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ABSORPTION REFRIGERATION UNIT WITH A CENTRIFUGAL SEPARATOR

Filed June 30, 1951

3 Sheets-Sheet 1

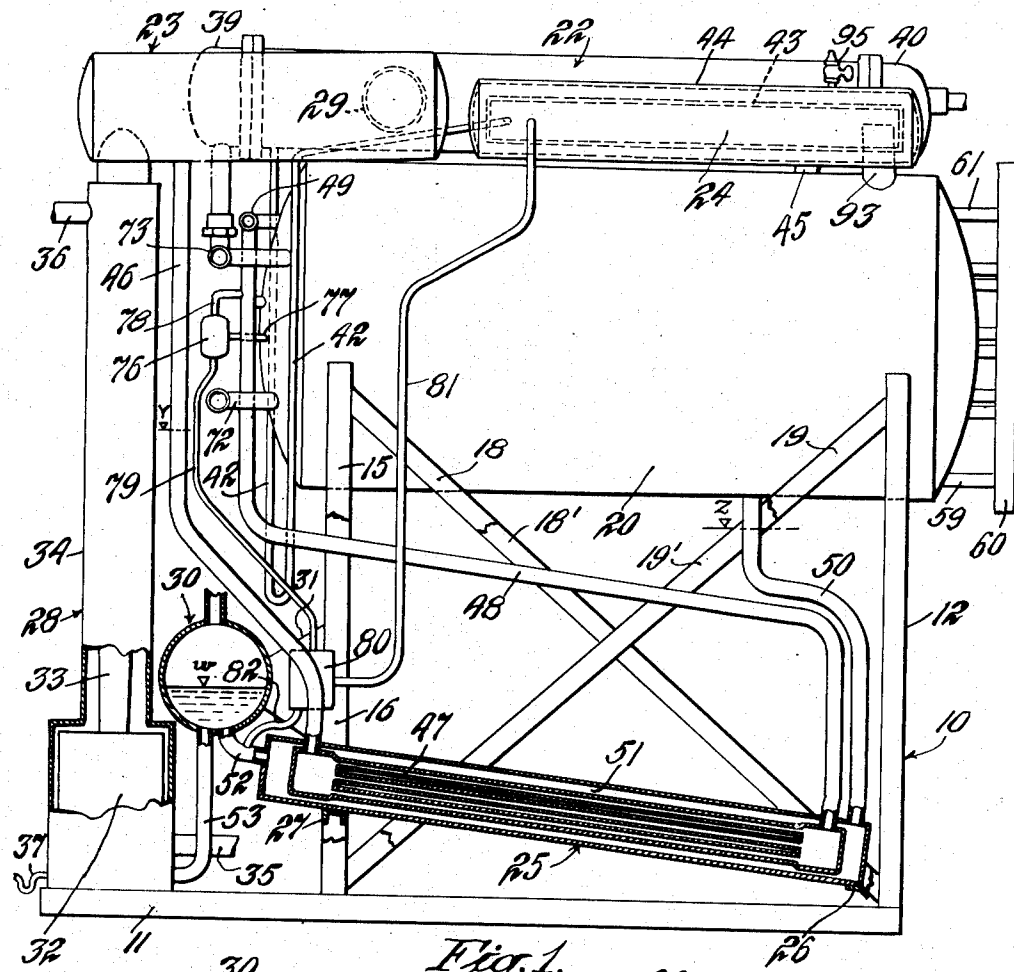


Fig. 1.

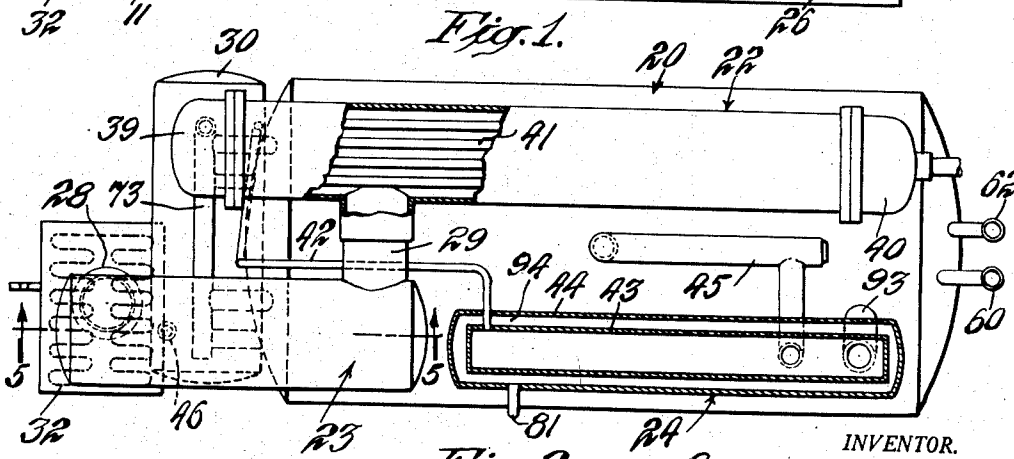


Fig. 2.

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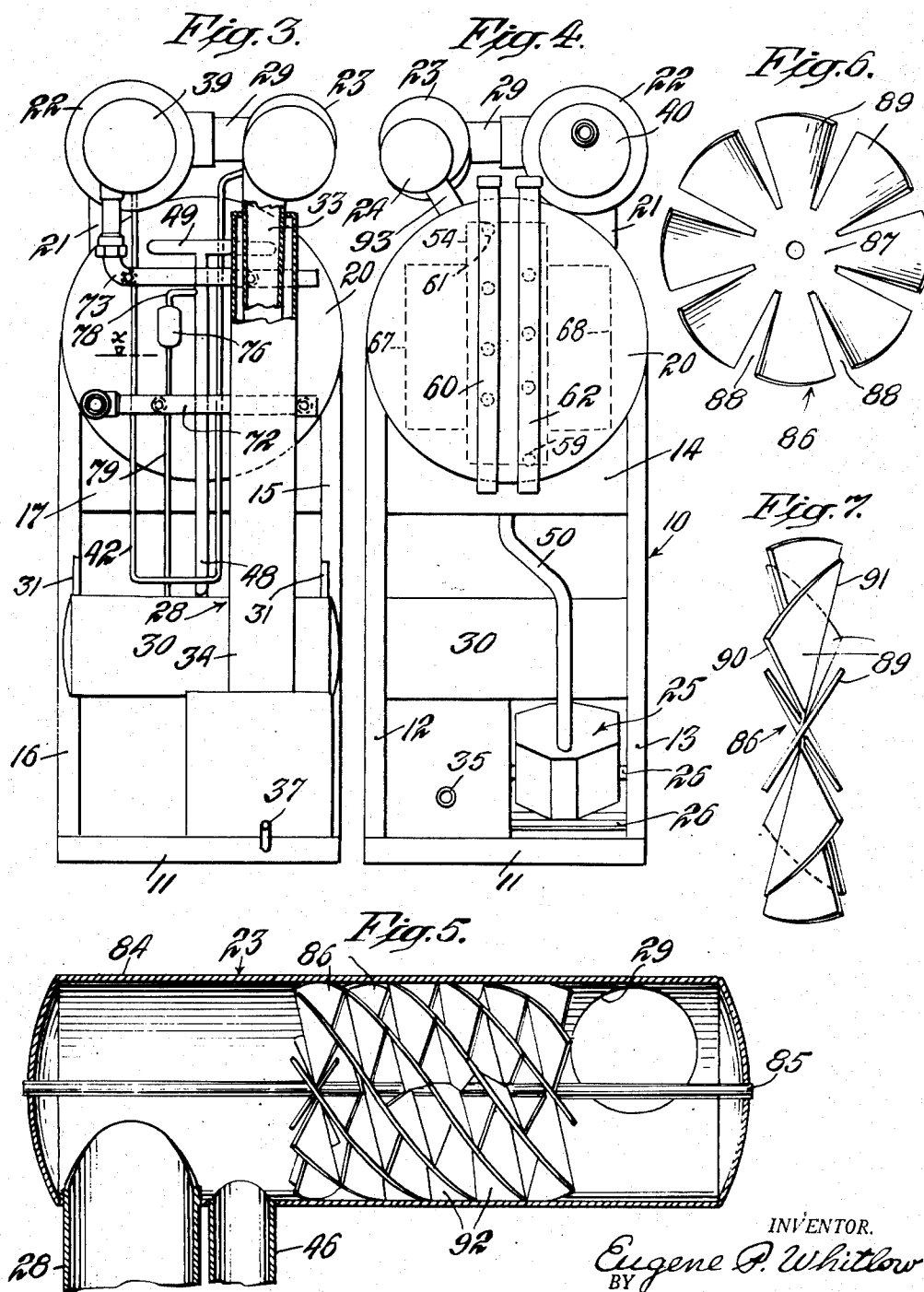
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3 Sheets-Sheet 2



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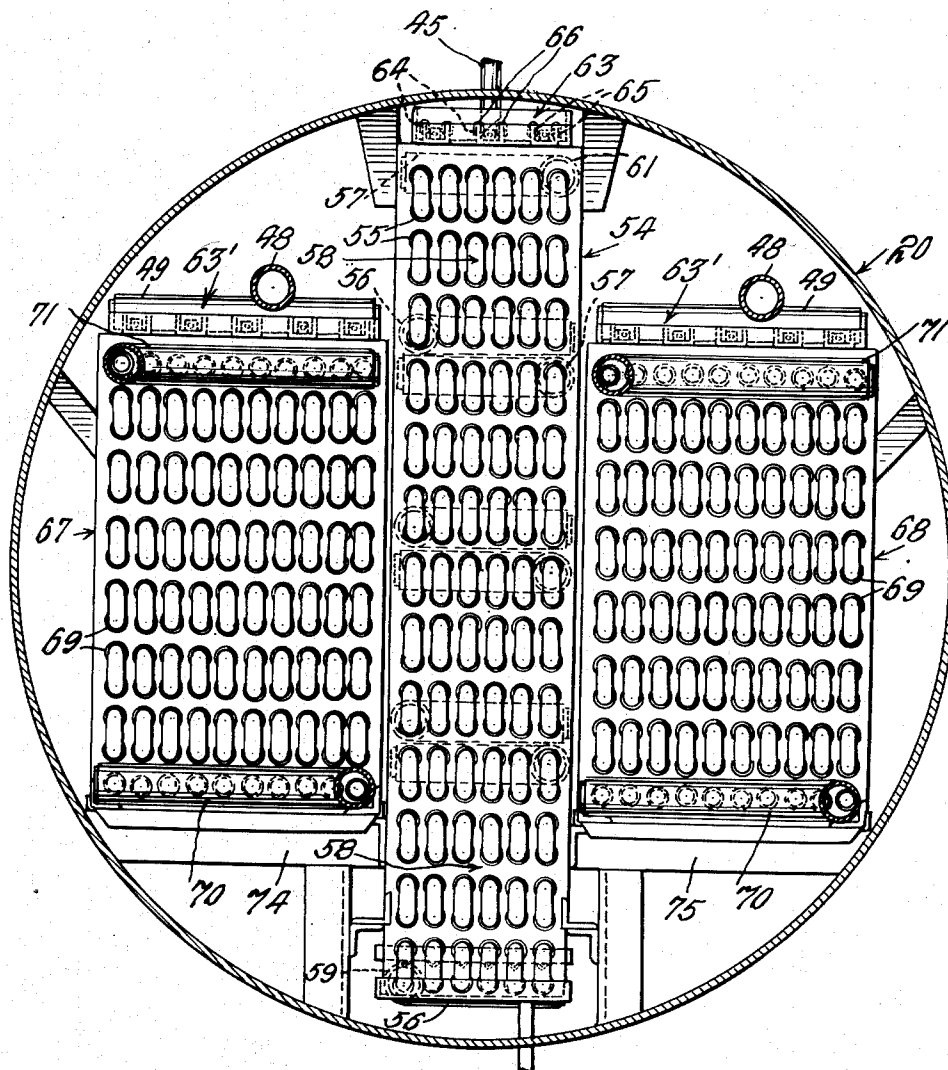
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3 Sheets-Sheet 3

Fig. 8.



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ABSORPTION REFRIGERATION UNIT WITH
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Application June 30, 1951, Serial No. 234,525

11 Claims. (Cl. 62-119)

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The present invention relates to refrigeration and more particularly to a self-contained absorption type refrigeration unit.

Relatively small self-contained vacuum type absorption refrigeration units of up to five-tons ice melting capacity a day have been extensively used for air conditioning. In such units the refrigerant is evaporated at the interior of a finned coil and the air to be cooled passes over the exterior of the coil and between the fins. In units of larger capacity such a direct expansion evaporator is impractical in a self-contained unit because it increases the size and weight of the unit to such a degree as to prevent it from being transported through door openings of usual dimensions and presents a problem of air distribution. Furthermore, in such units of larger capacity the separation of liquid absorbent from vapor and the cooling of the larger volume of liquid refrigerant present additional problems.

One of the objects of the present invention is to provide a novel construction and arrangement of elements to provide a self-contained vacuum type absorption refrigeration unit of relatively large capacity which is adapted to be transported through conventional door openings.

Another object is to provide a vacuum type absorption refrigeration unit in which a primary refrigerant is utilized to cool a secondary refrigerant which, in turn, is used to cool the air to provide a more compact construction and a greater flexibility of installation.

Another object is to provide a vacuum type absorption refrigeration apparatus of the type indicated with a centrifugal separator for directing expelled vapor in a circular path at high velocity to separate liquid therefrom by centrifugal force.

Another object is to provide a vacuum type absorption refrigeration apparatus with a flash chamber for cooling liquid refrigerant from the condenser to the evaporator temperature before it is introduced into the latter by evaporating a portion of the refrigerant and utilizing the vacuum of the system to insulate the flash chamber from the ambient.

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:

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Fig. 1 is a side elevational view of a self-contained vacuum type absorption refrigeration unit and showing the construction and arrangement of the parts thereof;

Fig. 2 is a top plan view of the apparatus showing the centrifugal separator and insulated flash chamber and showing their relationship to the other elements of the unit;

Fig. 3 is an end elevational view of the left hand end of the apparatus as viewed in Fig. 1;

Fig. 4 is an end elevational view of the right hand end of the apparatus as viewed in Fig. 1;

Fig. 5 is a transverse sectional view of the centrifugal separator taken on line 5-5 of Fig. 2 and showing a plurality of discs arranged in a cylindrical casing to provide helical paths therein;

Fig. 6 is a front view of one of the discs;

Fig. 7 is a side elevational view of a disc showing the blades twisted at an angle to the plane of the disc; and

Fig. 8 is a sectional end view of the combined evaporator and absorber and showing the banks of tubes constituting a centrally located evaporator with absorber sections at each side.

One of the features of the invention is the construction and arrangement of elements to provide a self-contained vacuum type absorption refrigeration unit. The unit comprises a frame 10 having a rectangular base 11 formed by angle irons welded at the corners. Angle iron stanchions 12 and 13 project upwardly from the corners at one end of the base and have a saddle 14 at their upper ends, see Fig. 4. Another pair of stanchions 15 and 16 project upwardly from the side rails of the base 11 intermediate their ends and have a saddle 17 at their upper ends. Cross-struts 18 and 19 extend between the stanchions 12 and 15 and similar cross-struts 18' and 19' extend between the stanchions 13 and 16. A cylindrical shell 20 enclosing the combined evaporator and absorber, later to be explained in detail, is mounted on the saddles 14 and 17.

The cylindrical shell 20 has spaced brackets 21 on the top thereof at one side of the center for mounting a condenser 22 which extends longitudinally of the shell. A centrifugal separator 23 is located at the top of the cylindrical shell 20 at the opposite side of its center from the condenser 22. At the rear of the centrifugal separator 23 is a combined flash chamber and gas storage vessel 24 also extending longitudinally of the shell and supported in position thereon by its connections with the shell.

A liquid heat exchanger 25 is located below the

cylindrical shell 20, between the upright stanchions 12, 13, and 15, 16 and is supported at one end by a bracket 26 between the cross-struts 18 and 18' and at its opposite end by a bracket 27 between the stanchions 15 and 16. The liquid heat exchanger 25 is inclined at an acute angle to the horizontal adjacent the base 11 and located below the shell 20 a distance sufficient to provide a liquid column of solution therebetween of a height to balance the difference in pressure between the high and low pressure sides of the system.

Mounted on the base 11 beyond the stanchions 15 and 16 is a combined generator and vapor liquid-lift 28 which extends upwardly above the cylindrical shell 20 at one end thereof. The upper end of the lift 28 is connected to one end of the centrifugal separator 23 tangentially thereof, see Fig. 3, and the opposite end of the latter is connected to the condenser 22 by a vapor pipe 29, see Fig. 2, which support it above the cylinder shell. A horizontally arranged cylindrical leveling vessel 30 is located between the vapor liquid-lift 28 and the liquid heat exchanger 25 and is supported by brackets 31 projecting from the stanchions 15 and 16. The elements are connected by suitable conduits to provide circuits for the refrigerant and absorbent and the conduits are supported by the various elements to provide a self-contained unit. It will be noted by reference to Figs. 3 and 4 that all of the elements are confined within the lateral dimensions of the stanchions 15 and 16 and that all of the elements are located between the base 11 and top of the condenser 22. These dimensions are less than the usual door opening sizes so that the unit may be transported through such openings to the location where it is to be used. For example, a self-contained vacuum type absorption refrigeration system of twenty-five tons ice melting capacity per day utilizing water as a refrigerant and a lithium bromide solution as an absorbent and constructed and arranged as described above has a width of 30 inches, a height of 83 inches and a length of 89 inches.

The combined generator and vapor liquid-lift 28 is described and claimed in an application for United States Letters Patent of Walter M. Simpson Serial No. 219,777, filed April 7, 1951. Suffice it to state herein that the combined generator and vapor liquid-lift comprises a lower portion 32 providing an extended heating surface, see Fig. 2, and an upper tapered lift portion 33. The lower portion 32 and lift portion 33 are enclosed in a jacket 34 throughout their length and the jacket is provided with a steam inlet port 35, a vent pipe 36 adjacent its upper end and a condensate drain 37 at its lower end.

The centrifugal separator 23 comprises a cylindrical casing having means therein for directing vapor in a helical path at high velocity, as later explained in detail. The condenser 22 comprises a shell with headers 39 and 40 at each end and tubes 41 extending through the shell and into the headers. The bottom of the condenser 22 is connected to the combined flash chamber and gas storage vessel 24 by a U-shaped conduit 42. The combined flash chamber and gas storage vessel 24 comprises an inner flash chamber 43 and an enclosing jacket 44, as later explained in detail, and the inner chamber 43 is connected to the shell 20 by an insulated conduit 45 for delivering liquid refrigerant to the evaporator.

Liquid absorbent is delivered from the casing of the centrifugal separator 23 to the absorber

in shell 20 in a path of flow including conduit 46, inner passages 47 of the liquid heat exchanger 25, conduit 48 and T-shaped manifold 49, see Figs. 1 and 3. Absorbent liquid strong in refrigerant is delivered from the shell 20 to the base of the combined generator and vapor liquid-lift 28 in a path of flow including conduit 50, outer passages 51 of liquid heat exchanger 25, conduit 52, leveling vessel 30 and conduit 53.

The combined evaporator and absorber is described and claimed in an application for United States Letters Patent of Lowell McNeely filed concurrently therewith. As shown in Fig. 8, the evaporator comprises a bank 54 of tubes 55 arranged one over the other in vertical rows from the top to the bottom of the bank. Groups of the tubes in each of the rows are connected at alternate ends to provide a plurality of vertically aligned serpentine coils in each row and the ends of the corresponding coils in the plurality of rows are connected by headers 56 and 57 to provide individual sections 58. Headers 56 are connected by conduits 59 to an upright inlet manifold 60 and headers 57 are connected by conduits 61 to an upright outlet manifold 62, see Fig. 4, so that a secondary refrigerant to be cooled may flow concurrently through the sections 58 in parallel to reduce the pressure drop in the evaporator. Overlying the top of the bank 54 of tubes 55 constituting the evaporator is a liquid distributor 63 having a plurality of parallel troughs 64. The parallel troughs are so arranged as to provide a side wall 65 overlying each vertical row of tubes 55 and each wall is provided with a capillary feeding means 66 for delivering liquid refrigerant onto the uppermost tube of each row as illustrated and described in detail in the McNeely application.

The absorber comprises banks 67 and 68 of tubes 69 on either side of the bank of tubes 55 constituting the evaporator. The tubes 69 are arranged one over the other in vertical rows from the top to the bottom of the bank and the tubes of each row are connected alternately at opposite ends to provide a plurality of vertical serpentine coils arranged in parallel. A liquid distributing means 63' like that described for the evaporator overlies each of the banks 67 and 68 of absorber tubes 69 for distributing absorbent for gravity flow over each coil and absorbent is supplied to each distributing means by conduit 48 and manifold 49. The ends of the coils of each bank are connected by headers 70 and 71 which, in turn, are connected to horizontal manifolds 72 and 73, see Figs. 1 and 3. Manifold 72 may be connected to any source of cooling water supply such as a cooling tower or water main and manifold 73 is connected to the header 39 of condenser 22. The banks 54, 67 and 68 of tubes 55 and 69 constituting the evaporator and absorber sections are supported in the cylindrical shell 20 by brackets 74 and 75.

A purging arrangement is provided for withdrawing non-condensable gases from the combined evaporator and absorber shell 20 and comprises a vessel 76 connected to the shell through a suction tube 77 and to the conduit 48 for absorbent weak in refrigerant by a connection 78. The purge vessel 76 constitutes an auxiliary absorber for creating a relative partial vacuum to withdraw non-condensable gases from the shell 20. A fall tube 79 connects the bottom of the vessel 76 to a separating chamber 80 and a conduit 81 connects the side of the separating chamber adjacent the top thereof to the jacket 44 of

the combined flash chamber and gas storage vessel 24. The bottom of the separating chamber 80 is connected by a conduit 82 to the line for solution strong in refrigerant flowing toward the generator 28.

Another feature of the present invention is the novel construction of the centrifugal separator 23 as illustrated in detail in Figs. 5, 6 and 7. The centrifugal separator 23 comprises a cylindrical shell 84 slightly inclined downwardly to the left as viewed in Fig. 5 with a rod 85 located axially thereof and mounting a plurality of discs 86. The discs 86 are mounted on the rod 85 at the central portion of rod 85 between conduit 46 and vapor pipe 29 to provide an open swirl chamber above the lift conduit 33. As illustrated in Fig. 6, each disc 86 has a central hub 87 and a plurality of radial slots 88 forming blades 89, eight of such blades being shown in Fig. 6. The blades 89 are twisted at an acute angle to the plane of the disc 86 and the plurality of discs are so arranged on rod 85 that the leading edge 90 of each blade forms a continuation of the trailing edge 91 of a blade of the preceding disc at their outer ends. The inclined faces of the blades 89 of adjacent discs 86 will thus direct vapor through a plurality of helical paths 92 in shell 84. When discs 86 with eight blades 89 are provided, the gas will be directed in eight helical paths 92 formed by the blades 89 and casing 84. Vapor entering the cylindrical separator casing 84 tangentially thereof is given an initial circular motion or swirl which is continued through the helical paths 92 and, due to the high velocity of the vapor flowing toward the condenser, any liquid in the vapor is thrown outwardly against the wall of the casing by centrifugal force. The liquid flows down the sides of the casing and along the inclined bottom of the casing into the conduit 46.

Still another feature of the invention resides in the combined flash chamber and gas storage vessel 24. The inner flash chamber 43 receives liquid refrigerant from the condenser 22 through the U-tube 42 at a temperature corresponding to its vapor pressure in the condenser and reduces the temperature of the refrigerant to the evaporator temperature by evaporating a portion of the refrigerant at the vapor pressure in the evaporator and absorber. Because of the rapid boiling and agitation of the refrigerant during flashing, such flashing is performed in the flash chamber 43 before it is introduced into the evaporator. Liquid refrigerant flows from the bottom of the chamber 43 to the liquid distributor 63 for the bank 54 of evaporator tubes 55 through insulated liquid pipe 45 and a vapor pipe 93 extends upwardly from shell 20 through the jacket 44 and chamber 43 and terminates above the liquid level. Flashed vapor flows from chamber 43 through vapor pipe 93 into shell 20 where it is absorbed in absorption solution.

In accordance with the present construction, the jacket 44 is connected to the refrigeration system to provide a vacuum insulating space 94 around the chamber. The apparatus is initially evacuated to the lowest pressure that can be produced by known pumps, less than 1 mm. Hg absolute, and is then charged with a water solution of lithium bromide. A pressure will exist in the space 94 corresponding to the vapor pressure of refrigerant at the temperature of the flash chamber 43, and provide a relatively low vacuum in space 94 to heat insulate the flash chamber from

the ambient. Such vacuum insulation reduces the heat loss from the system and avoids condensation on the wall of chamber and the general nuisance of such condensate dripping from the chamber over the other parts of the apparatus.

Non-condensable gases withdrawn from the shell 20 by the purging vessel 76 are delivered by the fall tube 79 to the separating chamber 80 and as they accumulate therein they will escape through the conduit 81 into the space 94. Such gases will mix with refrigerant vapor when delivered to the vacuum space 94 and will exist therein at relative partial pressures. The gases are generated in the system at a very slow rate, probably as a result of corrosion, and will gradually increase the total pressure but not by an amount to appreciably affect the insulating quality of the space. When a sufficient amount of gas has been delivered to the space 94 to cause an appreciable increase in the pressure, the gases may be withdrawn from the jacket 44 by a suitable vacuum pump through an exhaust valve 95. After the apparatus has been fabricated to provide an hermetically sealed system, evacuated to a low pressure and charged with the refrigerant-absorbent solution, it is intended to operate for a period of at least twelve years except for removing gases from jacket 44 once a year at the beginning of a cooling season. One form of the invention having now been described in detail, the mode of operation of the unit is explained as follows:

The self-contained refrigeration unit is transported to the location where it is to be used, the manifolds 60 and 62 connected to an auxiliary cooling system containing a secondary refrigerant such as chilled water and manifold 72 is connected to a supply of cooling water such as a cooling tower. It will be understood that the secondary refrigerant in the auxiliary cooling system, not shown, will be circulated through the evaporator tubes 55 and one or a plurality of heat exchange elements in the enclosures to be cooled and that cooling water will be circulated through the absorber tubes 69 and condenser 22.

To initiate operation of the apparatus steam is supplied to the combined generator and vapor liquid-lift 28 through the conduit 35 and the steam is maintained at atmospheric pressure in the jacket 34 by the vent pipe 36. The heat of the steam is transferred through the extended wall surface of the lower portion 32 and through the wall of the lift tube 33 to the solution therein to expel refrigerant vapor therefrom. Due to the correlation of the rate of vapor generation to the cross-sectional area of the lift conduit 33 the vapor will flow upwardly through the lift conduit at high velocity and lift absorption solution at a controlled rate of relative circulation. For example, each pound of refrigerant vapor expelled will lift fourteen pounds of solution to the centrifugal separator 23.

Due to the tremendous volume of the expelled vapor at the low pressure existing in the apparatus the vapor flows at very high velocity from the upper end of lift conduit 33 toward the condenser 22. As the vapor enters the cylindrical casing 84 of the centrifugal separator 23 tangentially thereof, see Figs. 3 and 5, it is given an initial circular swirling motion which causes most of the liquid absorbent to be thrown against the wall of the casing by centrifugal force. As the vapor continues its flow toward condenser

22 at high velocity it is directed by the discs 86, see Fig. 5, through the helical passages 92 to continue its circular motion. Any liquid absorbent remaining in the vapor is thrown outwardly by centrifugal force against the wall of casing 84. The expelled liquid flows down the sides and along the inclined bottom of casing 84 and into the conduit 46. It has been found that with such a centrifugal separator 23 as shown in Fig. 5 all of the absorption solution is removed from the vapor and due to the spacing between the outer edges of successive blades 89 of the disc 86 the liquid flows by gravity into the conduit 46. The vapor continues its flow from the casing 84 of the centrifugal separator 23 through the vapor pipe 29 into the condenser 22 where it is condensed to a liquid.

Absorbent solution weak in refrigerant flows by gravity from the centrifugal separator 23 to the liquid distributing means 63' for the banks 67 and 68 of absorber tubes 69 in a path of flow comprising the conduit 46, inner passages 47 of liquid heat exchanger 25, conduit 48 and manifold 49. The liquid absorbent is uniformly distributed along the uppermost tube 69 of each vertical row of tubes in banks 67 and 68 and drips from each tube to the next lowermost from the top to the bottom of the rows of tubes. The liquid absorbent flowing over the tubes in thin films provides an extensive surface of absorption solution and, due to its affinity for refrigerant, it absorbs refrigerant vapor as fast as it is formed. Absorption solution, strong in refrigerant, flows from the bottom of shell 20 to the lower end of portion 32 of combined generator and vapor liquid-lift 28 in a path of flow comprising conduit 50, outer passages 51 of liquid heat exchanger 25, conduit 52, leveling vessel 30 and conduit 53 to complete a cycle of operation. The absorption of refrigerant vapor produces a low pressure in the cylindrical shell 20, for example, 7 mm. Hg absolute, at which pressure the refrigerant, water, will evaporate at 43° F. to produce a refrigerating effect.

The difference in pressure between the condenser 22 and shell 20 is maintained by a column of liquid refrigerant in the U-tube 42 and the difference in pressure between the cylindrical shell 20 and the combined generator and vapor liquid-lift 28 is maintained by columns of liquid absorbent in the conduits 48 and 50. For example, the liquid will stand at some level x in the U-tube 42, see Fig. 1, at a level y in conduit 46 connected to conduit 48 through the liquid heat exchanger 25, at a level z in conduit 50 and at a level w in the leveling vessel 30.

Liquid refrigerant entering the flash chamber 43 is cooled from the temperature of the condenser 22 to the temperature of the evaporator by flashing a portion of the liquid. This flashing occurs automatically because of the reduced pressure in the cylindrical shell 20 and is in the form of a violent boiling. This violent boiling is performed in the flash chamber 43 before the liquid refrigerant is introduced into the evaporator to prevent agitation and spilling of refrigerant therein. The liquid refrigerant flows from the flash chamber 43 through the liquid line 45 to the liquid distributor 63 in shell 20 which distributes it for gravity flow over the rows of evaporator tubes 55. As tubes 55 are closely adjacent to and in open communication with the banks 67 and 68 of absorber tubes 69, the refrigerant will evaporate at low temperature on the exterior of the tubes and cool the secondary re-

frigerant flowing through the interior of the tubes. The refrigerant vapor is absorbed in the absorption solution flowing in parallel paths with the liquid refrigerant and the solution strong in refrigerant then flows back to the base of the generator 28 as previously explained.

The flash chamber 43 is insulated from the ambient by the jacket 44. When no gases are present the space 94 will contain refrigerant vapor at a vapor pressure corresponding to the temperature of the flash chamber 43 and produce a low vapor pressure or vacuum in the space. For example, with a refrigerant temperature of 43° F., a pressure of 7 mm. Hg absolute will exist in the space 94. The higher pressure in vessel 80 at the lower end of the fall tube 79 will force a column of liquid up the conduit 81 to seal the jacket from the remainder of the system.

During the operation of the system non-condensable gases will be withdrawn from the shell 20 and transferred through the fall tube 79 to the separating chamber 80. When sufficient gas accumulates in the separating chamber 80 to depress the liquid level below the conduit 81, gas will escape through the conduit and into the jacket 44. Such gas will mix with the refrigerant vapor in space 94 and the total pressure therein will increase above the vapor pressure of the aqueous lithium bromide solution at its concentration and temperature in conduit 81. As the amount of gas in the jacket 44 increases it will gradually increase the pressure therein and from time to time, once a year or less, the gases are withdrawn through the exhaust valve 94 by a suitable suction pump. Liquid absorbent flows from the vessel 80 through conduit 82, heat exchanger 25 and conduit 52 to leveling chamber 30.

It will now be observed that the present invention provides a self-contained vacuum type absorption refrigeration system of relatively large capacity having a novel construction and arrangement of elements to reduce its overall dimensions to a minimum. It will also be observed that the present invention provides a centrifugal separator for separating liquid absorbent from refrigerant vapor by centrifugal force. It will still further be observed that the present invention provides a combined flash chamber and gas storage vessel for insulating the flash chamber from the ambient.

While a single form of the invention is herein illustrated and described, it will be understood that modifications may be made in the construction and arrangement of elements without departing from the spirit or scope of the invention. Therefore, without limitation in this respect, the invention is defined by the following claims.

I claim:

1. A self-contained vacuum type absorption refrigeration apparatus comprising a frame having a base and spaced upright stanchions, a shell mounted on the stanchions above the base and having an evaporator and absorber therein, a condenser mounted on the top of the shell, a generator mounted on the base and having a vapor liquid-lift projecting upwardly above the shell at one end thereof, a centrifugal separator having a horizontal casing connected between the upper end of the vapor liquid-lift and condenser with means therein for directing vapor in a helical path, a liquid heat exchanger mounted on the base of the frame below the shell, and conduits connecting the elements for the gravity flow of a refrigerant and absorbent raised by the

vapor liquid-lift and providing liquid columns between the shell and liquid heat exchanger.

2. A self-contained vacuum type absorption refrigeration apparatus comprising a frame having a base and spaced upright stanchions with saddles at their upper ends, a cylindrical shell mounted on the saddles above the base and having brackets at its top and an evaporator and absorber therein, a condenser supported on the brackets at the top of the shell at one side thereof, a generator mounted on the base and having a vapor liquid-lift projecting upwardly above the shell at one end thereof, a horizontal separating chamber connected between the upper end of the vapor liquid-lift and condenser and supported thereby at the side of the shell opposite the condenser, a flash chamber mounted on the top of the shell at one end of the separating chamber, a liquid heat exchanger mounted on the base of the frame between the upright stanchions, and conduits connecting the elements for the gravity flow of refrigerant and absorbent raised by the vapor liquid-lift and providing liquid columns between the shell and liquid heat exchanger.

3. A self-contained vacuum type absorption refrigeration apparatus comprising a frame having a base and spaced upright stanchions with saddles at their upper ends, a shell mounted on the saddles above the base and having brackets at its top and an evaporator and absorber therein, a condenser supported on the brackets at the top of the shell, a generator mounted on the base and having a vapor liquid-lift projecting upwardly above the shell at one end thereof, a centrifugal separator connected between the upper end of the generator and condenser and comprising a horizontal shell having means therein for directing vapor in a helical path to cause liquid to be thrown outwardly by centrifugal force, a liquid heat exchanger mounted on the base of the frame, and conduits connecting the elements for the gravity flow of refrigerant and absorbent raised by the vapor liquid-lift and providing liquid columns between the shell and liquid heat exchanger.

4. A self-contained vacuum type absorption refrigeration apparatus comprising a frame having a base and spaced upright stanchions with saddles at their upper ends, a shell mounted on the saddles above the base and having brackets at its top and an evaporator and absorber therein, a condenser supported on the brackets at the top of the shell, a generator mounted on the base and having a vapor liquid-lift projecting upwardly above the shell at one end thereof, a centrifugal separator extending horizontally between the upper end of the vapor liquid-lift and condenser and supported thereby, a liquid heat exchanger mounted on the base of the frame, a leveling vessel between the liquid heat exchanger and vapor liquid lift and supported by the stanchions of the frame, and conduits connecting the elements for the gravity flow of refrigerant and absorbent raised by the vapor liquid-lift and providing columns between the shell and liquid heat exchanger.

5. A self-contained vacuum type absorption refrigeration apparatus comprising a frame having a base and spaced upright stanchions with saddles at their upper ends, a shell mounted on the saddles above the base and having brackets at its top and an evaporator and absorber therein, a condenser supported on the brackets at the top of the shell, a centrifugal separator connected between the upper end of the vapor liquid-

lift and condenser and supported thereby, a liquid heat exchanger mounted on the base and having inner and outer passages extending lengthwise of the base at an acute angle thereto, and conduits connecting the elements for the gravity flow of refrigerant and absorbent raised by the vapor liquid-lift and providing liquid columns between the condenser and shell and between the shell and liquid heat exchanger.

6. A self-contained vacuum type absorption refrigeration apparatus comprising a frame having a base and spaced upright stanchions with saddles at their upper ends, a shell mounted on the saddles above the base and having brackets at its top and an evaporator and absorber therein, a condenser supported on the brackets at the top of the shell, a generator mounted on the base and having a vapor liquid-lift projecting upwardly above the shell at one end thereof, a separating chamber connected between the upper end of the vapor liquid-lift and condenser, a flash chamber mounted on the top of the shell, a jacket enclosing the flash chamber in spaced relation thereto to provide an insulating space therebetween, a liquid heat exchanger mounted on the base of the frame below the shell, conduits connecting the elements for the gravity flow of refrigerant and absorbent raised by the vapor liquid-lift and providing liquid columns between the condenser and shell and between the shell and liquid heat exchanger, and said jacket enclosing the flash chamber being connected to the system to produce a vacuum therein.

7. In a vacuum type absorption refrigeration system, a generator, a condenser, an evaporator, an absorber, a combined flash chamber and gas storage element comprising two vessels arranged one within the other in spaced relation, a device through which refrigerant flows from the condenser to the evaporator for maintaining a difference in pressure, conduits interconnecting the elements to provide paths of flow for refrigerant and absorbent, the conduit between the condenser and evaporator comprising a pipe connecting the pressure maintaining device to the inner flash chamber vessel, connecting means extending through the outer storage vessel to deliver a liquid and vapor refrigerant from the flash chamber vessel to the evaporator, means for purging non-condensable gases from the refrigeration system, and a riser tube extending above the highest level to which liquid can rise at the pressure in the refrigeration system and connected between the purge device and outer gas storage vessel to store gas and provide an insulating layer of low pressure gases around the flash chamber.

8. In a vacuum type absorption refrigeration system, a generator, a condenser, an evaporator, an absorber, a combined flash chamber and gas storage element comprising two vessels arranged one within the other in spaced relation, conduits interconnecting the elements to provide paths of flow for refrigerant and absorbent, the conduit between the condenser and evaporator comprising a U-tube and the inner flash chamber vessel, a liquid pipe extending from the bottom of the inner flash chamber vessel through the outer storage vessel to the evaporator, a vapor pipe extending from above the bottom of the inner flash chamber vessel through the outer vessel to the evaporator, means for purging non-condensable gases from the refrigeration system, and a riser pipe extending above the highest level to which liquid can rise at the pressure in the re-

frigeration system and connected between the purging means and outer gas storage vessel to store gas and provide an insulating layer of low pressure gases around the flash chamber.

9. In a vacuum type absorption refrigeration system, a vapor liquid-lift for raising liquid by vapors expelled therefrom, and a centrifugal separator at the upper end of said lift for separating the liquid from the vapor, said centrifugal separator having a horizontally arranged cylindrical casing connected tangentially to the lift and having baffles therein for directing the vapor in a helical path to cause liquid to be thrown outwardly against the wall of the casing by centrifugal force as the vapor flows there-through.

10. In a vacuum type absorption refrigeration system, an upright vapor liquid-lift for raising liquid by vapor expelled therefrom, a condenser above the vapor liquid lift, a centrifugal separator having a laterally extending casing, the upper end of the vapor liquid-lift being connected tangentially to the side of the casing at one end and the opposite end of the casing being connected to the condenser, and baffles in the casing forming a plurality of helical passages for directing the vapor in helical paths to cause liquid to be thrown outwardly against the wall of the casing by centrifugal force as the vapor flows from the upper end of the lift toward the condenser.

11. In a vacuum type absorption refrigeration system, an upright vapor liquid-lift for raising liquid by vapor expelled therefrom, a condenser above the upper end of the lift, a centrifugal

separator having a cylindrical vessel extending laterally between the vapor liquid lift and condenser, the upper end of the lift being connected tangentially to the cylindrical vessel at one end and the opposite end of the vessel being connected to the condenser, an axial rod extending longitudinally of the cylindrical vessel, a plurality of discs mounted on the rod and having radial slots to provide blades twisted at an angle to the plane of the discs, the trailing edge of each blade being aligned with the leading edge of a blade on the next adjacent disc to form a plurality of helical passages, and said helical passages directing the vapor to cause it to flow in helical paths at high velocity and expel liquid therefrom by centrifugal force.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
417,774	De Rycke	Dec. 24, 1889
482,694	Falson	Sept. 23, 1892
553,681	Kunzel	Jan. 28, 1896
630,023	Baker	Aug. 1, 1899
948,062	Morgan	Feb. 1, 1910
1,077,947	Abrames	Nov. 4, 1913
2,193,209	Sandberg	Mar. 12, 1940
2,337,439	Anderson	Dec. 21, 1943
2,352,814	Thomas	July 4, 1944
2,365,797	Bichowsky	Dec. 26, 1944
2,370,629	Appeldoorn	Mar. 6, 1945
2,473,602	Loumiet	June 21, 1949
2,485,844	Reid	Oct. 25, 1949
2,565,943	Berestneff	Aug. 28, 1951