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METHOD AND MEANS FOR AIR CONDITIONING

Filed Aug. 21, 1940

2 Sheets-Sheet 1

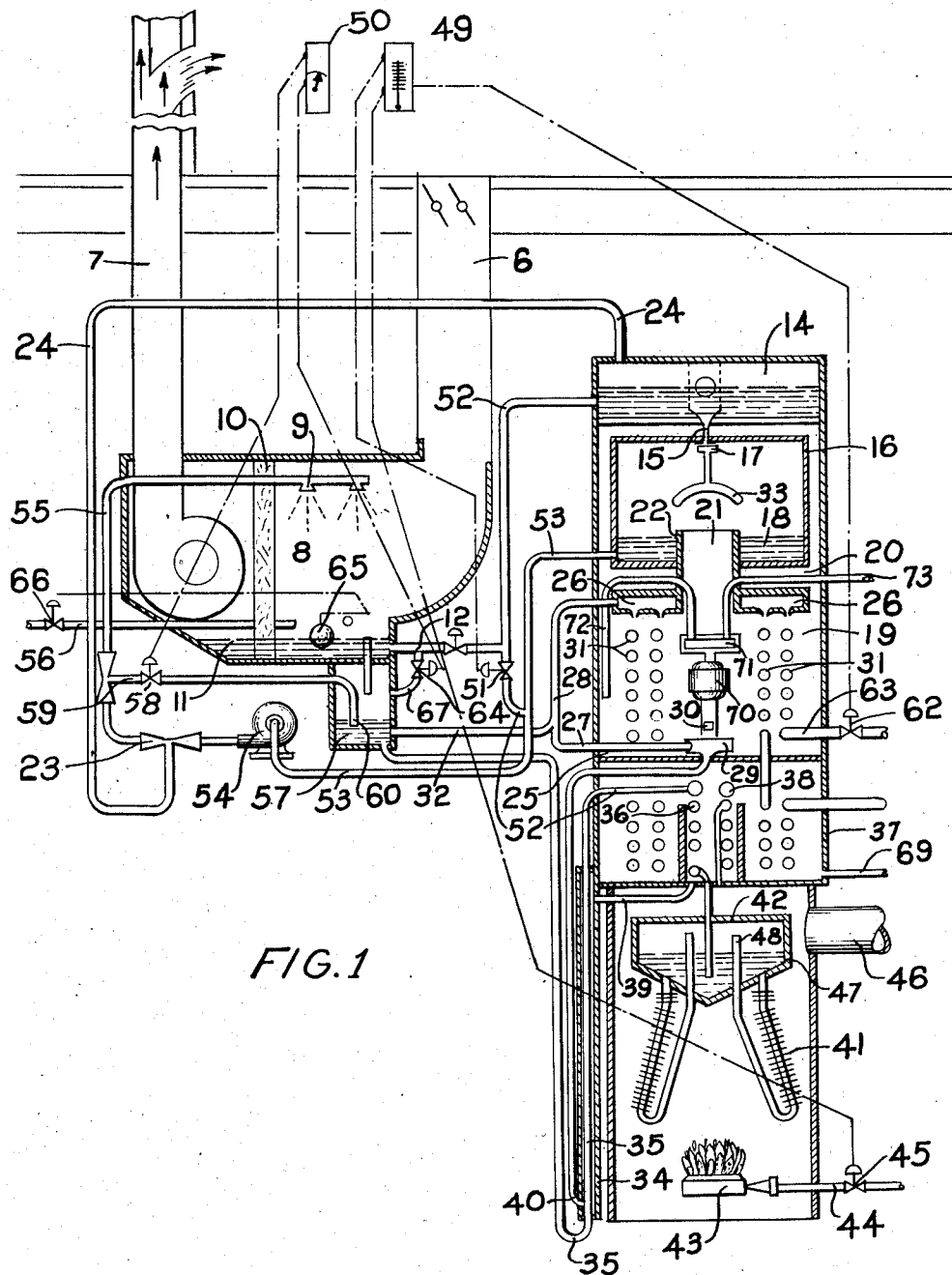


FIG. 1

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2 Sheets-Sheet 2

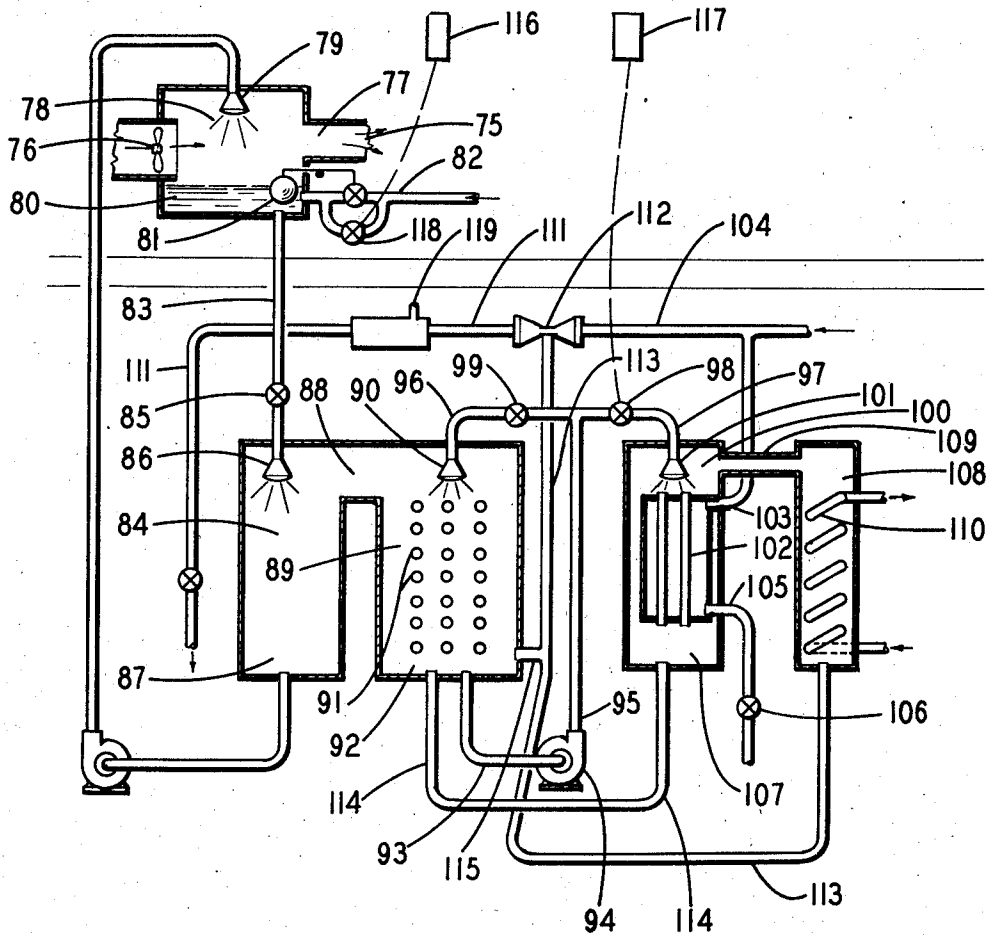


FIG. 2.

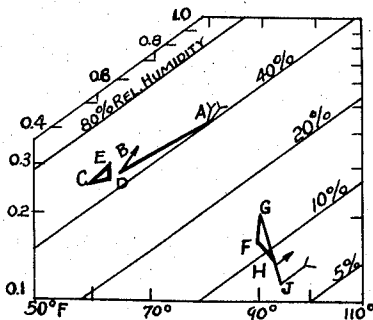


FIG. 3.

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## UNITED STATES PATENT OFFICE

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METHOD AND MEANS FOR AIR  
CONDITIONING

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15 Claims. (Cl. 257-3)

This invention relates to improved methods of conditioning air and apparatus therefor. More specifically the invention is concerned with an improved method of controlling the temperature, the humidity and the purity of air.

The present invention, then, comprehends a method of complete air conditioning which includes controlling the temperature, the humidity and the purity of the air used in an enclosure.

It is among the objects of the present invention to provide apparatus capable of being operated either to heat or to cool, to humidify or to dehumidify air passed therethrough. Another object of the invention is to provide apparatus in which independent control of both the temperature and the humidity of air going to an enclosure such as a room may be exercised. A further object of the invention is to provide automatic and efficient means for the control of the hereinbefore-mentioned apparatus. A primary object of the invention is to provide an apparatus which completely conditions the air in buildings in winter and/or summer.

To the accomplishment of the foregoing and related ends, the invention, then, consists of the methods and means hereinafter fully described and particularly pointed out in the claims, the annexed drawings and the following description setting forth in detail certain methods and means for carrying out the invention, such disclosed methods and means illustrating, however, but several of various ways in which the principle of the invention may be utilised.

In said annexed drawings: Figure 1 is a cross-sectional elevation of a specific embodiment of the principle of the present invention. Figure 2 is a diagrammatic modification of a specific embodiment of the principle of the present invention. Figure 3 is a portion of a psychrometric chart illustrating graphically a specific example of the process.

In Figure 1: Air is conditioned by withdrawing it from an enclosure through the duct 6, passing it through a conditioning chamber 8 and ejecting it into an enclosure from the duct 7.

Air entering by the duct 6 is sprayed with an absorbent solution, i. e., lithium chloride, calcium chloride, etc., descending from the distributors 9. The air is then passed through a filter 10 and returned to the enclosure.

The absorbent solution, after descending from the distributors 9, collects in a sump 11 and is passed through a pipe 12 into a pipe 52 and thence into a purge chamber 14. The purge chamber 14 is part of a vacuum absorption refriger-

erator. From the purge chamber 14 the absorbent solution is passed through the outlet 15 into a vaporizer chamber 16 and is broken up into droplets and distributed therein by the distributing device 17. A portion of the absorbent solution then collects in the sump 18 formed in the bottom of the vaporizer chamber 16. The vaporizer chamber 16 is insulated from the absorber chamber 19 by the space 20 therebetween and vapor flows from the vaporizer chamber 16 to the absorber chamber 19 through the passage 21. A jet evacuator 23 is disposed in the pipe 24. The vacuum thus produced in the purge chamber 14 serves to keep said chamber at lower than atmospheric pressure as well as to remove entrained air from the absorbent solution, thus increasing the efficiency of the vaporizer chamber 16. A reflector 33 is placed in the chamber 16 above the opening into the absorber chamber 19 so as to reflect any heat originating in the absorber chamber 19 into the latter.

A sump 25 is formed on the floor of the absorber chamber 19. Absorbent solution reaching the distributor 26 is pumped from the sump 25 by means of the pump 29 through the pipe 27. The sump 25 communicates with the pump chamber 29 by the opening 30. The major portion of the absorbent solution passing from the pump 29 through the pipe 27 is thus returned to the distributor 26 by means of the pipe 28. The absorbent solution then flows through the distributor 26 onto a cooling coil 31 and absorbs solvent vapor coming into the absorber chamber 19 from the vaporizer chamber 16 by means of the passage 21. This solution is then collected in the sump 25 for recirculation. Mounted on the motor 70 is a vacuum pump 71 which draws entrained air from the absorber 19 through the pipe 72 and discharges this air to the atmosphere by the pipe 73. The pipe 72 leads from near the bottom of the absorber 19 since, due to the sweep of water vapor from the chamber 16, most of the air will tend to accumulate near that point.

The minor portion of the solution flowing in the pipe 27 is passed by the pipe 32 into a sump 57 and thence by the pipe 35 through the heat exchanger 34 into the regenerator-condenser chamber 37 where it is distributed by a distributing device 38 over a heating coil 36. The condensing vapor in the heating coil 36 preferably has a boiling point somewhat higher than that of the absorbent solution at the highest concentration utilised. This solution flowing over the heating coil 36 is, thus, boiled and some of the solvent vaporized thereby. The solution thus

concentrated by removal of solvent vapor and purified by the removal of noisome odours contained therein is passed by the pipe 39 through the heat exchanger 34 and the pipe 40 to the inlet of the pump 29 in the absorber chamber 19. In the pump chamber the concentrated solution and the solution entering by the opening 30 are mixed and passed through the pipe 27 in the manner previously described.

In reference to the material utilised in the heating coil 36, steam has been found to serve satisfactorily but a stable organic liquid boiling from about 155° C. to about 175° C. is preferred. Examples of such liquids are brombenzene and orthodichlorobenzene. The vapors to be condensed may be drawn from any source such as the steam line of the building or produced in a boiler as shown. In the particular embodiment illustrated, the boiler 42 is provided with a finned tube 41 protruding from the base of the boiler over a burner 43 connected to a source of fuel 44 fitted with a valve 45. Flue gases are vented by the stack 46. The liquid to be vaporized is contained in the boiler 47, a portion of the same passing down into the partially finned pipe 41 and vaporizing therein. The vapor thus produced then passes through the outlet 48 and collects in the upper portion of the hereinbefore-mentioned boiler 47 and is forced by the resulting pressure into a heating coil 36 in the regenerator-condenser chamber 37. After condensation the drips pass out of the heating coil 36 and are collected for re-utilisation in the boiler 47. Further details of the apparatus are disclosed in the following description of the operation thereof.

Under average summer conditions it is generally desirable to maintain a low relative humidity and a temperature to adjust the condition of the air of the building to what are known to those skilled in the art as "comfort conditions." Automatically to maintain the temperature and relative humidity at their predetermined values a thermostat 49 and a humidostat 50 are provided. The purpose of the thermostat 49 is to actuate a control circuit when the temperature exceeds the predetermined range and to actuate a second control circuit when the temperature reaches a point below the lower limit of said predetermined range. The humidostat functions in the same manner to regulate the relative humidity. Thus, if the temperature in the building being conditioned rises above the upper limit a valve 51 in the pipe 52 is closed or partially closed so that a lesser amount of the absorbent solution leaving the sump 11 flows back thereto by the pipe 12, the pipe 52, the pipe 53, the pump 54, the jet evacuator 23, the pipe 55, and the distributors 9. The immediate result of this action is that more of the warm liquid leaving the sump 11 is passed by the pipe 52 into the chamber 14 and thence into the vaporizer chamber 16 where a portion of the solvent of the weak absorbent solution evaporates in the high vacuum therein obtaining, thus cooling the remaining absorbent solution. Thus, since less warm liquid is being returned to the sump and a greater relative portion of cooler liquid is entering therein, the temperature of the air being passed therethrough is lowered and the condition which originally caused the function is obviated. Should the relative humidity in the building being conditioned rise above the upper limit desired, the humidostat 50 automatically partially or wholly closes the valve 58 in the pipe 59 which enters the sump 57 thus decreasing the flow of liquid from

the sump 57 through the pipe 59, the pipe 66, through the distributors 9 into the conditioning chamber 8. Since the relative humidity of air passing in contact with absorbent solution varies substantially inversely with the strength of the absorbent solution, the result of not diluting the solution passing to the chamber 8 by means of the pipe 55, the dilution from the pipe 52 being now decreased, is to lower the humidity of the air in the building being conditioned and thus correct the undesirable condition. A further effect of the flow of solution of increased strength is to raise the level of the liquid in the sump 11, the excess liquid therein overflowing by the pipe 60 into the sump 57. A second function served by the overflow pipe 60 is to accommodate the increase in volume of the liquid in the sump 11 produced by the absorption of water from air. The combined action of these two effects is, while the unit is absorbing moisture, to weaken the liquid in the sump 57. As the absorbent solution in the sump 57 becomes weaker its boiling point falls farther and farther below the temperature of the heating medium in the regenerator heating coil 36; thus the absorbent liquid flowing over said heating coil has more and more water removed therefrom, the condensed vapor thereby resulting going to waste by means of pipe 69 and carrying therewith noisome odours while the non-boiling liquid flowing to the sump 57 by the pipe 39 and the pipe 35 is maintained at substantially constant concentration regardless of the overflow of absorbent liquid from the sump 11 due to the absorption of moisture from the building being conditioned.

It has been found that by means of this system of simultaneous control of humidity and temperature it is possible to operate with absorbent solutions of much less strength than have been necessary heretofore. For example, to maintain a relative humidity of 50% and a temperature of 80° F. in a building, it has usually been necessary or advisable to use in the scrubber solutions of very high concentrations, i. e., those having a drying power capable of reducing the relative humidity of air in contact with them to as low as 15% relative humidity. In the practice of the present invention it is possible to dispense with the use of these highly concentrated solutions and to use cheaper solutions, e. g., calcium chloride instead of lithium chloride, capable of giving air a relative humidity of only about 50%. This advantage obtains because by using relatively cold solutions for dehumidification, the dew point of the air passing in contact with a solution of a given concentration is much lower than where solutions are employed having approximately room temperature.

Under winter conditions the temperature of the air may fall below the minimum setting of the thermostat 49 thus actuating a valve 45 increasing the supply of fuel to the burner 43 through the pipe 44. The same actuation shuts down the flow of cooling water through the pipe 63 by means of the valve 62. The combination of increased heating and decreased cooling raises the temperature of the liquid leaving the pump 29 so that the refrigeration cycle previously described is reversed and refrigerant vapor flows from the absorber chamber 19 to the vaporizer chamber 16 thus raising the temperature of the liquid flowing through the pipe 53 so that it heats the air flowing through the scrubbing chamber 8. If the humidity now falls

below the predetermined value, the valve 64 in the bypass 67 is opened allowing the level of liquid in the sump 11 to fall to a point such that a float valve 65 actuates a fresh water supply means 66, adding water to the solution by means of the pipe 56; thus the relative humidity of the air is increased because of the decreased concentration of the absorbent solution.

In the embodiment of the present invention illustrated in Figure 2 air is conditioned by withdrawing it from a room, passing it through a conditioning chamber 78 and ejecting it into a room or other enclosure through the duct 75. One or more distributors 79 for absorbent solution are provided in the conditioning chamber or scrubber 78. A sump 80 is provided to collect the absorbent solution descending from the distributors 79. A float valve 81 is provided to control the introduction of additional water from the main 82 should the level of liquid in the sump 80 fall below a predetermined point. This same float valve may also be so disposed as to close the outlet line 83 from the sump 80 thus preventing air from being drawn into the pipe 83 in case of a dearth of liquid in the sump 80. In order to prevent too rapid a flow of liquid through the pipe 83 into the vaporizer chamber 84, a reducing valve 85 is introduced into said pipe. One or more distributors 86 are provided in the vaporizer chamber 84 similar to those provided in the scrubber 78, and adapted to disperse the liquid entering therein in a fine spray so that at least a portion of said liquid is evaporated under the vacuum obtaining in said chamber. Some of the absorbent solution entering the vaporizer chamber 84 by the distributors 86 collects in a sump 87 formed in the bottom of said chamber. The liquid utilized in this portion of the apparatus may be a solution of any suitable absorbent, e. g., calcium chloride.

The vaporized solvent obtaining in the vaporizer chamber 84 passes by the outlet 88 into an absorber chamber 89 where it is absorbed in a second absorbent solution which enters the absorber chamber 89 by means of the distributors 90. Cooling coils 91 are provided for the dual purpose of taking up the heat of absorption and providing an absorption surface. The second absorbent solution, now diluted by the addition of solvent, is collected in a sump 92 formed in the bottom of the absorber chamber 89. This solution is, then, withdrawn by the pipe 93, passed through the pump 94 and into the pipe 95 where the major portion is passed into the pipe 96, through the reducing valve 99 and back into the absorber chamber 89 by means of the distributors 90. The remainder of the solution is passed through the pipe 97, the control valve 98 and into a regenerator chamber 100 by means of the distributors 101 therein. This solution is then passed over a calandria 102. Steam for the calandria 102 is obtained by means of the pipe 103 from the steam line 104. Drips are collected and passed off by the pipe 105. This condensate may be returned to the hot water boiler by the valve 106 or other means, not shown.

The absorbent solution collecting in the sump 97 in the bottom of the regenerator chamber 100 is now concentrated since a portion of the solvent has been driven off as vapor and is passed into a condenser chamber 108 through the conduit 109 and condensed on the cooling coils 110 to be passed into the purge line 111 through the pipe 113 and the jet evacuator 112. The con-

centrated solution in the regenerator chamber 100 is, then, passed back into the absorber sump 92 by the pipe 114 to be circulated through the pipe 93, the pump 94, etc., in the manner previously described. A valve, not shown, of the type well known in the art may be provided in the line 114 to prevent vapor passing from the regenerator chamber 100 to the absorber chamber 89. In the preferred embodiment of the present invention the cooling water in the coil 110 in the condenser chamber 108 may be that leaving the cooling coil 91 in the absorber chamber 89. Such a procedure has been found to facilitate control of the apparatus to a considerable degree.

Air entering the evaporator chamber 78 has been found to dissolve in the solution leaving said chamber. For this reason a purge line 115 operably connected to a steam jet evacuator 112 in the present embodiment has been provided to maintain a vacuum in the vaporizer chamber 84 and the absorber chamber 89 and to remove the dissolved and entrained air from the absorbent solution.

It has been found convenient to operate the regenerator chamber 100 and condenser chamber 108 at pressures below atmospheric while the pressures in the vaporizer chamber 84 and the absorber chamber 89 are substantially under a high vacuum.

A humidistat 116 is provided in the room or enclosure from which air is being conditioned and said instrument is connected so that whenever the humidity in the enclosure becomes lower than the predetermined value, water enters the sump 80 by the opening of the valve 118. A thermostat 117 is provided and connected so that when the temperature becomes too high in the enclosure, a valve 93 is opened permitting more solution to flow to the regenerator chamber 100.

The absorbent liquid employed in the absorber and condenser chambers is, preferably, an absorbent of greater absorbent power than that utilized in the vaporizer and scrubber chambers, e. g., a concentrated solution of zinc chloride, but, if it is desired, the solutions in the two cycles may be of the same solute providing the solution in the absorber-regenerator cycle is maintained at a higher concentration than that in the vaporizer-scrubber cycle.

Figure 3 is a chart of the partial pressure of water vapor (in logarithmic scale) as ordinate and temperature (in arbitrary scale) as abscissa. Point A represents the temperature and partial pressure of water vapor in air of 80° F. and 40% relative humidity (0.42 inch of mercury).

As an illustrative example of the process of the invention air of this state, which may be air from the enclosure, or fresh air, or a mixture of fresh air and air from the enclosure, is led into contact with a solution of calcium chloride which is at a temperature of 60° F. and a partial pressure of 0.26 inch, and which is about 32% concentrated. Such a solution has the state indicated on the chart by the point C.

Due to the contact of the scrubbing solution of calcium chloride with air of state A, the air in the example is cooled to 65° F. and attains a vapor pressure of 0.31 inch. Air of this state, B, is returned to the enclosure where it picks up heat and moisture, returning after admixture to state A thus maintaining an enclosure in comfort conditions.

The solution at state C entering contact with the air at state A picks up moisture and is

warmed to the state D in the example, 62° F. and .027 inch; solution in the state D is then admixed with water, not substantially changing its temperature, whereby it reaches state E, 62° F., 0.29 inch. Solution of the state E is then concentrated and colled to the state C by, for example, being passed into an evacuated chamber so that the solution (state E) boils and cools.

This vacuum may be maintained by absorbing the water vapor produced by the evaporation of solution in state E, the vapor being absorbed into a strong solution of state F, 90° F. and 0.16 inch, which, for example, is the state of a solution of zinc chloride having a density of 2.0 (1% concentration). Because of the absorption of water vapor by strong solution of state F, heat is given to the solution which is diluted. It is convenient to cool the strong solution during or after this step, the solution, after cooling, having the state G, 90° F. and 0.19 inch. In order to maintain the strong solution in the state F, it is convenient to withdraw a portion of the strong solution at some point for example the state H, 93° F. and 0.15 inch, through a heat exchanger and to concentrate the withdrawn portion by boiling off a part of the water, conveniently at atmospheric pressure, at 298° F. (a state not shown on Figure 4), and returning the concentrated solution to the state J, 94° F. and 0.14 inch, the solution of state H being obtained by mixing solution of state G with solution of state J.

Other modes of applying the principle of this invention may be employed instead of those explained, change being made as regards the methods and means herein disclosed, provided those stated by any of the following claims or their equivalent is employed.

I therefore particularly point out and distinctly claim as my invention:

1. The method of modifying the temperature and humidity of air which comprises the steps of passing a primary absorbent solution in contact with air, passing said primary absorbent solution through an evacuated zone wherein a portion of the solvent is vaporized, absorbing said vaporized solvent in a solution of secondary absorbent, mixing a portion of said secondary absorbent with said primary absorbent, and recontacting mixed absorbent with air.

2. The method of modifying the temperature and humidity of air which comprises the steps of passing a primary absorbent solution in contact with air, passing said primary absorbent solution through an evacuated zone wherein a portion of the solvent is vaporized, passing said vaporized solvent through an absorption zone in contact with a secondary absorbent, passing the secondary absorbent-solvent mixture thus produced out of said absorption zone, recirculating a portion of said mixture into said absorption zone, passing the remainder of said mixture into a heating zone wherein a portion of the solvent is vaporized out of the liquid passed therein, returning the unvaporized portion of solution from the heating zone to the absorption zone, mixing a portion of said secondary absorbent with said primary absorbent and contacting the resulting mixture with air.

3. The method of conditioning air which comprises the steps of passing a primary absorbent solution in contact with air, passing said primary absorbent solution through an evacuated zone, passing a secondary absorbent solution through an absorption zone whereby solvent vapor is

transferred by flow induced by vapor pressure difference from said evacuated zone to said absorption zone, circulating secondary absorbent solution from said absorption zone, circulating a portion of said secondary absorbent solution into a heating zone, and returning the balance of said secondary absorption solution to said absorption zone.

4. The method of regulating the vapor pressure and temperature of a body of aqueous solution of an absorbent which comprises the step of transferring vapor in a vacuum in the absence of an inert gas between said first body of aqueous solution and a second body of aqueous solution of the same absorbent, said second solution having a different strength, so as to maintain said first body at a predetermined temperature; and transferring a portion of solution between said bodies so as to maintain the first body at a predetermined strength.

5. The method of modifying the temperature and humidity of the air which comprises the steps of contacting a body of air with a primary stream of an absorbent solution, changing the temperature of said primary stream of absorbent by transferring by flow due to vapor pressure difference of said primary absorbent and said secondary absorbent water vapor in a vacuum between said primary absorbent stream and a secondary stream of said absorbent at a different concentration; and regulating strength of said primary stream of absorbent by transferring liquid absorbent between said primary stream and said secondary stream.

6. The method of dehumidifying and cooling air which comprises the steps of contacting the air with a cool solution of a dehumidifying agent, evaporating in a vacuum from said solution a portion of the water therein thus cooling said solution, transferring by natural flow, absorbing in a vacuum the water vapor so produced in a second body of absorbent solution, heating a portion of said second body of solution so as to evaporate water therefrom, discarding said water, cooling said heated solution and returning it for re-use in absorption; returning the first body of solution, after cooling for re-use in contact with air.

7. The method of heating and humidifying air comprising the steps of contacting air with a hot body of absorbent solution thereby heating and humidifying said air, removing the resulting body of warm solution from contact with the air, evaporating water from a second body of solution and condensing it in said first body so as to heat said first body of solution transferring a portion of said first body of solution to said second body of solution and adding water to said solution and contacting the resulting solution with more air to be heated and humidified.

8. The method of controlling the condition of air in an enclosure comprising the steps of contacting the air in said enclosure with a primary body of absorbent solution, transferring water vapor in an evacuated chamber from said primary body of the solution to a secondary body of absorbent solution whenever the temperature in said enclosure exceeds a predetermined value, transferring water vapor in a vacuum from said secondary body of solution to said primary body of solution whenever the temperature in said enclosure falls below a certain value, increasing the concentration of the primary solution whenever the humidity in the enclosure exceeds a certain value and transferring moisture to said primary

body of solution whenever the humidity in said enclosure falls below a predetermined value.

9. The method of conditioning air which comprises the steps of contacting air with a primary absorbent solution, automatically controlling the temperature and concentration of said solution, exchanging moisture between said primary solution and a secondary solution of an absorbent by flow induced by vapor pressure difference of said primary and said secondary solution of absorbent, automatically controlling the temperature and concentration of said secondary solution.

10. Apparatus for air conditioning including an evacuated chamber, means for spreading an absorbent liquid therein, second evacuated chamber connected with the first, means for distributing a second stream of absorbent liquid therein, a third chamber, means for distributing a portion of the stream of absorbent liquid from said second chamber therein, means for heating said absorbent liquid for said third chamber, a sump, means for conveying liquid to and from said sump to said first evacuated chamber, a second sump, means for conveying a portion of a stream of liquid in said second evacuated chamber to said second sump, means for conveying a portion of the liquid from said second sump to said third chamber and of returning liquid from said third chamber to said sump, means for adding water to the first sump, means for conveying liquid to and from the first sump to the second sump, means for controlling the addition of water to the first sump, means for controlling the interchange of liquid between said sumps so as to regulate the liquid in said first sump at a predetermined concentration and temperature.

11. Air conditioning apparatus including an enclosure, a thermostat and a humidistat in said enclosure, means for introducing air into said enclosure, means for drawing air from said enclosure, means for treating a portion of the air withdrawn from said enclosure with a solution of an absorbent, means for returning a portion of the treated air to said enclosure, means for collecting said absorbent after treatment of said air and passing a portion of said absorbent to an evacuated chamber, means for returning a portion of said absorbent for re-use in contacting with said air, means for controlling the proportion of absorbent returned for re-use in accordance to the response of said thermostat in said enclosure, means for distributing absorbent in said evacuated chamber, means for transferring water vapor between said absorbent and another stream of said absorbent dispersed in a second evacuated chamber in communication with said first evacuated chamber, means for circulating a portion of said liquid in said second evacuated chamber for re-use in said chamber, means for circulating a portion of said stream from said second evacuated chamber to a regenerator cham-

ber, said regenerator chamber being maintained at atmospheric pressure, means for heating said absorbent stream in said regenerator chamber, said means including condensing a liquid having a boiling point above the normal boiling point of said absorbent liquid at the highest concentration used in thermal contact therewith so as to boil said absorbent liquid, means for discarding vapor produced by said boiling absorbent; means for returning said second stream of absorbent liquid, after boiling, through a heat-exchange means to the main body of said second stream of liquid, means for transferring a portion of said liquid in said second stream to said first stream, said means being under the control of said humidistat, means for conveying a portion of said liquid from said first stream to said second stream, said means being under control of the thermostat, means for supplying heat, said means being under control of said thermostat.

12. In a vacuum absorption refrigerator a single container including an evaporator section, an absorber section situated below and communicating with said evaporator section through an open throat, inclosed in said absorber section a totally enclosed motor in operative relation to a pump, said pump being adapted to remove liquid absorbent from said absorber, below said absorber and sealed therefrom, a regenerator section, means for passing liquid from said absorber to said regenerator.

13. In a vacuum refrigerator of the absorption type, a regenerator, a condenser, a boiler containing an organic liquid with normal boiling point slightly above the boiling point of an absorbent at a predetermined concentration and pressure, means for conveying vapor from said boiler into thermal contact with said absorbent in said regenerator and condensing said vapor, means for returning said condensate to said boiler, said boiler and said regenerator being operated at approximately atmospheric pressure.

14. Apparatus for conditioning air temperature and humidity, comprising air-liquid contact means, an evacuated vaporizer, a purge chamber, and means for purging air from liquid in said purge chamber, means for passing liquid from said air-liquid contact means to the purge chamber and means for passing liquid from the purge chamber to the vaporizer.

15. Apparatus for conditioning air including a contacting chamber wherein said air is contacted with a primary absorbent solution, an evacuated chamber, a secondary body of absorbed solution, said evacuated chamber comprising two parts, means in one part for evaporating a portion of said absorbent solution, means in the second part for absorbing said evaporated portion, a passage allowing free unidirectional flow from one part to the other of said parts.

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