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Mamiya

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[54] **MULTI-STAGE ABSORPTION REFRIGERATION SYSTEM**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 180,640, Sept. 15, 1971, Pat. No. 3,742,728.

[52] **U.S. Cl.** **62/476,** 62/483, 62/489, 62/497

[51] **Int. Cl.** **F25b 15/06**

[58] **Field of Search** 62/101, 476, 483, 489, 62/497

[56] **References Cited**

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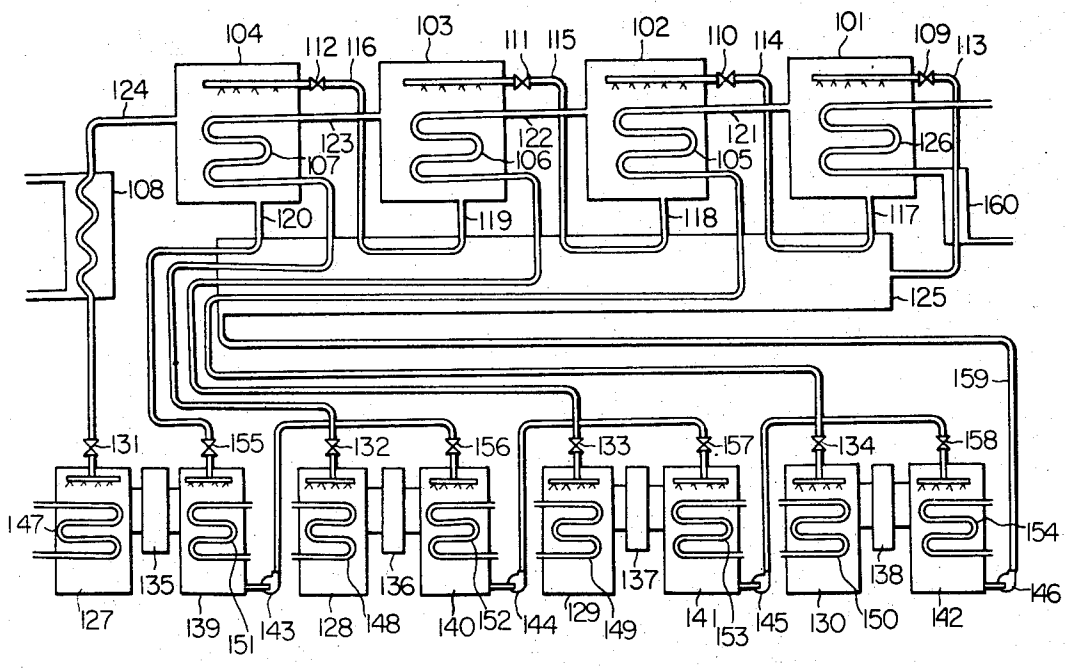
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Primary Examiner—William F. O'Dea
Assistant Examiner—Peter D. Ferguson

[57] **ABSTRACT**

There is provided an improved multi-stage absorption refrigeration system employing a highly concentrated solution of refrigerant to obtain an increased refrigeration effect relative to the quantity of input heat to the system as compared with a conventional system, comprising a multi-stage regenerator-condenser system and at least a one-stage evaporator-absorber system provided with a pressure elevating device therebetween.

6 Claims, 5 Drawing Figures



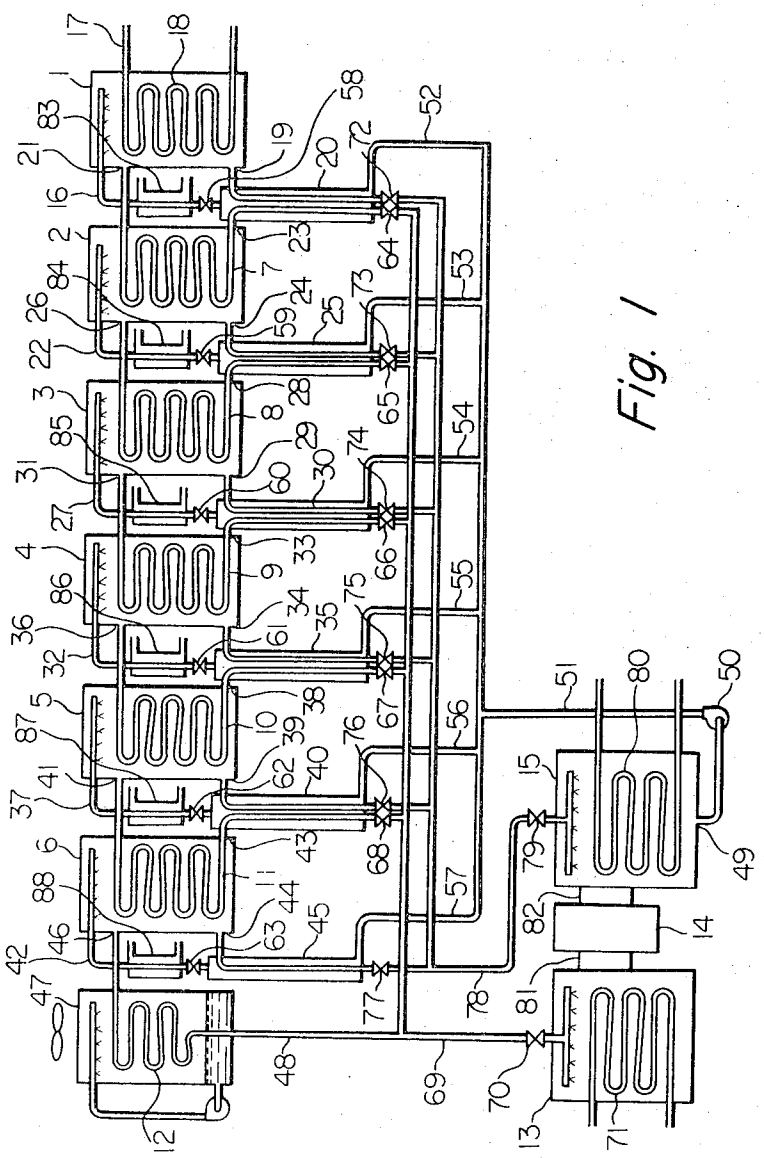
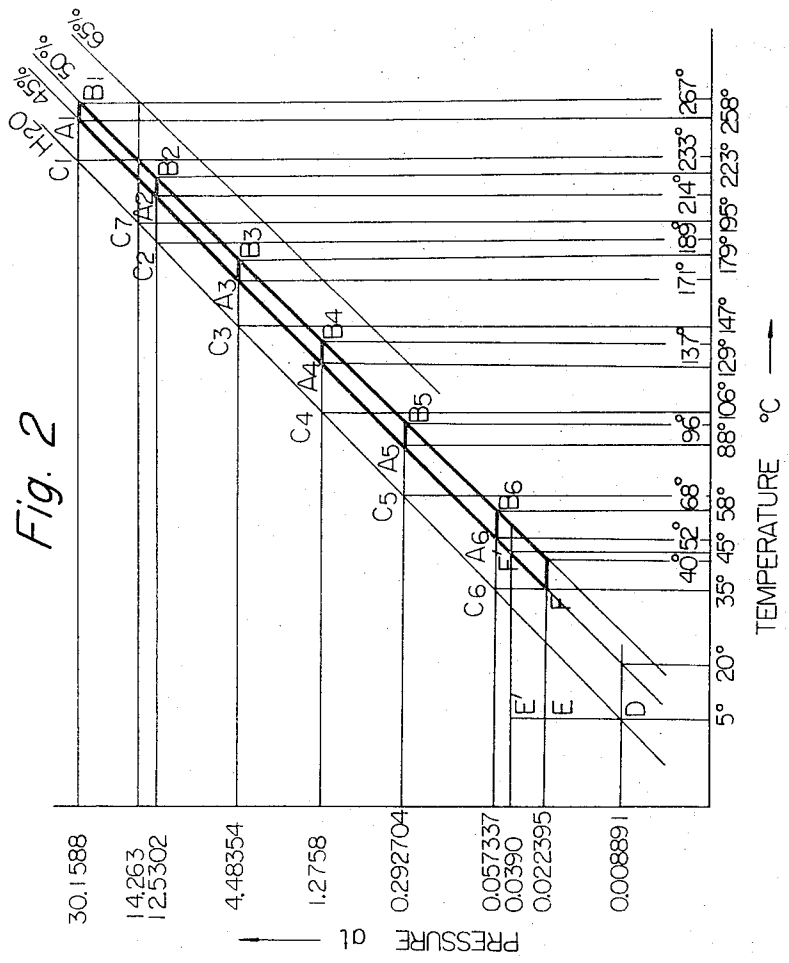


Fig. 1


Fig. 2
PRESSURE atm
30.1588
14.263
12.5302
4.48354
1.2758
0.292704
0.057337
0.0390
0.022395
0.00889
TEMPERATURE °C
5° 20° 35° 45° 58° 68° 88° 106° 129° 147° 179° 195° 214° 223° 233° 258° 267°
40° 52° 96° 137° 171° 189°
H2O
C1 A1 B1
C7 A2 B2
C2 A3 B3
C3 A4 B4
C4 A5 B5
C5 A6 B6
C6 F' F E' E D

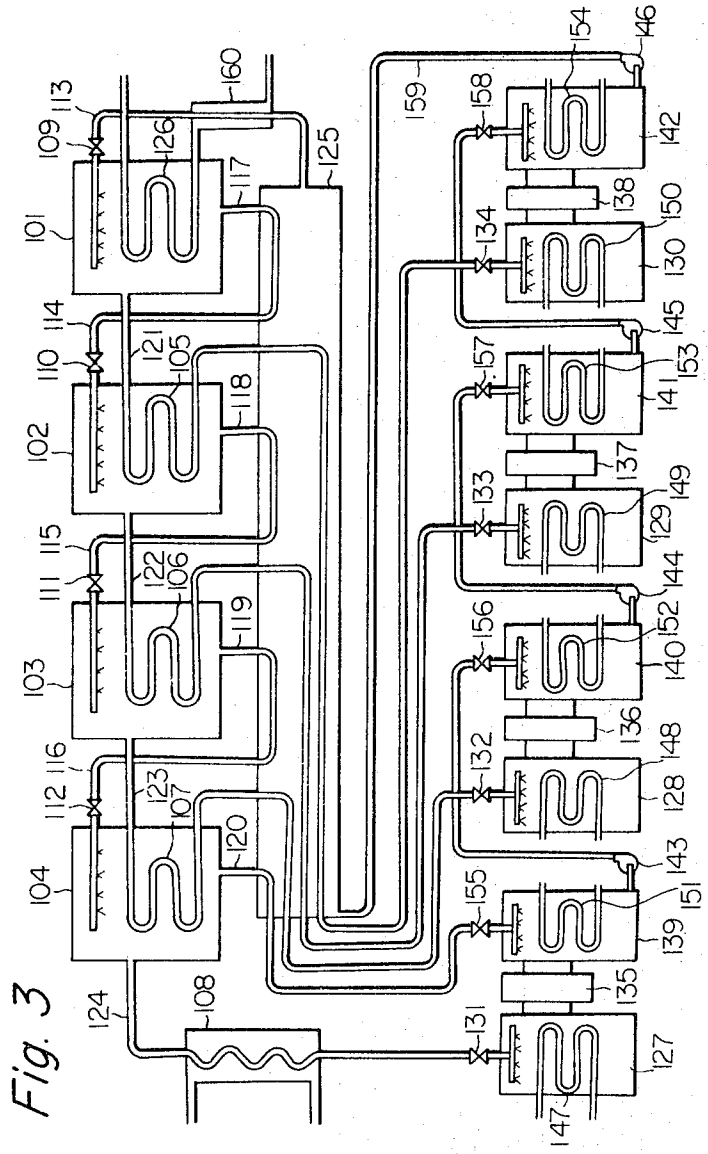

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Fig. 3

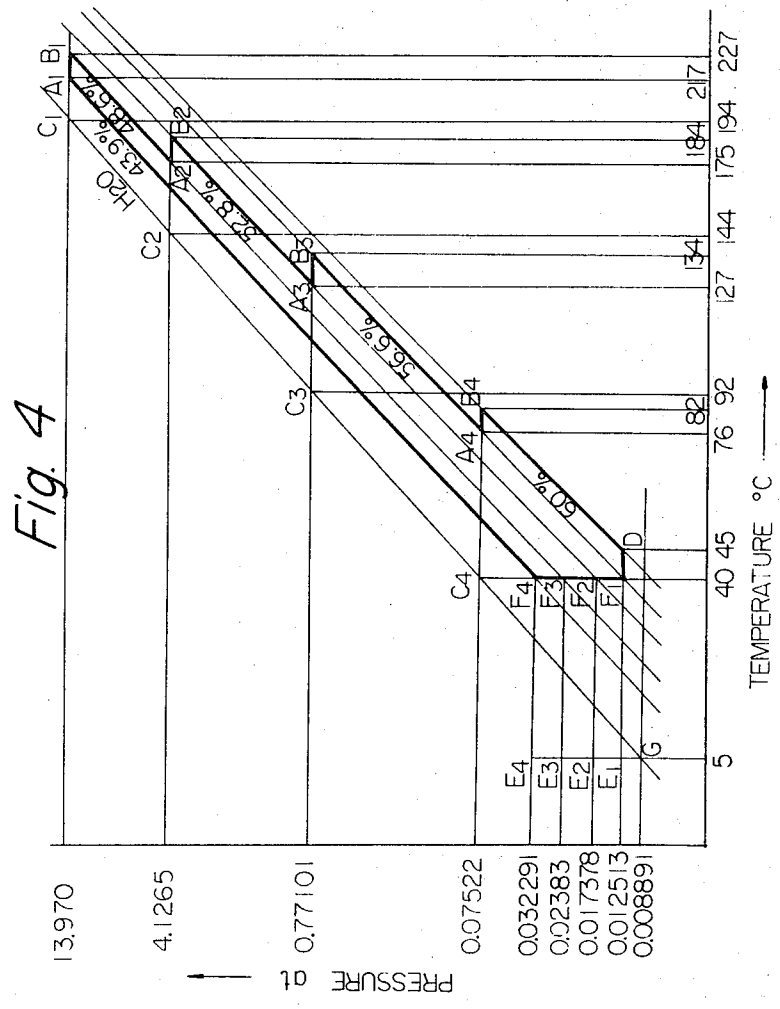

A1 B1
C1
B2
A2
C2
B3
A3
C3
B4
A4
C4
D
E4 E3 E2 E1
F4 F3 F2 F1
G
H2O
43.9%
52.8%
56.6%
60%
13.970
4.1265
0.77101
0.07522
0.032291
0.02383
0.017378
0.012513
0.008891
PRESSURE at
5 40 45 76 82 92 127 134 144 175 184 194 217 227
TEMPERATURE °C

Fig. 4

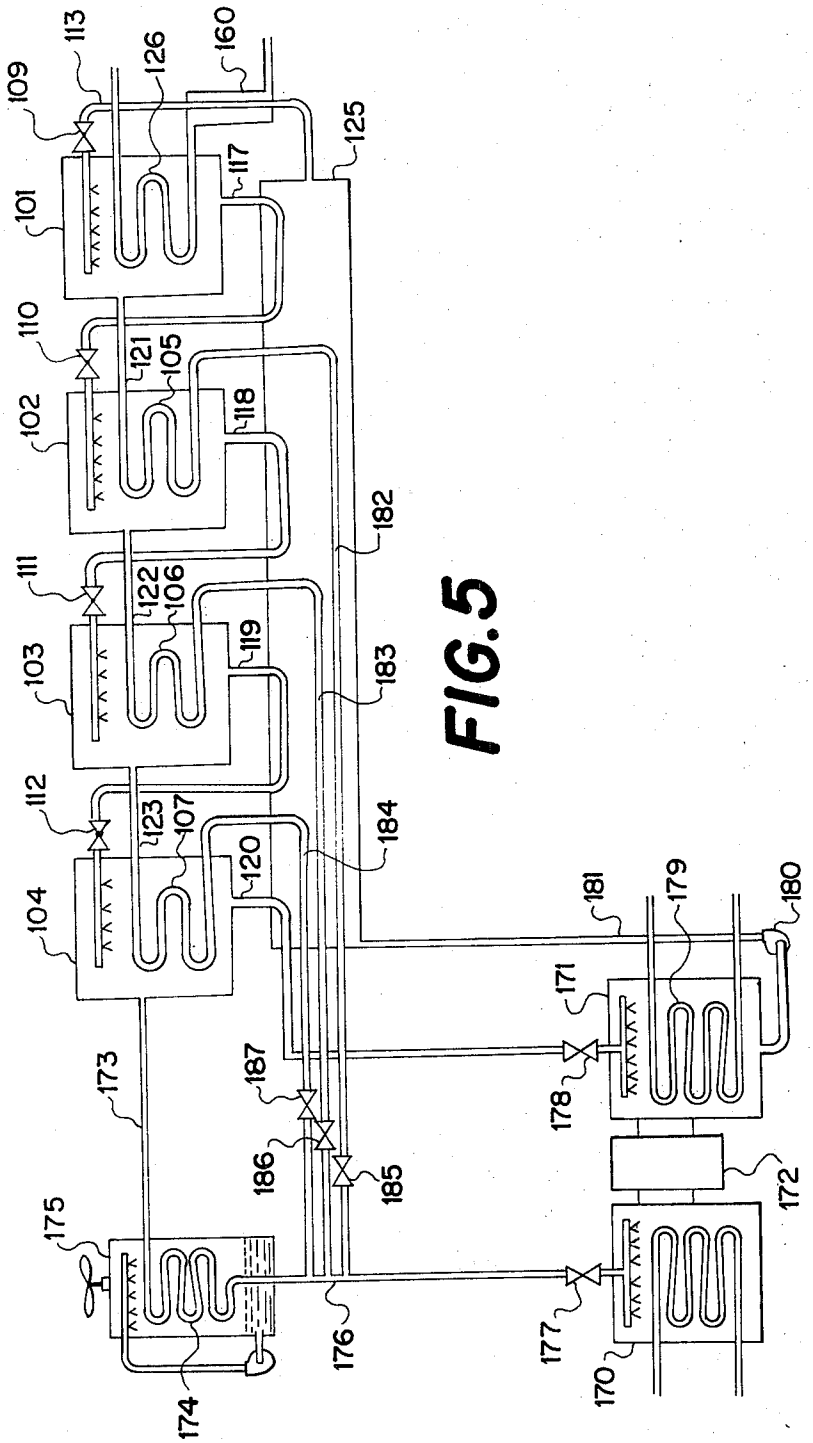

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126
160
125
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FIG. 5

MULTI-STAGE ABSORPTION REFRIGERATION SYSTEM

This application is a continuation-in-part of copending application, Ser. No. 180,640, filed Sept. 15, 1971, now U.S. Pat. No. 3,742,728, issued July 3, 1973.

In this evaporator-absorber system, the refrigerant from said regenerator-condenser system is vaporized in the evaporator, subsequently increased in pressure through the pressure elevating device and then absorbed at the increased pressure in the absorber.

The present invention relates to an absorption refrigeration system, particularly a multi-stage absorption refrigeration system employing a highly concentrated solution of refrigerant and has as its objective the provision of such system in an improved form of greater efficiency, that is, a greater refrigeration effect relative to the quantity of heat energy supplied to the system than the conventional system.

In accordance with the invention, there is provided a multi-stage absorption refrigeration system comprising a multi-stage regenerator-condensor system and at least a one-stage evaporator-absorber system provided with a pressure elevating device therebetween, wherein the refrigerant regenerated from the concentrated refrigerant solution in the regenerator-condenser system is vaporized under low temperature and pressure conditions in the evaporator to create a refrigeration effect. The refrigerant is subsequently increased in pressure through the pressure elevating device and then absorbed at the increased pressure in the absorber by the refrigerant introduced thereinto from said regenerator-condenser system directly or through the leading evaporator-absorber system. The concentrated refrigerant solution is thus produced and returned to said regenerator-condenser system from the final absorber.

The invention will be described in detail with reference to the accompanying drawings, wherein:

FIG. 1 is a schematically illustrated flow diagram for a multi-stage absorption refrigerator according to the invention,

FIG. 2 is a diagram showing the cycle of refrigerant vapor and solution in the apparatus of FIG. 1 with reference to pressure, temperature and concentration,

FIG. 3 is a schematically illustrated flow diagram for another multi-stage absorption refrigerator according to the invention,

FIG. 4 is a diagram showing the cycle of refrigerant vapor and solution in the apparatus of FIG. 3 with reference to pressure, temperature and concentration; and

FIG. 5 is a schematically illustrated flow diagram of a multi-stage absorption refrigeration system that is a modification of the system of FIG. 3.

FIG. 1 shows one of the embodiments of the multi-stage absorption refrigerator according to the invention, which has six stages of regenerators and condensers. The apparatus comprises regenerators **1** to **6**, condensers **7** to **12**, an evaporator **13**, a pressure elevating device **14** and an absorber **15**. Part of a concentrated refrigerant soltuion is delivered through line **16** to the first regenerator **1**, where it is heated by a vaporous external heat source which is supplied to heater **18** disposed in the regenerator **1** through line **17**, thereby regenerating a refrigerant vapor from the solution and thus producing a diluted residue of the refrigerant solution. The diluted residue in the first regenerator **1** then passes through outlet **19** to heat exchanger **20**, while the refrigerant vapor regenerated in the first regenerator **1** passes through outlet **21** to the condenser **7** disposed in the second regenerator **2** and heats thereby another part of the concentrated refrigerant solution delivered to the second regenerator **2** through line **22** to regenerate a refrigerant vapor from the heated solution, whereby it is condensed to a liquid which subsequently passes to the heat exchanger **20** through outlet **23.** The diluted residue of the refrigerant solution from which the refrigerant vapor has been regenerated in the second regenerator **2** passes to heat exchanger **25** through outlet **24.** The refrigerant vapor in the second regenerator **2** passes through outlet **26** to the condenser **8** disposed in the third regenerator **3** and heats thereby a further part of the concentrated refrigerant solution which has been flashed into the third regenerator through line **27** to regenerate a refrigerant vapor from the solution, whereby it is condensed into a liquid which subsequently passes to the heat exchanger **25** through outlet **28.** A diluted residue of the refrigerant solution from which the refrigerant vapor has been regenerated in the third regenerator **3** passes through outlet **29** to heat exchanger **30.** The refrigerant vapor in the third regenerator **3** passes through outlet **31** to the condenser **9** disposed in the fourth regenerator **4** and heats thereby another part of the concentrated refrigerant solution which has been delivered to the fourth regenerator **4** through line **32** to regenerate a refrigerant vapor from the solution, whereby it is condensed into a liquid which subsequently passes to the heat exchanger **30** through outlet **34.**

In each following regenerator **4, 5, 6** such processes as described above are also carried out. However, the refrigerant vapor produced in the final regenerator **6** is introduced through outlet **46** to a condenser **12** in a evaporative condenser **47** or a condenser of a cooling water type to condense it into a liquid which subsequently passes through line **48** to flow into the combined line **69.** On the other hand, the remaining refrigerant at high temperature produced in the regenerators excluding the sixth regenerator **6** is cooled in the heat exchangers **20, 25, 30, 35** and **40** by the parts of the concentrated refrigerant solution which are distributed from the absorber **15** to the regenerators through outlet **49,** pump **50,** line **51** and distributing lines **52** to **57,** the heat exchangers and then lines **16, 22, 27, 32, 37** and **42** respectively.

Each cooled refrigerant flows through each reducing valve **64, 65, 66, 67** or **68** into the combined line **69** together with the refrigerant from the condenser **12.** THe confluent flow of the refrigerant through line **69** is introduced at a reduced pressure through reducing valve **70** to the evaporator **13,** so that it is vaporized at a low temperature corresponding to its reduced pressure maintained in evaporator **13,** thereby creating the target refrigeration effect for cooling a fluid passing through a heat exchanger **71** disposed in the evaporator **13.** On the other hand, the dilute refrigerant solutions which have been cooled through the respective heat exchangers **20, 25, 30, 35, 40** and **45** are reduced in pressure through the respective reducing valves **72** to **77** and flow into the combined line **78.** The combined solution is reduced in pressure through reducing valve **79** and then is flashed into the absorber **15.**

The refrigerant vapor produced by the refrigeration effect in the evaporator **13** is transferred through the pressure elevating device **14** to the absorber **15** in which it is absorbed by the dilute refrigerant solution flashed into the absorber. The heat generated by the absorption at this time is absorbed by cooling water which passes through cooler **80** disposed in the absorber **15.**

In conventional apparatus, evaporators such as evaporator **13** and absorbers such as absorber **15** maintain the refrigerant vapor at constant pressure. The apparatus according to this invention employs a more highly concentrated refrigerant solution for obtaining a greater refrigeration effect than conventional apparatus. Therefore, in a case where the vapor is passed to the absorber **15** without a pressure increase from the pressure elevating device **14** the temperature of the dilute refrigerant solution in the absorber must be lowered to effect the same degree of absorption. However, it is difficult to obtain such lower temperature by applying cooling water such as well water or water supplied from a cooling tower.

In view of this fact, a pressure elevating device **14** such as an electric fan connecting the evaporator **13** and the absorber **15** therewith is provided in this invention. In the arrangement, the refrigerant vapor produced as a result of the evaporation for creating the refrigeration effect in the evaporator **13** is fed through passage **81** to the pressure elevating device **14,** where it is increased in pressure and then at the higher pressure is introduced through passage **82** to the absorber **15** which is maintained at the same high pressure. In other words, pressure elevating device **14** is provided for introducing the refrigerant vapor at a higher pressure corresponding to the temperature of the solution in the absorber which temperature may be attained easily by applying cooling water such as previously described.

The refrigerant vapor thus introduced into the absorber **15** is absorbed effectively by the dilute refrigerant solution which has been fed to the absorber **15** through the reducing valve **79,** whereby the dilute refrigerant solution is converted into a concentrated refrigerant solution. The concentrated refrigerant solution is discharged from outlet **49** of the absorber through line **51** to pump **50** disposed therein, by which it is pressurized. The pressurized solution is distributed to the regenerators **1** to **6** through distributing lines **52** to **57,** the first heat exchangers **20, 25, 30, 35, 40** and **45,** regulating valves **58** to **63** and second heat exchangers **83** to **88,** respectively. On the way to the regenerators the respective solutions are heated by the first heat exchangers and then supplementally heated by the second heat exchangers up to the necessary temperature for effecting their subsequent vaporization in the regenerators as previously described.

The refrigeration effect thus is obtained by repeating the cycle operation set forth above in the refrigerator.

FIG. **2** illustrates a cycle of a refrigerant solution with reference to pressure, temperature and concentration in the case where water is used as a refrigerant material and a water-lithium bromide solution is used as the refrigerant solution in the apparatus shown in FIG. **1.**

Concentrations referred to hereinafter and in the drawings are those for lithium bromide in weight by percent in the refrigerant solution.

In this example, a 45 percent solution of lithium bromide is distributed from the absorber to the respective regenerators wherein the distributed solution is vaporized up to a 50 percent solution, and the resultant solutions are subsequently returned to the absorber **15** after they are cooled by the heat exchangers **20, 25, 30, 35, 40** and **45.**

Referring to FIG. **2,** the first 45 percent solution at a pressure of 30.1588 atm., at a temperature of 258°C corresponding to point A_1 is introduced into the first regenerator **1,** where it is heated to 267°C at point B_1, and thus a refrigerant vapor at 233°C at point C_1 is generated from it, whereby it is concentrated to a 50 percent solution, where is a dilute refrigerant solution. The second 45 percent solution at a pressure of 12.5302 atm. and at a temperature of 214°C corresponding to point A_2 is introduced into the second regenerator **2,** where it is heated to a temperature of 223°C at point B_2 by the latent heat of condensation of the regenerated vapor introduced from the first regenerator at a temperature of 233°C at the point C_1 and thus a refrigerant vapor is regenerated from it at a temperature of 189°C at point C_2, whereby it is concentrated to a 50 percent solution as a dilute refrigerant solution.

In such processes as described above, the third, fourth, fifth and sixth **45%** solutions corresponding to points A_3, A_4, A_5 and A_6 are introduced into the respective regenerators, where they are heated to the temperatures shown at points B_3, B_4, B_5 and B_6 by the latent heat of condensation of the regenerated vapors introduced from the loading regenerators corresponding to points C_2, C_3, C_4 and C_5 respectively and thus refrigerant vapors corresponding to C_3, C_4, C_5 and C_6 are respectively regenerated from them, whereby they are concentrated to 50 percent solutions as dilute refrigerant solutions. Subsequently, the regenerated vapors excluding C_6 are condensed to liquids and then cooled to a temperature of 40°C by the heat exchangers **20, 25, 30, 35** and **40** respectively, while the remaining vapor C_6 is condensed at a temperature of 35°C to a liquid at the same temperature by the evaporative condenser **47.**

All the condensed refrigerants flow into the evaporator through line **69** and then the combined liquid refrigerant is vaporized under the conditions corresponding to point D to create the refrigeration effect.

For effecting the absorption of the resultant vapor by the 50 percent solution in the absorber under the same pressure as the evaporator, it would be necessary for the solution in the absorber to be cooled to a temperature below 20°C. However, according to the invention, the pressure of the refrigerant vapor corresponding to the point D is raised to the pressure corresponding to point E by the pressure elevating device **14** and introduced into the absorber **15** which is maintained at the same elevated pressure, while the 50 percent solution is introduced from the respective regenerators to the absorber in a combined flow through the line **78** after being cooled by the respective heat exchangers. In this connection, the refrigerant vapor is absorbed by the dilute refrigerant solution of 50 percent lithium bromide under the conditions corresponding to point F so as to change it to a concentrated refrigerant solution of 45 percent lithium bromide. Therefore, the above absorption process may be carried out effectively if the solution in the absorber is cooled to a temperature of 35°C or lower.

Alternatively, when the refrigerant vapor is pressurized to a pressure at the point E', the refrigerant vapor may be absorbed by the 50 percent colution in the absorber at the same pressure. In this case, an effective absorption would be carried out by cooling the solution in the absorber to a temperature of 45℃ or lower which may be attained more easily than in the former case.

In this example, if the 45 percent solutions introduced into the regenerators **1** to **6** are 10,000 kg/h, 7,437 kg/h, 5,336 kg/h, 4,703 kg/h, 3,854 kg/h and 3,250 kg/h respectively, the regenerated refrigerants in the regenerators amount to 1,000 kg/h, 743.7 kg/h. 583.6 kg/h, 470.3 kg/h, 385.4 kg/h and 325 kg/h, respectively. The total amount of the regenerated refrigerant is 3,508 kg/h, so that the corresponding total refrigeration capacity is equivalent to 1,963,647 Kcal/h. The substantial refrigeration capacity becomes 1,767,282 Kcal/h (196,364 × 0.9), assuming that the heat exchanging efficiency in the heat exchanger **71** is 0.9.

The total quantity of heat externally supplied to the heaters **18** and **83** to **88** is 836,354 Kcal/h, assuming that the heat exchanging efficiency of each heater is 0.9. Of the total quantity of the input heat, the heater **18** disposed in the first regenerator **1** requires a quantity equivalent to 539,855 Kcal/h and the respective heaters **83** to **88** for heating supplementally the dilute refrigerant solutions require quantities equivalent to 120,528.8 Kcal/h, 75,521 Kcal/h, 49,469.8 Kcal/h, 29,410.2 Kcal/h, 14,736.6 Kcal/h and 6,832.2 Kcal/h, which amount to 296,499 Kcal/h. Accordingly, the ratio of the refrigeration capacity to the total quantity of the input heat is as follows.

1,767,282 Kcal/h : 836,354 Kcal/h = 211.3 : 100

The conventional absorption refrigerator provides a refrigeration capacity of 70 Kcal/h relative to an input heat of 100 Kcal/h. Comparing the refrigerator according to the present invention with the conventional refrigerator the former has a refrigeration capacity approximately three times greater (211.3/70 = 3.01).

FIG. **3** shows a diagram of another embodiment of the refrigerator according to the present invention wherein the refrigerant solution is circulated successively through all the refrigerators in series.

In the refrigerator shown in FIG. **3,** a concentrated refrigerant solution is introduced through line **113** and valve **109** from a central heat exchanger **125** to a first regenerator **101,** where it is heated by an external heat source supplied to heat exchanger **126** disposed in the first regenerator, thereby regenerating a refrigerant vapor and thus producing a dilute residue. The resultant solution with the lower concentration of the refrigerant is fed to a second regenerator **102** through line **117** passing through the heat exchanger **125** and through valve **110,** while the resultant vapor is fed to condenser **105** disposed in the second regenerator **102** through line **121.**

On the way to the second regenerator **102,** the dilute refrigerant solution is cooled to the necessary temperature by the heat exchanger **125.** The refrigerant vapor passing through the condenser **105** heats the dilute solution flashed into the second regenerator **102** from the first regenerator **101** by its heat of condensation to regenerate a refrigerant vapor from the solution and produce a diluted residue thereof, whereby it is condensed to a refrigerant liquid. The diluted residue of the solution in the second regenerator **102** with lower concentration of the refrigerant than in the first regenerator **101** is introduced to a third regenerator **103** through line **118** passing through the heat exchanger **125** and through valve **111,** while the regenerated vapor is fed to a condenser **106** disposed in the third regenerator **103** through line **122.**

On the way to the third regenerator, the lower concentrated solution is cooled to the necessary temperature by the heat exchanger **125.** The refrigerant vapor in the condenser **106** heats the lower concentrated solution flashed into the third regenerator **103** to regenerate a refrigerant vapor from the solution and produce a diluted residue thereof, whereby it is condensed to a refrigerant liquid. The diluted residue of the solution with lower concentration of the refrigerant than in the second regenerator is introduced to a fourth regenerator **104** through line **119** passing through the heat exchanger **125** and through valve **112,** while the refrigerant vapor is fed to condenser **107** disposed in the fourth regenerator **104** through line **123.** On the way to the fourth regenerator, the lower concentrated solution is cooled to the necessary temperature by the heat exchanger **125.**

The refrigerant vapor in the condenser **107** heats the lower concentrated solution flashed into the fourth regenerator to regenerate a refrigerant vapor from the solution and to produce diluted residue thereof, whereby it is condensed to a refrigerant liquid. The diluted residue of the solution with the lower concentration of the refrigerant than in the third regenerator is passed to the heat exchanger **125** through line **120** to be cooled to the necessary temperature, while the refrigerant vapor is passed through line **124** to heat exchanger **108,** where the vapor is condensed to a refrigerant liquid.

The refrigerant condensed in the condenser **108** and the other refrigerant cooled in the heat exchanger **125** may be combined as a fluid to be subsequently vaporized for creating a refrigeration effect and then absorbed at an increased pressure of the resultant vapor in a single stage of the evaporator and the absorber which are connected to the pressure elevating device as shown in FIG. **1.** However, in the embodiment shown in FIG. **3,** the respective refrigerants are to be processed for effecting evaporation, pressurization and then absorption in the respective stages of the units, each of which comprises an evaporator, a pressure elevating device and an absorber. In this embodiment, a more complicated system is required, while the necessary energy for driving the pressure elevating device is lower in comparison with the embodiment of FIG. **1.**

The evaporation and absorption processes in FIG. **3** are now explained in detail as follows.

The respective refrigerants regenerated in the regenerators and then condensed in the condensers are fed through reducing valves **131** to **134** to evaporators **127** to **130,** where they are vaporized to create the refrigeration effect for cooling fluids passing through respective heat exchangers **147** to **150** disposed in the evaporators. The resultant vapors then pass through pressure elevating devices **135** to **138** and are introduced at the increased pressure to absorbers **139** to **142,** respectively.

The dilute refrigerant solution from the final regenerator **104** is flashed into the first absorber **139** through

reducing valve **155** and then absorbs the pressurized vapor which has been introduced from the first evaporator **127** to the absorber at the same pressure through the pressure elevating device **135.**

The resultant solution in the first absorber **139** is then introduced through pump **143** and reducing valve **156** to the second absorber **140,** where it absorbs the vapor which has been produced in the second evaporator **128** and then increased in pressure by the pressure elevating device **136.** The resultant solution in the second absorber **140** is then introduced via pump **144** and reducing valve **157** to the third absorber **141,** where it absorbs the vapor which has been produced in the third evaporator **129** and then pressurized by the pressure elevating device **137.** The resultant solution in the third absorber **141** is then introduced through pump **145** and reducing valve **158** to the fourth absorber **142,** where it absorbs the vapor which has been produced in the fourth evaporator **130** and then elevated in pressure by the pressure elevating device **138.** The resultant concentrated solution of the refrigerant in the final absorber **142** is fed to the central heat exchanger **125** through pump **146** and line **159.**

In the heat exchanger **125,** the concentrated solution is heated and passed to the first regenerator **101** through line **113** and thus the process of the refrigerant solution from the first regenerator **101** to the fourth regenerator **104** is repeated as previously set forth for creating the refrigeration effects in the respective evaporators.

The refrigerant solutions in the respective absorbers **139** to **142** are cooled by cooling water passing through coolers **151** to **154** disposed therein.

FIG. **4** shows an example of the cycle of the refrigerant solution with reference to pressure, temperature and concentration, when water is used as a refrigerant material and a water-lithium bromide solution is used as the refrigerant solution in the apparatus shown in FIG. **3.**

The concentrations shown in FIG. **4** indicate those of lithium bromide in weight by percent in the solution.

Referring to FIG. **4,** when the aqueous solution of lithium bromide corresponding to point A_1 is introduced to the first regenerator **101** and heated therein, a refrigerant vapor of wator corresponding to point C_1 is regenerated from the solution. The diluted residue of the solution at B_1 is cooled by the heat exchanger **125,** reduced in pressure by the reducing valve **110** and fed to the second regenerator **102** under the condition corresponding to point A_2. When the solution at A_2 is heated by the refrigerant vapor at C_1 to be given a latent heat of condensation thereby, it regenerates a refrigerant vapor corresponding to point C_2, whereby it is changed to a solution corresponding to point B_2.

By successively carrying out such processes as the above in order to change the state of the refrigerant solution from that at point B_2 to the state at points A_3, B_3, A_4 and finally B_4, refrigerant vapors corresponding to points C_3 and C_4 are obtained.

The refrigerant at the point C_4 is condensed into liquid which is subsequently vaporized in the first evaporator **127** under the condition corresponding to point G, thereby creating a refrigeration effect. The resultant vapor is increased in pressure at point E_1 through the pressure elevating device **135** and thus introduced to the first absorber **139,** where it is absorbed by the refrigerant solution introduced through a valve **155** at point D, whereby a concentrated solution at point F_1 is produced.

The refrigerant at the point C_3 is condensed into a liquid which is subsequently vaporized in the second evaporator **128** under the condition corresponding at the point G, thereby creating a refrigeration effect. The resultant vapor is increased in pressure at point E_2 through the pressure elevating device **136** and thus introduced to the second absorber **140,** wherein it is absorbed by the refrigerant solution introduced from the first absorber **139,** whereby a more concentrated solution at point F_2 is produced. By successively carrying out such processes as described above, the refrigerants at the points C_2 and C_1 are also vaporized in the third and the fourth evaporators **129** and **130** under the conditions at the point G, and more concentrated solutions at points F_3 and F_4 are produced in the third and the fourth absorbers **141** and **142,** respectively.

The final concentrated solution at the point F_4 in the final absorber **142** is then passed to the heat exchanger **125** via the pump **146** and the line **159.**

When a 43.9 percent aqueous solution of lithium bromide at a pressure of 13.97 atm. and at a temperature of 217°C corresponding to the point A_1 is introduced into the first regenerator **101** from the heat exchanger **125** at a flow rate of 10,000 kg/h and the cycle operation as shown in FIG. **4** is carried out, quantites of heat of 565,181.8 Kcal/h and 35,467.3 Kcal/h (i.e. total amount of 600,649.1 Kcal/h) are required to be supplied to the heat exchanger **126** and **160** respectively, whereby a refrigeration effect equivalent to 1,340,684.3 Kcal/h is obtained overall. The refrigeration capacity obtained is thus 223.2 Kcal/h relative to an input heat to the system of 100 Kcal/h (1,340,684.3 + 600,649.1 × 100 = 223.2).

The conventional absorption refrigerator provides a refrigeration effect of 70 Kcal/h relative to a supplied quantity of heat of 100 Kcal/h. Comparing the illustrated apparatus of the present invention with a conventional refrigerator, it has a refrigeration capacity approximately 3.19 times that of the conventional refrigerator (223.2 + 70 = 3.19).

FIG. **5** illustrates a diagram of a further embodiment of the refrigerator according to the present invention wherein the regenerator-condenser system is arranged successively in the manner of the embodiment of FIG. **3.** Portions of the embodiment of FIG. **5** corresponding to those of FIG. **3** as above described are hence provided with the same reference numerals.

Referring now to FIG. **5,** a concentrated refrigerant solution is introduced by way of line **113** and valve **109** from a central heat exchanger **125** to a first regenerator **101,** where it is heated by an external heat exchanger source supplied to the heat exchanger **126** disposed in the first regenerator, in order to regenerate a refrigerant vapor and produce a dilute residue. The resultant solution having a lower concentration of refrigerant is applied to the second regenerator **102** by way of line **117,** which passes through the heat exchanger **125,** and the valve **110.** The vapor in the regenerator **101** is applied to the condenser **105** in the regenerator **102** by way of line **121.** Further, as in the arrangement of FIG. **3,** dilute refrigerant solution from the regenerator **102** is applied to the regenerator **103** by way of line **118** passing through the heat exchanger **125** and valve **111,** and dilute refrigerant solution from the regenerator **103** is applied to the regenerator **104** by way of line **119**

also passing through the heat exchanger **125** and the valve **112.** Similarly, vapor from the second regenerator **102** is passed by way of line **122** to the condenser **106** in the regenerator **103,** and vapor from the regenerator **103** is applied by way of line **123** to the condenser **107** in the regenerator **104.** The arrangement of FIG. **5** is provided with a single evaporator **170,** a single absorber **171,** and a pressure elevating device **172** is provided for applying refrigerant vapor from the evaporator **170** to the absorber **171.** Vapor from the regenerator **104** is passed by way of line **173** to a condenser **174** in an evaporative condenser **175** or a condenser of a cooling water type to condense it into a liquid which is subsequently passed by way of line **176** and reducing valve **177** to the evaporator **170,** so that it is vaporized therein at a low temperature corresponding to its reduced pressure maintained in the evaporator **170.** Dilute residue from the regenerator **104** is passed in line **120** through the heat exchanger **125** and by way of the reducing valve **178** to the absorber **171,** wherein the dilute residue is flashed. Heat generated by absorption in the absorber is absorbed by cooling water which passes through the cooler **179** disposed within the absorber **171.** The concentrated solution of refrigerant in the absorber **171** is pumped to the central heat exchanger **125** by way of pump **180** and line **181.**

Refrigerants regenerated in the regenerators **102, 103** and **104** and condensed in the condensers **105, 106,** and **107** are fed by way of lines **182, 183,** and **184** respectively to join the line **176,** by way of reducing valves **185, 186** and **187** respectively. The lines **182, 183** and **184** pass through the heat exchanger **125.**

The arrangement of FIG. **5** operates in a manner similar to that of the arrangement of FIG. **3** as above described.

According to the invention, since a more highly concentrated solution of refrigerant is employed than in the conventional refrigerator, a vapor is generated with a considerably higher temperature than in the conventional refrigerator for the same temperature of the refrigerant solutions. For example, in the embodiment shown in FIG. **2,** vapor at a temperature of 233℃ is regenerated from a 50 percent solution of lithium bromide at a temperature of 267℃, while vapor at a temperature of 195℃ (at point C_7) is regenerated from a 65 percent solution at a temperature of 267℃.

In view of this fact, a system of the multi-stage type according to the invention is distinguishably suitable for employing a more concentrated refrigerant solution, thereby obtaining a greater refrigeration effect than heretofore known.

Further, according to the present invention, even if an aqueous solution of lithium bromide is employed as a refrigerant solution, crystallization of lithium bromide will not occur under the lower temperature employed in the present system, because the concentration of lithium bromide employed is lower than in the conventional system.

What is claimed is:

1. An absorption refrigeration system comprising

a plurality of successive regenerator condensor vessels each having a heat exchange therein,

an evaporator system,

an absorber system,

and a highly concentrated refrigerant solution therein,

said system further comprising means for applying heat to the heat exchanger of a first one of said vessels,

means for passing concentrated refrigerant solution from said absorber system to said first one of said vessels for absorbing heat from the heat exchanger therein to regenerate a refrigerant vapor and a dilute residue of solution therein,

means for passing dilute residue from all but a second of said vessels to a succeeding vessel for absorbing heat from the heat exchanger in the respective succeeding vessel to regenerate a refrigerant vapor and a dilute residue of solution therein,

means for passing refrigerant vapor from all but said second vessel to the heat exchanger of a succeeding vessel,

means for condensing vapor from said second vessel to a liquid,

means for passing liquid from said means for condensing and from said heat exchanger of all but said first vessel to said evaporator system for vaporization therein,

means for passing dilute residue from said second vessel to said absorber system,

and means for increasing the pressure of vapors in said evaporator system and applying them to said absorber system for absorption therein.

2. The absorption refrigeration system of claim **1** wherein said evaporator system comprises a single evaporator, and said absorber system comprises a single absorber.

3. The absorption refrigeration system of claim **2** wherein said means for passing concentrated refrigerant solution from said absorber system comprises means for passing concentrated refrigerant solution from said absorber in heat transfer with said means for passing liquid from said heat exchangers to said evaporator system and in heat transfer relationship with said means for passing dilute residue from said vessels to a succeeding vessel, to said first one of said vessels.

4. The absorption refrigeration system of claim **1** wherein said evaporator system comprises a plurality of evaporators and said absorber system comprises a plurality of absorbers, said means for increasing the pressure of said vapors comprising separate pressure elevating means interconnected in each evaporator with a separate absorber to form a plurality of evaporator absorber units, further comprising means for passing concentrated solution of refrigerant produced in all but a last one of said units successively from a first of said units to the absorber of a succeeding one of said units, said means for passing concentrated refrigerant solution from said absorber system comprising means for passing concentrated refrigerant solution from the absorber of said last unit to said first vessel, said means for passing liquid comprising means for passing liquid in succeeding order from the heat exchanger of said vessel next succeeding the first vessel to the evaporators of said units in an order succeeding from said last unit, and means for passing liquid from said means for condensing to the evaporator of said first unit, said means for passing dilute residue from said second vessel comprising means for passing dilute residue from said second vessel to the absorber of said first unit.

5. The absorption refrigeration system of claim **4** comprising means for passing said concentrated refrigerant solution from the last absorber in heat transfer

relationship to said means for passing liquid in succeeding order and in heat transfer relationship to dilute residue passed from each of said vessels.

6. The absorption refrigeration system of claim 1, wherein the concentrated refrigerant solution to be passed from said absorber system to said first one of said vessels comprises a water-lithium bromide solution having a water concentration in excess of 45 percent by weight or a lithium bromide concentration less than 55 percent by weight.

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