partial vacuum and utilizes water as a refrigerant, a condenser connected to said system, a water-operated aspirator connected to said condenser, conduits providing a path of flow for cooling water through the condenser and aspirator successively, said conduits being connected to the condenser to cause the cooling water to flow therethrough in the same direction as the refrigerant vapor therein, the temperature and vapor pressure of the cooling water in the aspirator decreasing proportionately to the amount of non-condensible gases present in the condenser, and a check valve between the condenser and aspirator for permitting the flow of non-condensible gases to the aspirator while preventing the flow of atmospheric air to the system, said check valve being loaded to reduce the pressure at which media will flow from the condenser to the aspirator to cool the gases to a temperature substantially lower than the condensing temperature.

17. In an absorption refrigeration system of the type which operates in a partial vacuum and in which non-condensible gases may accumulate, a condenser connected in said system, a water-operated aspirator connected to said condenser, means providing a path of flow for water through the condenser and aspirator successively, a check valve between the condenser and aspirator, and a packing in the connection between the condenser and aspirator, said check valve and packing cooperating to produce a pressure drop between the condenser and aspirator.

18. In an absorption refrigeration system of the type which operates in a partial vacuum and in which non-condensible gases may accumulate, a generator, a condenser, an evaporator, an absorber, means interconnecting the elements to provide a closed circuit for the circulation of a refrigerant and absorbent, an auxiliary condenser connected to the main condenser, a water-operated aspirator connected to the auxiliary condenser, conduits providing a path of flow for cooling water through the auxiliary condenser and aspirator successively, said conduits being connected to the auxiliary condenser to cause the cooling water to flow in a direction countercurrent to the direction of flow of refrigerant vapor therein, and a check valve for producing a pressure drop in the connection between the condenser and aspirator.

19. In an absorption refrigeration system of the type which operates in a partial vacuum and utilizes water as a refrigerant, a generator, a condenser, an evaporator, an absorber, means interconnecting the elements to provide a closed circuit for the circulation of a refrigerant and absorbent, means including a fall tube pump for continuously transferring non-condensible gases from the various elements to the condenser, an auxiliary condenser connected to the main condenser, a water-operated aspirator connected to the auxiliary condenser, conduits providing a path of flow for cooling water through the auxiliary condenser and aspirator successively, said conduits being connected to the auxiliary condenser to cause the cooling water to flow therethrough in a direction countercurrent to the flow of refrigerant vapor therein, and a check valve to produce a pressure drop in the connection between the condenser and aspirator.

20. In an absorption refrigeration system of the type which operates in a partial vacuum and utilizes water as a refrigerant, a generator, a condenser, an evaporator, an absorber, means interconnecting the elements to provide a closed circuit for the circulation of a refrigerant and absorbent, means including a fall tube pump for continuously transferring non-condensible gases from the various parts of the system to the condenser, an auxiliary condenser connected to the main condenser, a water-operated aspirator connected to the auxiliary condenser, means providing a path of flow for cooling water through the auxiliary condenser and aspirator successively to condense refrigerant vapor in the condenser and produce a pressure in the aspirator corresponding to the vapor pressure of the cooling water flowing therethrough, the temperature and vapor pressure of the cooling water in the aspirator decreasing proportionately to the amount of non-condensible gases present in the condenser, and a check valve between the condenser and aspirator to materially reduce the pressure at which media will flow from the condenser to the aspirator.

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