Sept. 17, 1940. R. B. P. CRAWFORD 2,214,880

REGENERATIVE COOLING SYSTEM

Original Filed Jan. 25, 1933 2 Sheets-Sheet 1

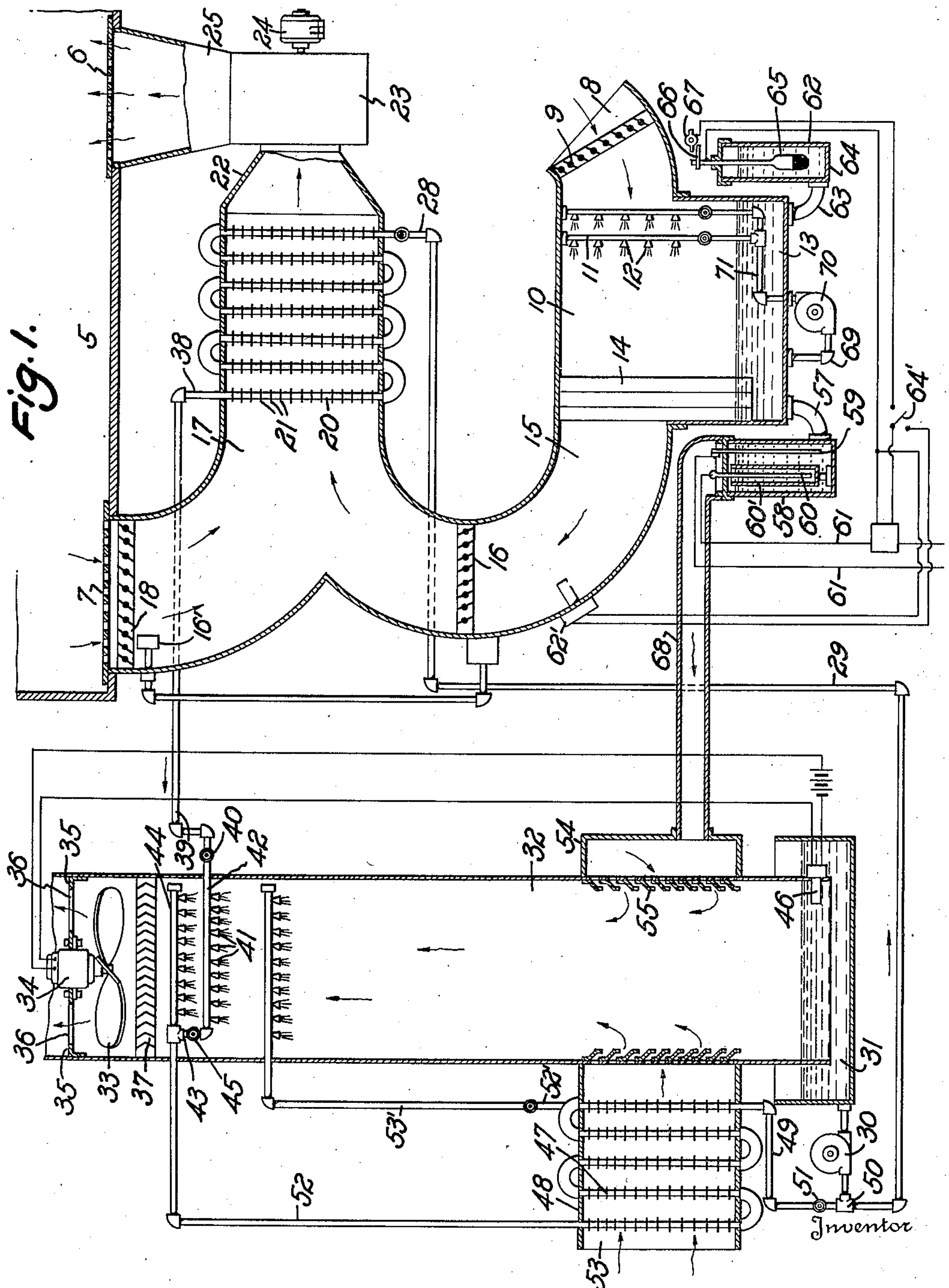
Fig. 1.

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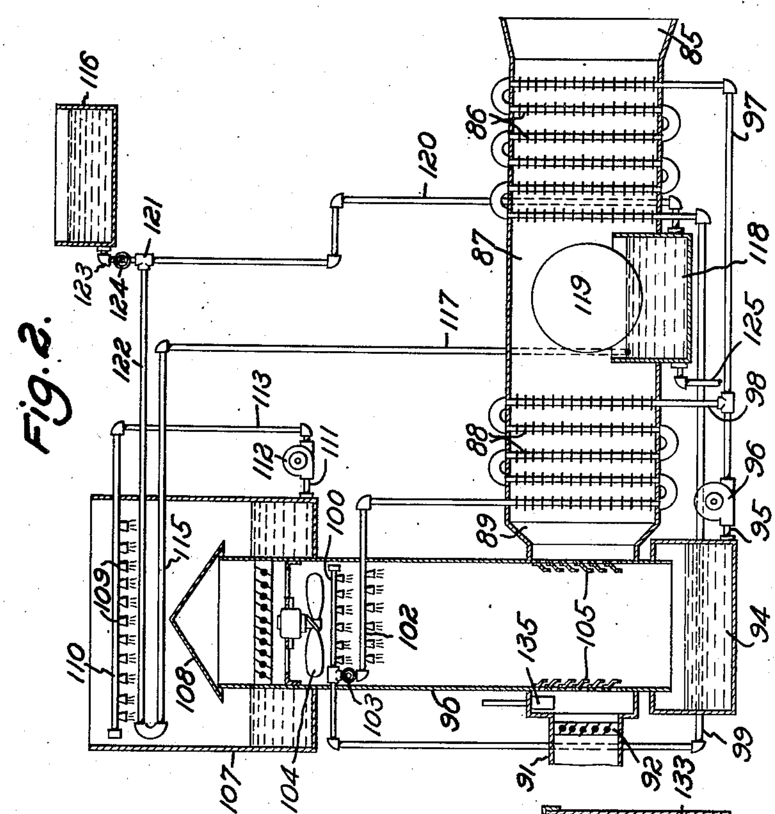

Fig. 2.

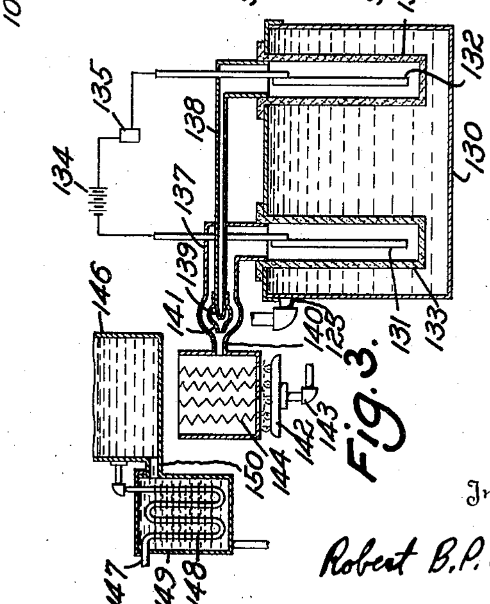

Fig. 3.

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UNITED STATES PATENT OFFICE

2,214,880

REGENERATIVE COOLING SYSTEM

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4 Claims. (Cl. 261—2)

This invention relates to air conditioning systems and more particularly to air conditioning systems of the type which are regenerative in character.

In the ordinary type of air conditioning systems, or other systems, such as refrigerating, heating and ventilating systems, the dehumidification of the air has ordinarily been accomplished by chilling the air through the medium of refrigerating coils, cold water sprays, or the like, to condense out the moisture and increase the saturation of the air. However, such methods of dehumidification have numerous disadvantages, such as cooling the air to an extremely low temperature in order to remove the required amount of moisture, which necessitates increased heating or the air at a later stage of the conditioning process. I therefore contemplate the provision of suitable dehydrating means for performing this dehumidification, whereby the moisture contained in the air is absorbed by a suitable material, such as a chemical absorbent. Various chemical solutions, such as Prestone, ethylene-glycol, glycerine, soluble oils, or some of the hygroscopic salts, such as chlorides of lithium, calcium, or zinc, may be employed. Also, I contemplate the use of dry adsorbents, such as silica gel, green sand, lamisilite, and the like, wherein the incoming air is passed over the adsorbent and the moisture thereby removed onto the surface of the adsorbent.

It is a principal object of the present invention to provide an improved air conditioning system, the type utilizing a dehumidifying agent whereby operation of the dehumidifying agent is controlled in accordance with the humidity of the air which has been acted upon by the dehumidifying agent.

Another object of the present invention is to provide means responsive to the humidity of the air leaving the dehydrating chamber for controlling the operation of the concentrating means.

Other objects and advantages of the present invention will appear more fully from the following detailed description, which, taken in connection with the accompanying drawings, will disclose to those skilled in the art the particular construction and operation of a preferred form of my invention.

In the drawings:

Figure 1 is a diagrammatic sectional view of a simplified embodiment of my invention, wherein the water is removed from the absorbing chamber by means of an electrolyzing cell;

Fig. 2 is a diagrammatic sectional view of a modified embodiment of the invention; and

Fig. 3 is a detailed sectional view of a modified form of concentrating means.

Referring now in more detail to Figure 1, I have disclosed in this diagram a simplified air conditioning system for supplying conditioned air to a room or other spacial chamber or compartment. This chamber is indicated generally by the reference numeral **5**, and is provided with a pair of registers or grilles, the incoming register being indicated at **6**, and the exhaust, or outlet register being indicated at **7**.

The fresh air inlet is indicated generally by the reference numeral **8**, and is provided with a suitable damper, or closure means, such as the louvres **9**, which may be either automatically or manually operated for controlling the quantity of fresh air admitted into the conditioning apparatus. The fresh air enters through the inlet **8**, past the louvres **9**, and thence directly into the dehydrating chamber, indicated generally at **10**. If desired, suitable cooling coils, connected to the regenerative cooling system, can be disposed adjacent the louvres **9** for precooling the air stream, or may be placed in the solution for isothermally dehumidifying the air. Positioned at the inlet side of this chamber are a plurality of vertically extending pipes, indicated at **11**, provided with suitable nozzles, or jets **12**, which are adapted to spray the dehydrating solution into the air stream. It is to be understood that the number of spray nozzles, as well as the number of pipes, may be varied as desired, depending upon the capacity of the system, and the amount of dehydration that is desired. These pipes are so arranged that practically all of the air is intimately contacted by the dehydrating solution in order to provide efficient dehumidification thereof.

The chamber **10** is provided with a sump **13**, which is adapted to collect the sprayed solution and the moisture collected from the air. Positioned at the outward side of the chamber **10** are a plurality of vertically extending baffles **14** which are adapted to remove any entrained particles of solution from the air, so that the air passes into the conduit **15** in a perfectly homogeneous mixture containing no particles of the dehydrating solution. The solution entrained by the baffles is returned to the sump **13**. From the conduit **15** the air is led past a suitable damper **16** and is adapted to be mixed with the return air from the room **5** in the conditioning or mixing space indicated at **17**.

The quantity of return air is controlled by means of a damper **18**, which damper may be automatically or manually controlled. I contemplate, in the present invention, any suitable means for controlling the dampers, and the dampers may be so connected that opening movement of one will cause closing movement of the other. The quantity of fresh unconditioned air and the quantity of return room air is thus properly proportioned and mixed in the space 17.

The mixture of fresh and return air is then passed over the coils 20, which coils are of appreciable length, and are provided with the extending radial fin members 21 for the purpose of providing an extended surface contact. As the air passes over these coils, it is progressively cooled, giving up its heat to the fluid circulating in the coils, and in this cooled, conditioned state, passes through the tapered portion 22 of the conditioning unit and into the blower 23. A suitable humidity sensing device, indicated at 16′, is positioned in the path of the return air stream, and is adapted to regulate the quantity of fresh air being mixed with the return air by regulating the position of the damper 16. This is, however, only one manner in which this control may be effected, and I do not intend to limit the invention thereto. The blower 23 is of any suitable form, and is operated by means of an electric motor or other operating mechanism 24. The air is blown or forced through the delivery duct 25 and past the grille or register 6 into the room 5.

Referring now in more detail to the cooling coils, indicated at 20, these coils have a suitable valve controlled inlet indicated at 28. A supply line 29 leads from a delivery pump 30 to the inlet 28. The delivery pump 30 draws water from the sump 31 disposed adjacent the lower end of the cooling tower 32, and delivers water to the cooling coils 20.

This tower 32 comprises a vertically extending cylindrical shell which has its ends open, the lower end opening into the sump 31. At the upper end, a suitable exhaust fan 33 is provided, this fan being actuated by the motor 34. The motor 34 is supported by means of suitable brackets 35 secured to the wall of the cooling tower shell 32. Suitable openings 36 are provided for permitting air to pass from the interior of the shell outwardly past the bracket members 35. Disposed immediately below the fan 33 is a suitable baffle or eliminator member 37, this member serving to remove any entrained water particles from the air being exhausted from the tower.

The outlet of the refrigerating coil 20 is indicated at 38, and is connected by means of the pipe 39, controlled by the valve 40, to the laterally disposed spray nozzle 41 disposed within the interior of the cooling tower 32. The pipe 42 containing the spray nozzle 41 is connected at its end, by means of coupling 43, with a second pipe 44 which contains another set of spray nozzles. A suitable valve 45 is adapted to control the connection between these two sets of spray nozzles. The water from the nozzle 41 is discharged downwardly against the upwardly moving stream of air being withdrawn by the fan 33 from the tower, and is progressively cooled, approximating the wet bulb temperature of the air as it nears the lower end of the tower. In certain instances, as pointed out below, the wet bulb temperature of the air is substantially reduced before the air enters the tower, thus effecting a much greater cooling. This water is collected in the pump 31 and is delivered by the pump 30 back into the coil 20. These spray nozzles are so arranged that the pipe containing fluid at the higher temperature will discharge at the upper end of the tower, with the remaining pipe disposed below in accordance with the temperature existing therein. Thus a true countercurrent effect is produced.

A thermally sensitive member 46 is disposed in the sump, and is subject to the temperature of the water therein. This member 46 is adapted to control the speed of the motor 34 in accordance with the temperature of water in the sump, for controlling the quantity of air being exhausted from the tower, thus regulating the temperature of the water, within limits.

In the preferred embodiment of my invention, I also employ a series of precooling coils, these coils being disposed in the path of the incoming air stream being supplied to the cooling tower. These coils are indicated generally by the numeral 47 and are positioned in the duct 48 which conducts the fresh incoming air to the cooling tower 32. The coils 47 receive their supply of water from the pipe 49 which is connected at the T connection 50 with the pump 30. A suitable valve 51 controls the quantity of water sent through the coils 47. The other end of the coils 47 leads, by means of pipe 52, to the spray nozzle pipe 44 disposed within the cooling tower. Connected to the first coil of the series of coils 47, as at 52′, is a second pipe 53′ which is adapted to enter the cooling tower 32 at a point below the spray nozzle 41, and is provided with a suitable nozzle for discharging water into the current of air passing upwardly through the tower. This pipe 53′ conducts liquid at a cooler temperature than the liquid conducted by the pipe 52, inasmuch as it is positioned at the beginning of the series of coils 47.

The conduit 48 comprises an inlet indicated at 53, and a surrounding cylindrical portion extending about the cooling tower and indicated by the numeral 54. The cooling tower is provided with a series of openings struck inwardly from the surface, indicated at 55, through which the air is drawn upwardly by means of the fan 33. It therefore comes into intimate contact with the spray water being discharged downwardly, and the evaporation produced lowers the temperature of the water to a temperature approximating the wet bulb temperature of the air.

Considering now in more detail dehydration chamber 10, this chamber is provided, as pointed out, with a sump or discharge portion 13. A suitable discharge outlet 57 is provided for the purpose of withdrawing a portion of the solution from the sump. This discharge outlet 57 leads into an electrolyzing cell indicated at 58, this cell comprising the anode 59 and the cathode 60, these parts being well known and needing no further description. The cathode 60 is disposed within a porous cup 60′, for a purpose to be hereinafter disclosed. Suitable electrical connections, indicated at 61, are led out from the two poles of the cell, and the energy controlling the cell is actuated by means of a suitable hydrometer switch, indicated in its entirety by the reference numeral 62.

The switch 62 comprises an outlet 63 leading from the sump 13 to a suitable container 64 which is provided with an hydrometer float 65. The upper end of the hydrometer float has an electrical contact member 66, which is adapted to make contact with a suitable contact member 67 positioned either above or below the cell, so that upon moving of the hydrometer 65 an electrical contact will be made to actuate the cell 58, Thus, as the water in the dehydrating solution increases, the specific gravity thereof decreases causing the hydrometer to sink and make contact, this contact energizing the cell **58** and thus producing electrolytic action in the cell. If a solution is used which has a specific gravity of a value less than that of water, wherein the addition of water serves to raise the specific gravity, the hydrometer switch can be so arranged, as illustrated, to make contact when the hydrometer rises. This electrolyzes the water into its constituent components, namely, hydrogen and oxygen, which are discharged into the duct **68**, which leads into the cooling tower **32**. If desired, the respective constituents may be collected in suitable containers instead of being transmitted to the tower.

As shown, there is also provided a suitable outlet from the bottom of the sump **13**, indicated at **69**, which leads to the inlet side of a pump **70**, the pump **70** having its outlet connected through pipe **71** to the pipe **11** and spray nozzle **12**. This pump provides the necessary circulation for forcing the solution in spray form from the nozzle **12** into the dehydrating chamber **10**.

It is therefore apparent that the control of the concentration of the dehydrating solution used in the air conditioning system is effected by the specific gravity of the solution, as determined by the hydrometer switch **62**. Thus, the electrolytic cell is energized at such times as this concentration falls below that desired, and the water is thus removed to again bring the concentration back to the point desired. Thus an automatic control of the concentration of this solution is effected.

If desired, the concentration of the solution may be maintained in accordance with the humidity of the air stream after it leaves the baffles **14**. A suitable humidity sensing device **62'** is placed in the conduit **15**, and is connected by suitable leads to a two-way switch **64'** which intercepts the leads from the hydrometer switch **62**. The operation of the cell is the same regardless of the control used, since the operator may optionally place the switch **64'** in position to connect the hydrometer contacts **66**, **67** to the cell **58**, or may move the switch to its other position to connect the humidity sensing device **62'** to the cell.

Referring now to the embodiment disclosed in Figure 2, is this embodiment I have provided an air conditioning and regenerative cooling system, in which the air used for the air conditioning system is drawn in to the same air inlet as that used in the cooling tower. In this system, the air inlet is designated by the reference numeral **85**. The air passes through this inlet, and comes into contact with the coils **86**, and from these coils passes into the dehydrating chamber **87**. The coils **86** serve to precool the air, and the moisture is removed from the air in the dehydrating chamber **87**. The coils **86** and dehydrating chamber **87** can be combined to give isothermal dehumidification, if desired.

From the chamber **87**, the air passes through a second set of cooling coils **88**, and into the air inlet **89** leading to the cooling tower **90**. A portion of the air from the air inlet **89** passes the cooling tower and enters the conduit **91** leading into the air inlet of the room. This conduit **91** corresponds to the conduit **15** of Figure 1, and the air passing the dampers **92** is mixed in proper proportion with return air and delivered, by means of a suitable blower or the like, to the room through suitable conduits. Cold water from the sump **94** may be used to sensibly cool the return air in conduit **91**, or may be used directly in the unit coolers placed in the rooms, if desired, this water being then returned through the spray nozzles **102**.

The cooling tower **90** is similar to that disclosed in Figure 1, and comprises the lower sump portion **94**, which is provided with an outlet **95** connected to the inlet side of a pump **96**. The pump **96** is adapted to force the water collected in the sump **94** through the coils **86** and **88**, respectively, by means of pipes **97** and **98**.

The return from the coils **86** is led through the return pipe **99** to a spray nozzle pipe **100** disposed in the upper portion of the cooling tower. The return from the coils **88** is led through the pipe **101** to a spray nozzle pipe **102** disposed in the cooling tower. The pipes **100** and **102** are provided with spray nozzles of the same type as disclosed in connection with Figure 1, and a connection may be made therebetween, if desired, as by means of the valved coupling **103**. At the upper portion of the tower, a fan **104**, corresponding to the fan **33** of Figure 1, is provided for exhausting air upwardly through the tower. The tower is provided adjacent the air inlet **89** with a plurality of openings **105** for allowing a portion of the air to enter the lower portion of the cooling tower to be drawn upwardly by the fan **104**.

Disposed adjacent the upper end of the tower **90** is a cylindrical tank **107**, and the air discharged from the tower **90** is deflected out of the sides of the hood **108** and passes upwardly past the spray nozzles **109** carried by the pipe **110**. The bottom of the tank **107** forms a sump, and a suitable outlet **111** is provided therefor, leading from the sump to a pump **112** connected by means of the pipe **113** to the pipe **110** carrying the spray nozzles **109**. It is thus apparent that the fluid in the tank **93** is continuously withdrawn from the sump and discharged at the top of the tank. If desired, a portion of the water from the highly atomized spray nozzles in bank **100** may be entrained with the air and used to cool coil **115** without the use of the additional sump **107**. This also, therefore, provides a regenerative cooling cycle.

The spray nozzles **109** are adapted to discharge directly upon a coil **115** located adjacent the top of the tank **107**, the coil **115** containing the dehydrating solution coming from the solution tank **116**. The solution in this tank **116** is at a relatively high temperature, due to the chemical reaction accompanying the formation of the dehydrating solution, and some means must be provided for cooling the solution before it is delivered to the dehydrating chamber **87**.

I have therefore provided, leading from the outlet **111** of the tank, a suitable T connection whereby the solution is led over the coil **115** and then downwardly through the pipe **117** to the dehydration chamber **118**, the dehydration chamber **118** being placed in the path of the fresh air stream leading to the cooling tower **90**. The dehydrator **118** is preferably of the film humidifying type, and comprises rotating disc members **119** which have the lower periphery of their surfaces dipping into the dehydrating solution carried in the dehydrator **118**. From the dehydrator **118**, the solution is led back through the pipe **120** to the T connection **121** located adjacent the solution tank. A suitable pump may be provided to effect this circulation. This T connection **121** comprises, preferably, a swing check valve which permits the solution in the pipe 120 to enter the pipe 122 leading to the coil 115, but does not permit solution leaving the tank 116 by means of the outlet pipe 123 to pass into the pipe 120. A valve 124 may be provided for replacing a portion of the solution in the tank 118 with fresh solution from the makeup tank 116 when desired. In this manner, the dehydrating solution in the dehydrator 118 is maintained at a relatively cool temperature at all times by means of the regenerative cooling cycle associated with the tank 107. The dehydrator 118 is provided with a suitable outlet connection 125 which leads to suitable apparatus for removing the water from the dehydrating solution. It is thus possible to maintain the solution in the dehydrator 118 both cool and relatively concentrated at all times. In many cases coils 86 are not necessary.

A concentrating system for use in connection with the dehydrator 118 is shown in detail in Figure 3. In this figure, the outlet 125 from the dehydrator 118 leads to an electrolytic cell indicated generally at 130. The cell 130 is provided with an anode 131 and a cathode 132, preferably enclosed in suitable porous cups 133. The electrodes of the cell are connected in a suitable electrical circuit having the supply 134 and a switch 135.

This switch 135 may be a humidity responsive switch located in the air inlet 89 leading to the conduit 91 and thence to the delivery duct. Upon an increase in humidity beyond that desired in the air entering the room, the switch 135 is adapted to be closed, completing a circuit between the electrodes 131 and 132, and thus tending to electrolyze the water out of the dehydrating solution. As this water is removed, the solution becomes concentrated, and therefore is capable of absorbing more water from the incoming air. The humidity of the air thus decreasing, and after reaching a point lower than that desired, the humidity responsive switch 135 will open the circuit and thus allow the dehydrating solution to become diluted. Thus the concentration of the solution is maintained substantially constant and a constant humidity is present in the air entering the conduit 91 at all times.

In the operation of the electrolytic cell, oxygen is given off at the anode 131, and is collected in the conduit 137. Hydrogen is given off at the cathode, and is collected in the conduit 138. The hydrogen is conducted through the relatively restricted portion of the conduit 138 to a nozzle 139, and is projected from the nozzle into a combustion space 140 provided by the enlarged portion of the conduit 137. Suitable baffles 141 are provided for preventing back firing of the flame into the hydrogen conduit 138.

I also preferably provide a burner 142, supplied with fuel through the conduit 143, for heating a plurality of tuyères or baffle members 144 and for thus applying heat to the tank 146. The tank 146 is adapted to receive a portion of the solution from the dehydrator 118, and the heat from the burner 142 and the burning of the oxygen and hydrogen is adapted to provide energy for evaporating any water which may be present in the solution in the tank 146. The incoming solution is led into the tank to the conduit 147 which passes into a plurality of coils 148 disposed in an interchanger 149.

The hot concentrated solution returning from the tank 146 is led through the conduit 150 into the interchanger and comes into contact with the coils 148. In this manner, the incoming solution is heated by the concentrated outgoing solution, and therefore less heat is necessary in order to effect evaporation of the water.

It is thus apparent, in this system, that both electrical and thermal means are utilized for removing the absorbed moisture from the dehydrating solution. In this manner, the dehydrating solution may be kept at a relatively high or constant concentration, and thus a relatively constant humidity may be imparted to the air.

It is to be understood that various modifications and rearrangements of the individual parts of the air conditioning system disclosed in the accompanying drawings may be made without departing from the spirit of the invention.

I therefore do not intend to be limited to the exact embodiment of my invention disclosed in the drawings, but only in so far as defined by the scope and spirit of the appended claims.

This application is a division of my application Serial No. 653,362, filed January 25, 1933.

I claim:

1. In an air conditioning system having a return air duct and a fresh air duct, humidity control means for regulating the air drawn through one of said ducts, and means for tempering the admixture of air from said ducts before it passes into a delivery duct, the combination of a dehydrating chamber in said fresh air duct, means for intimately contacting the fresh air drawn through said duct with a dehydrating solution, and means responsive to the humidity of said fresh air leaving said chamber and prior to its admixture with said return air for maintaining said solution at a substantially constant concentration.

2. In an air conditioning system, a fresh air duct, a return air duct, means for dehumidifying the air in said fresh air duct, means for admixing said dehumidified air with the return air from said return air duct, means for tempering said admixed air, means for controlling the relative proportions of said air mixture, and means responsive to humidity of said dehumidified air stream prior to its mixture with said return air for controlling the dehumidifying means.

3. The method of conditioning air for an enclosure which comprises passing a stream of fresh air through a dehumidifying solution, sensing the humidity of said air as it leaves said solution, controlling the concentration of said solution in accordance with said humidity sensing, subsequently mixing said air with return air, controlling the relative proportion of said mixture in accordance with the humidity of said return air, and tempering said mixture prior to its delivery to said enclosure.

4. The method of conditioning air for an enclosure, which comprises passing said air into a dehydrating chamber, spraying said air with a dehydrating solution to effect absorption of moisture from said air independently of temperature differences between said air and solution, sensing the humidity of said dehydrated air stream, adiabatically controlling the concentration of said solution in accordance with said humidity sensing, mixing said air with return air from said enclosure, and tempering said mixture prior to its delivery to said enclosure.

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