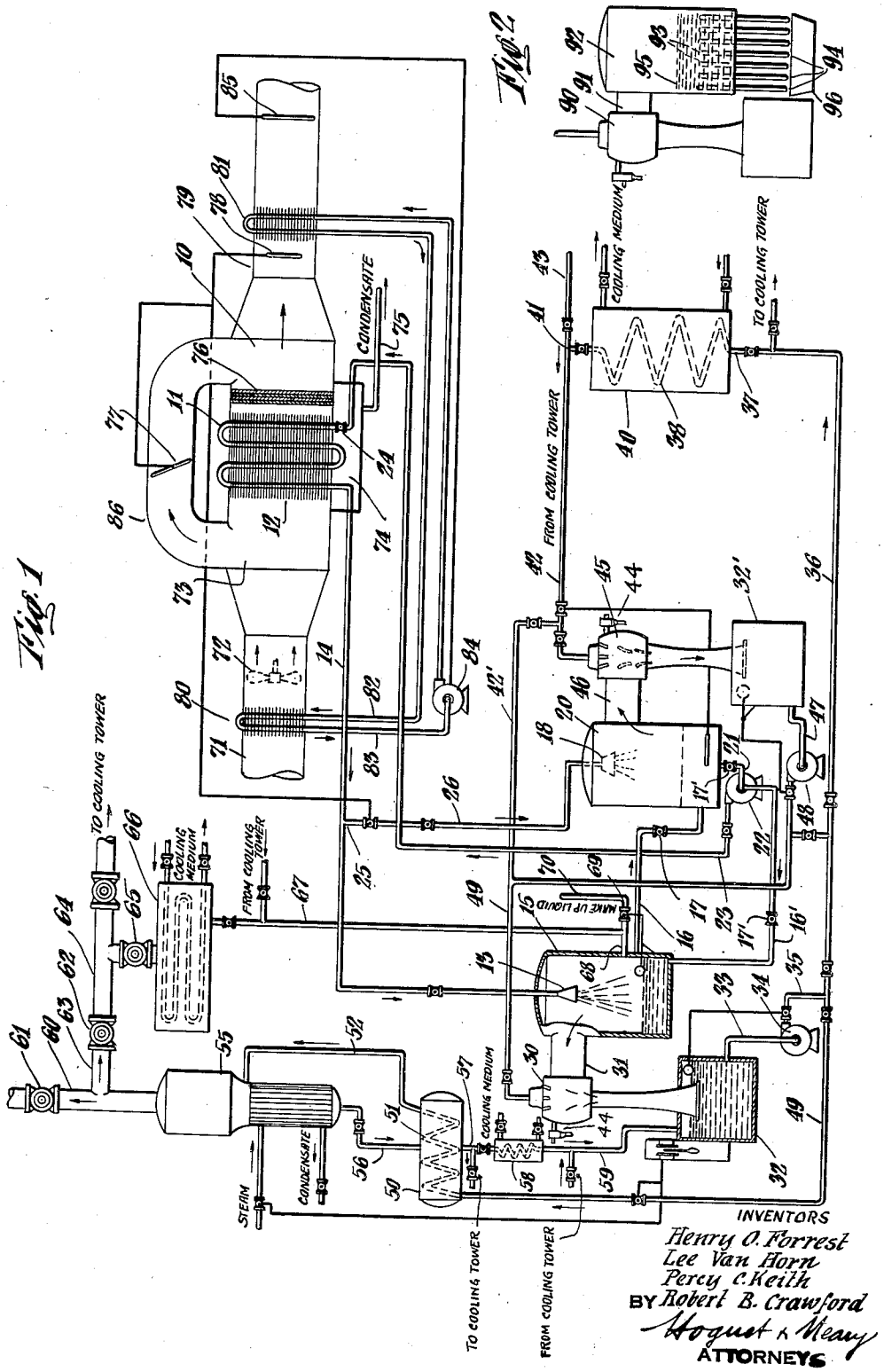
Jan. 9, 1934. H. O. FORREST ET AL 1,943,116

REFRIGERATING SYSTEM

Filed March 14, 1932 2 Sheets-Sheet 1



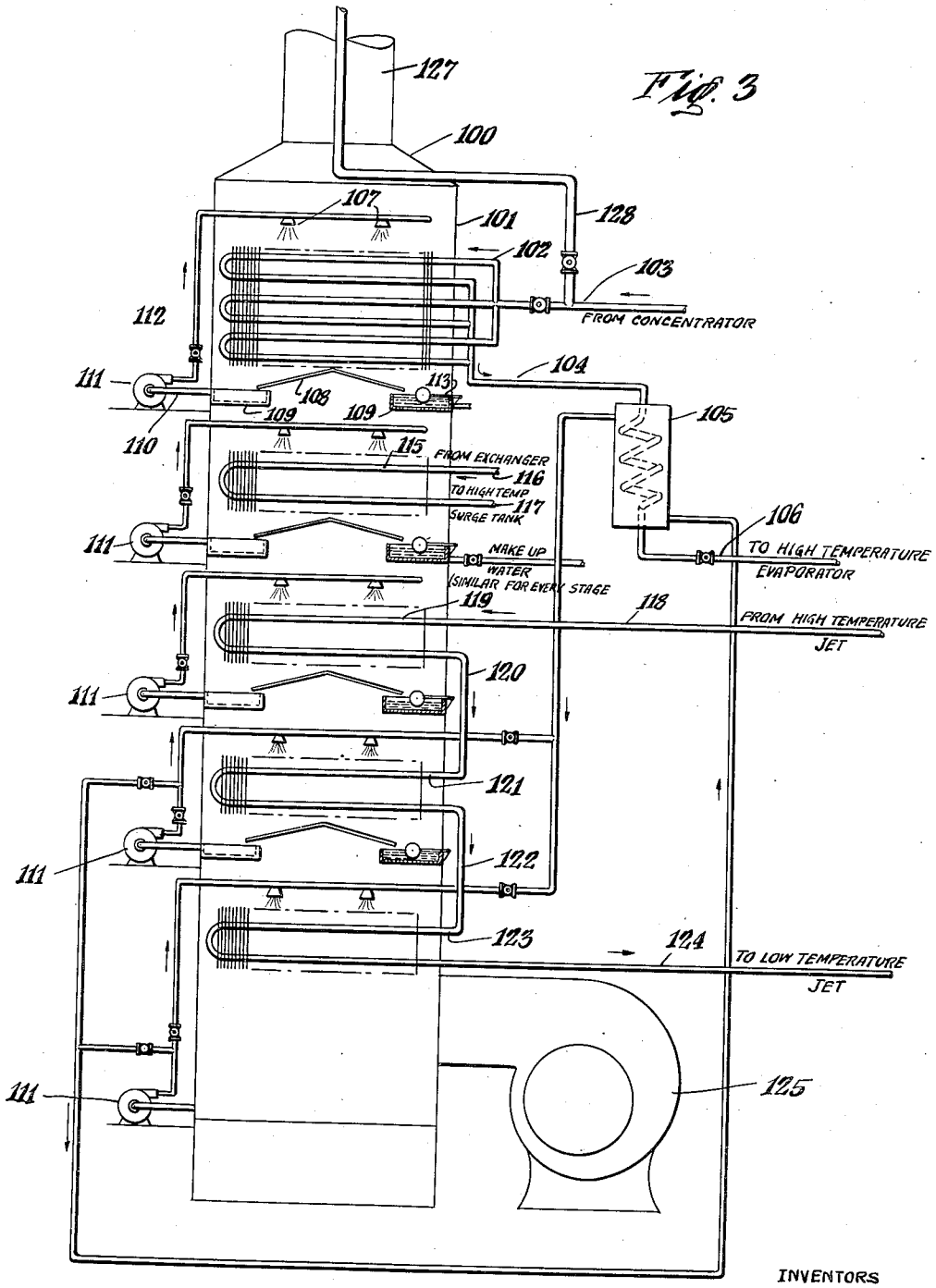
INVENTORS
Henry O. Forrest
Lee Van Horn
Percy C. Keith
BY Robert B. Crawford
Hoguet & Neary
ATTORNEYS

Jan. 9, 1934. H. O. FORREST ET AL 1,943,116

REFRIGERATING SYSTEM

Filed March 14, 1932 2 Sheets-Sheet 2

Fig. 3



INVENTORS
Henry O. Forrest
Lee Van Horn
Percy C. Keith
BY Robert B. Crawford
Hoguet & Meary
ATTORNEYS

Patented Jan. 9, 1934 1,943,116

UNITED STATES PATENT OFFICE

1,943,116

REFRIGERATING SYSTEM

Henry O. Forrest, West Englewood, Lee Van Horn, Elizabeth, and Percy C. Keith, Short Hills, N. J., and Robert B. Crawford, Brooklyn, N. Y.

Application March 14, 1932. Serial No. 598,558

8 Claims. (Cl. 62—170)

This invention relates to refrigerating systems and particularly to refrigerating systems wherein a refrigerating medium is cooled by subjecting it to the influence of a medium having lower vapor pressure characteristics than said refrigerating medium.

In accordance with a part of this invention, a refrigerating medium is circulated through suitable coils in a chamber wherein cooling is to be effected. These coils may be suitably finned coils contacted by air for air conditioning purposes, although other uses of the cooling effect of the refrigerating medium are contemplated as a part of this invention.

The refrigerating medium that has absorbed heat in the refrigerating chamber, by conduction through the finned coils, is next conveyed to a suitable cooling or evaporating chamber where it is subjected to the action of a liquid having lower vapor pressure characteristics than the refrigerating medium. By virtue of this association of the two mediums, evaporation of a portion of the refrigerating medium takes place with the subsequent cooling of the remaining portion. Any two liquids of the same nature having substantially different vapor pressure characteristics may be used in the refrigerating system contemplated as a part of this invention with the liquid having the lower vapor pressure characteristic used to absorb vapor from a portion of the refrigerating liquid for the purpose of cooling the refrigerating liquid. In addition, however, to the difference in vapor pressure of the two liquids under the absorbing conditions they should have different physical or chemical characteristics whereby separation of the refrigerating liquid from the absorbing liquid may be readily effected to permit continuous operation of the system. As contemplated by this invention, separation may be effected by employing liquids of different boiling points, specific gravities, electrical characteristics, freezing points or the like so that they may be separated from each other by distillation, evaporation, freezing, mechanical separation, osmosis, electro-osmosis, electrolysis, dialysis, molecular filtration or the like.

To increase the absorbing effect of the medium having lower vapor pressure characteristics than the refrigerating medium, this absorbing medium may be forced through a jet condenser using its kinetic energy for creating a vacuum in the evaporating chamber into which the refrigerating medium may be sprayed.

By virtue of the differences in vapor pressures of the two liquids, it is possible to transfer vapor from a refrigerating liquid at a low temperature to an absorbing liquid at a higher temperature, this latter temperature being sufficiently high that the heat may be dissipated to an available cooling medium such as cooling water or air both at ordinary temperatures. In some cases the preferred liquids may not give sufficient differential between the desired refrigeration temperature and the available heat dissipation temperature with a single stage of absorption. An advantage contemplated as a part of this invention is that a plurality of absorbing stages and evaporating chambers may be used, thus providing a higher temperature and differential and permitting heat absorption at a relatively high level.

When two stages of absorption are used to effect cooling, the absorbing liquid which has been utilized in the first stage of absorption is pumped through a suitable cooling chamber, where heat of absorption is removed, to a second stage of absorption where, since the refrigerating liquid has also been conveyed to the second stage of absorption, additional cooling of the refrigerating liquid is effected. The cooled refrigerating liquid from the second evaporating chamber is pumped through suitable conduits to finned coils in a refrigerating chamber and thence returned to the condenser evaporator in the first stage of absorption, thus completing a refrigerating circulatory system. If it is not deemed desirable to cool the refrigerating liquid to an extremely low temperature, either of the stages of absorption may be by-passed and just one relied upon to effect the desired degree of cooling.

Two mediums having no absorptive affinity for each other, such as liquid diphenyl, in the jet condenser and water in the evaporating chamber of the absorption stages, may be used in the system forming a part of this invention by relying entirely upon the compression power of the diphenyl, due to its kinetic energy, with respect to water vapor.

It is also contemplated as a part of this invention to provide suitable auxiliary devices including liquid separating devices such as evaporators and the like, and heat exchangers and cooling towers for the purpose of reactivating the absorbing medium and for removing from the absorbing medium heat of absorption caused by its association with the refrigerating medium. A single cooling tower may be provided to effect the various steps of cooling of the absorbing medium.

An object of the invention is to provide a refrigerating system wherein cooling is effected by evaporation of a refrigerating medium.

Another object of the invention is to provide in a refrigerating system a device for removing heat of absorption from an absorbing medium.

A further object of the invention is to provide a method of refrigeration permitting continuous circulation of a refrigerating and a cooling medium.

Another object of the invention is to provide a refrigerating system for conditioning air.

These and other objects will be apparent to

those skilled in this particular art from the claims and the description in the specification in connection with the drawings in which:

Figure 1 is a diagrammatic view of a refrigerating system forming an illustrative embodiment of this invention.

Figure 2 is a diagrammatic view of a modified device adapted to be used in the system illustrated in Figure 1.

Figure 3 is a diagrammatic view of a cooling device adapted to be used in the system illustrated in Figure 1.

In the embodiment of the invention which has been chosen for purposes of illustration and referring now to the drawings, in Figure 1 is shown a refrigerating chamber 10 in which a plurality of refrigerating coils 11 is disposed. The coils 11 may be provided with a plurality of fins 12 in thermal contact therewith for the purpose of providing additional convection surfaces.

A suitable conduit 14 is connected with the coils 11 and conveys a refrigerating medium which has been circulated through the coils and which has absorbed heat from within the chamber 10 to a spray member 13 disposed within an evaporating chamber 15.

A pipe 16 having a valve 17 is connected to a lower portion of the evaporation chamber 15 and conveys refrigerating liquid therefrom to a second evaporating chamber 20.

A pipe 16' controlled by suitable valves 17' may be used in connection with pump 22 and pipe 23 to bypass the second stage evaporator 20 in which case a valve controlled pipe 42' will be used to bypass jet condenser 45.

A suitable pipe 21 connects the lower portion of the chamber 20 with a pump 22 which forces refrigerating liquid from the chamber 20 through a pipe 23 to an inlet end 24 of the coils 11. A T-connection 25 in the pipe 14 and a suitable connecting pipe 26 connecting the T-connection with the evaporating chamber 20 through a spray member 18 may be used to bypass evaporating chamber 15, if deemed desirable.

A jet condenser 30 is connected by means of a suitable duct 31 with the evaporating chamber 15 and an absorbing medium is forced through the jet condenser 30 to a surge tank 32. From the surge tank 32 a portion of the absorbing medium may be forced by means of a pump 34 and suitable pipe connections 33, 35, 36 and 37 through coils 38 in a cooling chamber 40, a T-connection 41 and a suitable pipe 42 to a second jet condenser 45. The jet condenser 45 is connected by means of a suitable conduit 46 with the evaporating chamber 20 and because of the lower vapor pressure characteristics of the absorbing liquid circulated therethrough and because of the vacuum created in evaporating chamber 20 since this absorbing liquid is forced through the jet condenser 45, additional evaporation of the refrigerating liquid is effected in this chamber and its temperature is further lowered.

The absorbing liquid forced through the jet condenser 45 falls into a surge tank 32' and is drawn therefrom through a suitable pipe 47 by a pump 48 and forced through a pipe 49 to the jet condenser 30. A vacuum creating jet 44 or a vacuum pump may be associated with the jet condensers 30 and 45 if deemed desirable.

The portion of the absorbing liquid drawn from the surge tank 32 that is not pumped to the jet condenser 45 is pumped through a pipe 49 to a heat exchanger 50 through which it is forced through coils 51 disposed therein to a pipe 52 and delivered to a suitable concentrator 55.

In the concentrator 55 the absorbed refrigerating liquid is separated and the concentrated absorbing fluid flows through a pipe 56 to the heat exchanger 50 contacting the coils 51 therein and imparting much of the heat required to effect the separation of the absorbing and refrigerating liquid to the liquid being pumped to the evaporator. From the heat exchanger 50 the reactivated absorbing medium flows through a pipe 57 to a cooler 58 where the excess heat not imparted to the cool liquid in the heat exchanger is removed. The cooled and reactivated absorbing liquid then flows through the pipe 59 to the surge tank 32 and increases the concentration of the liquid contained therein.

In connection with the refrigeration system just described, it is to be noted that the absorbing liquid of highest concentration and lowest temperature flows through the jet condenser 45 which is associated with the evaporating chamber 20 which contains the refrigerating medium at lowest temperatures and that the absorbing medium flowing through the jet condenser 30 and coming in association with the refrigerating liquid contained in the evaporator 15 is of lower concentration and higher temperature and effects refrigerating liquid of higher temperature. Such a system of contact forms a counter flow system and hence increases the efficiency of cooling and the maximum differential between desired refrigerating temperature and heat dissipation temperature.

When the refrigerating system just described uses water as a refrigerating medium and some hygroscopic liquid such as solutions of sodium or potassium hydroxide, sulphuric acid or lithium, calcium or zinc chlorides as the absorbing medium, separation of the refrigerating and absorbing medium may be effected in the evaporator 55 by the application of sufficient heat to convert a desired amount of water into steam and the steam may be discharged to the atmosphere through a valve control outlet 60. Other liquids of like nature having different vapor pressures and different boiling points may be used just as readily however. For example, a heavy petroleum oil, such as straw oil, may be used in the jet condenser and a light petroleum product such as butane in the refrigerating system. When two liquids such as these are used the valve 61 located in the outlet 60 would be closed and a valve 62 in a branch duct 63 opened, whereby the butane which would be evaporated first would flow through the duct 63, valve 62, duct 64 and valve control branch 65 to a condenser and cooling chamber 66 and from there would flow through a suitable pipe 67 and pipe 68 to the evaporating chamber 15. The pipe 68 is furnished with a valve 69 to admit make-up refrigerating liquid through the make-up pipe 70.

When the refrigerating chamber 10 is used for air conditioning purposes it is provided with an inlet duct 71 in which is disposed a fan 72 for insuring an adequate supply of conditioned air. The air drawn in by this fan passes into the main body of the chamber 73 where it contacts the finned tubes 11. By virtue of this contact with the finned tubes 11 through which is circulated a refrigerating medium, the temperature of the air is reduced to below the dew point and water is condensed therefrom and forms on the fins 11 and drips off, falling to a sump 74. This water may be removed from the sump by means of a

suitable outlet pipe 75. Suitable baffling 76 is provided beyond finned tubes 11 to catch any of the condensate that might be entrained by the current of air passing through the chamber 10. Entrained water stopped by the baffling 76 flows to the sump 74. A suitable duct 86 is provided to bypass the tubes 11, the amount of air which is permitted to flow through the bypass 86 being governed by a damper 77 actuated by a thermostat or hygrostat 78.

Instead of this by-pass system a finned coil 80 may be provided at the inlet end 71 of the chamber 10 and a similar finned coil 81 may be provided at the outlet end 79 of this chamber. Pipes 82 and 83 connect these coils and by means of a suitable pump 84 controlled by a thermostat 85 disposed in the outlet end 79 of the chamber 10, the rapidity of circulation of liquid through these two coils may be controlled giving a fine balance control of the temperature of the air being carried from the chamber 10 by the outlet duct 79, for the air striking the coils 80 will tend to warm the liquid circulated through this balancing system and hence to raise the temperature of the air contacting the coil 81 at the outlet end. This arrangement of coils will enable the system to be operated so that air can be cooled to a high degree to effect high dehumidification and warmed again to a comfortable dry bulb temperature without any substantial loss of sensible heat since a mere exchange of sensible heat is involved. This arrangement provides for control of humidity and temperature independently, and essentially reduces humidity and raises sensible heat for a given amount of refrigerating work in the coils 11.

In Figure 2 is shown a modification of an evaporating chamber in association with a jet condenser and which is especially adapted for use in individual rooms or where compact complete refrigerating units are desired. In this modification is shown a jet condenser 90 similar in character to the jet condensers 30 and 45 previously described and which is connected by a duct 91 to an evaporating chamber 92. The evaporating chamber 92 has disposed in the bottom thereof a plurality of metallic fins 93 having portions 94 extending through the bottom thereof. When, through the action of the jet condenser 90, refrigerating liquid 95 is evaporated and cooled the fins 93 and their projecting portions 94 are cooled and by circulating a current of air across the projecting portions 94 the air contacting these fins may be cooled and the temperature of a room may be lowered. Any water condensed from this air upon the fins 94 may be collected in a suitable sump 96 and removed therefrom in any manner deemed desirable.

In Figure 3 is shown a cooling device 100 in the form of a cooling tower which may be substituted for the several cooling chambers 40, 58 and 66, described in connection with the refrigerating system illustrated in Figure 1 and which in addition may be used to cool make-up liquid supplied to the system.

This device consists of a casing 101 in which a plurality of independent cooling stages is located. In the upper part of the casing 101 is located a plurality of finned coils 102 adapted to receive vapor from the evaporator 55, illustrated in Figure 1. This vapor is received through an inlet pipe 103 and flows through the several tubes 102 to an outlet pipe 104. Pipe 104 carries this condensed refrigerating medium through a cooler 105 and then by means of a pipe 106 the cooled refrigerating medium is delivered to the high temperature evaporator. This condenser will be used when the liquid used in the refrigerating system as a refrigerating medium is some valuable liquid such as butane, or even water in places where the supply of suitable water is limited.

To cool the liquid circulated through the finned tubes 102 spray members 107 are provided which provide a spray of water across these tubes. This water strikes a suitable baffle plate 108 and is deflected to a suitable tank 109 provided at the periphery of the casing. A pipe 110 connects the tank 109 to a suitable pump 111. The pump 111 forces the water through a pipe 112 to the spray members 107. A suitable float valve 113 insuring an adequate supply of make-up water is provided in this circulatory cooling system.

A similar spray system is disposed just below the cooling system just described and insures that an adequate supply of water is sprayed across finned tubes 115 through which is circulated reactivated absorbing liquid pumped from the exchanger 50 described in connection with Figure 1, through a pipe 116. The cool absorbing liquid is carried by a pipe 117 back to the high temperature surge tank 32.

Disposed just below the circulatory cooling system just described is a plurality of similar circulatory systems, each of which is adapted to spray water, as just described, across a series of tubes through which absorbing medium from the high temperature jet condenser 30 is circulated. This liquid is pumped through a pipe 118 to the first series of coils 119 and flows through connecting pipe 120 to the second series of coils 121 and then through a similar connecting pipe 122 to another set of cooling coils 123. From this last set of cooling coils 123 the liquid is pumped through a pipe 124 to the low temperature jet 45. Obviously more than three cooling stages may be provided for cooling the absorbing medium if three stages do not provide sufficient range of cooling.

The pumps 111 that supply the cooling medium sprayed across the lower sets of tubes may also furnish a supply of the cooling medium to cooling tank 105. A blower 125, having an outlet connected to the lower portion of the casing 101, supplies a steady current of air across all of the heat transfer tubes and by evaporating a portion of the water sprayed across these tubes increases the cooling effect by lowering its temperature. This air with the water it has evaporated is carried out the casing 101 through a suitable duct 127. A branch pipe 128 is connected with the pipe 103 for discharging vapor to the atmosphere through the duct 127 when it is not necessary to conserve the supply of refrigerating medium, such as when water is used.

The latent heat of the refrigerating medium, whether water or butane in the examples given, may be recovered for useful purposes in the condenser 66 if desired. For example hot water for domestic, boiler feed, or other purposes may be obtained from this condenser and an auxiliary liquid cooler added to remove the sensible heat of the refrigerating liquid. In this way a large proportion of the heat required in the evaporator 55 is recovered adding to the efficiency of the refrigerating unit as a whole. This heat may be used to reheat air if the temperature of the air is reduced to too low a degree during the air conditioning process.

In many cases the disposal of the heat from

the refrigeration system is a problem. In most cases the operating and installation costs will be less the smaller the quantity of air which is required by the solution cooler for dissipation of the heat to the atmosphere. Since the removal of the heat is dependent upon the evaporation of the water into the air the limiting factor will be the water carrying capacity of the air. The water carrying capacity of air increases very rapidly with increase in temperature. The temperature of the exit air from the cooler must be lower than that of the solution coming to the cooler, consequently the quantity of air required for the cooler is a function of the solution temperature discharging from the condenser.

In general the amount of solution which must be supplied to the condenser is determined by the allowable temperature rise in the condenser, in other words, for a constant duty the quantity of solution is inversely proportional to the temperature rise. It is obvious that it is desirable to handle as small a quantity of solution as possible. On the other hand, the temperature level obtainable in the evaporator is a direct function of the condenser discharge temperature. In order to obtain a desirable low water temperature in the water evaporator at the same time obtaining the advantages of high condenser discharge temperature we use a counter current system comprising a plurality of condensers and water evaporators as illustrated in Figure 1. For the sake of simplicity only two stages are shown in the illustration but it is understood that we may use any number.

As an example of the operation of this system just described consider that it is desired to cool water from 60° F. to 40° F. when utilizing a 50% by weight caustic soda solution in the condenser. It will be assumed that the friction loss in each evaporator is 3.0 mm. The vapor pressure of water at 40° F. is 6.3 mm. Therefore the condenser discharge temperature in a single stage system as shown in the drawings could not be greater than 101° F. since the water vapor pressure of such a 50% solution would be 3.3 mm. at that temperature. By using a two stage system the water can be cooled 60° F. to 50° F. in one stage and then from 50 to 40° F. in another stage with the solution and water to be cooled flowing countercurrently. The solution would be heated to 101° F. in the cold water stage as in the single stage system. At 50° F. the vapor pressure of water is 9.1 mm. and allowing 3 mm. friction in the evaporator the water vapor pressure at the condenser discharge must be not more than 6.1 mm, which corresponds to a solution temperature of 119° F. Thus by utilizing a two stage system it is possible to increase the final solution temperature by 18° F. and at the same time the quantity of solution flowing has been approximately cut in half. In the drawings there is indicated a solution pump 34 between the two stages, but we may within the spirit of the invention only pump once for two or more condensers and have no surge tanks between stages. The drawings also indicate gravity flow from one water evaporator to another, but in some cases for structural reason it is desirable to pump water from one stage to another. A single or multiplicity of vacuum pumps may be used in conjunction with the multi-stage system for removal of non-condensible gases if desired.

A specific refrigerating system and specific methods of operation have been described in some detail but it is to be understood that changes, additions, substitutions and omissions may be made in the structure of the device itself and in the materials used in its operation within the spirit of this invention as defined by the appended claims.

We claim:

1. A method of cooling a refrigerating medium including the steps of subjecting said medium to the action of a medium having lower vapor pressure characteristics than said refrigerating medium, cooling said second medium and subsequently subjecting said refrigerating medium to the action of said cooled medium of lower vapor pressure characteristics.

2. A method of cooling a refrigerating medium including the steps of subjecting said medium to the action of an absorbing medium having lower vapor pressure characteristics, removing the heat of absorption from said absorbing medium and subsequently contacting said refrigerating medium with said cooled absorbing medium.

3. A method of cooling a refrigerating medium including the steps of subjecting said medium to the action of a moving body of an absorbing medium having lower vapor pressure characteristics, removing heat of absorption from said absorbing medium and contacting said refrigerating medium with said cooled absorbing medium.

4. A method of cooling a refrigerating medium including the steps of subjecting a moving body of said refrigerating medium to the action of a moving body of an absorbing medium having lower vapor pressure characteristics than said refrigerating medium, removing heat of absorption from said absorbing medium and subsequently subjecting said refrigerating medium to the action of said absorbing medium.

5. A method of cooling a refrigerating medium including the steps of subjecting a moving body of said medium a plurality of times in a plurality of places to a moving body of an absorbing medium, removing heat of absorption from said absorbing medium after its final association with said refrigerating medium.

6. In a refrigerating system, a jet condenser associated with an evaporating chamber and through which an absorbing fluid is passed, a reactivating chamber adapted to receive a portion of the fluid from said jet condenser and evaporate absorbed refrigerating fluid therefrom, a cooling tower associated with said refrigerating system and having a plurality of independent groups of cooling coils, adapted to remove heat of absorption from said absorbing fluid in one group of coils, sensible heat from said reactivated fluid in another group of coils and latent and sensible heat from the fluid, separated from said absorbing fluid, in another group of coils.

7. In a cooling device a jet condenser associated with an evaporating chamber, a plurality of fin members disposed within said evaporating chamber and covered by a refrigerating liquid, said fins having extensions projecting a substantial distance beyond said evaporating chamber.

8. In a cooling device a jet condenser associated with an evaporating chamber, a plurality of fins disposed within said evaporating chamber and contacted by a refrigerating medium, said fins having extensions projecting a substantial distance beyond said evaporating chamber.

HENRY O. FORREST.
LEE VAN HORN.
PERCY C. KEITH.
ROBERT B. CRAWFORD.