Sept. 28, 1937. F. R. BICHOWSKY 2,094,343

AIR CONDITIONING

Filed April 10, 1936

FIG 1

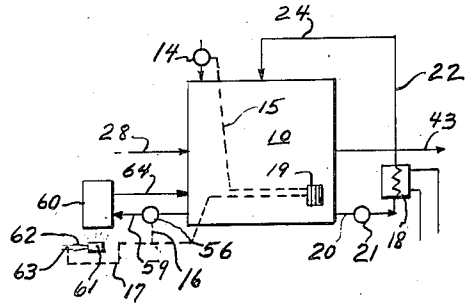
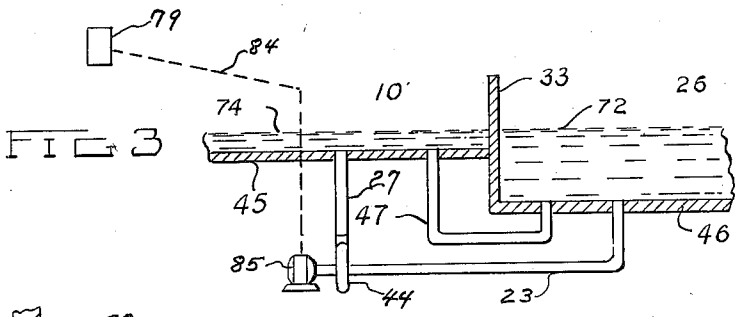


FIG 3



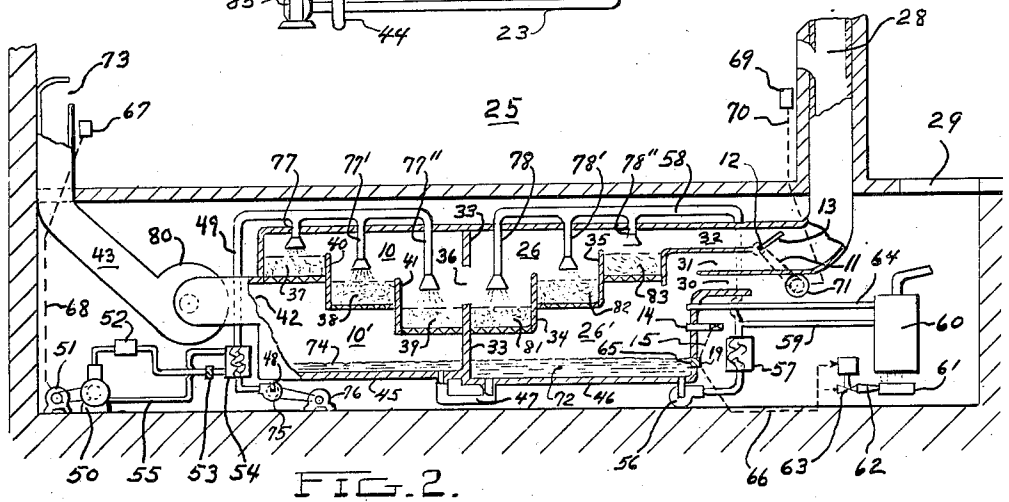


FIG. 2.

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AIR CONDITIONING

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9 Claims. (Cl. 261—98)

This invention pertains to air conditioning and includes the cooling of air by means of an aqueous solution without changing the moisture content of the air.

In the art of conditioning gases, it is frequently desirable to cool air or other gases without, at the same time, changing their moisture content. The customary method of doing this is to pass the gas or air in contact with a surface which is cooled to such a temperature that no part of that surface has a temperature below the dew point of the air being treated. In order to obtain satisfactory cooling of air with surfaces of this type, it has been essential that they be greatly extended. Such extended surfaces are very expensive to construct, offer considerable resistance to the passage of air, and use very large amounts of valuable floor space.

I have discovered that by the use of aqueous liquids of suitable type and under suitable conditions that it is possible to cool air without changing its moisture content, by circulating the air in contact with such a cooled solution. I have found that this contact between the air and the cooled solution may be made by various methods, as for example, in contact towers of the spray or packed tower type. The words air or gas as used herein are understood to be interchangeable.

Objects of the invention include, the provision of a method of and means for cooling air or gas by contacting said gas with a liquid containing water without substantially changing the dew point of the gas in the cooling process. Another object is to dry air by contact with an aqueous solution and to subsequently cool the dried air by contact with an aqueous solution without changing the moisture content of the air. A further object is to effect a predetermined temperature and humidity condition of air by contact with an aqueous hygroscopic solution. Further objects and advantages will be pointed out hereinafter.

The invention will now be described with particular relation to the accompanying drawing, wherein

Fig. 1 shows diagrammatically an apparatus embodying the invention.

Fig. 2 shows one application of the invention to the air conditioning of an enclosure, air from which is dried in one chamber and cooled in another.

Fig. 3 shows a variation in the arrangement of Fig. 2, all portions of this figure which are omitted being the same as Fig. 2.

Referring now to Fig. 1, which shows apparatus embodying features of the invention, air enters the chamber 10 through the path 28 and leaves the chamber through the path 43 and is contacted in the chamber 10 with a cooled aqueous solution which enters through the path 24 and leaves through the path 20. An aqueous solution in equilibrium with air is generally used and it is possible to cool air in the given tower without changing its moisture content by contacting the air with this solution and furthermore by so doing the air will be cooled with the minimum expenditure of cooling possible with the given tower. For properties of two such solutions see the patent to Bichowsky 1,992,177.

The solution leaving through the path 20 is recirculated through the channel 22 by means of the pump 21 back to the path 24 for reuse. At some point in the path of the liquid entering the chamber 10 by way of the path 24, a cooling means 18 may be employed to cool the liquid. This means may be an evaporating refrigerant contained in a vessel 18 in thermal contact with the liquid traveling to the path 24. A control element 19 responsive to changes in the dew point of the inlet air is so arranged as to control the concentration of the solution, which is circulated in contact with the air. The control element may also be so arranged as to control the degree of contact between the liquid and the air, and hence the efficiency of the tower. This control device may be a device responsive to changes in the density of the solution and so arranged that as the density of the solution increases, due to the evaporation of moisture from the solution, moisture will be added through the channel 14 until such time as there is no further increase in density. It is also arranged so that as the density decreases due to the condensation of water in the solution, a portion of the solution will be withdrawn by pump 56 and sent through the pipe 59 to the concentrator 60 and subsequently returned through the pipe 64 to the space 10 so as to increase the density of the solution circulated in the space 10. To this end, the control means 19 is shown connected through the means 15, 16 and 17 so that it may effect control of valves, switches, pumps, or the like for varying the flow of heat to a concentrator 60, for varying the addition of stronger solution through the pump 56, or for the addition of water through the pipe 14.

The method of this invention has application in connection with air conditioning systems in which the air is first dried and then cooled. Fig.

2 shows the joint use of this method of cooling with drying systems using an aqueous solution of lithium chloride as the drying agent. Fig. 2 shows an embodiment of the invention, with parts having similar functions being numbered as in Fig. 1. A system of air conditioning is shown in which air is dried in the chamber 26 and cooled in the chamber 10. The air is conditioned in the apparatus comprising basically two chambers, one to the right of a central partition 33 and one to the left of this partition. In the chamber on the right air may be dried by contact with a liquid drying agent. In the left hand chamber the air may be subjected to cooling by contact with an aqueous solution. The right and left hand chambers are each divided into upper and lower compartments by partitions created by the contact devices 37 to 39 and 81 to 83.

The right hand chamber is substantially divided into upper and lower compartments 26 and 26', respectively. Air passing through the upper compartment remains substantially untreated and in effect by-passes the contact device 81, 82 and 83. Air passing into the lower compartment 26' passes over the main body 72 of the solution contained in the sump 46 located in the bottom of this compartment. The air then passes through the contact devices 81, 82 and 83 on its way into the upper compartment 26.

The air from the right hand chamber then passes through an opening 36 in central partition 33 and into the left hand chamber which is substantially divided into upper and lower compartments 10 and 10', respectively. The air which has been treated in this air conditioning apparatus may then pass by an opening 42 into a duct system which includes the fan 80. The air finally emerges from this duct system by way of openings 73 into the enclosure or enclosures being conditioned.

The air being treated may be supplied in whole or in part from the enclosure 25 by way of duct 28 or it may be supplied wholly or in part by air from the outside through opening 29 into the building and thence into the air conditioning apparatus by way of the inlet port 30. These two openings may, of course, be combined. The duct 28 is in communication with two ports 32 and 31 which open into the air conditioning apparatus. The opening 31 is in direct communication with the lower compartment 26' of the right hand or drying chamber while the opening 32 is in direct communication with the upper compartment 26 of the drying chamber which is a by-pass chamber in which the air is not treated. Air entering through the port 32 reaches the aperture 36 without contacting the absorbent solution being recirculated in the right hand portion of the apparatus.

The openings 30, 31 and 32, by which air enters the apparatus, may be provided with means for regulating the amount of air which flows through them. This regulating means may comprise a plurality of dampers but for the purpose of illustration and description, only one is shown. It comprises a single damper 13, pivotally mounted at a point 12, which is common to the two openings 31 and 32 and is so arranged that it may place both openings in unobstructed communication with the duct 28 or may close either passage in accordance with conditions existing in the enclosure. This control is accomplished by means responsive to conditions of humidity in the enclosure. It is illustrated as a humidistat 69. The means for operating the dampers may be an appropriate motor or other device 71 operatively connected to the damper 13 by a means 11'. It is controlled from the humidistat by way of the connection 70 which may be an interconnecting electric circuit. The outside fresh air can also be under the control of this same means with an appropriate damper which has been omitted for simplicity of illustration.

In accordance with this invention air to be conditioned, which air may be drawn in whole or in part from the room 25 through the duct 28, and which may partly be drawn from the outside through the openings 29 and the duct 30, may be led into the chamber 26 through the openings 30, 31 and 32. These openings are provided with shutters 13 to regulate the amount of flow entering respectively in the openings 30, 31 and 32, only one shutter is shown. The chamber 26 is conveniently divided into two parts, forming upper and lower compartments 26 and 26', and separated by pads of glass filaments or other types of gas and liquid contact means which may be conveniently arranged in a staggered manner as shown. Partitions 33, 34 and 35 are provided to direct the air flow so that air entering through the ports 30 and 31 is forced to flow through the bottom portion of the chamber 26 and upward through the contact devices and into the upper portion of the chamber 26. Air from the upper chamber 26, which may be treated or untreated air or combinations thereof, is led through the port 36 into the upper portion of the chamber 10. This latter chamber is also divided into upper and lower parts 10 and 10' by a series of glass wool pads 37, 38 and 39. Dividing partitions 40 and 41 are so arranged that air entering into the upper portion is forced to flow through the contact device into the lower portion and from here it is drawn through the port 42 by the fan 80 and discharged through the duct 43 back into the chamber 25.

The partition 33 separating the chamber 10 from the chamber 26 extends to the bottom so as to make two separate sumps 45 and 46, the sump 45 preferably having small capacity. The sumps are connected through a small opening or more preferably by a pipe 47.

Liquid 74 from the sump 45 flows out through the pipe 48 to the pump 75 driven by motor 76 and to the pipe 49 which is arranged with branches 77, 77', 77'', to distribute the liquid uniformly over a glass or other packing 37, 38 and 39, and so place the liquid circulated through these pipes in contact with the air passing from the upper portion 10 of the left hand chamber into the lower portion 10' of said chamber. Means are provided for cooling the liquid circulating through the channels 48 and 49 which means includes an interchanger 54 which is cooled in any suitable manner. For example, a refrigeration system including a compressor 50 driven by the motor 51 can be used, the refrigerant passing from the compressor 50, being condensed to liquid by the condenser 52, then passing through the valve 53 into an evaporation space 54 which evaporating space is in thermal contact with the liquid flowing through the pipe 49. The expanded vapor from the space 54 is led back to the compressor by the pipe 55.

The concentrated drying liquid 72 from sump 46 of the drying chamber 26 is drawn by the pump and pipe 56 to the cooler 57, which may be a water cooler, through pipe 58, and to spray heads 78, 78', 78'', whereby it is distributed uniformly over the contact means 81, 82 and 83. It

is here in intimate moisture exchange relationship with air passing from the bottom 26' of the chamber to the upper portion of the chamber 26 through the packing 81, 82 and 83. A by-pass 59 branching from the pipe 58 is adapted to lead a portion of the liquid into the concentrator 60. The concentrator is supplied with heat through the burner 61. Fuel for said burner may be led through the pipe 62 and the valve 63. In place of the burner 61 any other source of heat may be used such as steam, etc. Concentrated liquid from said concentrator is passed through the pipe 64 and returned to the sump 46. The by-pass 59 may preferably branch off ahead of cooler 57 so as to obtain greater economies.

A control device 65 is provided responsive to change in density of the liquid in the sump 46. This density control device 19 is connected by the means 66, which can be an appropriate electrical circuit, to valve 63 so that when the density of the liquid in the sump 46 falls below a certain point, the solenoid valve 63 is open and heat is supplied through the burner 61 to the concentrator 60, thus concentrating the liquid and maintaining the liquid in the sump 46 at an appropriate density. Device 65, by means of control circuit 15, provides for the addition of water from pipe 14 as previously described in connection with 19 in Fig. 1. With this arrangement, air passing into the compartment 26' will be dried to a desired degree while passing in contact with the liquid in the packing 81, 82 and 83, and the dry air which will have its dew point lowered to a certain degree will pass into chamber 10, where it will be cooled by the liquid circulating through the packs 37, 38 and 39.

Now, if, the concentration of the liquid circulating through the left hand chamber is such that moisture will be further extracted from the air in that chamber, the amount of liquid in the sump 45 will increase thus diluting the liquid therein so that there will come a point when it will no longer take up moisture from the air in chamber 10—10' and the air passing through chamber 10—10' will do so, therefore, without a change in dew point. This absorbed moisture will also cause a rise in the level of the liquid in the sump 45 and a consequent flow of liquid from sump 45 through pipe 47 into sump 46 because of the liquid seeking its own level.

Now, on the other hand, if the air passing into the chamber 10 is so dry that a certain amount of moisture is evaporated into the air from the liquid passing through chamber 10, the amount of liquid in the sump 45 will decrease, causing a flow of a concentrated liquid from the sump 46 through the pipe 47 and an increase in concentration of the liquid in sump 45 until such a point is reached that the concentration therein is such that the liquid will no longer be evaporated into the air. Then there will be no change in the dew point of the air in passing through the chamber 10—10'.

Now, if, the temperature of the liquid circulating through the circuit including the pipe 49 is controlled so that the temperature in the space 25 is maintained at a desirable value, it will automatically come about that the air discharged into the space 25 will have the correct temperature to maintain that space at its proper temperature and also will have a predetermined dew point.

As explained, the air was dried in the chamber 26—26' and cooled in 10—10'. It may be desirable to dry the air in 10—10' as well as cool it. In such a case a pump 44 may be placed in pipe 23—27 so that a definite amount of liquid circulation can be created without having to depend upon the flow by the liquid itself. The pipe 47 can be a plurality of pipes if necessary. The pump 44 will be controlled by a humidistat 79 responsive to the humidity in enclosure. The control may be an electric circuit 84 acting upon motor 85.

To regulate, under these supposed conditions, the temperature of the liquid circulating through the circuit including pipe 49, a dry bulb thermostat 67 responsive to conditions in the enclosure is connected by the means 68 to the motor 51, driving the compressor 50 in such a way that if the temperature in the space 25 falls below the desired temperature, the refrigeration to the cooler 54 will be stopped or decreased. It may also be connected in such a way that if the temperature in the space 25 lies above the desired amount, the supply of cooling to the cooler 54 will be increased. If the air entering through port 36 is appropriate for use in the enclosure, without further cooling, the apparatus may be so arranged that the air in compartment 10 can by-pass compartment 10' by means of a duct under the control of a damper. The damper to control this by-pass would then be operated by the thermostat 67 and the duct will connect compartment 10 to fan 80 so that the air need not pass through the contactors 37, 38 and 39. It is usually not unnecessary to provide special controls to maintain the humidity at a desired value since the density control 65, which indirectly and automatically controls the dew point of the outlet air, usually gives entirely satisfactory control of humidity conditions in the space 25. However, as ordinarily described, humidistat 69 connected by circuit 70 to a motor means 71 may be provided for controlling the condition of the damper 13 allowing the passage of a certain portion of the air from the duct 28 to flow into the upper portion of the chamber 26, thus mixing a certain portion of the dried air passing upwardly in the chamber through the packing with a certain portion of undried air entering through the passage 32.

This application is a continuation in part of my application Serial No. 27,452, filed June 19, 1935.

The method and operation of the apparatus selected for illustration as a preferred embodiment have been clearly set forth in connection with foregoing detailed description of the invention. Modifications embodying the invention will be apparent to those skilled in the art from the detailed description of the specification. However, it is to be understood that the words which have been used are words of description rather than of limitation and that changes within the purview of the claims may be made without departing from the true scope and spirit of the invention in all of its aspects.

What I claim is:

1. In air conditioning apparatus of the character described, a drying chamber; a cooling chamber; layers of packing material pervious to air and liquid arranged in staggered relationship and dividing each of said chambers into upper and lower portions; means providing communication between the upper portions of said chambers; means for conducting air streams into the upper and lower portions of the drying chamber; means for proportioning the air streams conducted into the drying chamber; means for circulating the air from the drying

chamber in a combined air stream through the packing means in the cooling chamber and to the place where the air is used; means for supplying liquid to the packing means in contact with air passing therethrough in each of said chambers; and means for cooling the liquid supplied to the packing means in the cooling chamber.

2. In air conditioning apparatus of the character described; a drying chamber, a cooling chamber, staggered layers of porous packing material transversely arranged in each of the chambers and dividing the chambers into upper and lower portions, a liquid collecting sump in the lower portion of each chamber, means for supplying liquid from the sump to the packing material in each of said chambers, means for conducting air into the drying chamber in separate streams above and below the packing material, said air streams combining in the upper part of the drying chamber, means for conducting air from the drying chamber into the upper portion of the cooling chamber, means for cooling the liquid in its passage from the sump to the packing material in the cooling chamber, and means for causing air from the upper portion of the cooling chamber to flow downwardly through the packing material in contact with the cooled liquid and to a point of use.

3. An air conditioning apparatus for air conditioning an enclosure having its inlet and outlet in communication with the enclosure comprising a drying chamber, a cooling chamber, gas and liquid contact devices in each of said chambers, a liquid collecting sump in the lower portion of each of said chambers, means for supplying liquid from the sump to the contact device in each chamber, means for cooling liquid in its passage from the sump to the contact device in the cooling chamber, means including a dry bulb thermostat adjacent the outlet of the apparatus in the enclosure for controlling said cooling means, means including a density responsive control device in the sump of the drying chamber for maintaining the density of liquid in the drying chamber sump within predetermined limits, means for introducing air from the enclosure and fresh outside air into the drying chamber, means including a humidistat within the enclosure for proportioning the amounts of air from the enclosure and outside air entering the drying chamber, and means for forcibly circulating the air through the drying chamber into the cooling chamber and into the enclosure.

4. In combination, an apparatus for conditioning air for an enclosure having its inlet and outlet in communication with the enclosure, said apparatus comprising a drying chamber, a cooling chamber, gas and liquid contact means in each of said chambers, a liquid collecting sump in the lower portion of each of said chambers, means for supplying liquid from the sump to contact means in each chamber, means for cooling liquid in its passage from the sump to the contact means in the cooling chamber, means for introducing air from the enclosure and fresh outside air into the drying chamber, means including a humidistat within the enclosure for proportioning the amounts of air from the enclosure and outside air entering the drying chamber, and means for circulating the air through the drying chamber into the cooling chamber in contact with the cooling liquid and into the enclosure.

5. An apparatus for conditioning air for an enclosure having its inlet and outlet in communication with the enclosure, said apparatus comprising a drying chamber, a cooling chamber, gas and liquid contact means in each of said chambers, a liquid collecting sump in the lower portion of each of said chambers, means for supplying liquid from the sump to the contact means in each chamber, means for cooling liquid in its passage from the sump to the contact means in the cooling chamber, means including a density responsive control device in the sump of the drying chamber for maintaining the density of liquid in the drying chamber sump within predetermined limits, means for introducing air from the enclosure and fresh outside air into the drying chamber, and means for circulating the air through the drying chamber and then through the cooling chamber and finally into the enclosure.

6. In an apparatus for cooling air without substantially changing the dew point of the air in the cooling process, a chamber in which the air is cooled, a body of aqueous hygroscopic liquid associated with said chamber, a cooling device, means for circulating liquid from said body through the cooling device and into contact with air in the chamber, a valved water connection for supplying additional water to the body of liquid, means including a fluid fuel burner and evaporator heated thereby for removing water from the liquid in said body, and means responsive to changes in density of the body of said liquid for controlling the addition of water by said valve connection to or the subtraction of water by said evaporator from said body of liquid.

7. In air conditioning apparatus of the character described; a drying chamber; a cooling chamber; packing means pervious to air and liquid dividing each of said chambers into upper and lower portions; means providing communication between the upper portions of said chambers; means for conducting air into the upper and lower portions of the drying chamber; means for circulating said air through the drying and cooling chambers, and means for supplying liquid to the packing means in each of said chambers for contacting air passing through the packing means.

8. An air conditioning apparatus comprising a drying chamber, a cooling chamber, means for circulating air through the drying and cooling chambers, means for circulating a liquid in contact with the air passing through said chambers, a sump associated with each of said chambers for collecting the liquid circulated therein, and means interconnecting said sumps so as to maintain the same liquid level in each sump and whereby the liquid can flow from either sump to the other as the liquid level in either sump changes.

9. Apparatus for conditioning air including a chamber wherein said air is dried by contact with a drying liquid containing water, means for conveying the dried air to a chamber in which air is contacted with a cool body of said liquid of a different concentration, means for circulating said cooled liquid in a continuous circuit, and common means for transferring a portion of said cooling liquid into said body of drying liquid when the volume of the cooling liquid increases and for transferring a portion of the drying liquid into the body of cooling liquid when the volume of the cooling liquid decreases.

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