Feb. 17, 1942.

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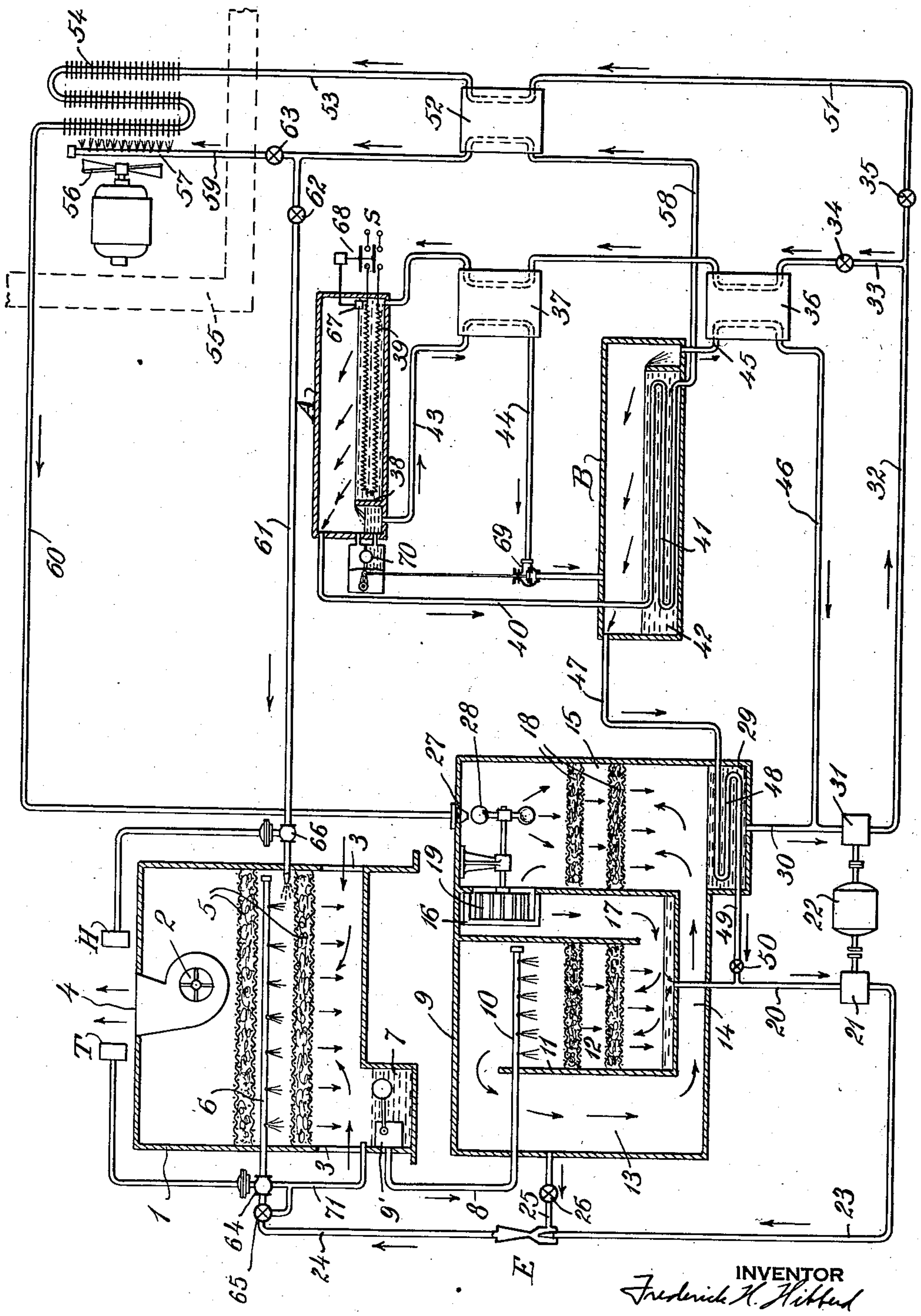
2,273,108

METHOD AND APPARATUS FOR TREATING AIR

Filed May 24, 1938



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Patented Feb. 17, 1942

2,273,108

UNITED STATES PATENT OFFICE

2,273,108

METHOD AND APPARATUS FOR TREATING AIR

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Application May 24, 1938, Serial No. 209,652

13 Claims. (Cl. 62—129)

This invention relates to air conditioning and more particularly concerns a method and apparatus for cooling and dehumidifying the air in rooms or other enclosures used for human occupancy.

The conditioning of air in the warmer seasons and climates involves cooling and dehumidification, and is usually accomplished by reducing the air temperature to a value below its dew point whereby water is condensed therefrom, after which the air is re-heated, by mixture with untreated air or otherwise, to a point where its temperature and relative humidity are near the desired values. Previously known air conditioning systems generally employ refrigerating mechanism of considerable capacity for cooling air to the low temperatures necessary to condense moisture therefrom. The large size and relatively high installation and operating costs of the refrigerating mechanism, which is usually of the compression type, has been a deterrent to the installation of air conditioning equipment, particularly in homes, offices and other relatively small enclosures. In the past, the more economically operating air conditioning systems have employed a single relatively large air conditioning unit, from which conditioned air is distributed through ducts to the various rooms or spaces to be conditioned. The installation of such systems in existing buildings is difficult and expensive and such installations are not ordinarily feasible where a relatively small proportion of the rooms, apartments or offices in a building are to be conditioned.

It has heretofore been proposed to provide relatively small cooling or air conditioning units for installation in offices, apartments or rooms. Because of certain inherent disadvantages, such units have not been widely adopted. These units cool and dehumidify the air by passing it over a refrigerating coil and employ compression type refrigerating mechanism which must be cooled by circulating air or water thereto to absorb heat from the compressed refrigerant. Water cooling requires the installation of water piping and drains, and precludes both the portability of the unit and its use in rooms where a supply of water is not available. If air is used as the cooling medium, the unit must either be located adjacent a window or connected with the outside of the building through ducts of relatively large section. Further, compression type refrigerating mechanism is noisy, is prone to develop refrigerant leaks and requires the provision of drains for the disposal of the water condensed from the air under treatment. Due to the relatively high cost of controls for independently varying the refrigerating and dehumidifying effect in such systems, room units of the type described are customarily furnished without controls and are merely turned on or off as needed. This gives inaccurate results since the relation between the humidity load and the temperature load varies widely under different conditions of room occupancy and outdoor atmosphere.

With the above and other considerations in mind, it is proposed in accordance with the present invention to provide an improved and effective air conditioning method and apparatus which, by reason of its unique operating characteristics, may be installed and operated at a low cost, and in which the dehumidifying and cooling effects produced may be independently regulated. A further object of the invention comprises the provision of an air conditioning method and apparatus which is readily adapted to installation in the form of small permanent or portable room-type units which do not require water supply or drain connections, window outlets or air ducts. Further objects of the invention include the provision of air conditioning apparatus which may be compactly constructed and which operates very quietly and efficiently.

In general, the above and other objects of the invention are carried out by employing a primary solution which may be water or a hygroscopic solution of a suitable salt such as lithium chloride or calcium chloride, simultaneously cooling and dehumidifying the air to be conditioned by contact with this solution, transferring heat and moisture from the primary solution to a secondary solution which is preferably a hygroscopic salt solution, and removing heat and moisture from the secondary solution. The secondary solution may be formed from a hygroscopic salt such as lithium chloride or calcium chloride. I prefer to effect the transfer of heat and moisture from the primary to the secondary solution by circulating air successively in contact with the two solutions and maintaining this air under partial vacuum whereby the transfer of heat from the secondary solution to the primary solution is minimized. In accordance with certain features of my invention, the flow of the primary solution is utilized to maintain the heat and moisture transferring fluid under partial vacuum, and the flow of the secondary solution is used to circulate the rarified air or other medium which transfers heat and moisture from the primary to the secondary solution. Additional features of the invention will be apparent from the following description.

In describing the invention in detail, reference will be made to the accompanying drawing in which the single figure represents, in a diagrammatic and simplified manner, an air conditioning system embodying my invention.

In general, my improved air conditioning system comprises three fluid circuits, namely, a primary solution circuit in which the primary solution is successively passed in contact with the air to be treated and with dry rarified air which removes heat and moisture from the primary solution, a transfer circuit in which air at subatmospheric pressure is circulated successively in contact with the primary solution and the secondary solution, and a secondary solution circuit in which this solution, after taking up heat and moisture from the transfer circuit, is regenerated by the extraction of moisture and heat therefrom.

Referring to the drawing, the air from the room or other conditioned space is circulated through an air treatment casing 1 by a fan 2, entering the casing through the side ports 3 and returning to the room through the upper outlet port 4. The fan may be driven by suitable means such as an electric motor, not shown. One or more eliminator mats or filters 5 are preferably disposed across the interior of the casing 1 between the air inlet and outlet ports 3 and 4. These mats may be formed of any suitable material such as shredded fibrous matter held between screens. The primary solution is sprayed downwardly in the casing 1 from a spray pipe 6 or equivalent means which is preferably situated between the two eliminator mats 5. After the primary solution has passed in contact with the room air flowing through the casing 1, it falls into a sump 7 from which it is removed by a pipe 8 under the control of a float valve or equivalent means 9'.

The primary solution may be pure water, and satisfactory results are obtained when water is used for this purpose. I have found however, that a considerably wider range of control of room air temperature and humidity is obtainable when a solution of a hygroscopic salt such as lithium chloride or calcium chloride is used as the primary solution. In this specification and the appended claims the term "primary solution" will be used broadly to designate both water and a hygroscopic salt solution of the type indicated.

As the relatively cool primary solution passes in intimate contact with the air under treatment in the casing 1, it both cools and condenses or absorbs moisture from this air, thus simultaneously lowering the relative humidity and the dry bulb temperature of the air expelled through the port 4 to the required values. The amount of cooling thus effected is determined by the temperature of the incoming primary solution, and when water is employed as the primary solution, its temperature also determines the dehumidifying effect. When a hygroscopic salt solution is used, the dehumidifying effect is separately variable in accordance with the concentration of the primary solution coming into contact with the air. The primary solution which passes off from the air treatment casing 1 through the pipe 8 is relatively warmer and contains the moisture it has absorbed or condensed from the treated air.

The primary solution next enters a transfer chamber 9 through the pipe 8 and is sprayed downwardly from suitable means 10 in a flue 11 within the chamber 9. The flue 11 is preferably provided with eliminator mats or filters 12 which may be similar to the mats 5 in the air treatment casing 1. The transfer chamber 9 is so constructed as to form a closed circuit for the circulation of rarified air or other heat and moisture transferring medium, the course of this circuit being indicated by the arrows. As shown, the upper end of the flue 11 is connected through a downwardly extending passage 13 and a horizontal passage 14 to the lower end of a vertical absorption flue 15, through which the secondary hygroscopic solution is passed as hereinafter described. The upper end of the flue 15 is connected through a fan casing 16 and a downwardly extending passage 17 to the lower end of the evaporation flue 11. Transverse eliminator mats or filters 18 are preferably provided in the flue 15, and a fan 19 in the casing 16 circulates the transfer fluid through the circuit just traced.

In accordance with my invention, the fluid circulated in the transfer chamber 9 is preferably under a partial vacuum which is preferably 15 inches of mercury or higher, and may be in the neighborhood of 25 to 28 inches of mercury. The fluid in this chamber may comprise air or other inert gas. The purpose of maintaining the chamber 9 under partial vacuum is to avoid substantial transfer of heat from the secondary hygroscopic solution passing through the flue 15 to the primary solution in the flue 11. Air under a vacuum of about 25 to 28 inches of mercury is so rarified that it cannot carry substantial quantities of heat in its return course from the absorption flue 15 to the evaporation flue 11. The rarified air in the transfer chamber 9 enters the lower end of the flue 11 in a very dry state, and moisture is evaporated in this air from the primary solution falling through the flue 11. This evaporation of moisture in the previously dehumidified air concentrates the primary solution if a salt solution is used and in any case, cools this solution due to the absorption of heat as latent heat of vaporization. The amount of moisture evaporated from the primary solution to the air in the flue 11 is somewhat greater than the amount of moisture previously condensed or asorbed by the primary solution from the room air in the air treatment casing 1. This is so because in regenerating the primary solution, it is not only necessary to remove the moisture it has condensed or absorbed, but also to remove the heat delivered to this solution as sensible heat from the room air in the casing 1. Accordingly, the amount of moisture evaporated from the primary solution in the flue 11 corresponds to the sum of the dehumidifying and cooling effects produced on the room air being conditioned. The excess of moisture removed from the primary solution in the flue 11 over that condensed or absorbed by this solution in the air treatment casing 1 is made up by returning water to the primary solution, either directly or in the casing 1, or both, as hereinafter described.

The cooled primary solution falls to the bottom of the flue 11 and is drawn out of the transfer chamber 9 through the pipe 20 by a circulating pump 21, driven by suitable means such as an electric motor 22. The pump 21 returns the cooled primary solution through pipes 23 and 24 to the spray pipe 6 of the air treatment casing 1.

The transfer chamber 9 may be maintained under partial vacuum by any suitable known means. In accordance with one feature of the invention, I prefer to employ the circulating primary solution for this purpose. As shown, a jet ejector or evacuator E of known construction is supplied with motive fluid comprising the return primary solution from the pipe 23, and the suction inlet of the ejector is connected to the transfer chamber 9 through a pipe 25. The ejector discharges into the air treatment casing supply pipe 24. Although higher degrees of vacuum may be used with satisfactory results, I prefer to reduce the operating cost of the system by maintaining a vacuum in the chamber 9 which is below that necessary to produce ebullition or flashing off of the primary solution in this chamber. Since the purpose of maintaining the chamber 9 under partial vacuum is to rarify the air therein to a point where heat transfer by the return air is maintained at a negligible value, comparatively low vacuums (15 to 28 inches of mercury) with attendant power economies can be used. The ejector E may be suitably adjusted to maintain the desired vacuum by any suitable means, such as the valve 26 in the suction pipe 25.

The secondary hygroscopic solution, in a highly concentrated condition, enters the transfer chamber 9 at the top of the flue 15 through a nozzle 27 and flows downwardly in spray form through this flue in contact with the rising stream of rarified air and water vapor delivered from the absorption flue 11 through the passages 13 and 14. Water vapor is absorbed from the rarified air by the secondary solution in the flue 15, and the solution is consequently heated and diluted. The dry and dehumidified air is delivered from the top of the flue 15 through the passage 17 to the bottom of the evaporation flue 11.

The rarified air in the chamber 9 may be circulated by any suitable means, and in accordance with one feature of my invention, the kinetic energy of the incoming secondary solution is employed for this purpose. As shown, the air circulating fan 19 is connected to and driven by an impulse turbine 28 or equivalent means disposed in the path of the jet of secondary solution entering the flue 15 from the nozzle 27. This arrangement not only effects operating economies but permits the location of all moving parts of the air circulating means within the partially evacuated transfer chamber 9, and the provision of stuffing boxes with attendant hazard of leaks is avoided.

The secondary solution which has absorbed heat and water from the transfer fluid collects in a sump 29 and is drawn off through a pipe 30 by a pump 31 which may conveniently be driven by the motor 22 as shown. This diluted secondary solution is at a relatively high temperature and is passed through a circuit in which it is concentrated by the evaporation of moisture therefrom and cooled by heat exchange with a suitable medium such as the outdoor air.

The secondary solution may be concentrated by various means, and in the disclosed embodiment, a two effect evaporator is employed for this purpose. The dilute secondary solution is delivered by the pump 31 through a pipe 32, and a portion of this solution is diverted through a pipe 33 to the evaporator system. The amount of secondary solution so diverted may be controlled by suitable means, such as the valves 34 and 35. In the evaporator system, the secondary solution passes successively through the heat exchangers 36 and 37 where its temperature is increased and then enters the evaporating pan 38 of a first effect evaporator A. The solution in the pan 38 is heated by suitable means, such as the electric heating coil 39, and the water vapor or steam evolved passes out of the evaporator A through a pipe 40 and to the heating coil 41 in the pan 42 of the secondary effect evaporator B. The secondary solution which has been concentrated in the first effect evaporator A flows over one end of the pan 38 and out of the evaporator through the pipe 43, passes through the heat exchanger 37 and is delivered to the pan 42 of the second effect evaporator B through the pipe 44. In the second effect evaporator B, the secondary solution is further concentrated and is delivered therefrom through the pipe 45, the heat exchanger 36 and the pipe 46 to the inlet pipe 30 of the pump 31, thus completing the concentration circuit.

The water vapor evolved in the second effect evaporator passes off through a pipe 47 to a condenser coil 48 located in the sump 29 of the absorption flue 15, and is there condensed, delivering heat to the dilute secondary solution in this sump. From the condenser 48, the water flows to the primary circuit pipe 20 through the pipe 49. The water thus returned to the primary solution circuit at least partially compensates for the excess of water evaporated from the circuit in the transfer chamber 9 over the water absorbed or condensed by that solution from the air under treatment. Further, the connection between the second effect evaporator B and the outlet pipe 20 of the transfer chamber 9 maintains the evaporator B under partial vacuum and thereby promotes evaporation of water from the secondary solution in this evaporator at the relatively low temperature produced by the exhaust steam from the first effect evaporator A. If desirable or necessary, the pipe 49 may be restricted by a suitable orifice or a valve 50 so that the condenser 48 may be maintained at a high enough pressure to insure the condensation of water vapor or steam therein.

The current supplied to the heating coil 39 is preferably regulated in accordance with the temperature of the solution in the evaporator A so that a substantially constant degree of concentration may be maintained. This may be accomplished by employing a thermostatically responsive element 67 in the evaporator A and governing the application of energy from a suitable source S to the coil 39 by suitable switch control mechanism 68 controlled by the element 67. In order to prevent the withdrawal of all the liquid from the evaporator A and a consequent breaking of the vacuum in the evaporator B, a valve 69 is provided in the pipe 44, and this valve is preferably controlled in accordance with the liquid level in the evaporator A by suitable means such as the float mechanism illustrated at 70.

The relatively hot concentrated secondary solution may be cooled by heat exchange with any suitable medium. In installations where tap water or other cooling medium supply is readily available and not too expensive, this solution may be cooled by heat exchange with such water or medium. It is usually preferable and often necessary to operate the system without any supply of water, and my system is admirably adapted to such installations in that the secondary solution may be cooled by direct heat exchange with the outdoor air. As shown in the drawing, the hot concentrated secondary solution passes through a pipe 51, a heat exchanger 52 and a pipe 53 to a cooling coil 54 which is preferably located in the outdoor atmosphere outside the wall 55 of the building in which air is to be conditioned. The coil 54 may be cooled by convection currents, but it is generally preferred to provide a motor driven fan 56 to circulate air over this coil. The cooling effect may be increased by cooling the outdoor air delivered to the coil 54, or at least the portion of such air which comes into contact with the final portions of this coil from which the cooled secondary solution is discharged. This may be accomplished by spraying water from a spray pipe 57 into the air delivered by the fan 56 to the outlet end of the coil 54, and water for this purpose may comprise the condensate from the heating coil 41 of the secondary effect evaporator B, delivered through pipes 58 and 59 and heat exchanger 52. The heat exchanger 52 is not essential, but may be used to cool the condensate by heat exchange with the secondary solution. The cooled and concentrated secondary solution is returned from the cooling coil 54 through the pipe 60 to the nozzle 27 in the absorption flue 15 of the transfer chamber 9, thus completing the circuit. The amount of water returned to the primary solution from the evaporator B may be supplemented by supplying a controlled amount of condensate from the heating coil 41 to the air treatment casing 1 through the pipe 61. The amount of water so returned may be regulated by the valve 62, and the amount of water supplied to the spray pipe 57 may be controlled by a valve 63.

In operating the system with hygroscopic salt solutions in both the primary and secondary solution circuits, the temperature and concentration of the hygroscopic salt solutions is so regulated as to produce the desired air cooling and dehumidifying effects. In a typical case, with the primary solution entering the air treatment casing 1 at about 65° F. and about 55° F. water vapor pressure (that is, a vapor pressure corresponding to that of water at 55° F.) and leaving this casing at about 75° F. and 65° F. water vapor pressure, the secondary solution may enter the transfer chamber 9 through the nozzle 27 at about 95° F. and 43° F. water vapor pressure, and leave this chamber at about 110° F. and about 58° F. water vapor pressure. A relatively small proportion of the secondary solution, of the order of 10%, is by-passed through the evaporator system, and this solution may be heated, in the exchangers 36 and 37, from about 110° F. to about 260° F. The concentrated solution may leave the first effect evaporator A at about 280° F. and enter the second effect evaporator B, after giving up heat in the exchanger 37 at about 210° F. The concentrated solution from the second effect evaporator B may have a concentration of about 45% and may be at about 120° F. after leaving the exchanger 36. The condensate from the second effect evaporator B may be cooled from an initial temperature of about 200° F. to about 125° F. in passing through the heat exchanger 52. If water is used as the primary solution, it may enter the air treatment casing at a somewhat lower temperature, in the neighborhood of 55° F.

The cooling and dehumidifying effects may be variably controlled by simple valve adjustments. Thus by adjusting a valve 64, which regulates the proportion of returned primary solution delivered to the spray pipe 6 and the proportion by-passed through the pipe 71, the amount of primary solution passed into contact with the room air may be altered, whereby the cooling effect may be changed. This operation may be performed in response to changes in room air temperature by employing a suitable temperature responsive device or thermostat T connected to operate a bypass valve 65 in the primary solution supply pipe 24. The dehumidifying effect may be variably controlled by varying the amount of moisture returned from the secondary solution to the primary solution in the air treatment casing 1 by suitable adjustment of the valve 62. If a hygroscopic salt solution is employed as the primary solution, the return of water thereto lowers its concentration and accordingly decreases the amount of moisture it absorbs from the room air. The return of moisture to the primary solution in the casing 1 may be varied in accordance with changes in the relative humidity of the room air by employing a hygrostat or wet bulb thermostat H connected to operate a suitable valve 66 in the pipe 61 through which moisture from the secondary solution is returned. The temperature and humidity responsive devices T and H as well as the valve mechanisms 65 and 66 operated thereby may be of any suitable known construction.

The extent to which the secondary solution is concentrated may be variably controlled by regulating the proportion of this solution which is diverted through the evaporator system by adjustment of the valves 34 and 35. The amount of concentration may be further adjusted by suitably regulating the control thermostat 67 governing the energy delivered to the heating coil 39 in the first effect evaporator A.

As will be evident from the foregoing description, my improved method consists generally in absorbing heat and moisture from the room air by contact with a primary solution, transferring the heat and moisture so absorbed from the primary solution to a secondary hygroscopic salt solution, preferably by circulating a rarified inert gas in successive contact with the two solutions, and concentrating and cooling the secondary solution. By this method, the heat absorbed from the room air may be dissipated to the outdoor air at relatively high temperatures and without the use of compression apparatus. Since air cooling is used and the moisture absorbed from the room air is disposed of by evaporating it to augment the cooling effect of the outdoor air on the heat dissipating coil 54, the method can be performed without the use of either cooling water or drain connections. Further, since the heat resulting from air conditioning and also the heat of evaporation evolved in concentrating the secondary solution is dissipated from a single solution only, and the use of compression or other refrigerating apparatus requiring cooling is avoided, the method can be carried out without the use of bulky air ducts, and all window connections except a very small duct or opening for fresh air supply are eliminated. The system may be constructed in the form of a compact portable unit having small flexible tubular connections (comprising the pipes 53, 59 and 60) to an outdoor cooling coil, and with this arrangement, the air conditioning unit can be placed at any convenient point in a room or apartment without regard to existing window, water pipe or drain arrangements. The electric current consuming devices of the system, comprising the motors for driving the fans 2 and

56, the pump motor 22 and the heating unit 39, are all of relatively small capacity and accordingly may be individually connected to ordinary house lighting circuits without danger of overloads.

I claim:

1. A method of conditioning air in an enclosure which comprises circulating a primary solution in successive contact with the air in the enclosure and rarefied and dehumidified air whereby heat and moisture are removed from said enclosure air by said primary solution and transferred from said primary solution to said rarefied air by evaporation, circulating said rarefied air successively in contact with said primary solution and a secondary hygroscopic solution whereby moisture evaporated from said primary solution in said rarefied air is absorbed by said secondary solution, evaporating the moisture so absorbed from said secondary solution by the application of heat thereto, cooling the secondary solution by heat exchange with a cooling medium and returning the cooled and concentrated secondary solution into contact with said rarefied air.

2. A method of conditioning air in an enclosure which comprises circulating a primary solution in successive contact with the air in the enclosure and rarefied and dehumidified air whereby heat and moisture are removed from said enclosure air by said primary solution and transferred from said primary solution to said rarefied air by evaporation, circulating said rarefied air successively in contact with said primary solution and a secondary hygroscopic solution whereby moisture evaporated from said primary solution in said rarefied air is absorbed by said secondary solution, evaporating the moisture so absorbed from said secondary solution by the application of heat thereto, cooling the secondary solution by heat exchange with a cooling medium, returning a part of the moisture evaporated from said secondary solution to said primary solution and returning the cooled and concentrated secondary solution into contact with said rarefied air.

3. A method which comprises circulating a solution and during its circulation bringing it into contact with a dehumidified inert gas under partial vacuum, whereby heat and moisture are absorbed from the solution by evaporation of moisture in the inert gas, maintaining said inert gas under partial vacuum by the circulatory movement of said solution, absorbing moisture from said inert gas and returning said dehumidified inert gas into contact with said solution.

4. A method which comprises circulating a primary solution and during its circulation bringing it into contact with a dehumidified inert gas under partial vacuum whereby heat and moisture are absorbed from said primary solution by evaporation of moisture in said inert gas, circulating said inert gas successively in contact with said primary solution and a concentrated secondary hygroscopic solution whereby moisture evaporated from said primary solution in said gas is absorbed from said gas by said secondary solution, circulating said secondary solution successively in contact with said inert gas and through evaporating and cooling means, and employing the circulatory movement of said secondary solution to circulate said inert gas.

5. A method which comprises circulating a primary solution and during its circulation bringing it into contact with a dehumidified inert gas under partial vacuum whereby heat and moisture are absorbed from said primary solution by evaporation of moisture in said inert gas, maintaining said inert gas under partial vacuum by the circulatory movement of said primary solution, circulating said inert gas successively in contact with said primary hygroscopic solution and a concentrated secondary hygroscopic salt solution whereby moisture evaporated from said primary solution is absorbed by said secondary solution, circulating said secondary solution successively in contact with said inert gas and through evaporating and cooling means and employing the circulatory movement of said secondary solution to circulate said inert gas.

6. An air conditioning system comprising means for circulating a primary solution in successive contact with air under treatment and a body of rarefied air whereby moisture removed from the air under treatment by the primary solution is evaporated in said rarefied air, means for maintaining said rarefied air in its rarefied condition, means for circulating said rarefied air in successive contact with said primary solution and a secondary hygroscopic solution whereby moisture evaporated from said primary solution in said rarefied air is absorbed by and transferred to said secondary solution, means for evaporating moisture from said secondary solution, means for cooling said secondary solution, and means for returning the cooled and concentrated secondary solution into contact with the rarefied air.

7. Apparatus of the kind described comprising means for circulating a primary solution, a closed chamber through which said primary solution passes during its circulation, means operated by such circulation of said primary solution for maintaining said chamber under a partial vacuum, means for circulating a secondary hygroscopic solution successively through said chamber and through moisture evaporating and cooling apparatus, and means for circulating rarefied air in successive contact with said primary solution and said secondary solution in said chamber.

8. Apparatus of the kind described comprising means for circulating a primary solution, a closed chamber through which said primary solution passes during its circulation, means for maintaining said chamber under a partial vacuum, means for circulating a secondary hygroscopic solution successively through said chamber and through moisture evaporating and cooling apparatus, and means operated by the circulation of said secondary solution for circulating rarefied air in successive contact with said primary solution and said secondary solution in said chamber.

9. Apparatus of the kind described comprising means for circulating a primary solution, a closed chamber through which said primary solution passes during its circulation, means operated by such circulation of said primary solution for maintaining said chamber under a partial vacuum, means for circulating a secondary hygroscopic solution successively through said chamber and through moisture evaporating and cooling apparatus and means operated by the circulation of said secondary solution for circulating rarefied air in successive contact with said primary solution and said secondary solution in said chamber.

10. Apparatus of the kind described comprising, means for circulating a primary solution, means for transferring moisture from said primary solution to a secondary hygroscopic solu-

tion, means for evaporating moisture from said secondary solution whereby said secondary solution is concentrated, means for condensing the moisture so evaporated from said secondary solution, means for returning a part of the moisture so condensed to said primary solution, a cooling coil, means for passing said concentrated secondary solution through said cooling coil from end to end thereof, means for passing a stream of outdoor air in contact with said cooling coil and means for evaporating a part of said condensed moisture in the part of said outdoor air stream which contacts the portion of said coil adjacent the end thereof from which said secondary solution is discharged.

11. Apparatus of the kind described comprising a closed chamber, means for passing a solution through said chamber, means for circulating air in said chamber in successive contact with said solution and a moisture absorbing agent whereby moisture is evaporated from said solution and said solution is cooled, a jet ejector connected to withdraw air from said chamber and means for propelling said solution from said chamber through said jet ejector whereby said ejector is operated by the movement of said solution to maintain the air in said chamber under partial vacuum.

12. Apparatus of the kind described comprising, means for circulating a primary solution, a closed chamber through which the primary solution passes during its circulation, means for circulating a secondary hygroscopic solution through said closed chamber, means for circulating an inert gas in said closed chamber in successive contact with said primary solution and said secondary solution, evaporator means for evaporating moisture from said secondary solution, means operated by the circulation of said primary solution for maintaining said closed chamber under partial vacuum and means for condensing some of the vapor from said evaporator means by heat exchange with the secondary solution as it leaves said closed chamber.

13. Apparatus of the kind described comprising means for circulating a primary solution, a closed chamber through which the primary solution passes during its circulation, means for circulating a secondary hygroscopic solution through said closed chamber, means for circulating an inert gas in said closed chamber in successive contact with said primary solution and said secondary solution, evaporator means for evaporating moisture from said secondary solution, means for maintaining said closed chamber under partial vacuum, means for maintaining said evaporator means under partial vacuum, and means for condensing vapor from said evaporator means by heat exchange with said secondary solution as it leaves said closed chamber.

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