

Sept. 17, 1929.

B. C. VON PLATEN ET AL

1,728,643

REFRIGERATION

Filed April 14, 1927

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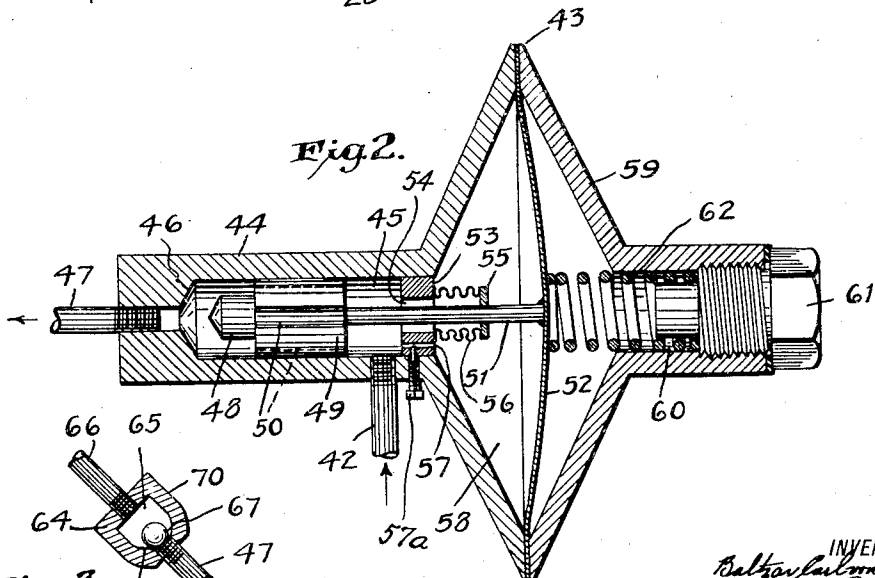
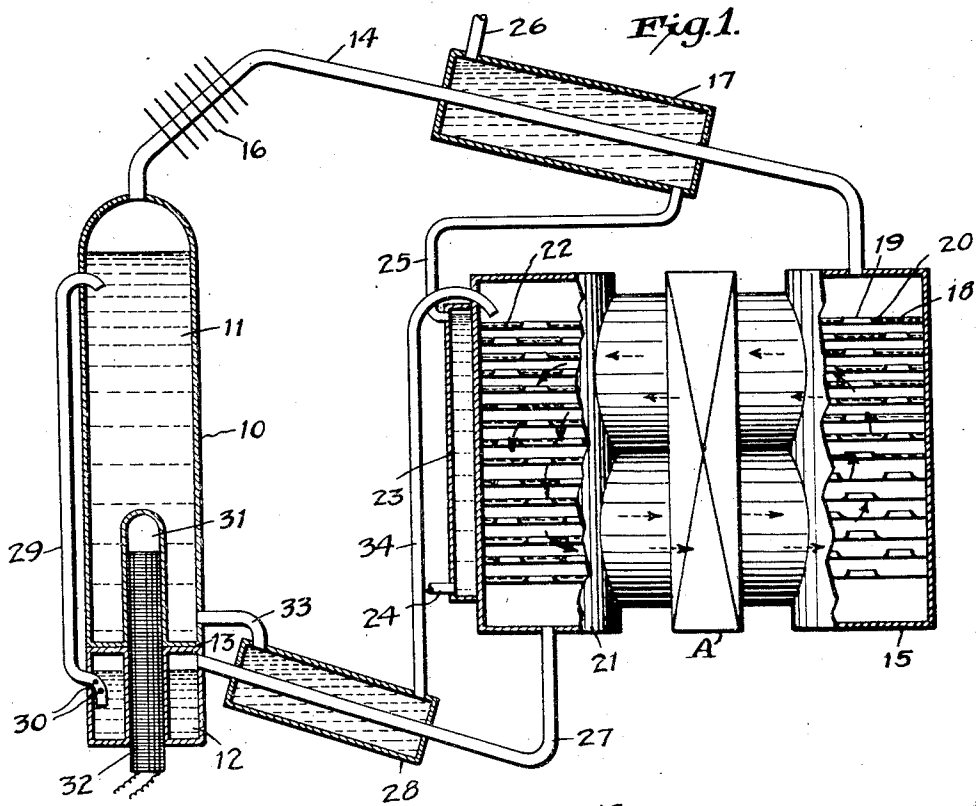
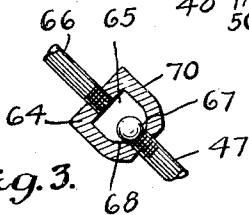


Fig. 3.



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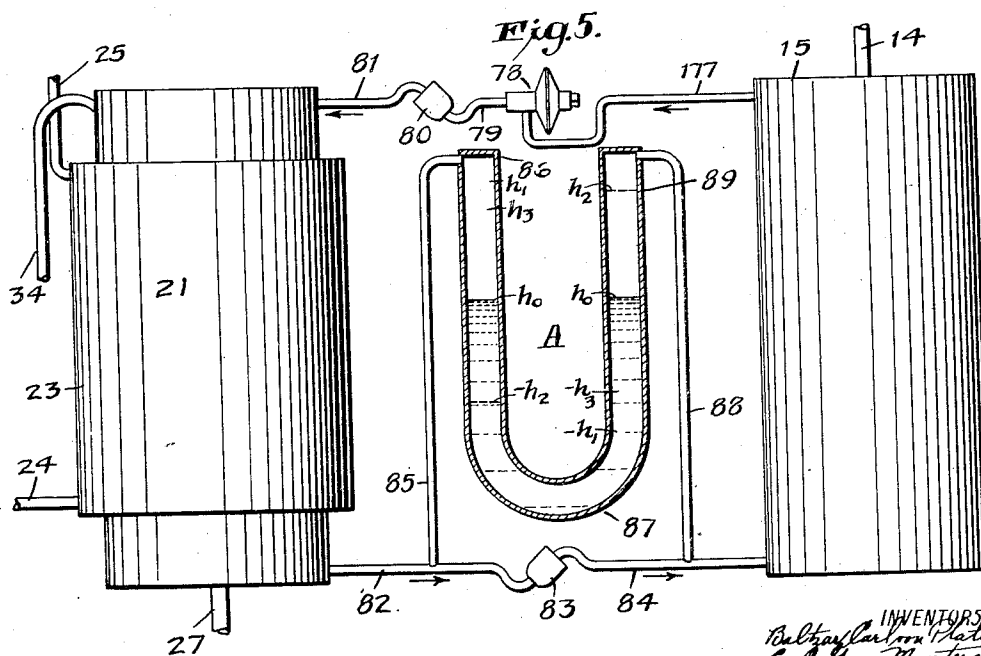
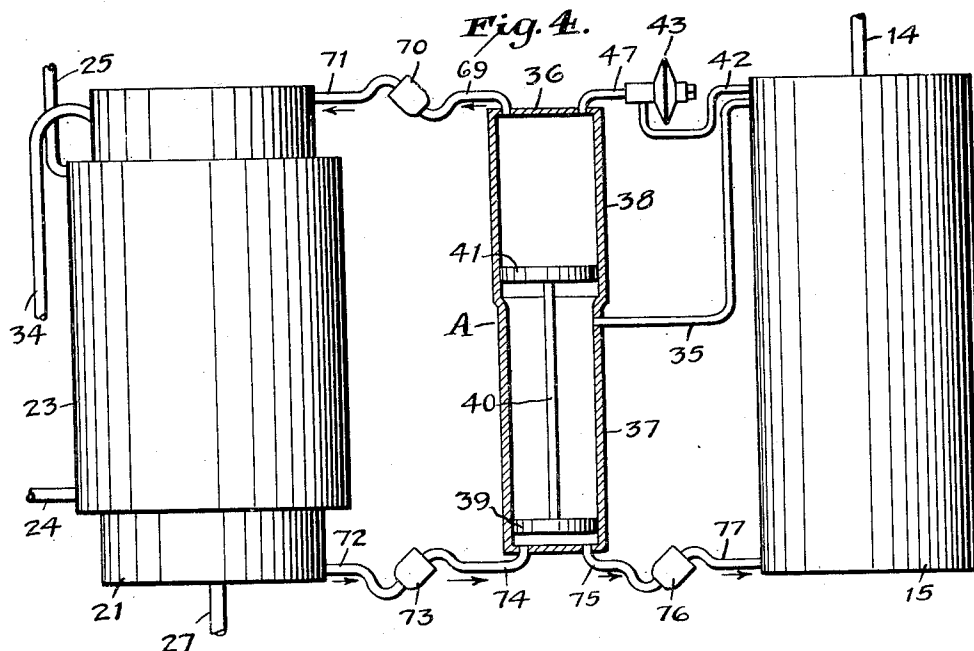
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5 Sheets-Sheet 2



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REFRIGERATION

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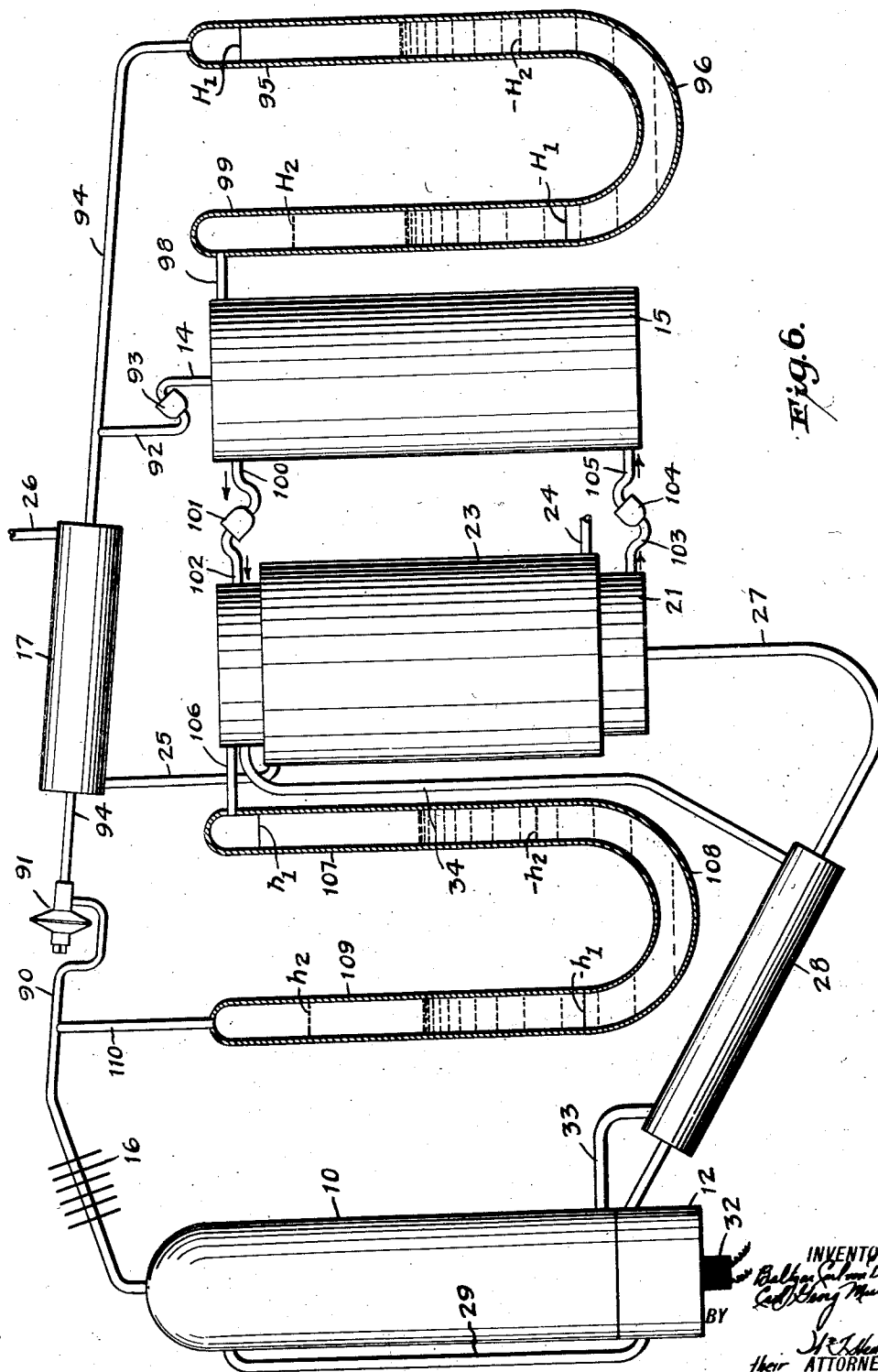


Fig. 6.

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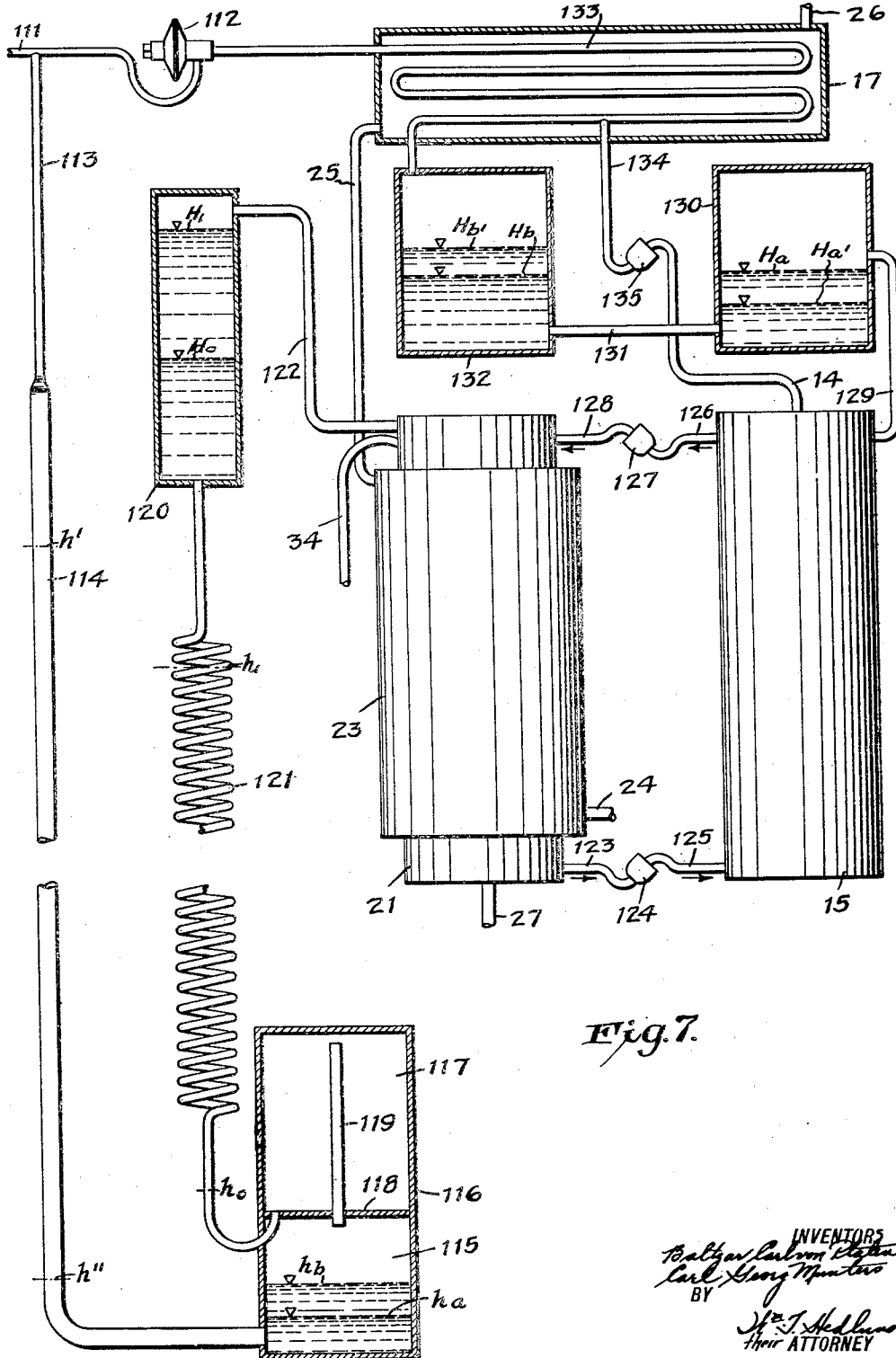


Fig. 7.

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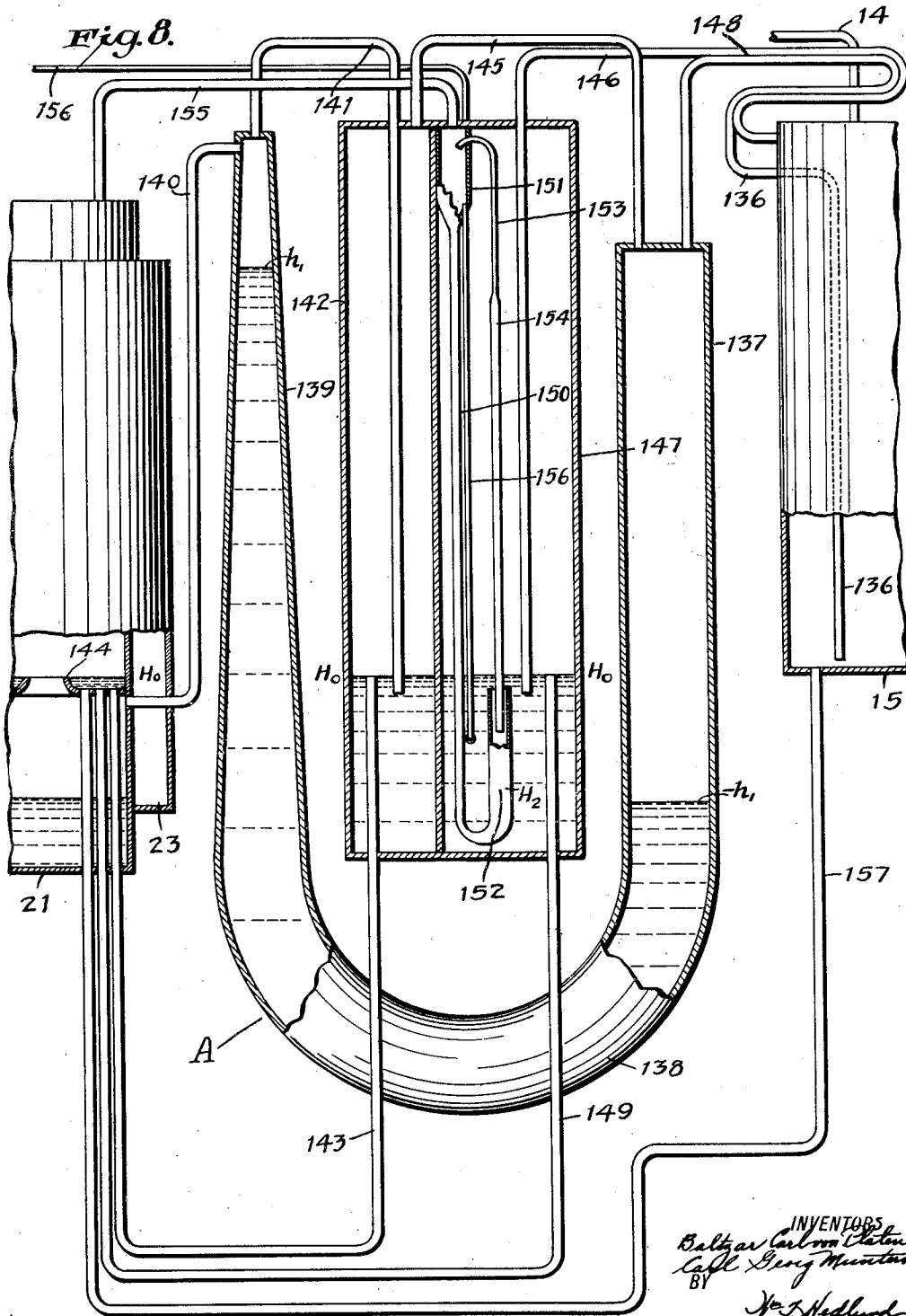
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REFRIGERATION

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5 Sheets-Sheet 5



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UNITED STATES PATENT OFFICE

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REFRIGERATION

Application filed April 14, 1927, Serial No. 183,675, and in Sweden May 1, 1926.

Our invention relates to the art of refrigeration and particularly to refrigerating systems of the absorption type in which the circulation of fluids is effected by forces generated entirely within the system.

Our invention contemplates various improvements in the method of circulating fluids within refrigeration systems. One characteristic of the present invention is the production of reciprocatory, oscillatory or similar movement to a body, the movement of which body causes fluid transportation within the system. We preferably utilize work developed within the system to move the body and, in the preferred form, a movement of liquid is produced due to rise of pressure and sudden release of pressure.

Other objects, the nature and advantages of the invention will appear from the following description and accompanying drawings, of which:

Fig. 1 shows diagrammatically an absorption refrigerating system embodying the invention;

Fig. 2 shows a valve, partly in cross-section, which may be used in carrying out the invention;

Fig. 3 shows another valve, partly in cross-section, which may be used in carrying out the invention;

Fig. 4 shows more or less diagrammatically one form of the invention;

Fig. 5 shows more or less diagrammatically a modification of the apparatus shown in Fig. 4;

Fig. 6 shows more or less diagrammatically another embodiment of the invention;

Fig. 7 shows more or less diagrammatically a modification of the embodiment shown in Fig. 6; and

Fig. 8 is a drawing, partly in cross-section, of an apparatus constructed according to the invention.

Referring more particularly to Fig. 1, reference character 10 designates a generator which is divided into a main generator 11 situated above an auxiliary generator 12 by a partition 13. A conduit 14 extends for some distance upwardly from the upper part of main generator 11 and thence downwardly

to the upper part of evaporator 15. The upwardly extending portion of conduit 14 is supplied with radiating fins 16 while the downwardly extending portion passes through a water jacket 17.

Within substantially the whole of evaporator 15 is situated a series of disks 18 in which are formed apertures 19 surrounded by raised rims 20. Reference character A designates generally apparatus, including conduits, the function of which is to promote circulation of vapor from the upper part of evaporator 15 to the upper part of an absorber 21 and from the lower part of absorber 21 to the lower part of evaporator 15 and may also include a means of heat exchange between the vapors so circulated.

Within absorber 21 is situated a series of disks 22 which may be similar to disks 18 in evaporator 15. Absorber 21 is partially surrounded by a water jacket 23. Cooling water is supplied to water jacket 23 through a conduit 24 and is discharged through conduit 25 to water jacket 17 from whence it is discharged through conduit 26. A conduit 27 communicates with the bottom of absorber 21, passes through heat exchanger 28, and communicates with the upper part of auxiliary generator 12.

A thermo-siphon conduit 29 connects auxiliary generator 12 with the upper part of main generator 11. A portion of conduit 29 extends for some distance downwardly within auxiliary generator 12 and is here provided with one or more capillary ports 30. A passageway 31, in which is situated a heating element 32, extends centrally through auxiliary generator 12 and for some distance within main generator 11. A conduit 33 connects the lower part of main generator 11 with heat exchanger 28 and a conduit 34 connects heat exchanger 28 with the upper part of absorber 21.

The operation of this apparatus is as follows:

Heating element 32 supplies heat to the solution of a refrigerant, for instance ammonia, dissolved in an absorbing medium, for instance water, which is contained in main generator 11. The application of heat drives

the ammonia out of solution and it passes upwardly as a vapor through conduit 14. Any water vapor that accompanies the ammonia vapor is condensed to a liquid in that upwardly extending portion of conduit 14 which is provided with radiating fins 16 and the water so formed runs back to generator 11. The dry ammonia vapor continues through conduit 14 and is condensed to a liquid in that downwardly extending portion of conduit 14 which is surrounded by water jacket 17. The liquid ammonia runs into the top of evaporator 15 where it is distributed over disks 18. Here the liquid ammonia comes in intimate contact with, and evaporates in the presence of, a gas, inert with respect to ammonia, for instance hydrogen, which is introduced into the evaporator at the bottom thereof. The evaporation of the ammonia results in a low temperature which produces refrigeration.

The gaseous mixture of ammonia and hydrogen passes out of the top of the evaporator under the influence of the circulatory means designated generally by A and enters the top of absorber 21. In the absorber the gaseous mixture comes in intimate contact with water which contains but relatively little ammonia in solution and which enters the top of absorber 21 through conduit 34. This water absorbs the ammonia gas while the hydrogen remains unabsorbed and passes out the bottom of absorber 21 under the influence of the circulatory means A and enters the lower part of evaporator 15. Heat generated by the absorption process is carried away by the cooling water in water jacket 23.

The strong solution of ammonia in water formed within absorber 21 runs by gravity therefrom through conduit 27 to auxiliary generator 12. The application of heat to the solution in auxiliary generator 12 causes the formation of vapor in the top thereof and this vapor passes through capillary ports 30 and forms gas bubbles in the liquid contained in thermo-siphon conduit 29. The presence of these gas bubbles in conduit 29 reduces the specific weight of the fluid column as a whole therein to such an extent that the liquid column in and below absorber 21 causes flow upwardly through conduit 29 to the upper part of main generator 11. In main generator 11 the ammonia is again driven out of solution, as previously described, and the weak solution passes downwardly therethrough and through conduit 33 to heat exchange member 28. Within member 28 heat passes from the hot weak solution to the cool strong solution in conduit 27, which serves to pre-heat the latter before it enters the generator, while pre-cooling the former before it enters the absorber. The weak solution passes from member 28 through conduit 34 to the top of the absorber. For further consideration of this type of ap-

paratus in general and its system of operation, reference may be had to our Patent No. 1,609,334 granted December 7, 1926.

The apparatus shown in Fig. 4 may be considered as a part of the apparatus of Fig. 1 and an evaporator 15, an absorber 21, and apparatus, designated generally by A, for the promotion of circulation between them. A conduit 35 connects the upper part of evaporator 15 with the central part of cylindrical member 36. Member 36 consists of two intercommunicating cylinders 37 and 38. Cylinder 37, which is below cylinder 38, has a somewhat smaller diameter than cylinder 38. A piston 39 is slidably mounted in cylinder 37, and piston 41 is slidably mounted in cylinder 38 and the two pistons are rigidly connected together by rod 40 of such length that the pistons will be in similar positions in their respective cylinders. A conduit 42 connects the upper part of evaporator 15 with a valve 43.

Valve 43 is shown more in detail in Fig. 2. It is so constructed as to open at a predetermined high pressure on its inlet side and to remain open for a predetermined period of time. Valve 43 comprises a housing 44, which has a central passageway 45. Inlet conduit 42 communicates with passageway 45 as shown. Passageway 45 is restricted so as to form a valve seat 46 and communicates with an outlet conduit 47. A valve member 48 is attached to member 49, which is slidable in passageway 45. Member 49 is provided with a number of longitudinal slots 50 through which fluid may pass. Member 49 is attached to a stem 51, which is secured in any suitable manner to diaphragm 52. One end of passageway 45 is partially closed by a partition 53. Stem 51 passes through an opening 54 in partition 53. A collar 55 is secured to stem 51 at some distance from the point where the stem passes through opening 54. One end of an expandible and contractable bellows or sylphon 56 is secured to partition 53, while the other end is secured to collar 55. A small passageway 57 allows a limited amount of communication between passageway 45 and diaphragm chamber 58. The circumference of diaphragm 52 is clamped between housing 44 and another housing 59. Diaphragm 52 is made of suitable stiff material, preferably metallic, and is dished so that it will not move in response to slight variations of pressure but will remain stationary until a considerable pressure difference has been developed when its more central portion will move a considerable distance with a snap. A central passageway 60 is formed within housing 59. The outer end of passageway 60 is provided with screw threads into which may be screwed a plug 61. Plug 61 serves to retain a spiral spring 62, the other end of which presses against the central part of diaphragm 52. Plug 61 may

be screwed varying distances into member 59 thereby varying the compression in spring 62, which may be used to determine the pressure at which diaphragm 52 will snap and open the valve. Conduit 47 connects the outlet of valve 43 with the top of cylinder 38. A conduit 69 connects the top of cylinder 38 with the inlet side of valve 70.

Valve 70 is shown more in detail in Fig. 3. Its purpose is to allow flow through it in one direction, but not in the other. Valve 70 comprises a housing 64 within which is formed a chamber 65. Chamber 65 communicates with inlet conduit 47 and outlet conduit 66. Housing 64 is placed in an inclined position as shown. The lower end of chamber 65 is formed spherically so as to form a valve seat 68 for ball 67. When no fluid is passing, ball 67 rests on valve seat 68 by gravity and prevents communication between conduit 47 and chamber 65. Any tendency towards flow from chamber 65 into conduit 47 will serve to force ball 67 more firmly against seat 68. On the other hand, for flow to take place from conduit 47 to chamber 65, it is not necessary that sufficient force be exerted to lift ball 67 bodily from seat 68 as it will roll slightly on seat 68 and thus uncover the opening.

A conduit 71 connects the outlet of valve 70 with the top of absorber 21. A conduit 72 connects the bottom of absorber 21 with the inlet of valve 73 which is another valve similar to valve 70. A conduit 74 connects the outlet of valve 73 with the bottom of cylinder 37. A conduit 75 connects the bottom of cylinder 37 with the inlet of valve 76, which again is a valve of the type of valve 70. A conduit 77 connects the outlet of valve 76 with the bottom of evaporator 15.

The operation of this form of the invention is as follows:

Liquid ammonia is introduced into evaporator 15 through conduit 14 and evaporates in the presence of hydrogen in a manner similar to that explained in connection with Fig. 1. Due to this evaporation, the pressure increases in evaporator 15. Valve 76 will not allow flow therethrough as it is a one way valve and allows only flow into the evaporator and valve 43 is closed as it is adjusted to open at a given pressure and this pressure has not as yet been reached. This pressure will, however, be transmitted through conduit 35 to the central part of cylindrical member 36 and will act downwardly on piston 39 and upwardly on piston 41. As piston 41 has a greater surface than piston 39, the assemblage consisting of pistons 39 and 41 and piston rod 40 will move upwardly. The vaporous mixture of ammonia and hydrogen which is in cylinder 38, as will be explained presently, is forced out through conduit 69, valve 70 and conduit 71 into absorber 21, where the ammonia is absorbed in a manner

similar to that described in connection with Fig. 1. At the same time relatively pure hydrogen is drawn from the bottom of absorber 21 through conduit 72, valve 73 and conduit 74 into cylinder 37. After piston 41 reaches the top of cylinder 38, the pressure in evaporator 15 continues to increase. This pressure is transmitted through conduit 42 to passageway 45 in valve 43 and from passageway 45 through opening 57 to diaphragm chamber 58 where it acts upon diaphragm 52. When this pressure has reached a predetermined value it causes diaphragm 52 to snap to the right, as viewed in Fig. 2, and which moves valve member 48 away from seat 46. The pressure in evaporator 15 drops and the pistons 39 and 41 and rod 40 descend due to gravity. The hydrogen in cylinder 37 is forced out through conduit 75, valve 76 and conduit 77 into the lower part of evaporator 15. A portion of the vaporous mixture of ammonia and hydrogen passes out of evaporator 15 through conduit 42, valve 43, and conduit 47, into cylinder 38. This flow is caused by the suction produced by piston 41 as well as by the excess pressure which exists in the evaporator at the instant valve 43 opens.

During the time taken for the piston assemblage to descend valve 43 remains open, for, although, the pressure existing in the evaporator decreases rapidly immediately following the opening of the valve, the pressure existing in diaphragm chamber 58 and acting upon diaphragm 52 decreases very slowly due to the smallness of opening 57. Opening 57 is so designed that it allows the pressure in chamber 58 to decrease at such a rate that it reaches a value that permits spring 62 to snap the diaphragm to the left and close the valve shortly after piston 39 has reached the bottom of cylinder 37. Opening 57 may be adjusted by means of any suitable device such as set screws 57^a.

As piston 41 has a greater displacement than piston 39, the volume of ammonia-hydrogen mixture circulated from the evaporator to the absorber is greater than the volume of hydrogen circulated from the absorber to the evaporator. Cylinders 38 and 39 are so designed that the displacements of their respective pistons 41 and 39 are to each other as the volume of hydrogen entering is to this volume of hydrogen, plus the volume of evaporated ammonia leaving the evaporator.

In Fig. 5 is shown a form of our invention similar to that illustrated in Fig. 4. The upper part of evaporator 15 is connected to the upper part of absorber 21 through conduit 177, valve 78, conduit 79, valve 80 and conduit 81. Valves 78 and 80 are similar to valves 43 and 70, respectively, in Fig. 4 and act in the same way. The lower part of absorber 21 is connected to the lower part of

evaporator 15 through conduit 82, valve 83 and conduit 84. Valve 83 is similar to valves 73 and 76 allowing flow as indicated by arrows. A conduit 85 communicates with conduit 82 and with the top of leg 86 of U-shaped member 87. A conduit 88 communicates with conduit 84 and with the top of leg 89 of member 87. U-shaped member 87 is partially filled, as shown, with a liquid which may be, for instance, a solution of ammonia in water.

The operation of this apparatus is as follows:

Assume the liquid in U-shaped member 87 to be in equilibrium, as shown, with the level h_0 existing in each leg. Evaporation of ammonia in evaporator 15 causes an increase in pressure therein as was explained in connection with Fig. 4. As valves 78 and 83 are closed, this pressure builds up through conduits 84 and 88 and leg 89 and forces the liquid downward in leg 89 to level $-h_1$ and upward in leg 85 to level h_1 . When these levels have been reached, the pressure in evaporator 15 is sufficient to suddenly open valve 78. The liquid column in leg 86 of member 87 then falls and due to its inertia the levels h_2 and $-h_2$ are attained. A quantity of hydrogen vapor proportional to the volume included between $-h_1$ and h_2 is forced from leg 89 to evaporator 15, while at the same time an equal volume of ammonia-hydrogen vapor is forced out of evaporator 15 to absorber 21 and also the same volume of hydrogen is sucked from absorber 21 to leg 86. The liquid column now oscillates in the other direction and the levels h_3 and $-h_3$ are reached. A quantity of hydrogen equal to the volume contained between levels $-h_2$ and h_3 has been forced out of leg 86 through conduits 85 and 82, valve 83 and conduits 84 and 88 into leg 87. During this oscillation, flow of vapor from the top of absorber 21 to the top of evaporator 15 has been prevented by the one way valve 80.

Valve 78 is so designed as to close at the time when the levels h_3 and $-h_3$ are reached and the oscillation of the liquid column is arrested. The pressure in evaporator 15 again increases and forces the column in member 87 to levels h_1 and $-h_1$. Thus after the first series of oscillations, it is only necessary to raise the column in leg 86 from h_3 to h_1 and to depress the column in leg 89 from $-h_3$ to $-h_1$. When valve 78 again opens, the hydrogen which was transferred to leg 89 during the previous series of oscillations is forced into evaporator 15. During each series a volume of ammonia-hydrogen vapor corresponding to the volumes included between levels $-h_1$ and h_2 is forced from the evaporator to the absorber, while a smaller volume of hydrogen, which corresponds to the volumes included between levels $-h_2$ and h_3 is forced from the absorber to the evaporator.

Valve 78 may also be so designed as to remain open until the oscillations of the liquid column have about ceased. In this case the operation of the apparatus each time will be as first described, that is, the column will start from rest at the level h_0 each time.

Fig. 6 shows an apparatus embodying a form of our invention which utilizes pressure generated in the generator to cause circulation between the evaporator and the absorber. Conduit 90 communicates with the vapor space of the main generator and with the inlet of valve 91, which may be similar to valve 43 shown in detail in Fig. 2. A conduit 94 connects the outlet of valve 91 with the top of leg 95 of U-shaped member 96. Conduit 94 passes through water jacket 17. Conduit 92 communicates with conduit 94 as shown and with the inlet of valve 93, which may be similar to valve 70 in Fig. 3. Conduit 14 connects the outlet of valve 93 with the top of evaporator 15.

A conduit 98 connects the top of leg 99 of U-shaped member 96 with the top of evaporator 15. A conduit 100 connects the top of evaporator 15 with the inlet of valve 101 which may be similar to valve 70 of Fig. 3. A conduit 102 connects the outlet of valve 101 to the top of absorber 21. A conduit 103 connects the bottom of absorber 21 with the inlet of valve 104 which may also be similar to valve 70. A conduit 105 connects the outlet of valve 104 with the bottom of evaporator 15. A conduit 106 connects the upper part of absorber 21 with the top of leg 107 of U-shaped member 108. The top of leg 109 is connected to conduit 90 by a conduit 110. U-shaped member 108 is partially filled, as shown, by a suitable liquid, as for instance mercury, while U-shaped member 96 is filled with approximately the same quantity of aqua-ammonia solution.

The mode of operation is as follows:

Assume, to start with, that valve 91 is closed. Pressure is built up in the generator and in conduits 90 and 110 and leg 109. This increase in pressure depresses the level of the mercury in leg 109 to $-h_1$ and raises it in leg 107 to h_1 . A quantity of vapor is forced through conduit 106 into absorber 21 and a similar quantity of hydrogen is forced from absorber 21 to evaporator 15 through conduit 103, valve 104 and conduit 105. As valve 93 prevents the passage of vapor out of evaporator 15 through conduit 14, a quantity of vapor, corresponding to the quantity of hydrogen forced into the bottom of the evaporator, is forced out through conduit 98 into leg 99. The level of the liquid in leg 99 is depressed to $-H_1$ and raised in leg 95 to H_1 . The ammonia vapor forced out of leg 95 passes into conduit 94 and is condensed to a liquid therein by the cooling effect of the water in water jacket 17 and runs into conduit 92.

When the level of h_1 is reached in leg 107

the pressure in conduit 90 is sufficient to open valve 91 and ammonia vapor passes there-through into conduit 94 where it is condensed to a liquid by the cooling action of water jacket 17. The liquid ammonia runs into conduit 92 and passes through valve 93 along with the ammonia that has previously collected behind the valve. Valve 93 had been kept closed by the excess pressure in evaporator 15. However, when valve 91 opens, an equalization of pressure throughout the system tends to take place and the liquid ammonia passes through valve 93. The ammonia enters the evaporator and evaporates in a manner similar to that described in connection with Fig. 1.

When valve 91 opens, the excess pressure in leg 109 is suddenly relieved and the column of mercury in U-shaped member 108 starts to oscillate. The pressure in leg 99 of member 96 is also reduced and the liquid in member 96 likewise starts to oscillate. The oscillations of the columns in members 108 and 96 are very nearly in phase, although there may be a slight lag of the latter behind the former. The first oscillation, that is, when the levels change from h_1 to $-h_2$, from $-h_1$ to h_2 , from H_1 to $-H_2$, forces vaporous ammonia-hydrogen from evaporator 15 through conduit 100, valve 101 and conduit 102 into absorber 21. When the two columns oscillate in the opposite direction, hydrogen is forced from absorber 21 through conduit 103, valve 104 and conduit 105 into evaporator 15. Thus circulation is maintained alternately from the evaporator to the absorber and from the absorber to the evaporator, until frictional losses cause the liquid column to come to rest. Valve 91 is so designed as to close at approximately the time when the oscillations cease or become comparatively small. The pressure in leg 109 again begins to build up and the operations are repeated.

In Fig. 7 is shown a form of the invention similar to that just described in connection with Fig. 6, but better adapted to a system employing as a refrigerant a medium which operates under comparatively low pressures. Triethylamine is such a medium and for convenience it will be assumed that this is the refrigerant employed. Triethylamine is readily absorbed by water and is inert with respect to hydrogen.

Conduit 111 communicates with the vapor space of the generator and with the inlet valve 112 which may be similar to valve 43 of Fig. 2. Conduit 113 communicates with conduit 111 as shown and terminates in a larger conduit 114. Conduit 114 communicates with the bottom of chamber 115 of vessel 116. Vessel 116 is divided into the lower chamber 115 and an upper chamber 117 by the partition 118. A conduit 119 extends from within the upper part of chamber 115 to within the upper part of chamber 117. A

vessel 120 is placed at a higher elevation than vessel 116. A conduit 121 connects the bottom of chamber 117 with the bottom of vessel 120. Although conduit 121 is of comparatively small bore, it is of considerable length wound in the form of a spiral, so as to contain a large volume. The upper part of vessel 120 is connected to the upper part of absorber 21 by a conduit 122. A conduit 123 connects the bottom of absorber 21 with the inlet of a valve 124 which may be similar to valve 70 shown in detail in Fig. 3. A conduit 125 connects the outlet of valve 124 with the bottom of evaporator 15. A conduit 126 connects the top of evaporator 15 with the inlet of valve 127 which may be similar to valve 70 of Fig. 3. A conduit 128 connects the outlet of valve 127 with the top of absorber 21. A conduit 129 connects the top of evaporator 15 with the vapor space of a vessel 130. A conduit 131 connects the liquid space of vessel 130 with the liquid space of a similar vessel 132. A conduit 133 connects the outlet of valve 112 with the vapor space of vessel 132 and passes for the greater part of its length through water jacket 17. A conduit 134 communicates with conduit 133 as shown and with the inlet of a valve 135 which may also be similar to valve 70 of Fig. 3. Conduit 14 connects the outlet of valve 135 with the top of evaporator 15.

This apparatus operates as follows:

Assume that valve 112 has just closed. Conduit 114 contains a suitable liquid, for instance mercury, up to a level h^1 . This body of mercury extends into chamber 115 and fills that chamber up to a level h_a . Another body of mercury is contained in conduit 121 and extends upwardly from the level h_0 therein and fills vessel 120 up to the level H_0 . The intervening space between these two bodies of mercury, that is, the upper part of chamber 115, all of conduit 119, all of chamber 117 and the lower part of conduit 121, is filled with a suitable gas, for instance hydrogen. The mercury does not fall down in conduit 121 as this conduit has a bore sufficiently small so that the force of capillary attraction between the walls of the conduit and the mercury is so great that the hydrogen is unable to pass upwardly through the conduit, which would relieve the pressure of the hydrogen, and thus allow the mercury to fall down. Furthermore, as mercury has no tendency to wet the walls of a capillary tube there is no tendency for the mercury to creep down the walls of conduit 121. Vessels 130 and 132 are filled to the levels H_a and H_b , respectively, with liquid triethylamine.

As valve 112 has just closed, the pressure in the generator increases, due to the application of heat thereto. This increase in pressure is transmitted through conduit 111 and 113 to conduit 114. The liquid level in conduit 114 is depressed from h^1 to h^{11} and the

level in chamber 115 is raised from h_a to h_b . This causes the bottom of the liquid column in spiral conduit 121 to ascend from h_0 to h_1 which raises the level in vessel 120 from H_0 to H_1 . However, inasmuch as the length of the column which extended from h_0 to H_0 was greater than the length of the column which now extends from h_1 to H_1 , the pressure head exerted by this latter column is less than that exerted by the former. Therefore, the hydrogen in vessel 116 is under less pressure and has hence increased in volume. If this increase in volume is designated by V_a and if the volume of mercury which was displaced in conduit 114 and passed into chamber 115 is designated by V_b , it is seen that the volume of mercury forced into chamber 120 is equal to $V_a + V_b$.

The increase in volume of mercury in vessel 120 displaces vapor therefrom through conduit 122 into absorber 21. Hydrogen is thereby forced from absorber 21 through conduit 123, valve 124 and conduit 125 into evaporator 15, from which it displaces vapor through conduit 129 into vessel 130. The vapor forced into vessel 130 depresses the level of the liquid triethylamine contained therein from H_a to H_a' . The liquid thus displaced passes through conduit 131 to vessel 132 where the liquid level is raised from H_b to H_b' . Vapor is displaced in vessel 132 and passes into conduit 133 where it is condensed to a liquid by the cooling effect of the cooling water in water jacket 17.

During these changes in levels, the pressure which exists in the apparatus, with the exception of the pressure in vessel 116 and in the generator, has changed but slightly. The slight increase in pressure in absorber 21 and evaporator 15 is due to the pressure head exerted by the unequal columns of liquid in vessels 130 and 132. This head is small as the vessels 130 and 132 have a comparatively large cross-section and hence a small difference in elevation of levels H_a' and H_b' corresponds to a large volume displacement. As the pressure has remained practically constant, it is seen that a volume of gas equal to V_b which entered conduit 114 has caused a larger volume of hydrogen, equal to $V_a + V_b$, to pass from absorber 21 to evaporator 15.

When the mercury level in conduit 114 has been depressed to h'' , the pressure in the generator and conduit 111 is sufficient to open valve 112. An equalization of pressure occurs throughout the system including the generator, absorber and evaporator and the liquid levels return to their original positions. The tendency for the liquids to oscillate in this apparatus is very small, due to the small bore of conduits 114, 121 and 131. The level of the liquid triethylamine in vessel 130 raises from H_a' to H_a which displaces vapor from this vessel through conduit 129 into evaporator 15. This displaced vapor has a volume practically equal to $V_a + V_b$ and serves to force a corresponding volume of gaseous ammonia-hydrogen mixture from evaporator 15 through conduit 126, valve 127 and conduit 122 into absorber 21.

While valve 112 is open ammonia passes therethrough into conduit 133 and thence through conduit 134, valve 135 and conduit 136 in a manner similar to that described in connection with Fig. 6.

The comparative values of the volumes V_a and V_b depend upon the relation of the pressure head exerted by the mercury column $H_b - h_0$ to the pressure which exists in the absorber and evaporator. This latter pressure is determined by the pressure required to condense the refrigerant at the temperature of the cooling water. For the value of V_a to be large compared to V_b , it is necessary that the pressure head be large compared to the pressure of the refrigerant. As constructional considerations limit the height of the mercury column, it is necessary, in order to obtain this difference in pressure, to select as a refrigerant one which will condense at a low pressure. Triethylamine is cited as an example of such a refrigerant.

In Fig. 8 is illustrated an apparatus in which is embodied a form of the invention similar to that embodied by the apparatus shown in Figs. 4 and 5. In Fig. 8, however, no mechanical valves are employed. The functions performed by the mechanical valves of Figs. 4 and 5 are herein performed by liquid devices operating as valves as will be explained.

The evaporator is again designated by numeral 15 and the absorber by numeral 21. Ammonia is supplied to evaporator 15 through conduit 14 and evaporates in the evaporator in a manner similar to that described in connection with Fig. 4.

A conduit 136 extends from near the bottom of evaporator 15 upwardly therethrough and communicates with leg 137 of U-shaped member 138. Leg 139 of member 138 is longer than leg 137 and tapered toward the top, so that a given volumetric expansion in evaporator 15 will cause a greater difference in level between the columns in the two legs. Member 138 is tapered in part rather than made of a uniform small bore, so as to reduce frictional losses.

A conduit 140 connects the lower part of absorber 21 with the top of leg 139. A conduit 141 extends upwardly from the top of leg 139 to a point some distance above a vessel 142 and thence downwardly within that vessel to a point a short distance below the level of the liquid maintained therein. A conduit 143 communicates with the lowest disk 144 of absorber 21 and extends upwardly within vessel 142 to a point slightly above the lower end of conduit 141. As the level

H_0 of the liquid on plate 144 is at all times constant, a constant level H_0 is likewise maintained in vessel 142 inasmuch as the top of conduit 143 is at the level H_0 . A conduit 145 connects the upper part of vessel 142 with the top of leg 137.

A conduit 146 communicates with the upper part of evaporator 15 and extends downwardly within a vessel 147 to a short distance below the normal level of the liquid maintained therein. Conduits 136 and 146 are arranged in heat exchange relation at 148. A liquid level H_0 is normally maintained in vessel 147 in a manner similar to the way in which it is maintained in vessel 142. A conduit 149 communicates with plate 144 and extends upwardly within vessel 147 to the level H_0 .

A conduit 150 is contained within vessel 147. Conduit 150 terminates at its upper end in a funnel shaped member 151 and at its lower end communicates with a larger conduit which latter conduit extends upwardly to a point a short distance below the level H_0 . A conduit 153 of small bore communicates with funnel shaped member 151 and with a larger conduit 154. Conduit 154 extends downwardly from conduit 153 to a point within and some distance below the upper end of conduit 152. A conduit 155 connects the top of funnel shaped member 151 with the top of absorber 21. A conduit 156 communicates with funnel shaped member 151 at a point near the bottom of the inclined side thereof. Conduit 156 passes downwardly and out of vessel 147 and thence upwardly so as to form a liquid seal and finally communicates with the upper part of the generator. A conduit 157 connects the bottom of evaporator 15 with plate 144 of absorber 21 and serves to drain off any liquid ammonia or other liquid that fails to evaporate in the evaporator and otherwise would tend to collect in the bottom thereof.

The operation of this form of our invention is as follows:

Liquid ammonia is admitted to evaporator 15 through conduit 14. The ammonia evaporates in the evaporator and the pressure therein increases as was described in connection with Figs. 4 and 5. This increase in pressure is transmitted through conduit 136 to leg 137 and depresses the liquid level therein to $-h_1$ and raises the level in leg 139 to h_1 . The increase in pressure is also transmitted through conduit 146 to within vessel 147 and through conduit 145 to within vessel 142. In vessel 147 it forces liquid upwardly through conduits 150 and 154. As conduit 149 cannot supply liquid fast enough to compensate for the liquid forced into conduits 150 and 154, the level in vessel 147 drops but obviously it can drop only to the top of conduit 152. Thereafter the level in conduit 152 is depressed and the liquid already in conduit 154 is forced up-

wardly therein and into conduit 153. When the level in conduit 152 has reached H_2 , the top of the column in conduits 154 and 153 has just reached the top of the latter conduit and the liquid is suddenly discharged into funnel shaped member 151. At this time the levels $-h_1$ and h_1 have just been reached in legs 137 and 139 respectively. Although the pressure in vessel 142 forces liquid upwardly through conduit 141, the top of this column will not reach the bend in conduit 141 and run into leg 139 as this bend is above the top of conduit 153. Hence this column of liquid in conduit 141 serves as a seal between vessel 142 and leg 139.

There is now an open passageway from evaporator 15, through conduits 146, 154 and 153, funnel shaped member 151 and conduit 155, to absorber 21 and also from absorber 21, through conduit 140 to leg 139. Thus the pressure in both legs is equalized and the liquid column in U-shaped member 138 starts to oscillate. During the first oscillation, hydrogen gas is sucked from absorber 21 through conduit 140 into leg 139 and hydrogen gas, the presence of which in leg 137 will be explained presently, is forced therefrom through conduit 136 to the lower part of the evaporator. This hydrogen displaces an equal quantity of ammonia-hydrogen gas and this latter gas passes from the upper part of the evaporator through conduits 146, 154 and 153, funnel shaped member 151 and conduit 155, to absorber 21. The lower end of conduit 154 has not as yet been sealed by liquid as the liquid in conduit 150 has not had time to pass downwardly therethrough in sufficient quantities to fill conduit 152 up to the lower end of conduit 154.

By the time this first oscillation is finished, that is, when the level in leg 137 is at its highest and the level in leg 139 is at its lowest point, sufficient time has elapsed for the lower end of conduit 154 to have been sealed by liquid in conduit 152 and the passageway from the evaporator to the absorber closed. When the level now rises in leg 139 and falls in leg 137, hydrogen in leg 139 is forced therefrom, through conduit 141, vessel 142 and conduit 145 into leg 137, where it remains until forced into evaporator 15 during the next series of oscillations.

As the communication between the evaporator and absorber has been interrupted, the pressure now starts to build up once more in the evaporator and the foregoing operations are repeated.

A portion of the liquid that is forced into funnel shaped member 151 passes therefrom through conduit 156 and enters the upper part of the generator. Additional liquid passes from absorber 21 through conduit 149 and an approximately constant quantity of liquid is maintained in vessel 147. Hence it is seen that the force generated, due to the evap-

oration of ammonia in the evaporator, may be utilized to promote circulation of liquid between the absorber and the generator as well as to promote the circulation of gases between the evaporator and the absorber.

While we have shown and described several forms of our invention, it is to be understood that the principles involved may be applied in other ways without detracting from the spirit of the invention and we are not limited by what we have disclosed except in the light of appended claims taken in connection with the state of the prior art.

Having thus described our invention, what we claim is:

1. Refrigerating apparatus comprising vessels constituting an absorber and an evaporator, an alternating motion member comprising a movable body, connections between said member and said vessels, said member being adapted upon movement of said body to transfer fluid through said connections from one vessel to the other and means motivated by changes of condition within said apparatus to actuate said member.

2. Refrigerating apparatus comprising vessels constituting an absorber and an evaporator, an alternating motion member comprising a reciprocating body, connections between said member and said vessels, said member being adapted, upon reciprocation of said body, to transfer fluid through said connections from one vessel to the other and means whereby changes of pressure within said apparatus reciprocate said body.

3. Refrigerating apparatus comprising vessels constituting an absorber and an evaporator, an alternating motion member comprising a movable liquid body, connections between said member and said vessels, said member being adapted upon movement of said liquid body to transfer fluid through said connections from one vessel to the other and means forming part of and operative due to factors wholly within said apparatus to move said liquid body.

4. Refrigerating apparatus comprising vessels constituting an absorber and an evaporator, an alternating motion member comprising a movable body, connections between said member and said vessels, said member being adapted upon movement of said body to transfer fluid through said connections from one vessel to the other and means to create a pressure differential within said apparatus acting on said body to move the same.

5. Refrigerating apparatus comprising vessels constituting an absorber and an evaporator, an alternating motion member comprising a movable liquid body, connections between said member and said vessels, said member being adapted upon movement of said liquid body to transfer fluid through said connections from one vessel to the other and means to create a pressure differential within

said apparatus acting on said body to move the same.

6. Refrigerating apparatus comprising vessels constituting an absorber and an evaporator, an alternating motion member comprising a pair of interconnected vertically disposed legs adapted to hold liquid, connections between said member and said vessels, said member being adapted, upon oscillation of liquid in said legs, to transfer fluid through said connections from one vessel to the other and means to oscillate liquid in said member.

7. Refrigerating apparatus comprising an evaporator, an absorber, a vessel, a U-tube, said vessel being divided into separated compartments, level equalizing conduits connecting said absorber with said compartments, a conduit connecting said absorber with one leg of said U-tube, a conduit connecting said evaporator with the other leg of said U-tube, conduits connecting one of said separated compartments of said vessel with different legs of said U-tube, a generator, conduits connecting one of said separated compartments with said generator, liquid-column pressure reactive means within one of said separated compartments connected to said absorber operative to cause oscillation of liquid within said U-tube, a conduit connecting said generator with said evaporator and means to liquefy fluid interposed in the last mentioned conduit.

8. Those steps in the process of refrigerating through the agency of an absorption system including an absorber and an evaporator which consist in alternately causing a rise and fall of pressure in the system, moving a body due to said rise and fall of pressure and transporting gaseous fluid between the evaporator and absorber due to movement of said body.

9. Those steps in the process of refrigerating through the agency of an absorption system including an absorber and an evaporator which consist in alternately causing a rise and fall of pressure in the system, moving a body due to said rise and fall of pressure and circulating gaseous fluid between and through the evaporator and absorber due to movement of said body.

10. Those steps in the process of refrigerating through the agency of an absorption system including an absorber and an evaporator which consist in producing a rise of pressure in the system, elevating a body due to said rise of pressure, suddenly releasing the pressure and causing the body to descend and transporting gaseous fluid between the evaporator and absorber due to the descent of said body.

11. Those steps in the process of refrigerating through the agency of an absorption system including an absorber and an evaporator which consist in producing a rise of pressure in the system, elevating a body of liquid due to said rise of pressure, suddenly releasing the

pressure and causing the body of liquid to descend and transporting gaseous fluid between the evaporator and absorber due to the descent of said body of liquid.

5 12. Those steps in the process of refrigerating through the agency of an absorption system including an absorber and an evaporator which consist in producing a rise and fall of pressure in the system, oscillating a body of
10 liquid due to said rise and fall of pressure and transporting gaseous fluid between the evaporator and absorber due to said oscillation.

13. Those steps in the process of refrigerating through the agency of an absorption system including an absorber and an evaporator which consist in producing a rise and fall of pressure in the system, oscillating a body of liquid due to said rise and fall of pressure and
20 circulating gaseous fluid between and through the evaporator and absorber due to said oscillation.

14. Those steps in the process of refrigerating through the agency of an absorption system including an absorber and an evaporator which consist in producing a rise and fall of pressure in the evaporator, oscillating a body of liquid due to said rise and fall of pressure and transporting gaseous fluid between the
30 evaporator and absorber due to said oscillation.

15. Those steps in the process of refrigerating through the agency of an absorption system including an absorber and an evaporator which consist in producing a rise of pressure in the system, elevating a body of liquid due to said rise of pressure, suddenly releasing the pressure and causing the body of liquid to oscillate and transporting gaseous fluid between the evaporator and absorber due to the
40 oscillation of said body of liquid.

16. Those steps in the process of refrigerating through the agency of an absorption system including a generator and an absorber which consist in alternately causing a rise and fall of pressure in the system, moving a body due to said rise and fall of pressure and transporting absorption liquid between the generator and absorber in response to movement
50 of said body.

17. Those steps in the process of refrigerating through the agency of an absorption system including a generator, an absorber and an evaporator which consist in alternately causing a rise and fall of pressure in the system, moving a body due to said rise and fall of pressure, transporting gaseous fluid between the evaporator and absorber due to movement of said body and transporting absorption liquid between the generator and absorber due to movement of said body.
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In testimony whereof we hereunto affix our signatures.

BALTZAR CARL VON PLATEN.
CARL GEORG MUNTERS.