

Jan. 10, 1956

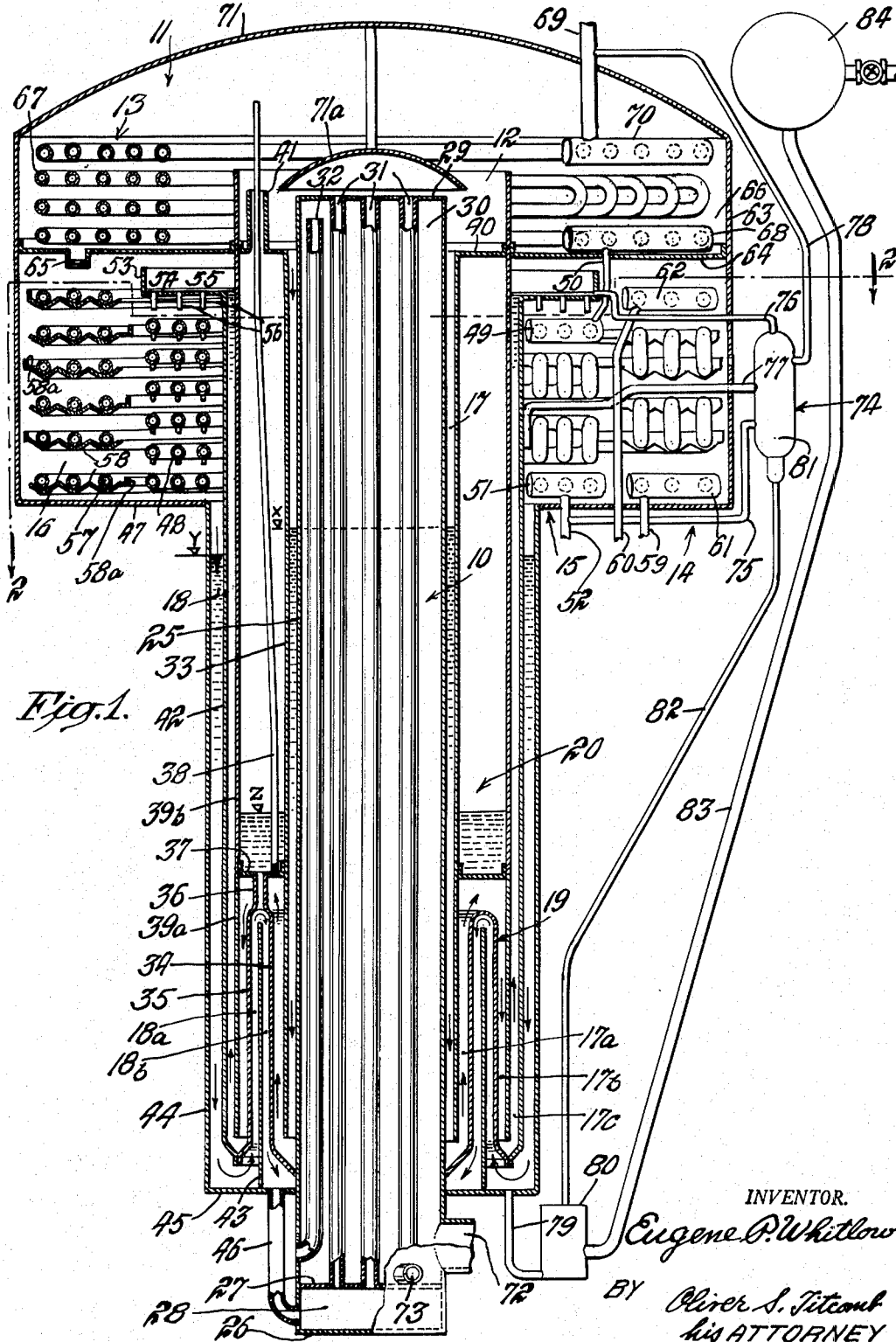
E. P. WHITLOW

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ABSORPTION REFRIGERATION APPARATUS

Filed July 11, 1952

3 Sheets-Sheet 1



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Fig. 2.

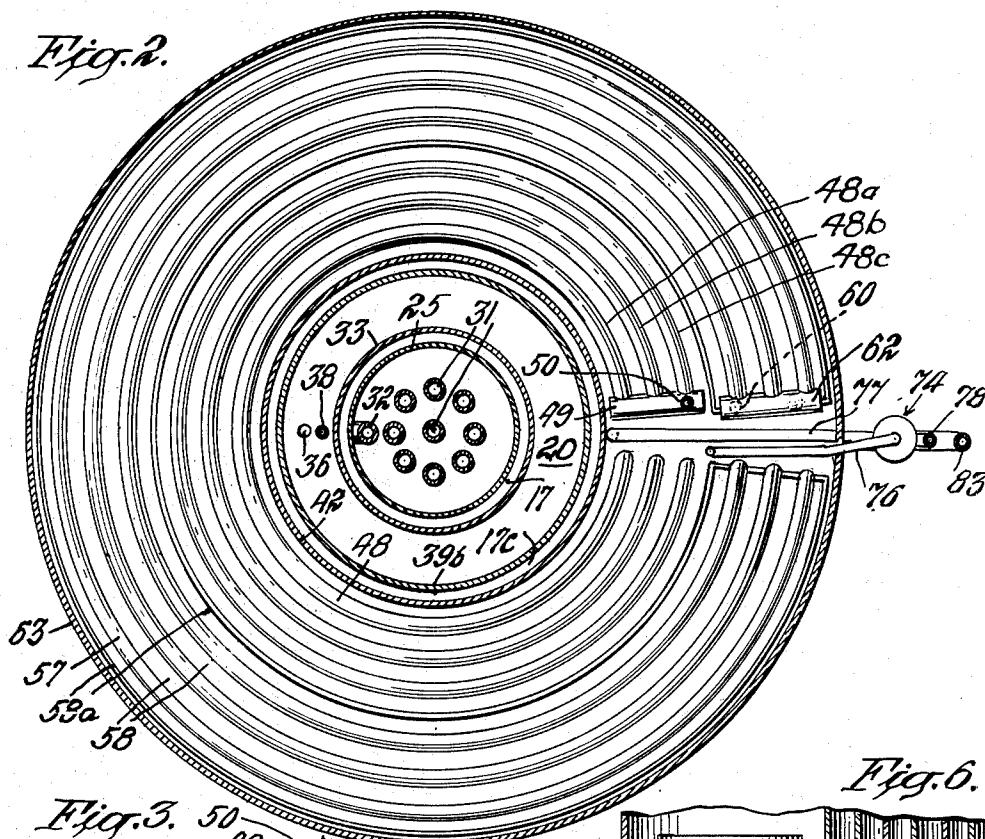


Fig. 3.

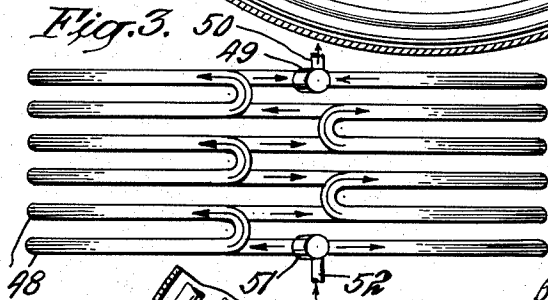


Fig. 5.

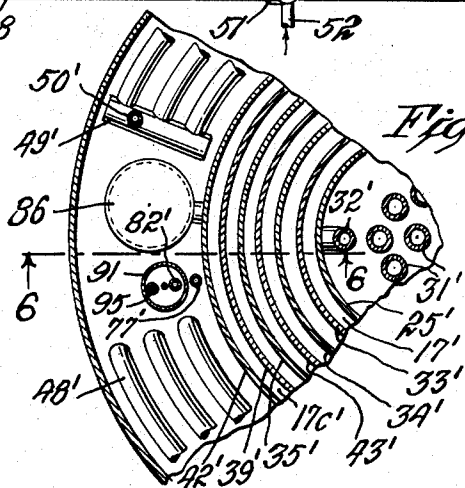
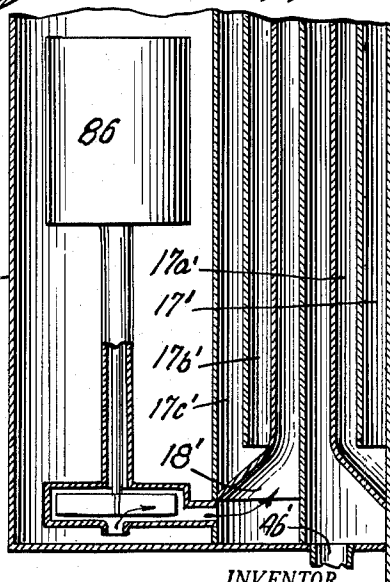


Fig. 6.



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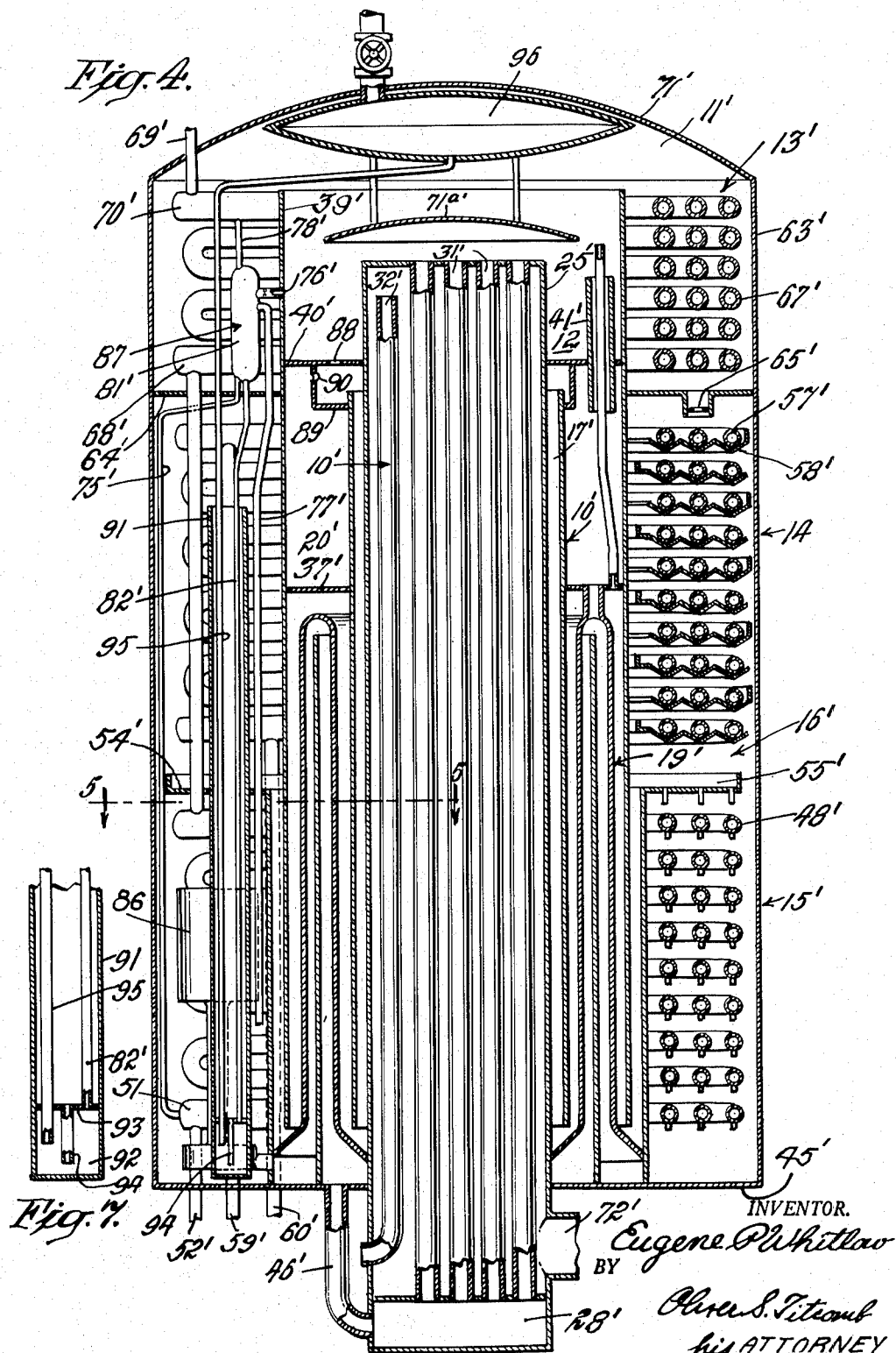
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ABSORPTION REFRIGERATION APPARATUS

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Application July 11, 1952, Serial No. 298,275

28 Claims. (Cl. 62—119)

The present invention relates to refrigeration and more particularly to a self-contained or unitary refrigeration apparatus of improved construction.

The principal object of the present invention is to provide a unitary refrigeration apparatus formed by connecting a series of nested shells and transverse walls to provide separate heat transfer chambers with passages connecting the chambers.

Another object is to provide a unitary apparatus of the type indicated in which all of the active elements of the refrigeration system are enclosed within an outer skin or casing to reduce the occurrence of atmospheric leaks and the time and labor necessary for leak testing.

Another object is to provide a unitary heat operated refrigeration apparatus of the type indicated which is heated at the interior and cooled adjacent the exterior with annular curtains of working fluid therebetween.

Another object is to provide a unitary heat operated refrigeration apparatus of cylindrical form in which adjacent concentric shells provide heat exchange paths for working fluid flowing toward and away from a central heating element to produce a temperature gradient from the center to the periphery of the apparatus.

Another object is to provide a unitary refrigeration apparatus of the type indicated in which transverse walls divide the interior of the apparatus into high and low pressure sections with annular chambers and passages for gravity flow and storage of working fluid.

Another object is to provide a unitary absorption refrigeration apparatus of the type indicated having a centrally located generator, peripheral chambers in which refrigerant is condensed, evaporated and absorbed and intermediate heat exchange and liquid storage passages.

Another object is to provide a vacuum type absorption refrigeration apparatus of the type indicated in which the annular passages between adjacent shells maintain pressure balancing liquid columns of the working fluid between high and low pressure chambers.

Another object is to provide an absorption refrigeration apparatus of the type indicated having a centrally located generator and peripheral chambers surrounding the generator in which refrigerant is condensed, evaporated and absorbed as it flows from the top to the bottom of the apparatus.

Still another object is to provide a refrigeration apparatus of the type indicated which is of simpler construction requiring fewer parts and less material, more compact requiring less floor space and more economical to manufacture requiring fewer welds and less leak testing than previously known refrigeration units of the same capacity.

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 in-

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vention, reference being had for this purpose to the appended claims. In the drawings:

Fig. 1 is a sectional view of a refrigeration apparatus incorporating the novel features of the present invention and showing the series of nested shells and transverse walls constituting a unitary refrigeration apparatus;

Fig. 2 is a transverse sectional view taken on line 2—2 of Fig. 1 and showing the arrangement of the annular evaporator and absorber coils in side by side relation in a chamber formed between adjacent shells;

Fig. 3 is an elevational view of a heat exchange coil and showing the manner in which a length of pipe is bent to provide a plurality of tube sections arranged one over the other;

Fig. 4 is a sectional view of a refrigeration apparatus of modified construction utilizing a pump to maintain the difference in pressure;

Fig. 5 is a sectional plan view taken on line 5—5 of Fig. 4 and showing the pump and purge device located in the radial space between the ends of the annular absorber coil;

Fig. 6 is a detail sectional view taken on line 6—6 of Fig. 5 and showing the connection between the pump and heat exchanger; and

Fig. 7 is a sectional view of the lower end of the automatic purge device.

For the purpose of illustration, the invention is shown applied to a refrigeration system of the type described and claimed in United States Letters Patent to Albert R. Thomas et al. No. 2,282,503, issued May 12, 1942, and entitled Refrigeration. Such a refrigeration system operates in a partial vacuum and utilizes a refrigerant such as water and an absorbent such as a water solution of lithium bromide or the like.

In its broadest aspect the apparatus of the present invention comprises a series of nested shells and transverse walls dividing its interior into separate heat exchange chambers and passages through which working fluid flows between chambers. In the embodiment of the apparatus illustrated in Fig. 1, transverse walls divide the apparatus into high and low pressure sections. The high pressure section comprises a centrally located generator 10 constituting the core of the apparatus and a chamber 11 at the top of the apparatus having a centrally located liquid collecting trough 12 and a condenser 13 surrounding the trough. The low pressure section comprises an evaporator 14 and absorber 15 located in a chamber 16 surrounding the generator 10 below the condenser 13 in chamber 11. Between the generator 10 and chamber 16 are annular passages 17 and 18 through which absorption solution flows between the high and low pressure sections of the apparatus and portions of the passages below the chamber 16 constitute a heat exchanger 19. Between the generator 10 and chamber 16 above the heat exchanger 19 is an annular space 20 connected to the passage 18 and constituting a reservoir and leveling vessel for maintaining a hydrostatic reaction head on generator 10. In the embodiment of the apparatus illustrated in the drawings, the shells are shown in the form of cylinders and the transverse walls in the form of discs or annular plates but it will be understood that the shells may have other shapes such as oval, rectangular or square. It will also be understood that the adjacent shells forming annular liquid passages may be arranged very close to each other to reduce the amount of liquid in the passages to a minimum.

For the purpose of simplifying the detailed description of the apparatus, its construction is described in accordance with the method of assembling the parts. The centrally positioned generator 10 constituting the core of the apparatus comprises a cylindrical shell 55 having transverse walls 26 and 27 forming a lower solution cham-

ber 28 and a transverse wall 29 at its upper end to provide a heating chamber 30 above the solution chamber. Tubes 31 extend between the walls 27 and 29, constituting tube sheets, from the lower solution chamber 28 through the heating chamber 30. The tubes 31 are first welded to the tube sheets 27 and 29, the tube bundle inserted in the shell 25, the tube sheets welded to the shell and the lower transverse wall or plate 26 welded to the bottom edge of the shell. A vent tube 32 has its upper end adjacent the top of the heating chamber 30 and its lower end projects through an opening in the wall of the shell 25 adjacent the bottom of the heating chamber and is welded thereto.

After the parts of the generator 10 have been assembled a shell or tube 33 is telescoped over the shell 25 of generator 10 which constitute the outer and inner wall of the passage 17 and is welded in proper position thereon by means of suitable spacers, not shown. Shells 34 and 35 constituting dividing walls of heat exchanger 19 are joined together at their upper edges with a tube or tubes 36 projecting upwardly therefrom and the assembly is telescoped over the shell 33 adjacent the lower end of the latter. The lower edge of shell 34 is folded inwardly to engage shell 25 of the generator 10 and is welded thereto. A transverse wall 37 in the form of an annular plate is slid downwardly over the shell 33 and the plate has an opening therein adapted to align with the tube 36 and a vent tube 38 projecting upwardly therefrom. The transverse wall 37 is preferably provided with peripheral flanges to facilitate welding and the inner flange of the plate is welded to the shell 33 and the upper end of tube 36 is welded to the plate. After the inner edge of the annular wall or plate 37 has been welded in place on the shell 33, the lower portion 39a of a shell 39 is slid downwardly over the previously assembled parts to the position illustrated in Fig. 1 where it is welded to the outer flange of the transverse wall or plate 37. Thereafter, the upper portion 39b of shell 39 having an annular transverse wall 40 welded therein adjacent its upper edge is slid into position in alignment with the portion 39a and welded thereto and the inner edge of the plate 40 is welded to the top of the shell 33. The upper end of shell 39 and transverse wall 40 form the annular liquid collecting trough 12 and the wall has a standpipe 41 projecting upwardly from an opening therein through which the vent tube 38 extends. The next concentric shell 42 is then slid upwardly from the bottom until its lower inwardly inclined end contacts the lower outwardly inclined end of shell 35 and the ends of the two shells are welded together. A sub-assembly consisting of an intermediate shell 43 and outer shell 44 projecting upwardly from an annular plate 45 constituting a bottom transverse wall is then slid upwardly to position the intermediate shell 43 between shells 34 and 35 and the inner edge of plate 45 is welded to the outer periphery of the shell 25. This construction completes the heat exchanger 19 including the passages 17, 17a, 17b and 17c through which absorption solution flows in one direction and passages 18, 18a and 18b through which solution flows in the opposite direction. A pipe conduit 46 is then welded between wall 45 adjacent its inner periphery and solution chamber 28 to complete the solution circuit.

The bottom of the chamber 16 containing evaporator 14 and absorber 15 is formed by a transverse wall 47 in the form of an annular plate which is lowered over the assembled parts and its inner edge welded to the top of the shell 44. The absorber 14 comprises a heat exchange element 48 in the form of a series of annular pipe coils, see Figs. 2 and 3. In the illustrated embodiment the pipe coils comprise three separate pipes 48a, 48b and 48c bent in concentric annuli in a horizontal direction and in serpentine in a vertical direction to provide a series of pipe sections arranged one over the other in vertical rows. The upper ends of the three

separate pipes 48a, 48b and 48c are connected to a header 49 having an upwardly projecting nipple 50 and the lower ends are connected to a header 51 having a depending nipple 52 to provide a unitary coil structure.

The annular heat exchange element or coil structure 43 is then lowered into position onto the bottom wall 47 of chamber 16 and anchored thereon by suitable means, not shown, with the nipple 52 depending from header 51 projecting through a suitable opening in the bottom wall 47. A relatively short shell 53 welded to the outer edge of an annular transverse plate 54 is then lowered into position over the absorber coil 15 and its inner edge welded to the upper edge of the shell 42. The shell 53 and transverse plate 54 constitute a liquid distributing trough 55 having depending drippers 56 overlying the uppermost pipe section of each row of coil 43.

The evaporator 14 comprises a heat exchanger 57 of a coil construction like the absorber coil 48 previously described but has trays or pans 58 underlying each horizontal layer of pipe sections to hold liquid refrigerant in contact with the outer surface of each coil section. Preferably, the exterior surfaces of the coil are serrated in the manner described and claimed in a United States Letters Patent of John G. Reid, Jr., No. 2,485,844, issued October 25, 1949, to cause liquid to be lifted from the pans 58 by capillary action and wet the entire outer surface of the coil. As shown in Fig. 1, each pan 58 is adapted to overflow from one side into the next lowermost pan and alternate adjacent pans are provided with a lip or flange 58a on opposite sides to cause the liquid to overflow into successive pans from the top to the bottom of the evaporator. The evaporator coil 57 is mounted on the bottom wall 47 of chamber 16 in any suitable manner with pipe nipples 59 and 60 depending from headers 61 and 62 at the lower and upper ends of the coil and projecting through suitable holes in the transverse wall 47.

The outer shell 63 is lowered over the assembled parts and the lower edge of the shell is welded to the outer edge of the transverse wall 47. An absorption solution line 76 and suction line 77 of a purging device 74, later to be explained in detail, are then inserted in the arcuate space between the ends of the coils 48 and 57 and welded in place. Solution line 76 has its inner end connected to the wall 53 of the liquid distributor 55 and projects outwardly through a hole in shell 63 to which it is welded and the suction line 77 has its inner end bent at right angles and welded to shell 42 with its opposite end projecting through shell 63 to which it is welded. An annular transverse plate 64 is lowered between shells 39 and 63 and welded at its inner and outer edges to the respective shells. The bottom wall 47, shell 63 and transverse wall 64 then complete an enclosure constituting the chamber 16 containing the evaporator 14 and the transverse wall has an orifice 65 overlying the evaporator coil 57. The upper end of shell 39 and upper portion of shell 63 above the transverse wall 64 form an annular pocket or trough 66 in which coil 67 of the condenser 13 is mounted. The upwardly projecting pipe nipple 50 from header 49 of absorber coil 48 is then welded to the header 68 at the lower end of the condenser coil 67 and a pipe 69 projects upwardly from the header 70 at the upper end of the coil. Chamber 11 is completed by mounting a dome-shaped top plate or wall 71 on the assembly and welding its peripheral edge to the upper edge of the outermost shell 63, the pipe 69 extending through a hole in the dome and welded thereto. The top plate or wall 71 has a baffle plate 71a depending therefrom which overlies the top of the generator 10.

The above description completes the assembly of the apparatus except for auxiliaries such as the welding of a steam inlet nipple 72 and a condensate drain nipple 73 adjacent the bottom of the heating chamber 30. A sub-assembly constituting a purging device 74 is then

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attached to the exterior of the apparatus by welding the end of a water inlet connection 75 to the cooling water inlet pipe 52, the solution conduit 76 and suction tube 77 to the device, the outlet water connection 78 to conduit 69 and conduit 79 from separating chamber 80 to an opening in the transverse wall 45. The purge device 74 is generally similar to that disclosed in United States Letters Patent to Charles Roswell Re. 23,093, issued March 22, 1949, and entitled Refrigeration, and comprises a vessel 81 in the form of an auxiliary absorber for drawing non-condensable gases through the suction tube 77, a fall tube 82 connecting the bottom of the purge chamber 81 to the separating chamber 80, and a riser 83 connecting the side of the separating chamber to a gas storage vessel 84. The apparatus having now been described in detail, the mode of operation is explained as follows.

When steam is supplied to the heating chamber 30 it transmits its heat through the upright tubes 31 to expel refrigerant vapor from absorption solution therein. The refrigerant vapor rises in tubes 31 and lifts absorption solution into the chamber 11. Baffle plate 71a depending from top wall 71 separates the solution from the vapor and the latter flows to the condensing chamber 11. Simultaneously with the delivery of steam to the heating chamber 30, cooling water is supplied for flow through the absorber and condenser coils 48 and 67, successively. The cooling water flows in a path comprising water line 52, header 51, coil 48, header 49, conduit 50, coil 67 and conduit 69. Water to be chilled is circulated through the evaporator coil 57 in a path of flow comprising conduit 59, header 61, coil 57, header 62 and conduit 60. The relatively cold condenser coil 67 condenses the refrigerant vapor to liquid as fast as it is delivered to chamber 11 and the liquid refrigerant flows from the annular condenser trough 66 through the orifice 65 into the pan 58 underlying the upper course of coil sections of the evaporator coil 57. The liquid refrigerant will be drawn upwardly over the surface of the serrated coils by capillary action to wet the entire periphery of the coils. Surplus refrigerant overflows from the right-hand side of the uppermost pan into the next lowermost pan and successively through each course of evaporator coils from the top to the bottom of the evaporator.

Simultaneously with the condensing and delivery of liquid refrigerant to the evaporator 14, absorption solution weak in refrigerant flows by gravity from the collecting trough 12 to the liquid distributor 55 overlying the absorber coil 48 in a path of flow comprising the annular passages 17, 17a, 17b, and 17c between adjacent shells progressively from the center or core of the apparatus toward its outer periphery. The solution flows by gravity from the liquid distributor 55 through the drippers 56 onto the top of the uppermost coil section of absorber coil 48 and drips from each coil section onto the next lowermost coil section from the top to the bottom of the coil. Due to the high affinity of refrigerant vapor for absorption solution, the refrigerant evaporates at a low pressure and temperature on the evaporator coil 57 to cool the water flowing through the coil and the refrigerant vapor is absorbed in absorption solution on the absorber coil 48. The heat of absorption is transferred through the walls of the coil sections of the absorber coil 48 to the cooling water flowing therethrough to maintain a low vapor pressure and evaporator temperature in the chamber 16. The chilled water in the evaporator coil 57 is delivered to the place where it is to be used as a cooling medium such as a heat exchanger in a room, duct or the like.

The absorption solution strong in refrigerant flows by gravity from the bottom of the absorber 15 to the solution chamber 28 at the base of the generator 10 in a path of flow comprising the annular passages 18, 18a and 18b between adjacent shells and the conduit 46. The relatively cold solution flowing in passages 18, 18a and 18b

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from absorber 15 toward generator 10 exchanges heat with relatively hot solution flowing from the generator toward the absorber to maintain a temperature gradient from the center toward the periphery of the apparatus. In its path of flow some of the solution strong in refrigerant overflows through conduit 36 into the storage or leveling chamber 20 to maintain a substantially constant hydrostatic reaction head of solution on the solution chamber 28. Vent tube 38 also acts to vent the top of the passages 17a and 17b to prevent the accumulation of vapor or non-condensable gases therein.

Due to the difference in pressure in the high pressure chamber 11 and low pressure chamber 16 corresponding to the vapor pressures of refrigerant at the temperature of the condenser 13 and the vapor pressure of refrigerant in absorbent at the temperature of the absorber 15, pressure balancing liquid columns are maintained in the passages 17 and 18 between the generator 10 and absorber 15. For example, a liquid column is maintained in the passage 17c between a level x in passage 17 and the liquid distributor 55 and a liquid column is maintained in the annular passage 18 between the level y and level z in storage or leveling chamber 20.

Non-condensable gases in the apparatus accumulate in the interior of the absorber 15 adjacent the shell 42 where turbulence is at a minimum. These non-condensable gases are constantly withdrawn from chamber 16 through the suction tube 77 to the purge vessel 81 constituting an auxiliary absorber and are then transferred through the fall tube 82 to the separating vessel 80. Solution then flows through the conduit 79 to passage 18 of heat exchanger 19 and the gas accumulates in the top of separating vessel 80 until it can escape through riser 83 to the gas storage vessel 84. Thus, a residual amount of non-condensable gas is maintained in the separating vessel 80 which flows back into the active part of the refrigeration system between each period of operation.

Figs. 4 to 7 disclose a refrigeration apparatus of modified construction in which the overall height of the apparatus is decreased by an amount equal to the height of the pressure balancing liquid columns and the overall width is decreased by an amount equal to the width of the evaporator coil. To accomplish this economy of space the difference in pressure is maintained by a direct displacement pump 36 and the evaporator 14' and absorber 15' are arranged in vertical alignment in chamber 16' which extends vertically instead of horizontally. The modified construction also incorporates a purging device 87 located wholly within the apparatus.

The generator 10' and intermediate heat exchange structure 19' is generally similar to that illustrated in Fig. 1 except for their vertical location so that a detail description is unnecessary. The outer shells 44 and 63 of Fig. 1 are now combined in a single shell 63' which extends from the top wall 71' to the bottom transverse wall 45'. The absorber coil 48' is supported on the transverse wall 45' and underlies a liquid distributor 55' and evaporator coil 57' overlies the liquid distributor and is supported thereon. The evaporator coil 57', in turn, underlies the condenser coil 67' in the same way as illustrated in Fig. 1 so that condensed refrigerant flows by gravity onto the evaporator coil and vapor from the evaporator coil flows downwardly to the absorber coil from the top to the bottom of the apparatus.

Transverse wall 40' extends from the shell 25' of generator 10' to shell 39' to seal the high pressure section 11' from the low pressure side of the apparatus and the wall has an orifice 88 through which absorption solution flows by gravity at a substantially constant rate. A cup 89 underlies the transverse wall 40', receives the absorption solution and directs it into the annular passage 17', and the vertical wall of the cup 89 has an overflow passage 90. Thus, the annular trough 12' provides a liquid seal between the high pressure condensing chamber 11' and the low pressure chamber 16'.

Located in the arcuate space between the ends of the absorber coil 48' is a motor driven impeller type pump 86, see Figs. 5 and 6, which receives absorption liquid from the bottom of chamber 16' and delivers it under pressure through the passages 18' of the heat exchanger 19' to balance the difference in pressure between the generator 10' and absorber 15'.

The purging device 87 comprises a vessel 81' located in the arcuate space between the ends of the condenser coil 67' and has a solution conduit 76' connected directly to the shell 39' constituting the outer wall of the liquid collecting trough 12'. Suction tube 77' extends from vessel 81' through the transverse walls 64' and 54' to the inside of the absorber coil 48' where turbulence is at a minimum. Cooling water is supplied from inlet header 51' of absorber coil 48' and flows through a conduit 75' to a coil in the vessel 81' and the cooling water is discharged through a conduit 78' to the outlet header for the condenser coil 67'. Fall tube 82' extends downwardly through a standpipe 91 having a separate chamber 92 at its lower end, see Figs. 4 and 7. The separating chamber 92 is formed by a transverse wall 93 in the standpipe 91 having a depending conduit 94. Standpipe 91 is located in the arcuate space between the ends of the absorber coil 48' and evaporator coil 57', see Fig. 5, and extends upwardly through the transverse wall 54' of liquid distributor 55' to a height to maintain a pressure balancing liquid column therein. A riser tube 95 has its lower end projecting through the transverse wall 93 of the standpipe 91 into the separating chamber 92 for a distance equal to the gas storage space desired and the upper end of the riser is connected to a gas storage chamber 96 in the dome of the high pressure vapor chamber 11'.

The apparatus illustrated in Figs. 4 to 7 operates in substantially the same way as explained with respect to the construction illustrated in Figs. 1 to 3. Refrigerant vapor separated from absorption solution by the baffle 71a' is condensed by the condenser 13' and the solution flows by gravity through the orifice 88 at a constant rate and then through the passage 17' to the absorber 15'. Simultaneously, liquid refrigerant flows by gravity from the condensing chamber 66 onto the evaporator coil 57 where it evaporates to cool the medium flowing through the coil and the evaporated refrigerant vapor is absorbed in an absorption solution flowing over the absorber coil 48'. Absorption solution strong in refrigerant flowing from the lowermost pipe sections of the absorber coil 48' into the bottom of the chamber 16' is delivered by the pump 86 into the heat exchange passage 18' for flow back to the solution chamber 28' at the lower end of generator 10'. The pump maintains the difference in pressure between chamber 16' and generator 10' and provides a hydrostatic reaction head on the solution chamber 28'.

Simultaneous with the flow of solution from the collecting trough 12' solution also flows into the purge vessel 81' through the solution line 76' and the relatively cold cooling water flowing through a coil in the interior of the vessel cools the solution to produce a relatively low vacuum to draw in non-condensable gases from the absorber 15. The non-condensable gases are carried with solution through the fall tube 82' into the chamber 92, see Fig. 7. Solution overflows from chamber 92 through conduit 94 into the standpipe 91 and the gas accumulates in the chamber 92 under the transverse wall 93. The solution continues to accumulate in the standpipe 91 until it overflows the top thereof and drains into the liquid distributor 55'. The column of solution in the standpipe 91 is sufficiently high to balance the greatest difference in pressure expected to occur between the high and low pressure sides of the system so as to trap the gas in the chamber 92. When a sufficient amount of gas accumulates in the chamber 92 to depress the liquid level there-

in below the end of riser 95, gas will escape through the riser and flow to the storage chamber 96.

It will now be observed that the present invention provides a novel construction of refrigeration apparatus formed by connecting a series of nested shells and transverse walls to provide separate heat transfer chambers with passages connecting the chambers. It will also be observed that the apparatus of the present invention encloses all of the elements in an outer skin or casing having a heating element at the center and cooling element at the periphery to provide a temperature gradient therebetween. It will also be observed that the present invention provides a unitary refrigeration apparatus having transverse walls dividing the interior into high and low pressure sections with annular chambers and passages for gravity flow and storage of working fluid which also maintain pressure balancing liquid columns of the working fluid. It will still further be observed that the present invention provides a refrigeration apparatus which is of simple and compact construction and economical to manufacture.

While two embodiments of the invention are herein illustrated and described, it will be understood that further modifications may be made in the construction and arrangement of elements without departing from the spirit or scope of the invention. For example, the annular evaporator coil 57 may be located outside the enclosing shell directly in an air stream to be cooled and liquid refrigerant delivered from the condenser 13 into the upper header for gravity flow through the interior of the coil. Therefore, without limitation in this respect, the invention is defined by the following claims.

I claim:

1. A unitary refrigeration apparatus containing a working fluid and comprising a plurality of shells nested one within another from the outer shell inwardly, transverse walls between certain of the nested shells to seal the apparatus and provide separate concentric chambers therein, heat receiving and heat rejecting elements in the chambers, and the space between adjacent shells providing passages for the flow of working fluid between chambers in said apparatus.

2. A unitary refrigeration apparatus containing a working fluid and comprising a plurality of vertically arranged casings positioned one within the other, transverse walls between certain of the casing walls to seal the apparatus and provide separate inner and outer chambers, heat receiving and heat rejecting elements in the chambers, and adjacent casings forming separate heat exchange paths for working fluid flowing to and from a chamber.

3. A unitary refrigeration apparatus containing a working fluid and comprising a series of vertical shells of progressively increasing lateral dimensions and arranged concentrically, transverse walls connected across and between outer shells to provide an enclosing casing, transverse walls connected across and between inner and intermediate shells to provide separate inner and outer chambers and passages connecting the chambers for the flow of fluid therebetween, heat receiving and heat rejecting elements in the chambers, and the intermediate chambers and passages being wholly enclosed in the outer casing to reduce the occurrence of atmospheric leaks in the apparatus.

4. A unitary refrigeration apparatus containing a working fluid and comprising vertical shells of progressively increasing girth and arranged concentrically, transverse walls between certain of the concentric shells to seal the apparatus and provide high and low pressure inner and outer chambers, heat exchange elements in said chambers, and the space between adjacent shells providing passages for the flow of working fluid between the high and low pressure chambers.

5. A unitary refrigeration apparatus containing a working fluid and comprising a series of continuous walls arranged vertically in spaced relation from the center to

the outer periphery, transverse walls between certain of the vertical walls to provide an inner chamber to which heat is supplied to cause circulation of working fluid, an outer chamber to which cooling medium is supplied, and heat exchange passages for the flow of working fluid between chambers producing a temperature gradient from the inner to the outer chambers to utilize all of the heat supplied to the apparatus.

6. A unitary absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising vertically arranged concentric shells, a heat exchange element in the inner shell to expel refrigerant from absorbent and cause circulation of the absorbent, transverse walls between outer shells to provide an absorber chamber, a heat exchange element in said absorber chamber to remove heat therefrom, and adjacent outer shells providing separate heat exchange paths for solution flowing toward and away from the absorber chamber.

7. A unitary absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising a plurality of continuous walls arranged vertically in spaced relation from the center to the outer periphery, transverse walls between certain of the vertical walls to provide separate inner and outer chambers and passages for the flow of absorption solution between the chambers, the inner chamber constituting a generator to which heat is supplied and having vapor liquid-lift tubes for raising absorption solution for gravity flow, the outer chamber constituting an absorber to which cooling medium is supplied to remove the heat of absorption, and the passages between the inner and outer chambers providing separate paths for the flow of absorption solution weak in refrigerant and absorption solution strong in refrigerant flowing between the generator and absorber, and the passages constituting the separate paths of flow being in heat exchange relation with each other to provide a temperature gradient from the inner to the outer chambers of the apparatus.

8. A unitary absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising a plurality of vertically arranged concentric shells, transverse walls in the inner shell providing a lower solution chamber and a heating chamber above the solution chamber, vertical tubes between transverse walls extending from the solution chamber through the heating chamber, transverse walls between outer shells to provide an absorption chamber therebetween, a heat exchange element in said absorption chamber through which cooling medium is circulated, transverse walls connecting the ends of the shells located between the inner and outer shells to provide adjacent heat exchange passages, and the shell adjacent the inner shell cooperating therewith to provide a passage for solution flowing toward the absorption chamber, and the shell adjacent an outer shell cooperating therewith to provide a passage for solution flowing from the absorption chamber toward the solution chamber in the inner shell.

9. A unitary refrigeration apparatus containing a working fluid and comprising a plurality of concentric shells, transverse walls dividing the interior of the apparatus into upper and lower sections, one of the intermediate shells dividing the upper and lower sections into inner and outer compartments, said inner shell having heating means therein and extending upwardly through the lower into the inner compartment of the upper section, a heat exchange coil in the outer compartment of the upper section constituting a condenser, heat exchange coils in the outer compartment of the lower section and constituting an evaporator and absorber, respectively, an orifice in the transverse wall for delivering refrigerant from the condenser to the evaporator, and adjacent intermediate shells providing heat exchange passages connecting the inner compartment of the upper section to the outer compartment of the lower section and the outer compartment to the inner compartment of the lower section.

10. An absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising a plurality of vertical shells of progressively increasing girth nested one within the other, transverse walls in and between shells to provide a solution circuit having separate chambers and separate annular heat exchange passages between adjacent shells connecting the separate chambers, and means for circulating absorbent in the solution circuit.

11. A unitary absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising a plurality of vertically arranged concentric shells, transverse walls to seal the apparatus and provide separate and inner and outer chambers constituting a generator and absorber, respectively, heat exchange elements in said chambers, transverse walls connecting intermediate shells to provide separate heat exchange paths between the chambers for flow of solution weak in refrigerant and solution strong in refrigerant, and the separate heat exchange paths having a common wall formed by a single shell.

12. A unitary absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising vertically arranged concentric shells, transverse walls between certain of the concentric shells to seal the apparatus and provide separate inner and outer chambers, the inner chamber having a heating means therein to provide a generator, the outer chamber having cooling means therein to provide an absorber, and adjacent intermediate shells providing separate heat exchange paths for solution weak in refrigerant and solution strong in refrigerant flowing to and from the absorber and generator.

13. A unitary absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising a plurality of vertically arranged concentric shells, transverse walls between certain of the concentric shells to seal the apparatus and provide separate chambers, the innermost shell having transverse walls and connecting tubes to provide a combined generator and vapor liquid-lift, the outer shells having a space therebetween with a heat exchange element therein to provide an absorber, and adjacent intermediate shells between the absorber and generator being connected to provide separate heat exchange paths connecting the generator and absorber.

14. An absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising a plurality of vertically arranged concentric shells, transverse walls in and between shells to seal the apparatus and provide inner and outer chambers with annular connecting passages therebetween, heat receiving and heat rejecting elements in the inner and outer chambers, and adjacent shells between the inner and outer chambers providing a reservoir connected to one of the passages for receiving and storing surplus solution.

15. A unitary absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising a plurality of vertically arranged shells, transverse walls in the inner shell providing a lower solution chamber and a heating chamber above the solution chamber, vertical tubes between transverse walls extending from the solution chamber through the heating chamber, transverse walls between outer shells to provide an absorption chamber therebetween, a heat exchange element in said absorption chamber through which cooling medium is circulated, transverse walls connecting the ends of the shells between the inner and outer shells to provide adjacent heat exchange passages for solution flowing from the inner shell to the absorption chamber and from the absorption chamber back to the inner shell, and the space between two intermediate shells providing a reservoir for storing solution to maintain a substantially constant hydrostatic head on the solution in the solution chamber.

16. An absorption refrigeration apparatus containing a solution of refrigerant and absorbent and having a generator comprising vertically arranged concentric shells,

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the inner shell having transverse walls to provide a lower solution chamber and a heating chamber above the solution chamber, tubes between the adjacent transverse walls and extending from the solution chamber through the heating chamber, means supplying heating medium to the heating chamber for heating solution and lifting it above the inner shell, and the inner shell and adjacent concentric shell providing an annular passage through which the lifted solution flows by gravity in heat exchange relation with the outside wall of the heating chamber.

17. A unitary absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising vertically arranged concentric shells, the inner shell having transverse walls to provide a lower solution chamber and a heating chamber above the solution chamber, tubes between adjacent transverse walls and extending from the solution chamber through the heating chamber, a connection adjacent its lower end for supplying heating vapor to the heating chamber, a vent tube extending from the wall of the inner shell at the bottom of the heating chamber upwardly to the top of the heating chamber, the inner shell and adjacent shell providing a passage through which solution flows by gravity, and transverse walls in and between certain of the shells dividing the apparatus into upper and lower sections having inner and outer compartments.

18. An absorption refrigeration apparatus containing a solution of refrigerant and absorbent and having an absorber comprising vertically arranged concentric shells, transverse walls between adjacent shells to provide a chamber, a heat exchange element in the chamber, and adjacent shells providing annular passages for the flow of absorption solution to and from the absorber chamber with a common heat exchange wall therebetween.

19. An absorption refrigeration apparatus containing a solution of refrigerant and absorbent and having an absorber comprising a plurality of vertically arranged concentric shells, transverse walls between adjacent concentric shells to form an annular chamber, a heat exchange coil in said chamber having overlying pipe sections, a perforated transverse wall between adjacent shells in the chamber constituting a liquid distributor overlying the coil, and adjacent concentric shells providing heat exchange passages for delivering absorption solution weak in refrigerant to the liquid distributing means and absorption strong in refrigerant from the chamber.

20. A unitary absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising vertically arranged concentric shells, a heat exchange element in the inner shell constituting a generator, means for supplying heat to the heat exchange element to expel refrigerant from absorbent and cause circulation of absorbent, a heat exchange element between adjacent outer shells constituting an absorber, means for supplying cooling medium for circulation through the heat exchange element constituting the absorber, a second heat exchange element adjacent the first heat exchange element and constituting an evaporator, means for supplying medium to be cooled for circulation through the heat exchange element constituting the evaporator, intermediate shells being connected to provide separate heat exchange paths for solution flowing from the generator toward the absorber and from the absorber toward the generator, a heat exchange element above the evaporator for liquefying refrigerant vapor, and means for supplying liquid refrigerant from the heat exchange element constituting the liquefier to the exterior of the heat exchange element constituting the evaporator.

21. A unitary absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising vertically arranged concentric shells, a heat exchange element in the inner shell for expelling refrigerant from absorbent and circulating the latter, transverse walls between an inner and outer shell to provide upper and

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lower chambers, a heat exchange element in the upper chamber through which cooling medium is circulated and constituting a refrigerant condenser, a heat exchange element in the lower chamber through which medium to be cooled is circulated and constituting an evaporator, means for delivering liquid refrigerant from the upper chamber onto the exterior of the heat exchange element in the lower chamber, a heat exchange element in the lower chamber through which cooling medium is circulated and constituting an absorber, and walls connecting intermediate shells to provide separate heat exchange paths for delivering solution from the upper chamber onto the heat exchange element of the absorber and from the absorber back to the inner shell.

22. A unitary two pressure refrigeration apparatus containing a working fluid and comprising vertically arranged concentric shells, transverse walls between certain of the concentric shells to seal the apparatus and provide high and low pressure sections, heat receiving and heat rejecting elements in said sections, and the space between adjacent shells providing an annular passage between the high and low pressure sections for maintaining a pressure balancing liquid column of the working fluid therebetween.

23. A unitary two pressure vacuum type absorption refrigeration apparatus containing absorption solution and comprising vertically arranged concentric shells, transverse walls dividing the inner shell into a lower solution chamber and a heating chamber above the solution chamber, tubes between transverse walls extending from the solution chamber through the heating chamber, transverse walls between the inner and outer shells adjacent the top of the inner shell to divide the apparatus into high and low pressure sections, a heat exchange element in the upper section constituting a refrigerant condenser, transverse walls between adjacent outer shells forming a chamber surrounding the inner shell below the condenser, heat exchange elements in the chamber constituting an evaporator and absorber, transverse walls between intermediate shells providing a heat exchanger surrounding the inner shell below evaporator and absorber chamber, and adjacent shells providing passages between the absorber chamber and heat exchanger for maintaining pressure balancing liquid columns of solution.

24. A unitary absorption refrigeration apparatus containing absorption solution and comprising a plurality of concentric shells, transverse walls between shells to divide the interior of the apparatus into upper and lower sections, adjacent outer shells dividing the upper and lower sections into inner and outer compartments, the inner shell constituting a generator in the inner compartment and extending from the lower to the upper section, heat exchange elements arranged in alignment one over the other in the outer compartments of the upper and lower sections and constituting a condenser, an evaporator and an absorber, adjacent shells in the inner compartment of the lower section providing heat exchange passages for the flow of solution between the generator and absorber, and a pump in the outer compartment of the lower section for circulating absorption solution.

25. A unitary absorption refrigeration apparatus containing absorption solution and comprising a plurality of concentric shells, the inner shell having heating means therein and constituting a generator, a plurality of annular heat exchange coils arranged in alignment one over the other in a chamber between outer shells and constituting a condenser, an evaporator and an absorber, adjacent shells between inner and outer shells providing heat exchange paths connecting the generator to the absorber, each of said heat exchange coils comprising a plurality of pipes bent in concentric annuli horizontally and in serpentine vertically to provide a series of pipe sections arranged one over the other in vertical rows with a radial space between the bent ends, and a pump

in the radial space connected to circulate absorption solution.

26. A unitary absorption refrigeration apparatus containing a solution of refrigerant and absorbent and comprising vertically arranged concentric shells, transverse walls in the inner shell forming a lower solution chamber and a heating chamber above the solution chamber, tubes between adjacent transverse walls and extending from the solution chamber through the heating chamber, transverse walls between the inner and outer shells to provide an upper high pressure section and a lower low pressure section, an intermediate shell dividing the upper and lower sections into inner and outer compartments, a cooling coil in the outer compartment of the upper high pressure section for condensing refrigerant vapor, an evaporator coil underlying the condenser coil in the outer compartment of the lower low pressure section, an absorber coil underlying the evaporator coil, an orifice in the transverse wall in the outer compartment between the condenser and evaporator coils, an orifice in the transverse wall between the inner compartments, walls connecting the intermediate shells to provide heat exchange paths between the inner compartment of the upper chamber and the absorber and the bottom of the outer compartment in the lower section and solution chamber in the inner shell, and a pump in the outer compartment of the lower section for circulating solution in the last named path.

27. A unitary absorption refrigeration apparatus containing absorption solution and comprising a plurality of concentric shells, the inner shell having heating means therein and constituting a generator, a plurality of annular heat exchange coils arranged in alignment one over the other in a chamber between outer shells and constituting a condenser, an evaporator and an absorber, adjacent shells between inner and outer shells providing heat exchange paths connecting the generator to the absorber, each of said heat exchange coils being of annular form with a radial space at one side, a pump in the radial space at the bottom of the chamber and connected to circulate absorption solution, a gas storage vessel in the apparatus, and a purge device in the radial space of the coils for continuously withdrawing non-condensable gases from the chamber and transferring them to the gas storage vessel.

28. A unitary absorption refrigeration apparatus containing absorption solution and comprising concentric shells, transverse walls between shells dividing the in-

terior of the apparatus into an upper high pressure section and a lower low pressure section, adjacent outer shells dividing the upper and lower sections into inner and outer compartments, a generator at the center of the apparatus extending upwardly through the inner compartments from the lower to the upper section, annular coils in the outer compartments of the upper and lower sections and comprising a condenser, an evaporator and an absorber, passages connecting the compartments for the flow of refrigerant and absorber, means for circulating absorption solution, each of said annular coils having a radial space, a standpipe in the radial space having a transverse wall forming a chamber with an overflow tube depending into the chamber, a purge device in the radial space and having an auxiliary absorber vessel connected to the inner compartment in the upper section, and a fall tube depending from the auxiliary absorber vessel through the standpipe into the chamber whereby absorption solution from the fall tube overflows into the standpipe to maintain a pressure balancing liquid column in the standpipe.

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