

March 30, 1943.

A. D. SIEDLE

2,315,356

REFRIGERATION

Filed April 6, 1940

3 Sheets-Sheet 1

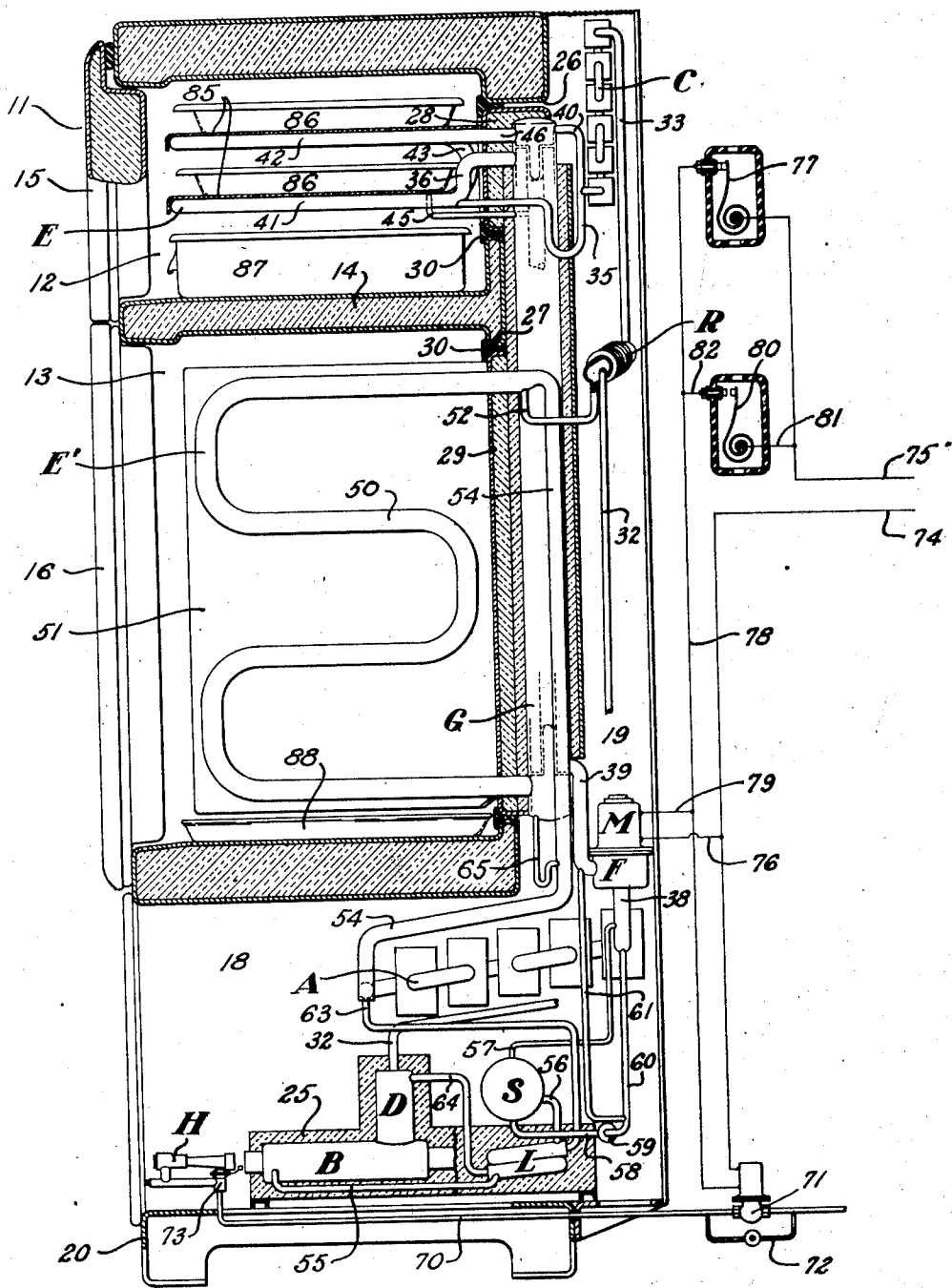


Fig. 1

INVENTOR

Arnold D. Siedle

BY

Harry S. Druar

ATTORNEY

March 30, 1943.

A. D. SIEDLE

2,315,356

REFRIGERATION

Filed April 6, 1940

3 Sheets-Sheet 2

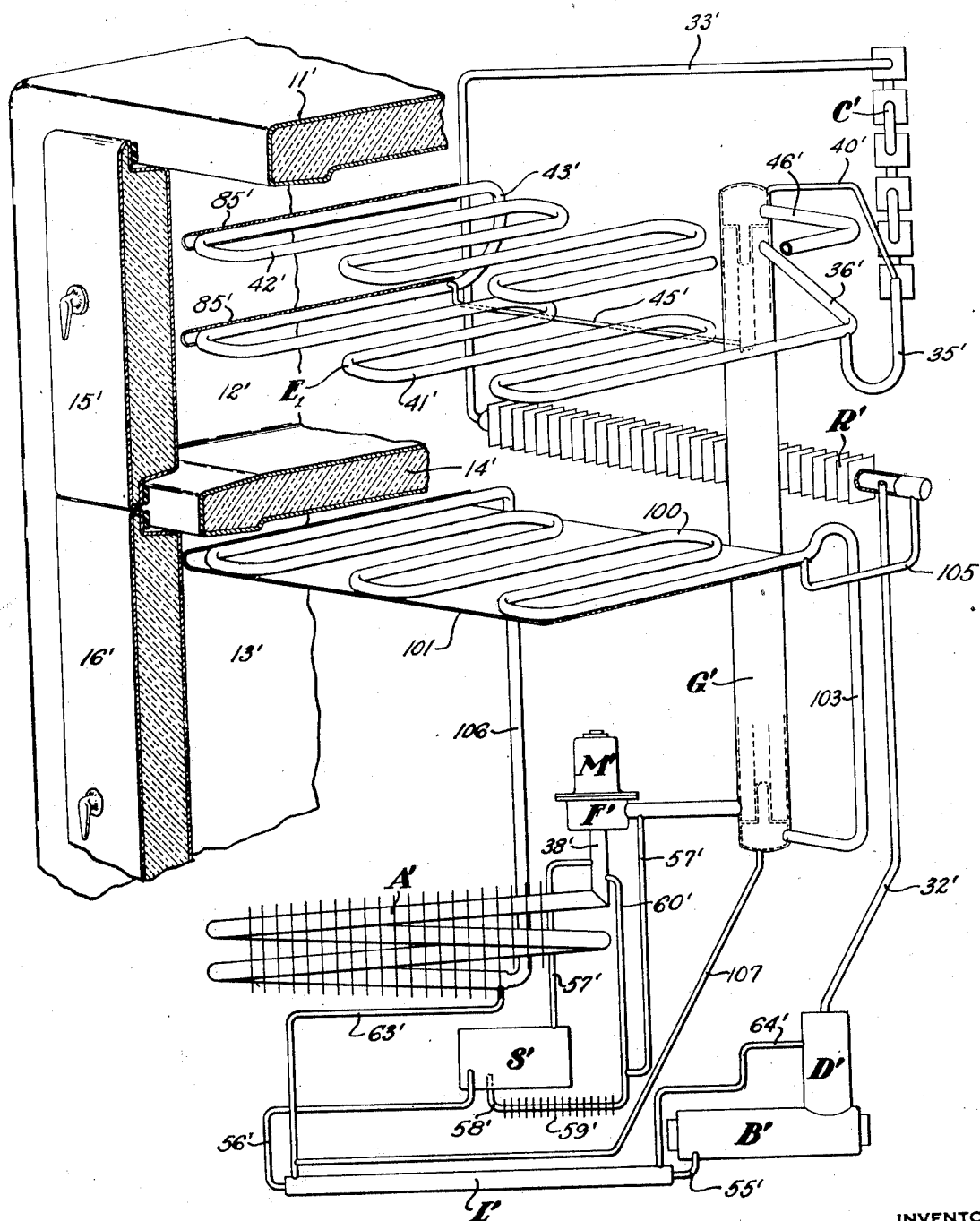


Fig.2

INVENTOR

Arnold D. Siedle

BY

Harry S. Drimmer

ATTORNEY

March 30, 1943.

A. D. SIEDLE

2,315,356

REFRIGERATION

Filed April 6, 1940

3 Sheets-Sheet 3

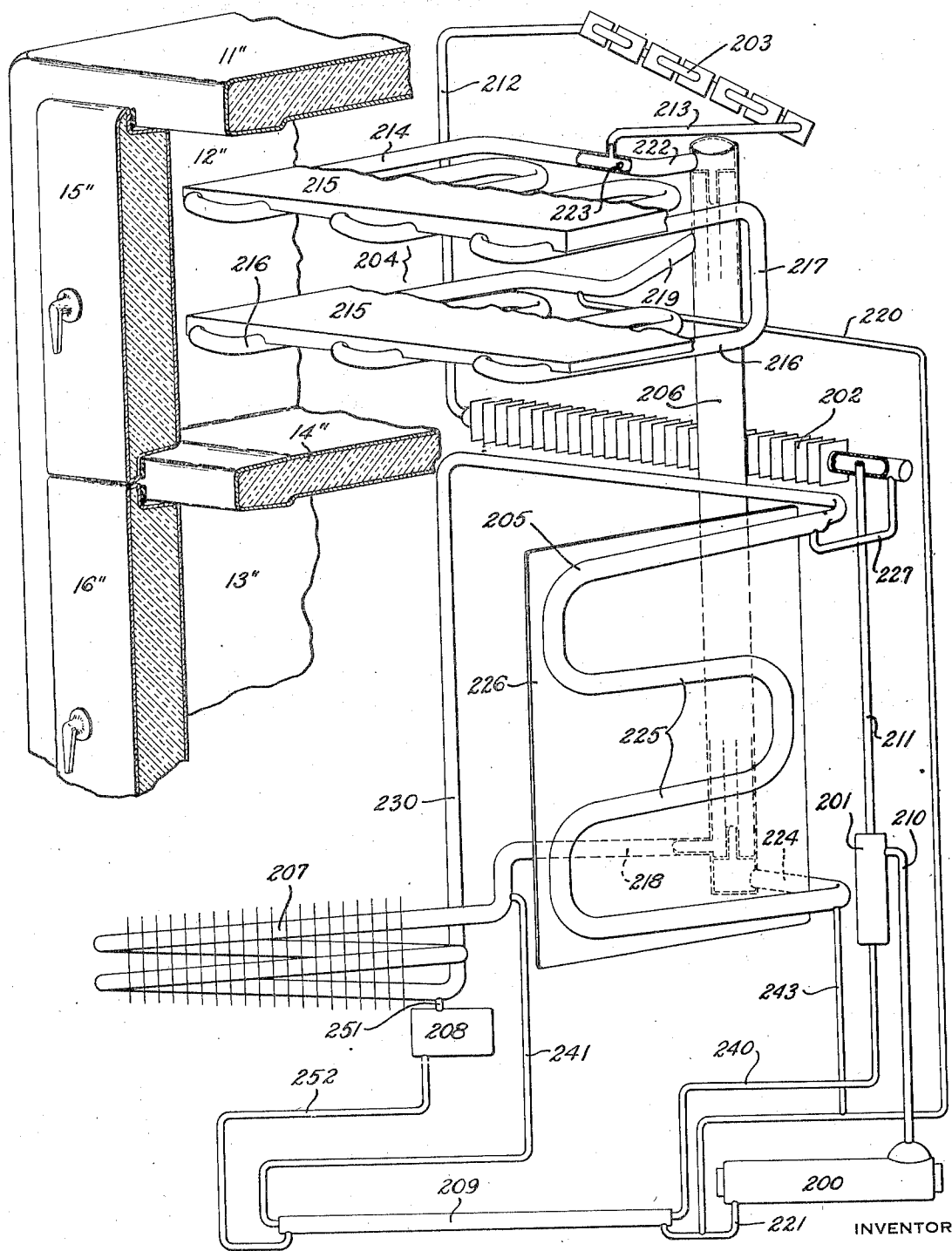


Fig. 3

BY

Arnold D. Siedle

Harry E. Demarest
ATTORNEY

ATTORNEY

UNITED STATES PATENT OFFICE

2,315,356

REFRIGERATION

Arnold D. Siedle, Canton, Ohio, assignor to The
Hoover Company, North Canton, Ohio

Application April 6, 1940, Serial No. 328,196

27 Claims. (Cl. 62—119.5)

This application relates to the art of absorption refrigerating apparatus and more particularly to a novel construction of such apparatus which provides refrigeration at a plurality of temperature levels.

Heretofore attempts have been made to provide absorption refrigerating machines which will produce refrigeration simultaneously at a plurality of temperature levels. These machines meet the technical difficulty that the necessary high temperature evaporating level, which preferably should be above the freezing point of water to eliminate the frost problem, necessitate the use of prohibitively large evaporating elements and even then tend to collect frost at certain localized areas thereof and do not provide desirable distribution of the refrigerating effect. Another difficulty with prior systems is due to the fact that very low temperature refrigeration is difficult to achieve in the low temperature refrigerating element because of the presence of small amounts of absorbing solution which find their way into the evaporator. Necessarily prior systems are limited to a rather narrow range of refrigerating temperatures due to the inherent limitations involved in the use of a single refrigerant within the system.

It is a principal object of the invention to provide a multi-temperature three fluid absorption refrigerating system which avoids the above mentioned difficulties and possesses numerous other advantages peculiar unto itself.

It is a principal object of the present invention to provide an absorption refrigerating apparatus in which refrigeration may be produced at a plurality of separated temperature levels within a single system.

It is a further object of the present invention to obtain refrigeration at separate temperature levels within a single system by evaporation of refrigerants which are selectively condensed from the vapor produced by the boiler.

It is a further object of the present invention to provide an absorption refrigerating machine of the pressure equalized type in which low temperature refrigeration is provided by the evaporation of substantially pure anhydrous refrigerant produced in a condenser into a pressure equalizing medium and in which higher temperature refrigeration is produced by evaporation into a pressure equalizing medium from a solution of the absorbent medium and refrigerant medium which solution is condensed in a separate condenser or rectifying element.

It is an object of the present invention to pro-

vide an absorption refrigerating machine in which refrigeration is produced at different temperature levels by evaporation of refrigerating medium which is fractionally condensed from the vapors produced in the generator.

It is another object of the invention to utilize the condensate produced by rectification of vapors produced in the boiler as a refrigerating fluid before returning such condensate to the boiler.

It is a further object of the invention to reject a portion of the heat of the vapors produced by the boiler of an absorption refrigerating system at a high temperature level and to reject the balance of the heat of such vapors at a low temperature level.

It is another object of the invention to produce a plurality of cooling mediums within a single absorption refrigerating system by fractional condensation of vapors expelled by the application of heat to a solution of a refrigerant and an absorbent.

It is a still further object of the present invention to provide a compact and economical arrangement of a multi-temperature refrigerating mechanism in a cabinet construction to the end that a minimum of space is utilized by the refrigerating mechanism and to the further end that the rejection of heat from various heat rejecting elements of the apparatus is allowed to proceed in a highly efficient fashion.

Other objects and advantages of the invention will become apparent as the description proceeds when taken in connection with accompanying drawings, in which

Figure 1 is an elevational sectional view of a refrigerating mechanism embodying the present invention.

Figure 2 is a partial section and partial diagrammatic perspective view of a modified form of the invention, and

Figure 3 is another partially sectioned and perspective diagrammatic representation of another modified form of the invention.

Referring now to the drawings in detail and, first to Figure 1 thereof, there is shown a refrigerating system which comprises an insulated cabinet 11 having an upper low temperature compartment 12 which is separated from a lower high temperature refrigerating compartment 13 by means of an insulated partition 14 which is, or may be, made integrally with the cabinet wall. The compartments 12 and 13 are provided with suitable insulated pivoted closures or doors 15 and 16, respectively. The cabinet construction also

includes a mechanism and heat rejecting compartment which is composed of a lower chamber 18 positioned beneath the compartment 13 and a rear vertically extending air flue portion 19. The cabinet construction as a whole is supported on a suitable foot member 20.

A refrigerating system which includes a plurality of separate elements is associated with the cabinet 11 in the following manner. A boiler B, an analyzer D, and a liquid heat exchanger L are suitably encased in a body of insulating material 25 and are mounted in the bottom portion of the compartment 18. A solution reservoir S is positioned just above the liquid heat exchanger L and an inclined tubular air-cooled absorber A extends forwardly and downwardly of the compartment 18 from a position beneath the flue 19. A circulating centrifugal fan F which is driven by a superposed electric motor M, is mounted in the corner of the compartment 19 just above the absorber A. A slightly inclined tubular air-cooled rectifier R, or primary condenser, extends transversely of the compartment 19 at an intermediate level therein and a tubular air-cooled condenser C is mounted in the upper portion of the chamber 19. A low temperature evaporator E is mounted in the compartment 12 and a high temperature evaporator E' is mounted in the compartment 13. A gas heat exchanger G is inserted in the rear insulated wall of the compartments 12 and 13 and extends vertically therein. The evaporators E and E' are inserted into the compartments 12 and 13, respectively, through openings 26 and 27, respectively, which are shaped to receive the evaporators E and E'. The openings 26 and 27 are closed by suitable insulated closure panels 28 and 29, respectively, and each is sealed by a suitable gasket 30.

The elements of the above described refrigerating apparatus are suitably connected by various conduits to form a plurality of gas and liquid circuits which constitute a complete refrigerating mechanism.

The refrigerating mechanism will be charged with a suitable refrigerant such as ammonia, a suitable absorbent therefor such as water and a suitable pressure equalizing medium, preferably a dense inert gas like nitrogen.

A suitable gas burner or similar source of heat H, is mounted in the compartment 18 in a position to heat the boiler B. The gas burner H and the electric motor M are controlled in a manner to be described hereinafter.

The application of heat to the boiler B generates refrigerant vapor and some vapor of the absorbing solution from the rich solution normally therein contained. The vapor so produced passes upwardly through the analyzer D in counterflow relationship with absorbing solution flowing downwardly therethrough and which is supplied from a source to be described hereinafter. In the analyzer, further refrigerant vapor is added to the vapor supplied from the boiler and some of the absorption solution vapor is removed from such vapor.

After passing through the analyzer D, the partially purified vapors are conveyed therefrom to the lower end of the slightly inclined tubular air-cooled rectifier R by means of a conduit 32. In this construction, the element R performs the usual function of a rectifier but it also abstracts sufficient heat to condense a part of the ammonia vapor supplied thereto by the conduit 32. Consequently, the condensate formed in the rectifier R is a very strong solution of the refrigerant

in the absorbent. In the case of ammonia and water, for example, the rectifier R may be designed to produce a condensate which is composed of approximately 20 percent absorbent and 80 percent refrigerant. Due to the fact that the element R condenses an appreciable quantity of the ammonia vapor, the vapors discharged therefrom to the condenser through the conduit 33 are substantially pure anhydrous ammonia and have had their temperature lowered to a point approaching the condensing temperature. Therefore a part of the condensing load is carried by the element R which rejects an appreciable quantity of heat at a high temperature level and may be made relatively small in size as compared with the quantity of heat which it is called upon to dissipate.

The substantially pure anhydrous ammonia or refrigerant vapor which is supplied to the upper end of the condenser C, is liquefied therein by heat exchange relationship with the cooling air flowing through the flue 19. The resulting liquid ammonia is conveyed from the condenser C to the bottom portion of the evaporator E by means of a conduit 35 which includes a downwardly extending U-shaped portion adapted to form a pressure balancing liquid column. The conduit 35 joins the evaporator E adjacent its point of connection with the gas supply conduit 36.

Lean inert gas which is produced in the absorber is conveyed from the upper portion thereof into the suction side of the circulating pump F by means of the conduit 38 and after being placed under a slight pressure by the fan, it is conveyed therefrom to the bottom portion of the evaporator E by way of conduit 39, the outer pass of the gas heat exchanger G and the aforementioned conduit 36.

It is apparent that the pressure prevailing in the conduit 36 will approach that prevailing in the discharge conduit 39 of the fan. It is disadvantageous to permit this pressure to be reflected back through the condenser to the boiler and for this reason the condenser side of the U-shaped conduit 35 is vented to the rich gas side of the gas heat exchanger G by means of a conduit 40. The pressure differential between conduits 40 and 36 is balanced by a liquid column in the conduit 35.

The evaporator E comprises a pair of vertically spaced substantially horizontal pipe coils 41 and 42 which are serially connected by a suitable riser conduit 43. The form of the evaporator E is preferably substantially identical with that disclosed in connection with the modification illustrated in Figure 2 to be described hereinafter. Evaporator E is provided with an anti-blocking drain 45 which is connected between the upper portion of the bottom coil 41 and the rich gas side of the gas heat exchanger G.

The conduits forming the evaporator E have a relatively small cross-sectional area whereby the inert gas stream flows therethrough with a velocity sufficient to propel the liquid refrigerant therethrough by the frictional drag exerted on the liquid by the inert gas stream. Consequently the liquid refrigerant supplied by the conduit 35 is circulated through all portions of the evaporator E by the inert gas as the liquid is evaporating into the inert gas.

The evaporator E is supplied with substantially pure anhydrous liquid ammonia and with very lean inert gas. Therefore it operates at a temperature materially below the freezing point of water.

After traversing the evaporator E the partially enriched inert gas is exhausted from the coil 42 thereof by the conduit 46 which connects to the rich gas side of the gas heat exchanger. After traversing the inner pass of the gas heat exchanger G, the resulting inert gas is discharged into the bottom portion of the evaporator coil E'.

The evaporator coil E', as illustrated, is positioned in a substantially vertical position and is preferably adjacent one side wall of the compartment 13 though it is within the scope of the invention to position the evaporator E' in other ways, for example, along the rear wall of the compartment 13. The evaporator E' comprises a vertically extending coil 50 which is constructed of relatively large diameter tubing whereby the inert gas will flow therethrough at a relatively low velocity. The vertically extending coil 50 is preferably bonded to a vertically extended air cooling plate 51 in order to provide a large heat transfer area.

The condensate formed in the rectifier and primary condenser element R is conveyed from the lower end thereof into the upper end of the coil 50 by means of a U-shaped liquid sealing conduit 52 which passes into the rear wall of the cabinet construction. The coil 50 is provided with a slight continuous downward slope whereby the ammonium hydroxide which is supplied thereto from the rectifier R may flow downwardly by gravity in counterflow relationship to the inert gas stream which flows upwardly through the coil 50.

In the evaporator E' the refrigerant is a very rich ammonium hydroxide solution and its boiling point at the partial pressure prevailing in the coil 50 is appreciably above the boiling point of the anhydrous ammonia which is supplied to the evaporator E. Consequently, evaporation which occurs into the inert gas stream flowing through the coil 50 from the ammonium hydroxide supplied thereto occurs at a temperature which is above the freezing point of ice in order to prevent formation of frost on the coil 50 and plate 51 but which is sufficiently low in view of the heat transfer area provided by the plate 51 to maintain safe refrigerating temperatures within the compartment 13.

The rectifier is preferably so designed that it will form a solution of the refrigerant in the absorber of such strength that safe refrigerating temperatures will be maintained in the compartment 13 without forming frost on the cooling elements therein. As has been indicated above, a solution containing approximately 20 percent absorbent and 80 percent refrigerant is one example of the solution suitable for this purpose.

After traversing the coil 50 the enriched inert gas is conveyed from the upper end thereof to the bottom portion of the absorber A by means of the conduit 54. The rich inert gas then flows upwardly through the absorber A in counterflow to lean solution flowing downwardly therethrough with the result that the solution is enriched by absorption of the refrigerant vapor content of the inert gas and the resulting heat of absorption is rejected to cooling air flowing over the exterior walls of the absorber conduit and the cooling fins attached thereto. The resulting lean inert gas is then conveyed by the conduit 38 into the fan in the manner described heretofore.

The lean solution formed in the boiler B by the generation of refrigerant vapor therefrom is conveyed from the boiler to the solution reservoir S by way of conduit 55, the liquid heat exchanger L

and the conduit 56. The upper portion of the reservoir S is vented to the suction conduit 38 and the fan F by means of the conduit 57 whereby the solution rises in the reservoir S to a level above the liquid level prevailing in the boiler analyzer system a distance equal to a distance sufficient to balance the pressure differential existing between the suction conduit 38 of the circulating fan and the vapor discharge conduit 32 of the boiler analyzer system which is vented through the conduit 40 to the rich gas side of the gas heat exchanger G.

The lean solution is conveyed from the reservoir S to the suction conduit 38 of the fan which opens directly into the upper end of absorber A by means of the conduit 58 which includes a finned portion 59 in order to precool the solution and discharges into a gas lift pump conduit 60 which opens directly into the conduit 38. Pumping gas is conveyed by a conduit 61 from the discharge conduit 39 of the fan into the gas lift pump conduit 60 at a point below the liquid level normally prevailing therein. Consequently, the lean solution is elevated into the upper end of the absorber by gas lift action.

The lean solution flows downwardly through the absorber by gravity in counterflow relationship with the inert gas refrigerant vapor mixture flowing upwardly therethrough and becomes enriched in the manner heretofore described.

The rich solution formed in the absorber is returned from the lower end thereof to the upper portion of the analyzer D by means of the conduit 62, the liquid heat exchanger L and conduit 64 thus completing the absorption solution circuit.

The material supplied to the evaporator E' will not evaporate totally and there will be a material residue which will flow from the lower end of the coil 50 into the bottom portion of the gas heat exchanger G from which it is drained into the rich gas return conduit 54 by means of the conduit 65. The conduit 65 includes a U-shaped portion to form a short pressure balancing column to balance the pressure differential which exists between the bottom portion of gas heat exchanger G and the conduit 54. This pressure differential is brought about by the drop in pressure which occurs in the inert gas as it flows through the coil 50. This residue solution then flows through the conduit 54 and into the strong solution and into the conduit 63 where it mingles with the strong solution discharged from the absorber and then returns to the boiler system in the manner heretofore described.

For purposes of illustration, the boiler B herein has been shown as being heated by a suitable gas burner H to which gas is supplied by means of a suitable conduit 70 which includes a solenoid control valve 71. A suitable by-pass 72 is provided around the valve 71 in order to supply fuel for a small igniting pilot flame which will be maintained on the burner H when the valve 71 is in closed position. The burner H also includes a suitable flame failure safety cut-off device 73 of a known type.

Electrical energy for operating the electrical motor M and the solenoid valve 71 is provided by means of a pair of electrical conductors 74 and 75. The conduit 74 connects directly to the solenoid valve 71 and is also connected to the motor M by means of a conductor 76. The conductor 75 connects directly to a thermostatic switch 77 which in turn is connected by means of a conductor 78 directly to the solenoid valve

71. The conductor 78 is also connected to the electrical motor M by means of an electrical conductor 79. A second thermostatic switch 80 is bridged across the conductors 75 and 78 in parallel relationship with the thermostatic switch 77 by means of a pair of electrical conductors 81 and 82.

In order to facilitate the illustrations herein, the control switches 77 and 80 have been illustrated rearwardly of the cabinet. However, in actual practice, the switch 77 will be placed within the compartment 12 preferably in a position to respond directly to the temperature of the evaporator. The switch 80 will be placed within the compartment 13 preferably in a position to respond to the temperature of the air circulating therethrough. The switches 77 and 80 have been illustrated diagrammatically herein but it is to be understood that known types of variable refrigerant controls may be substituted for each of these thermostatic switches within the scope of the present invention.

It is apparent from the electrical circuit that completion of the circuit by either of the switches 77 and 80 will simultaneously energize the motor M of the circulating fan F and will energize the solenoid valve 71 to raise the same to open position whereby a full flame will be carried upon the burner H and sufficient heat will be applied to the boiler B to generate refrigerant vapor and vapor of the absorption solution therefrom.

Preferably each of the coils 41 and 42 is provided with an overlying flat metal plate 85 which forms a support for suitable receptacles such as ice tray 86. The space within the compartment 12 beneath the coil 41 may be utilized for refrigerating foodstuffs and a suitable tray 87 may be provided for this purpose.

It is preferred to mount an elongated narrow condensate collecting pan 88 in the lower portion of the compartment 13 directly beneath the plate 51 to collect moisture dripping. In the normal operation of the apparatus there will be some collection of moisture on the plate 51 and coil 50 which will not freeze into frost because these elements will operate at a temperature above the melting point of ice. A high relative humidity will be maintained in the compartment 13 because of the relatively high temperature of the refrigerating elements. These conditions are particularly desirable in order to provide desirable refrigeration of foodstuffs without drying the same by moisture collecting in the form of frost in a low temperature evaporator. The high humidity which will be maintained in the compartment 13 will inhibit serious loss of moisture from foodstuffs stored therein.

The bottom portion of the compartment 18 which is formed by the base element 20 and particularly that portion of the compartment 18 directly under the chamber 19 will be provided with suitable openings or will be left substantially entirely open to allow free flow of cooling air into the compartments 18 and 19. Cooling air will flow first over the solution precooler 59, then over the air-cooled absorber A, then over the rectifier and primary condenser R, and ultimately over the condenser C after which it will exhaust through the top portion of the compartments or ducts 19.

The present invention provides a refrigerating mechanism in which separate refrigerating elements are placed in distinct refrigerating chambers and are supplied with refrigerants having different characteristics but all coming from a

single source. Refrigeration is produced within accurately controllable but distinct temperature ranges. Thus, low temperature refrigeration will be produced by evaporation of substantially anhydrous ammonia into an inert gas such as nitrogen and higher temperature refrigeration will be produced by evaporation from a solution of ammonia in water, ammonium hydroxide, into the inert gas; and both the anhydrous ammonia and the ammonium hydroxide will be supplied from a single refrigerating system.

Due to the parallel connection of the control switches 77 and 80, the refrigerating mechanism will be energized to produce refrigeration whenever there is demand for refrigeration in either of the compartments 12 or 13 and such production of refrigeration will continue until such time as the refrigerating demands of both compartments have been satisfied. This insures that no part of the apparatus whatever will be without the ability to meet its refrigerating load.

Referring now to Figure 2, there is illustrated a modified form of the invention. This form of the invention is identical with that disclosed in Figure 1 except for the arrangement of the high temperature refrigerating element. Consequently, the refrigerating mechanism's relationship to the cabinet structure has not been shown except the relationship of the evaporating elements to the refrigerating compartment. It will be understood that this arrangement is identical with that disclosed in Figure 1. In order to eliminate needless duplications of description, those portions of the mechanism of Figure 2 which are identical with portions of the apparatus previously described in connection with Figure 1 are given the same reference characters primed except that the low temperature evaporator is given a subscript 1.

In this form of the invention the high temperature refrigerating compartment 13' is refrigerated by a horizontal coil 100 which lies in the upper portion thereof or just below the insulating dividing panel 14'. A sheet metal heat transfer plate 101 is mounted in heat exchange relationship with the under side of the coil 100 in order to provide a large heat transfer area.

The inert gas flows from the circulating fan F' through the evaporator E₁ and discharges through the conduit 46' into the inner pass of the gas heat exchanger exactly in the manner heretofore described in connection with the corresponding elements of Figure 1. The partially enriched gas then flows through the inner pass of the gas heat exchanger G' and is conveyed from the bottom end thereof into one end of the horizontal coil 100 by means of conduit 103. The inner pass of the gas heat exchanger G' is drained to the strong solution return conduit 63' by a drain conduit 107.

The evaporator coil 100 is made of a small diameter conduit whereby the inert gas flows therethrough with a velocity sufficient to propel or distribute the liquid refrigerant therethrough by the frictional drag of the inert gas stream. The condensate formed in the rectifier R' is conveyed from the lower end thereof into the coil 100 adjacent its junction with the conduit 103 by means of a downwardly extended U-shaped conduit 105 which will provide a pressure balancing column to maintain the pressure differential which normally exists between the conduit 103 and rectifier R'.

The condensate which is discharged into the coil 100 is propelled therethrough by the inert

gas which is evaporating and produces refrigeration at a temperature which is low enough to maintain safe refrigerating conditions in the compartment 13' but which is high enough to maintain a relatively high humidity condition in the compartment 13'.

The rich gas and unevaporated liquid which completely traverses the coil 100 is conveyed therefrom to the bottom portion of the absorber A' by means of conduit 106. The gas then flows upwardly through the absorber in the manner described in Figure 1 and the liquid flows through the conduit 63' and ultimately returns through the conduit 64' to the upper portion of the analyzer D'.

This form of the invention operates identically with that described heretofore in connection with Figure 1 and will be provided with an identical control and heating system.

In this form of the invention, however, the high temperature evaporator is horizontally positioned in the upper portion of the high temperature compartment 13' whereby it consumes a minimum of space therein and the refrigerating liquid supplied to the coil 100 flows therethrough in parallel flow relationship with and under the propelling force of the inert gas as distinguished from the arrangement disclosed in Figure 1 in which the liquid refrigerant in the coil 50 flows by gravity in counterflow relationship to the inert gas. Also in this form of the invention, the openings and inserts therefore in the rear wall of the cabinet will naturally extend transversely thereof on a horizontal plane instead of vertically as is the case in connection with the apparatus described in connection with Figure 1 because of the horizontal evaporator construction used in the compartment 13'.

Referring now to Figure 3 there is disclosed another modified form of the invention in which the inert gas is circulated by the density differential existing between cold rich gas discharged from the evaporator and warm lean gas discharged from an absorber and in which the absorbing solution is circulated by means of a heat operated vapor lift pump.

The cabinet construction preferably utilized in this form of the invention is identical with that preferably utilized in the form of the invention discussed above in connection with Figure 1. Therefore, only a portion of the cabinet has been shown in order to illustrate its relationship to the cooling elements and identical portions of the cabinet in Figures 1 and 3 have been given the same reference characters except those in Figure 3 are double primed.

This form of the invention comprises a boiler 200, an analyzer 201, an elongated slightly inclined tubular finned rectifier and primary condenser 202, a tubular air-cooled condenser 203, a low temperature evaporator 204, a high temperature evaporator 205, a gas heat exchanger 206, an inclined tubular air-cooled absorber 207, a solution reservoir 208, and a liquid heat exchanger 209. These elements are suitably connected by various conduits to form a complete refrigerating system.

The thus described refrigerating system will be charged with a suitable refrigerant such as ammonia, a suitable absorbent therefore such as water, and a pressure equalizing medium preferably a light inert gas like hydrogen.

The control mechanism for this form of the invention may be identical with that disclosed in connection with Figure 1 except that there

will be no connection for controlling a circulating fan.

The application of heat to the boiler 200 produces vapor of refrigerant and absorption solution therein which flows upwardly through the vapor lift pump 210 and conveys solution upwardly therethrough into the separation chamber 201. From the separation chamber 201, the vapors are conveyed to the lower end of the rectifier 202, by means of the conduit 211. After passing through the rectifier 202, the resulting anhydrous ammonia vapor is conveyed therefrom to the upper end of the condenser 203 by means of conduit 212. The vapor is then liquefied in the condenser, and is discharged therefrom through the conduit 213 into the upper coil 214 of the evaporator 204.

The evaporator coil 214 is given a slight downward inclination in order to provide for gravity flow of the liquid refrigerant therethrough. The coil 214 is in heat exchange relation with a plate 215 which is preferably of aluminum and has a horizontal upper surface. The distance between the horizontal upper surface of the plate 215 and the coil positioned therebelow increases from the liquid inlet portion of the coil to the liquid outlet portion thereof. Coil 214 is serially connected to a lower identical coil 216 by means of a conduit 217. The coil 216 is likewise in heat exchange relation with a heavy plate 215.

Lean inert gas formed in the absorber 207 is conveyed therefrom to one end of the lower coil 216 of the evaporator by way of the conduit 218, the outer pass of the gas heat exchanger 206 and the evaporator gas supply conduit 219.

The inert gas flows upwardly through the evaporator 204 in counterflow relationship with the liquid refrigerant flowing downwardly therethrough. The liquid refrigerant evaporates into the inert gas which produces refrigerating effect at a low temperature.

Any material which is not evaporated in the evaporator drains therefrom adjacent its junction with the inert gas supply conduit 219 through a drain conduit 220 which connects to the strong solution return conduit 221 of the boiler.

After traversing the evaporator 204, the partially enriched inert gas is discharged therefrom through the conduit 222 into the rich gas side of the gas heat exchanger 206. A small dam 223 is provided in conduit 222 to prevent liquid refrigerant supplied from the condenser from flowing into the gas heat exchanger. After traversing the gas heat exchanger, the inert gas then flows through the conduit 224 into the bottom portion of an evaporator coil 225 which has attached thereto an extensive air cooling plate 226.

The condensate formed in the rectifier 202 is conveyed from the lower end thereof into the upper end of the coil 226 by means of a U-shaped conduit 227. The liquid refrigerant flows downwardly through the coil 225 by gravity in counterflow relationship to the inert gas flowing upwardly therethrough. The refrigerant evaporates into the inert gas to produce a refrigerating effect at a temperature such that frost deposition upon the coil 225 and plate 226 will be inhibited and safe refrigerating temperatures will be maintained in the compartment 13'.

The resulting rich gas formed in the coil 225 is conveyed from the upper end thereof to the bottom portion of the tubular inclined absorber 207 by means of a conduit 230. The rich inert

gas then flows upwardly through the absorber in counterflow relationship with the lean absorption solution flowing downwardly therethrough. The refrigerant vapor content of the gas is absorbed in the liquid and the resulting heat of absorption is dissipated to cooling air flowing over the exterior walls of the absorber conduit and the cooling fins attached thereto. Resulting lean gas is then discharged from the upper end of the absorber by means of the conduit 218 in the manner described above.

Circulation of inert gas is achieved in the following manner: A cold dense column of gas discharging through the conduit 222 is maintained in the inner pass of the gas heat exchanger 206. This gas has a greater weight than the warmer and lighter lean gas which is flowing upwardly through the outer pass of the gas heat exchanger from the absorber. There is also maintained a cold dense, rich gas column in the conduit 230 which has a greater average density than the gas column in the evaporator coil 225. These factors contribute to produce a circulation of the inert gas by gravity.

Although the evaporator for the compartment 13" has been described as a vertical pipe which may be positioned adjacent one side or the rear wall of the compartment 13", it is within the scope of the present invention to place this coil in a horizontal position inclined slightly to produce flow in the top part of the compartment 13" just beneath the partition 14".

The lean solution which is discharged into the separation chamber 201 by the vapor lift pump 210 is conveyed therefrom to the upper end of the absorber 207 by gravity through the conduit 240; the liquid heat exchanger 209 and conduit 241. The absorbing solution flows downwardly through the absorber 207 by gravity counter to the inert gas flowing upwardly there-through and is strengthened by absorbing refrigerant vapor from that gas. The resulting strengthened absorbing solution is drained from the bottom portion of the absorber into the solution reservoir 208 by means of the conduit 251. The solution is then conveyed from reservoir 208 to the boiler 200 by means of the conduit 252, the liquid heat exchanger 209 and the conduit 221.

There is a considerable quantity of non-volatile liquid which flows through the evaporator coil 225. This liquid is conveyed from the bottom portion of the coil 225 to the boiler by means of the conduit 243, the conduit 220 and the boiler return conduit 221.

It will be understood that the absorber, rectifier, condenser, and boiler will be arranged in the cabinet similarly to the manner in which the corresponding elements are arranged in the apparatus illustrated in Figure 1.

This form of the invention, like those described heretofore, provides low temperature refrigeration by evaporation from substantially anhydrous refrigerant in a low temperature evaporator and provides higher temperature refrigeration by evaporation from a very strong solution of refrigerant in the absorbent in a high temperature evaporator. All circulation of the refrigerant is by gravity as is the circulation of the inert gas and circulation of solution is achieved by a heat operated pump.

Thus, the present invention provides an absorption refrigerating apparatus in which low temperature refrigeration is achieved by evaporation of liquid refrigerant into the inert gas and in which high temperature is achieved by

evaporation into the inert gas from a solution of the refrigerant in the absorbent.

In accordance with the present invention, a single refrigerating system is provided with a plurality of evaporators designed to operate at different temperature levels and is so constructed and arranged as to supply refrigerating liquids having different characteristics to separate evaporators without the utilization of a complex refrigerating fluid.

The illustrated location of the rectifier is most convenient structurally as it allows the use of short direct connections to the boiler and low temperature evaporator. However, the rectifier can be positioned above or on a level with the condenser thus placing the high temperature heat rejector at the top of the air flue.

The disclosed arrangement in which the inert gas traverses the low temperature evaporator before traversing the high temperature evaporator is regarded as best for general usage but the difference between the operating temperature ranges of the evaporators can be reduced by supplying the lean gas directly to the high temperature evaporator and by supplying the low temperature evaporator with gas which has previously traversed the high temperature evaporator.

While I have illustrated and described only one embodiment of my invention, it is capable of expression in other constructional forms and variations without departing from the spirit thereof or the scope of the appended claims.

I claim:

1. That method of producing a refrigerating effect at a plurality of temperature levels which includes the steps of expelling vapor from a solution of refrigerant and an absorbent, liquefying such vapors to produce liquids of different refrigerant concentration, and evaporating such liquids of different refrigerant concentration in separate evaporating zones.

2. That improvement in the art of absorption refrigeration which includes the steps of applying heat to a solution of a refrigerant in an absorbent to expel vapors therefrom, rectifying such vapors by the extraction of heat therefrom in an amount sufficient to liquefy substantially all vapor of the absorbent and to liquefy a portion of the vapor of the refrigerant, liquefying the residue vapor to produce refrigerant liquid which is substantially free of absorbent contacting the refrigerant liquid with an inert gas to produce a refrigerating effect at a first temperature level, and contacting an inert gas with the liquid produced by rectification to produce refrigeration at a second temperature level.

3. That method of producing a refrigerating effect at a plurality of temperature levels which includes the steps of expelling vapor from a solution of refrigerant and an absorbent, liquefying such vapors to produce liquids of different refrigerant concentration, and evaporating such liquids of different refrigerant concentration in separate evaporating zones in contact with a pressure equalizing medium which is inert with respect to the refrigerant and the absorbent and while the pressure equalizing medium and all liquids of different refrigerant concentrations are subjected to substantially the same total pressure.

4. That improvement in refrigerating systems of the type in which a refrigerant vapor is expelled from solution in an absorbent by the application of heat, the refrigerant is separated from vapor of the absorbent by condensation of

such absorbent vapor and a portion of the refrigerant vapor and the remaining vapor is separately condensed to liquid refrigerant which includes the steps of flowing an inert gas in contact with the aforesaid liquid refrigerant to produce a first refrigerating effect, thereafter flowing said inert gas into contact with the said condensed absorbent and the refrigerant condensed therewith, and thereafter passing said inert gas into contact with solution from which refrigerant vapor has been expelled previously.

5. In an absorption refrigerating mechanism, means for expelling refrigerant vapor and absorbent vapor from a solution of refrigerant and absorbent, condensing means for condensing said vapors and for separately discharging a first liquid which contains the condensed absorbent and a portion of the condensed refrigerant vapor and a second liquid which contains the residue of the refrigerant vapor condensed to liquid phase, a first cooling unit, means for supplying said first liquid thereto for evaporation to produce a refrigerating effect at a first temperature level, a second cooling unit, and means for conveying said second liquid into said second cooling unit for evaporation to produce a refrigerating effect at a second temperature level.

6. In an absorption refrigerating mechanism, means for expelling refrigerant vapor and absorbent vapor from a solution of refrigerant and absorbent, fractional condensing means for condensing said vapors and for separately discharging a first liquid which contains the condensed absorbent and a portion of the condensed refrigerant vapor and a second liquid which contains the residue of the refrigerant vapor condensed to liquid phase, a first cooling unit and a second cooling unit connected to be subjected to the same total pressures, and means for supplying said first and second liquids to said first and second cooling units, respectively, for evaporation therein whereby refrigeration is produced in said first and second cooling units at different temperature levels while said cooling units are maintained at the same total pressure.

7. In a refrigerating device, a cabinet including a mechanism compartment arranged to allow a flow of cooling air therethrough and an insulated compartment divided into a freezing chamber and a storage chamber, a refrigerating mechanism comprising a freezing unit in said freezing chamber, a cooling unit in said storage chamber, means in said mechanism compartment for producing vapor of a refrigerant mixed with vapor of an absorbent, an air-cooled rectifier positioned to be contacted by cooling air in said compartment, means for conveying said vapors to said rectifier, means for conveying condensate formed in said rectifier into said cooling unit, an air-cooled condenser positioned to be contacted by cooling air in said compartment connected to receive vapors not condensed in said rectifier and to discharge condensate into said freezing unit, and means for removing vapors from said freezing and cooling units.

8. A refrigerating apparatus comprising a solution circuit including a generator and an absorber, an inert gas circuit including said absorber and first and second evaporators, a rectifier connected to receive vapors from said generator and to discharge condensate into said first evaporator, and a condenser connected to receive vapor from said rectifier and to discharge condensate into said second evaporator, said inert gas circuit being so arranged that inert gas flows

through one of said evaporators counter to the direction of flow of condensate therethrough.

9. A refrigerating apparatus comprising a solution circuit including a generator and an absorber, an inert gas circuit including said absorber and first and second evaporators, a rectifier connected to receive vapors from said generator and to discharge condensate into said first evaporator, a condenser connected to receive vapor from said rectifier and to discharge condensate into said second evaporator, and means in said inert gas circuit for propelling inert gas through one of said evaporators with a velocity sufficient to distribute the condensate therethrough by the frictional drag of the inert gas.

10. A refrigerating apparatus comprising a solution circuit including a generator and an absorber, an inert gas circuit including said absorber and first and second evaporators, said first evaporator comprising an upstanding conduit, said second evaporator comprising a substantially horizontal conduit, a rectifier connected to receive vapors from said generator and to discharge condensate into the upper portion of said first evaporator for gravity flow therethrough, and a condenser connected to receive vapor from said rectifier and to discharge condensate into said second evaporator.

11. A refrigerating apparatus comprising a solution circuit including a generator and an absorber, an inert gas circuit including said absorber and first and second evaporators, said first and second evaporators comprising substantially horizontal conduits, a rectifier connected to receive vapor from said generator and to discharge condensate into said first evaporator, a condenser connected to receive vapor from said rectifier and to discharge condensate into said second evaporator, and means in said inert gas circuit for propelling inert gas through said evaporators with a velocity sufficient to sweep or drag the condensate therethrough.

12. An absorption refrigerating apparatus comprising a first evaporator having a slope sufficient to cause liquid to flow therethrough by gravity, a second evaporator positioned above said first evaporator and also having a slope sufficient to cause liquid to flow therethrough by gravity, means for supplying a refrigerating liquid to the upper portion of each of said evaporators, an absorber positioned below said evaporators, a gas conduit system for conveying lean inert gas from said absorber to said second evaporator, a gas conduit system for conveying inert gas from said second evaporator downwardly to the lower end of said first evaporator, and a gas conduit system for conveying inert gas from the upper end of said first evaporator downwardly to said absorber whereby flow of inert gas through said second evaporator is produced by the density differential between the warm lean gas ascending from said absorber to said second evaporator and the cold partially enriched gas descending from said second evaporator to said first evaporator and flow of inert gas through said first evaporator is produced by the density differential between the gas ascending through said first evaporator and the colder richer gas descending from the upper portion of said first evaporator to said absorber.

13. Refrigerating apparatus comprising a freezing chamber, an evaporator positioned within said freezing chamber comprising a substantially plane coil inclined slightly from the horizontal to provide for gravity flow of refrigerant there-

through, said coil comprising a plurality of elongated conduit portions serially connected at their ends, means for supplying refrigerant liquid to the upper portion of said coil, means for circulating an inert gas through said coil, and a metallic plate overlying and thermally bonded to at least the major area of one side of said coil, said plate having a substantially horizontal upper face to provide an untilted support for receptacles and the like, certain of said conduit portions of said coil underlying the central portion of said plate.

14. Refrigerating apparatus comprising a refrigerating compartment, means separating said compartment into a low temperature refrigerating chamber and a high temperature refrigerating chamber, an evaporator in said low temperature refrigerating chamber comprising a substantially plane coil inclined slightly from the horizontal to provide gravity flow of refrigerant therethrough, a metallic heat conducting plate having a horizontal upper surface to provide a horizontal support for material being directly refrigerated by said coil in heat exchange relationship with said plane coil, an upstanding plane coil in heat exchange relationship with an upstanding plate which is arranged to refrigerate the air in said high temperature chamber, means for supplying a refrigerant liquid to each of said coils, and means for circulating an inert gas through each of said coils in contact with the refrigerant liquid supplied thereto.

15. In a refrigerating apparatus, a cabinet structure having an insulated refrigerating chamber divided into superposed high and low temperature refrigerating compartments, a mechanism compartment extending below said high and low temperature compartments and vertically along one wall of said chamber, an absorption refrigerating mechanism associated with said cabinet comprising an evaporator in each of said refrigerating compartments, an air-cooled absorber lying in said mechanism compartment below said evaporators, means providing an inert gas circuit including said evaporators and said absorber, and means for supplying refrigerant liquid to the evaporator in said low temperature refrigerating compartment and for supplying a mixture of refrigerant liquid and absorption solution to the evaporator in said high temperature refrigerating compartment including air-cooled condensing means mounted in the vertically extending portion of said mechanism compartment.

16. In a refrigerating apparatus, a cabinet structure having an insulated refrigerating chamber divided into high and low temperature refrigerating compartments and a mechanism compartment structure extending below and along one wall of said refrigerating chamber, an absorption refrigerating mechanism comprising an evaporator in each of said refrigerating compartments, an absorber in said mechanism compartment, a generator in said mechanism compartment connected to said absorber in an absorbing solution circuit, means connecting said evaporators and said absorber in an inert gas circuit, condensing means positioned in said mechanism compartment adjacent one wall of said chamber and connected to receive vapors from said generator, said condensing means including a first air-cooled portion which rejects heat at a high temperature and supplies condensate including liquid refrigerant and absorption solution to the evaporator in said high tem-

perature refrigerating compartment, and a second air-cooled portion connected to receive vapors previously cooled in said first portion which rejects heat at a lower temperature level than said first portion and supplies refrigerant liquid to the evaporator in said low temperature refrigerating compartment.

17. That improvement in absorption refrigerating systems of the type involving expulsion of vapors from a solution of a refrigerant in an absorbent by the application of heat, liquefaction of the vapors by extraction of heat therefrom into a cooling air, evaporation of the liquid into a gas which is inert with respect to the refrigerant and the absorbent, and absorption of the vapor produced by evaporation from the inert gas by contacting the inert gas and vapor with solution from which the vapor was expelled previously which includes the steps of rejecting heat at a first temperature level from vapors freshly expelled from solution to convert a portion of such vapors to a liquid comprising refrigerant and absorbent, rejecting heat at a second temperature level from vapor not liquefied at said first temperature level to convert another portion of said vapor to liquid refrigerant, and producing refrigerating effects by evaporating liquids produced at said first and second temperature levels into a moving body of inert gas in separated evaporating zones.

18. That improvement in absorption refrigerating systems of the type involving expulsion of vapors from a solution of a refrigerant in an absorbent by the application of heat, liquefaction of the vapors by extraction of heat therefrom into a cooling air, evaporation of the liquid into a gas which is inert with respect to the refrigerant and the absorbent, and absorption of the vapor produced by evaporation from the inert gas by contacting the inert gas and vapor with solution from which the vapor was expelled previously which includes the steps of rejecting heat at a first temperature level from vapors freshly expelled from solution to convert a portion of such vapor to a liquid comprising refrigerant and absorbent, rejecting heat at a second temperature level from vapor not liquefied at said first temperature level to convert another portion of said vapor to liquid refrigerant, producing a first refrigerating effect by contacting the liquid produced at one of said temperature levels with a moving body of the inert gas, and producing a second refrigerating effect by contacting the liquid produced at the other of said temperature levels with said moving body of inert gas.

19. In a refrigerating apparatus a cabinet having a refrigerating portion and a mechanism and heat rejecting compartment arranged for flow of cooling air therethrough, an absorption refrigerating mechanism associated with said cabinet comprising a plurality of cooling units in heat exchange relationship with said refrigerating portion, means in said compartment for producing refrigerant vapor, and means in said compartment for selectively condensing said vapor to produce refrigerant liquids of different refrigerating characteristics and for supplying refrigerant liquids of different refrigerating characteristics to individual ones of said cooling units.

20. A refrigerating apparatus comprising a solution circuit including a generator and an absorber, an inert gas circuit including said absorber and a plurality of evaporators, a plurality of condensing elements which operate at different temperature levels, one of said condensing ele-

ments being so arranged with respect to said generator that it receives a vapor mixture of refrigerant and absorbent and discharges a liquid consisting of refrigerant and absorbent and substantially pure refrigerant vapor, another of said condensing elements being arranged to receive substantially pure refrigerant vapor from said one condensing element and to discharge substantially pure liquid refrigerant, and means for conveying condensate from each of said condensing elements into an associated evaporator.

21. In a device of the character described a cabinet structure including an insulated refrigerated chamber, an absorption refrigerating mechanism associated with said cabinet structure, said refrigerating mechanism including a freezing evaporator in said refrigerated chamber, an air cooling evaporator in said refrigerated chamber, a generator, a rectifier connected to receive vapors from said generator and to supply a mixture of condensed refrigerant and condensed absorbent to said air cooling evaporator, and a condenser connected to receive vapor from said rectifier and to discharge refrigerant liquid into said freezing evaporator, said rectifier and said condenser being positioned exteriorly of said refrigerated chamber.

22. In a device of the character described, a cabinet structure including a refrigeration chamber and a machinery compartment having an upstanding air flue, an absorption refrigeration mechanism associated with said cabinet structure including a generator, a rectifier, an absorber and a condenser in said mechanism compartment, a freezing evaporator positioned in the upper portion of said refrigerated chamber, a space cooling evaporator mounted in said refrigerated chamber below said freezing evaporator, said condenser being of the air cooled type and positioned in the upper portion of said air duct, said rectifier being of the air cooled type and positioned in said air duct beneath said condenser, means for conveying liquid refrigerant from said condenser to said freezing evaporator, means for conveying liquid refrigerant and condensed absorbent from said rectifier to said space cooling evaporator, means providing for circulation of an inert gas between said absorber and said evaporators, means providing for circulation of absorbent between said absorber and said generator, means for conducting vapor of refrigerant and absorbent from said generator to said rectifier, and means for conducting refrigerant vapor from said rectifier to said condenser.

23. That improvement in the art of refrigeration which includes the steps of expelling vapor of refrigerant and absorbent from a solution of refrigerant and an absorbent, condensing the vapor of the absorbent and part of the refrigerant vapor to produce a first refrigerant liquid, evaporating the first refrigerant liquid to produce a first refrigerating effect, condensing the balance of the refrigerant vapor to produce a second refrigerant liquid, and evaporating the second re-

frigerant liquid to produce a second refrigerating effect at a temperature level below the temperature level at which said first refrigerating effect is produced.

24. In an absorption refrigerating mechanism, means for expelling refrigerant vapor and absorbent vapor from a solution of refrigerant and absorbent, fractional condensing means for condensing said vapors and for separately discharging a first liquid which contains the condensed absorbent and a portion of the condensed refrigerant vapor and a second liquid which contains the residue of the refrigerant vapor condensed to liquid phase, a first cooling unit, a second cooling unit, means for conveying said first and second liquids to said first and second cooling units, respectively, means serially connecting said first and second cooling units for flow of an inert gas therethrough, means for supplying an inert gas to one of said units and means for removing inert gas from the other of said units.

25. A refrigerating apparatus comprising a solution circuit including a generator and an absorber, an inert gas circuit including an absorber and first and second evaporators, a rectifier connected to receive vapors from said generator and to discharge condensate into said first evaporator, and a condenser connected to receive vapor from said rectifier and to discharge condensate into said second evaporator.

26. A refrigerating apparatus comprising a solution circuit including a generator and an absorber, an inert gas circuit including an absorber and first and second evaporators, said first evaporator comprising an upstanding conduit, said second evaporator comprising a substantially horizontal conduit which is sloped slightly to provide for gravity flow of a liquid therethrough, a rectifier connected to receive vapor from said generator and to discharge condensate into the upper portion of said first evaporator, and a condenser connected to receive vapor from said rectifier and to discharge condensate into the highest end of said second evaporator, said inert gas circuit being so arranged that inert gas flows through said evaporators in counterflow relationship with the condensate supplied thereto.

27. An absorption refrigerating apparatus comprising a first evaporator, a second evaporator, a generator, a rectifier connected to receive vapors from said generator and to discharge condensate into said first evaporator, a condenser connected to receive vapor from said rectifier and to discharge condensate into said second evaporator, an absorber connected in circuit with said generator for circulation of an absorbing solution, a gas heat exchanger having one pass connected to receive lean inert gas from said absorber and to discharge such lean inert gas into said second evaporator, said gas heat exchanger having a second pass connected to receive rich inert gas from said second evaporator and to discharge such rich inert gas into said first evaporator.

ARNOLD D. SIEDLE.