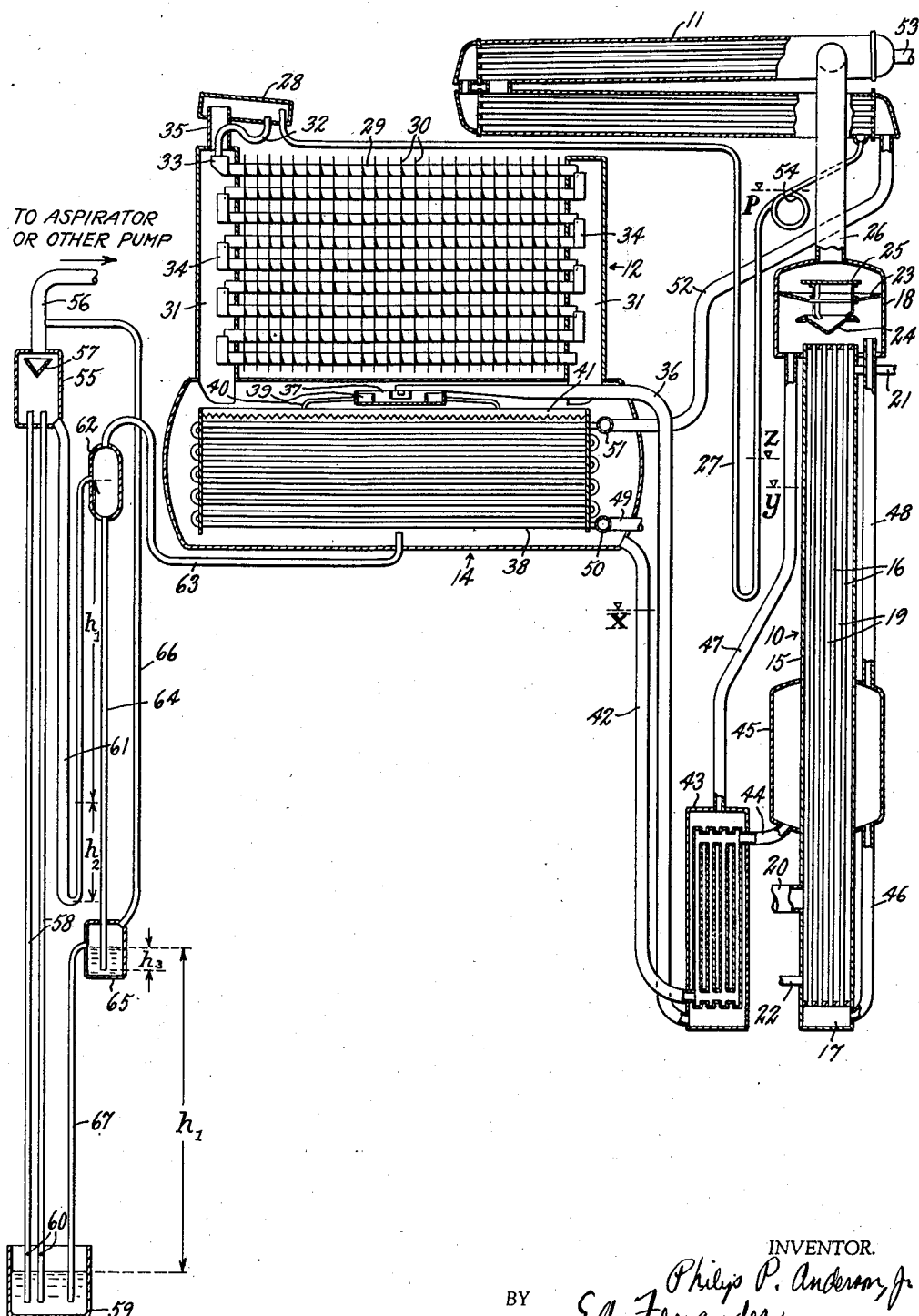


2,363,381

Filed Aug. 3, 1940



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UNITED STATES PATENT OFFICE

2,363,381

REFRIGERATION

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Application August 3, 1940, Serial No. 350,883

5 Claims. (Cl. 62—119)

This invention relates to refrigeration, and is particularly concerned with non-condensable gases that collect in refrigeration systems of the absorption type operated by heat.

In a low pressure system of this type containing only a refrigerant and an absorption liquid therefor as the two active fluid components, a generator and condenser operate at one pressure and an evaporator and absorber operate at a lower pressure, and the pressure differential therebetween may be maintained by liquid columns. In a refrigeration system of the type just referred to and having an ice melting capacity of five tons, with the system operating at full load and the evaporator at a temperature of about 50° F., the vapor pressure in the evaporator and absorber is approximately 9 mm. Hg, and the vapor pressure in the generator and condenser is approximately 56 mm. Hg.

During operation of the refrigeration system, non-condensable gases may collect in parts thereof to increase the vapor pressure in the system. The collection of non-condensable gases and the resulting increase in vapor pressure in the system is undesirable, because the efficiency of the refrigeration system is reduced and the normal operation thereof may be disturbed.

It is an object of this invention to provide an improvement for removing non-condensable gases from refrigeration systems. I accomplish this by providing, in a two-pressure system of the type described, an arrangement for utilizing flow of refrigerant from the condenser to the evaporator to effect removal of non-condensable gases from the generator and condenser to the evaporator and absorber. This is accomplished by providing a siphon trap in the conduit through which liquid flows from the condenser to the evaporator.

It is another object of the invention to provide an improved vacuum pump for trapping and removing non-condensable gases from a refrigeration system. In the present embodiment the vacuum pump is connected to the absorber although the pump may be connected to other parts of the system, such as, for example, the condenser. The vacuum pump is a two-stage device which possesses inherent advantages over a single stage pump. A distinct advantage is also obtained in the vacuum pump provided in that a uniform pressure drop is effected on both sides of a U-tube embodied in the pump when the pump is first started. The vacuum pump employs an aspirator which is exceptionally fast and can be used to reduce the vapor pressure in the re-

frigeration system to an extremely low value. Further, the vacuum pump embodying the invention can be connected either to the condenser or to the absorber of a two-pressure refrigeration system of the type described above, and ordinary variations in temperature of the water operating the aspirator will not greatly affect the operation of the vacuum pump.

Usually the purge valve of a refrigeration system to which a vacuum pump is connected can only be opened after the vacuum pump has lowered the pressure in the connection below the pressure existing in the refrigeration system. In the vacuum pump provided, after the vacuum has been pulled once and the pump left attached to the system, the purge valve may be opened even before operation of the vacuum pump has been started, so that the usual precaution that must be taken with respect to keeping the purge valve closed until a vacuum has been produced by the pump, is avoided. In addition to avoiding the usual precaution that must be taken with respect to keeping the purge valve of the refrigeration system closed until a vacuum has been produced, the vacuum pump provided eliminates a pressure indicating device in the vacuum pump connection to the purge valve of the system.

The invention, together with the above and other objects and advantages thereof, will be better understood from the following description taken in connection with the accompanying drawing forming a part of this specification, and of which the single figure more or less diagrammatically illustrates a refrigeration system and a vacuum pump embodying the invention.

Referring to the drawing, the present invention is shown in connection with a two-pressure absorption refrigeration system like that described in application Serial No. 239,762 of Albert R. Thomas and P. P. Anderson, Jr., filed November 10, 1938, now Patent No. 2,282,503, granted May 12, 1942. A system of this type operates at low pressures and includes a generator or expeller 10, a condenser 11, an evaporator 12 and an absorber 14 which are interconnected in such a manner that the pressure differential in the system is maintained by liquid columns.

The disclosure in the aforementioned Thomas and Anderson application may be considered as being incorporated in this application, and, if desired, reference may be made thereto for a detailed description of the refrigeration system. In Fig. 1 the generator 10 includes an outer shell 15 within which are disposed a plurality of ver-

tical riser tubes 16 having the lower ends thereof communicating with a space 17 and the upper ends thereof extending into and above the bottom of a vessel 18. The space 19 within shell 15 and about the tubes 16 forms a steam chamber to which steam is supplied through a conduit 20. The space 19 provides for full length heating of riser tubes 16, and a vent 21 is provided at the upper end of shell 15. A trap conduit 22 is connected to the lower part of shell 15 for draining condensate from space 19.

The system operates at a partial vacuum and contains a water solution of refrigerant in absorption liquid, such as, for example, a water solution of 40% lithium chloride by weight. With steam being supplied from conduit 20 to space 19, heat is applied to tubes 16 whereby water vapor is expelled from solution. The absorption liquid is raised by gas or vapor-lift action with the expelled water vapor forming a central core within an upwardly rising annulus of the liquid. The expelled water vapor rises more rapidly than the liquid and the latter follows the inside walls of tubes 16.

The water vapor flows upwardly through the tubes or risers 16 into vessel 18 which is provided with an apertured baffle 23 and deflectors 24 and 25 at each side of the aperture in the baffle. The baffle 23 and deflectors 24 and 25 serve as a vapor separator so that expelled water vapor is separated from raised absorption liquid in vessel 18 and flow through conduit 26 into condenser 11. The water vapor is liquefied in condenser 11 and the water thus formed flows through a U-tube 27 into a flash chamber 28 and then into evaporator 12.

The evaporator 12 includes a plurality of horizontal banks of tubes 29 disposed one above the other and to which are secured heat transfer fins 30 to provide a relatively extensive heat transfer surface. The end portions of the tubes 29 pass into spaced vertical headers 31. The water flows from flash chamber 28 through a trap conduit 32 into a liquid distributing trough 33 from which the water flows into the uppermost horizontal bank of tubes 29. The water passes through successively lower banks of tubes through upright open end sections 34 at the ends of tubes 29, whereby shallow pools of liquid are formed in the tubes 29 with excess liquid being discharged from the lower-most bank of tubes 29.

The water supplied to tubes 29 evaporates therein to produce a refrigeration or cooling effect with consequent absorption of heat from the surroundings, as from a stream of air flowing over the exterior surfaces of the tubes 29 and fins 30. The vapor formed in tubes 29 passes out through the distributing trough 33 and open end sections 34 into the headers 31 which are connected at their lower ends to absorber 14. To prevent disturbances in evaporator 12 the flash chamber 28 is provided to take care of any vapor flashing of liquid being fed to the evaporator through U-tube 27. The flashed vapor formed in the initial cooling of the liquid flowing from the condenser passes through a conduit 35 into one of the headers 31 and mixes with vapor formed in evaporator 12.

In absorber 14 refrigerant vapor is absorbed into concentrated absorption liquid which enters through a conduit 36. The absorption liquid flows from the upper end of conduit 36 into a liquid receptacle and distributor 37 in which liquid is distributed laterally of a plu-

rality of vertically disposed pipe banks 38 which are arranged alongside of each other. The liquid in the center compartment of receptacle 37 is sub-divided and passes into a plurality of smaller end compartments 39 from which liquid flows through conduits 40 into a plurality of liquid holders and distributors 41 extending lengthwise of and above the uppermost horizontal pipe sections of pipe banks 38. Absorption liquid siphons over the walls of the liquid holders 41 with drops of liquid falling onto and completely wetting the uppermost pipe sections. Liquid drips from each horizontal pipe section onto the next lower pipe section whereby all of the pipe sections are wetted with a film of liquid.

The water vapor formed in evaporator 12 passes through the headers 31 into the shell of absorber 14 and is absorbed into absorption liquid in the latter. The water vapor absorbed in the liquid dilutes the latter, and the diluted absorption liquid flows through a conduit 42, a first passage in liquid heat exchanger 43, conduit 44, vessel 45, and conduit 46 into the lower space 17 of generator 10. Water vapor is expelled out of solution in generator 10 by heating, and the solution is raised by gas or vapor-lift action in riser tubes 16, as explained above. The absorption liquid in vessel 18 is concentrated since water vapor has been expelled therefrom in generator 10. This concentrated absorption liquid flows through a conduit 47, a second passage in liquid heat exchanger 43, and conduit 36 into the upper part of absorber 14. This circulation of absorption liquid results from the raising of liquid by vapor-lift action in vertical riser tubes 16, whereby the liquid can flow to absorber 14 and return from the latter to the generator by force of gravity.

The vessel 45 is cylindrical in shape and disposed about shell 15 of generator 10. The heating effect of the steam in space 19 is transmitted through a portion of shell 15 to absorption liquid in vessel 45. In this manner the absorption liquid flowing to generator 10 through conduit 46 is preheated, as described more fully in Thomas application Serial No. 347,631, filed July 26, 1940. The upper part of vessel 45 is connected by a conduit 48 to vessel 18, so that the pressure in vessel 45 is equalized with the pressure in the upper end of generator 10 and condenser 11.

The heat liberated with absorption of water vapor in absorber 14 is transferred to a cooling medium, such as water, for example, which flows upward through the vertically disposed pipe banks 38. The cooling medium is supplied through a conduit 49 to a horizontal manifold 50 to which the lower ends of the pipe banks 38 are connected. The upper ends of the pipe banks 38 are connected to a manifold 51 to which is connected a conduit 52 through which cooling medium leaves the absorber 14. The conduit 52 is connected to condenser 11 so that the same cooling medium may be utilized to cool absorber 14 and condenser 11, with the cooling medium flowing from condenser 11 through conduit 53 to waste.

The system operates at a low pressure with the generator 10 and condenser 11 operating at one pressure and the evaporator 12 and absorber 14 operating at a lower pressure, the pressure differential therebetween being maintained by liquid columns. Thus, the liquid column formed in tube 27 maintains the pressure differential be-

tween condenser 11 and evaporator 12, the liquid column in conduit 42 maintains the pressure differential between the outlet of absorber 14 and generator 10, and the liquid column formed in conduit 36 and connected parts including conduit 47 maintains the pressure differential between the inlet of absorber 14 and generator 10. In operation, the liquid columns may form in conduits 42, 47 and the down-leg of tube 27 to the levels *x*, *y* and *z*, for example. The conduits are of such size that restriction to gas flow is effected without appreciably restricting flow of liquid.

The liquid column formed in vessel 45 and conduit 46 provides the liquid reaction head for raising liquid in riser tubes 16 by vapor-lift action. The vessel 45 is of sufficient volume to hold the liquid differential in the system and is of such cross-sectional area that the liquid level therein does not appreciably vary, so that a substantially constant reaction head is provided for lifting liquid in generator 10.

In accordance with this invention, in order to effect removal of non-condensable gases from condenser 11 to evaporator 12 and absorber 14, a liquid siphon trap 54 is provided in the U-tube 27. The siphon trap 54 may be of any desired shape, and, as shown, is in the form of a complete circular loop in the down-leg of U-tube 27.

During operation of the refrigeration system, liquid flows from the condenser into loop 54. When the liquid in the right-hand side of loop 54 reaches the level *p*, the liquid is siphoned from the loop into the down-leg of U-tube 27. The gas in the down-leg of U-tube 27, between loop 54 and the liquid level *z*, is trapped by the liquid siphoned from the loop. After the liquid has siphoned from the loop, gas freely passes from the condenser 11 through the loop 54 into the down-leg of U-tube 27. When the liquid from condenser 11 again reaches the level *p* in the right-hand side of loop 54, the liquid is again siphoned from the loop into the down-leg of U-tube 27, whereby the gas passing into the down-leg from condenser 11 before the liquid seal is formed in loop 54 is segregated by the liquid subsequently siphoned into the down-leg of the U-tube 27.

The gas segregated between the successive short liquid columns or slugs siphoned from loop 54 is compressed by the siphoned liquid and caused to pass through the U-tube 27 by the gravity flow of liquid from condenser 11 to evaporator 12. Thus, when the system is first started and before the pressure differential has been built up between the condenser and evaporator, the U-tube 27 completely fills with liquid and gravity flow of liquid is effected from the condenser to the evaporator. Even after the pressure differential has built up between the evaporator and condenser, and the liquid level is at *z*, for example, in the down-leg of U-tube 27 due to the higher pressure in condenser 11 than in evaporator 12, still flow of liquid is effected by gravity from the condenser to the evaporator. And it is with this gravity flow of liquid and siphoning thereof from loop 54 that effects trapping of gas in the down-leg of tube 27 and the transmission of the trapped gas by the liquid to the evaporator. In this way non-condensable gases collecting in the upper part of generator 10 and condenser 11 are effectively removed from these parts of the system to the evaporator 12 and absorber 14 to which the vacuum pump, embodying another feature of the inven-

tion, is connected for removing non-condensable gases from the refrigeration system.

The vacuum pump includes an upper closed vessel 55 which is connected by a conduit 56 to an aspirator or other suitable pump. An aspirator, in which a suction or vacuum is produced in vessel 55 by connecting the aspirator to a tap supplied with city water at the usual pressures, has been successfully employed. The vessel 55 is provided with a suitable baffle 57 to separate from liquid the gas or vapor which is drawn through conduit 56 by the action of the aspirator. Into the lower part of vessel 55 extend riser tubes 58 through which a liquid, such as mercury, for example, is raised from a lower vessel or well 59. The vessel 59 is open at the top and the riser tubes 58 are formed with openings 60 to allow air to enter into the tubes 58, so as to break up the mercury in the extreme lower parts of the tubes into drops which are raised in the riser tubes 58 due to the vacuum in vessel 55 produced by the operation of the aspirator. The tubes 58 extend above the bottom of vessel 55, and the raised mercury flows into the down-leg of U-tube 61, while the air passes through conduit 56 to the aspirator. The internal diameter of the down-leg of U-tube 61 is sufficiently large to permit the escape of any air which is entrained by the mercury flowing from vessel 55 into the U-tube. The mercury flows through U-tube 61 into a vessel 62 having the upper part thereof connected by a conduit 63 to the absorber 14 of the refrigeration system.

The non-condensable gases collecting in the evaporator 12, including the gases removed from the generator 10 and condenser 11 through U-tube 27 in the manner described above, are heavier than the water vapor formed in evaporator 12. The water vapor passes from the evaporator 12 to the absorber 14 at a relatively high velocity. In a refrigeration system having a capacity of five tons, with the system operating at full load and the evaporator at a temperature of about 50° F., the average velocity of the vapor passing from the evaporator to the absorber is about 130 feet per second for the pressure existing in the system. Under these conditions, the heavier non-condensable gases are swept by natural convection to the farthest point of the path of flow of vapor, which is midway between the headers 31 at the extreme lower part of the absorber 14, as described more fully in application Serial No. 350,236, of A. R. Thomas, filed August 3, 1940. In view of the foregoing, the conduit 63 terminates in the extreme lower part of the absorber at the middle or central portion thereof.

The mercury flowing from the U-tube 61 into vessel 62 forms slugs at the upper end of a vertical tube 64 connected to the lower part of this vessel. Gas is entrained between the slugs of mercury as they form at the upper end of tube 64. The gas entrained by the mercury slugs is drawn into vessel 62 through conduit 63 which, as pointed out above, terminates in the absorber 14 at the region where the non-condensable gases are swept by the vapor flowing from the evaporator to the absorber. In entraining gas by the mercury slugs at the upper end of tube 64, a relatively high vacuum is produced in the evaporator 12 and absorber 14. The trapped gas and mercury slugs fall in tube 64 which may be referred to as a fall tube pump. The gas and mercury slugs fall into a vessel 65 into which the lower end of tube 64 extends. From vessel 65 the gas flows through a conduit 66 to conduit 56

and then passes to the aspirator. The mercury passes from vessel 65 through an overflow conduit 67 to the well or open top vessel 59.

When the vacuum pump just described is not operating, the mercury column in U-tube 61 maintains the pressure differential between atmosphere, which is the pressure in vessel 55, and the vacuum in vessel 62 to which the absorber 14 is connected. Similarly, when the vacuum pump is not operating, the mercury column in fall tube 64 and vessel 65 maintains the pressure differential between atmosphere, which is the pressure in conduit 66, and the vacuum in vessel 62 and absorber 14. The quantity of mercury retained in vessel 65 must be such that there will be a sufficient amount to fill the fall tube 64 and still cover adequately the lower end of the fall tube. It is desirable to make the fall tube 64 as long as possible, and this tube must be as long as the barometric height.

When the vacuum pump is operating, the difference in liquid levels in the two legs of U-tube 61 will correspond to the difference in pressure maintained by the aspirator in vessel 55 and the pressure in vessel 62 in the high vacuum side. The mercury in conduit 67 is of a height equal to the vacuum pulled by the aspirator which is indicated in the drawing as h_1 . It will be noted that the U-tube 61 is also of barometric height h_1 with an additional length added thereto indicated as h_2 . The additional or extra length indicated as h_2 is added to the height of the U-tube 61 to insure a seal under all operating conditions encountered. For example, when the aspirator is shut off, surging occurs in the U-tube 61 due to the momentum of the mercury flowing from vessel 55 to vessel 62.

If the fall tube 64 extended from the vessel 62 into the well 59 and the vessel 65 and conduit connection 66 were omitted, a single stage pump would be provided with gas trapped in vessel 62 passing through tube 64 and rising from the lower end thereof directly to the atmosphere in well 59. However, by providing a fall tube 64 of the character shown and employing an additional vessel 65 to which the conduit 66 is connected at one end with the other end connected to the aspirator, a vacuum pump is provided which is essentially a two stage pump. The first pressure stage is from the high vacuum side with which vessel 62 is associated to the pressure maintained in conduit 66 by the aspirator plus the head of the liquid column in vessel 65 which is indicated as h_3 . The second pressure stage is from the aspirator pressure to atmospheric pressure.

By providing a two stage pump of the character described, the pressure is reduced evenly on both legs of the U-tube 61 when the operation of the vacuum pump is first started and the pressure in vessel 62 is relatively high and near atmospheric pressure, for example. This is due to the fact that the pressure in the left-hand leg of U-tube 61 is reduced by the action of the aspirator, and the pressure in the right-hand leg of U-tube 61 is also reduced by providing the conduit connection 66 so that the upper part of vessel 65 is subjected to the action of the aspirator. The lowering of the pressure in both legs of the U-tube 61 is even when the operation of the vacuum pump is first started, except for the constant pressure difference of the liquid column in vessel 65, which is indicated in the drawing as h_3 . Compensation is made for the constant pressure difference h_3

in vessel 65 by connecting the left-hand leg of U-tube 61 to vessel 55 a distance which is at least as great as the distance h_3 above the inlet to vessel 62.

If the conduit on 66 and vessel 65 were omitted and the fall tube 64 extended into the well 59, a single stage vacuum pump would be provided, as pointed out above. In a vacuum pump of this type circulation of mercury could only be started with much difficulty. In such case the fall tube 64 would necessarily extend into the well 59 a greater distance than the pump tubes 58 and the volume of vessel 55 must be sufficiently large to hold all of the mercury that would be pumped or raised from the well 59 through the tubes 58 to uncover the lower ends of the pump tubes 58. When operation of the aspirator is started and the pressure in vessel 55 is reduced, the fact that the conduit connection 66 is omitted would not permit an even pressure drop on both legs of the U-tube 61 and the mercury may tend to move upward in the left-hand leg of U-tube 61, especially when the pressure in vessel 62 is high and near atmospheric pressure. For this reason the aspirator action is such that a sufficient amount of mercury would have to be raised through the riser tubes 58 to uncover the lower ends thereof and allow air to pass through the tubes 58 to build up the pressure in vessel 55, so that flow of mercury therefrom into vessel 62 would be effected. As soon as sufficient mercury returns to the well 59 through the fall tube 64, which has been assumed in the foregoing description to be of sufficient length to extend into the well 59, the lower ends of the riser tubes 58 would again be covered and the cycle of operation just described would be repeated. These cycles would continue until the pressure in vessel 62 in the high vacuum side drops sufficiently for normal operation to occur, in the manner described above in connection with the embodiment of the invention illustrated.

In view of the foregoing, it will be apparent that in a two-stage vacuum pump of the character provided the starting operation is facilitated considerably, due to the manner in which the pressure drops on both legs of the U-tube 61. It has been observed that moisture in the mercury has no noticeable effect on the operation of the vacuum pump.

While a single embodiment of the invention has been shown and described, it will be apparent to those skilled in the art that various modifications and changes may be made without departing from the spirit and scope of the invention, as pointed out in the following claims.

What is claimed is:

1. An absorption refrigeration system having a generator and a condenser adapted to operate at one pressure and an evaporator and absorber adapted to operate at a lower pressure, and connections between the aforementioned parts to provide circuits for circulation of refrigerant and absorption liquid, said connections including a conduit connected to one of the parts at said one pressure and to another of the parts at said lower pressure and through which liquid is adapted to flow, the liquid in said conduit serving to maintain the pressure differential between the parts connected thereby, and a trap formed in said conduit arranged to receive liquid, the liquid flowing from said trap by siphon action when a predetermined quantity has accumulated therein, the successive bodies of liquid siphoned

from said trap segregating gas passing into said conduit during the periods when gas can flow through said trap, the gas segregated between the successive bodies of liquid being carried by the latter through said conduit from the said one part to said other part.

2. An absorption refrigeration system having a generator and a condenser adapted to operate at one pressure and an evaporator and absorber adapted to operate at a lower pressure, and connections between the aforementioned parts to provide circuits for circulation of refrigerant and absorption liquid, the circuit for circulation of refrigerant including a U-tube having a down-leg connected to the condenser and an up-leg connected to the evaporator, the liquid in said U-tube serving to maintain the pressure differential between the condenser and the evaporator, and a siphon trap arranged in the down-leg of said U-tube so that successive bodies of liquid form in said trap and intermittently flow therefrom to trap gas in said down-leg which passes therein during the periods when flow of the gas can take place from the condenser through said trap.

3. Structure for removing non-condensable gas from a refrigeration system operating at low pressures including an open well adapted to contain mercury, a first vessel at a higher level than said well, a riser tube having the lower end thereof extending below the liquid level of mercury in said well and the upper end thereof extending into said first vessel, vacuum producing means connected to said first vessel operative to reduce the pressure therein, the lower part of said riser tube having an air inlet opening whereby the mercury in the lower part of the tube is broken into drops and raised through the tube to said first vessel due to the reduced pressure in the latter, a second vessel connected to a part of the refrigeration system, a U-tube having one leg connected to the lower part of said first vessel

and the other leg connected to said second vessel, whereby mercury flows through said U-tube from said first vessel to said second vessel, a fall tube depending downward from said second vessel, the mercury entering said second vessel forming slugs and trapping gas at the upper part of said fall tube, a third vessel adapted to hold mercury and into which the lower end of the fall tube projects below the liquid level therein, a conduit for flowing mercury from said third vessel to said well, and a conduit connecting the upper part of said third vessel to said vacuum producing means whereby the vapor space above the mercury in said third vessel is also at a reduced pressure.

4. Structure for removing non-condensable gas from a refrigeration system operating at low pressures comprising a circuit for mercury including a fall tube in which gas from the system is trapped between successive slugs of mercury formed at the upper end of said fall tube, vacuum producing means, said circuit being so formed and arranged that circulation of mercury therein is effected by said vacuum producing means, a vessel containing mercury and into which the lower end of said fall tube extends, and said circuit including a connection whereby the pressure above the mercury in said vessel is reduced by said vacuum producing means.

5. Structure for removing non-condensable gas from a refrigeration system having a plurality of parts and operable below atmospheric pressure, said structure including a fall tube pump having the upper end in communication with a part of said system, a U-tube having one leg thereof connected to the upper end of said fall tube pump, means including said U-tube for supplying liquid to said fall tube pump for downward flow therethrough, and a vacuum producing device connected to the other leg of said U-tube and to the lower end of said fall tube pump.

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