Aug. 6, 1946. O. B. SUTTON 2,405,169

REFRIGERATION

Filed July 6, 1942 2 Sheets-Sheet 1

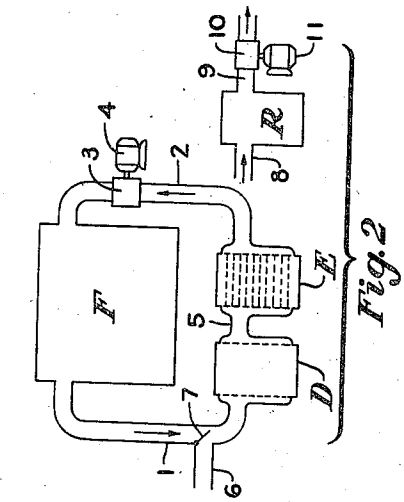


Fig. 2

Fig. 1

INVENTOR
Otis B. Sutton
BY
Harry S. Bware
ATTORNEY

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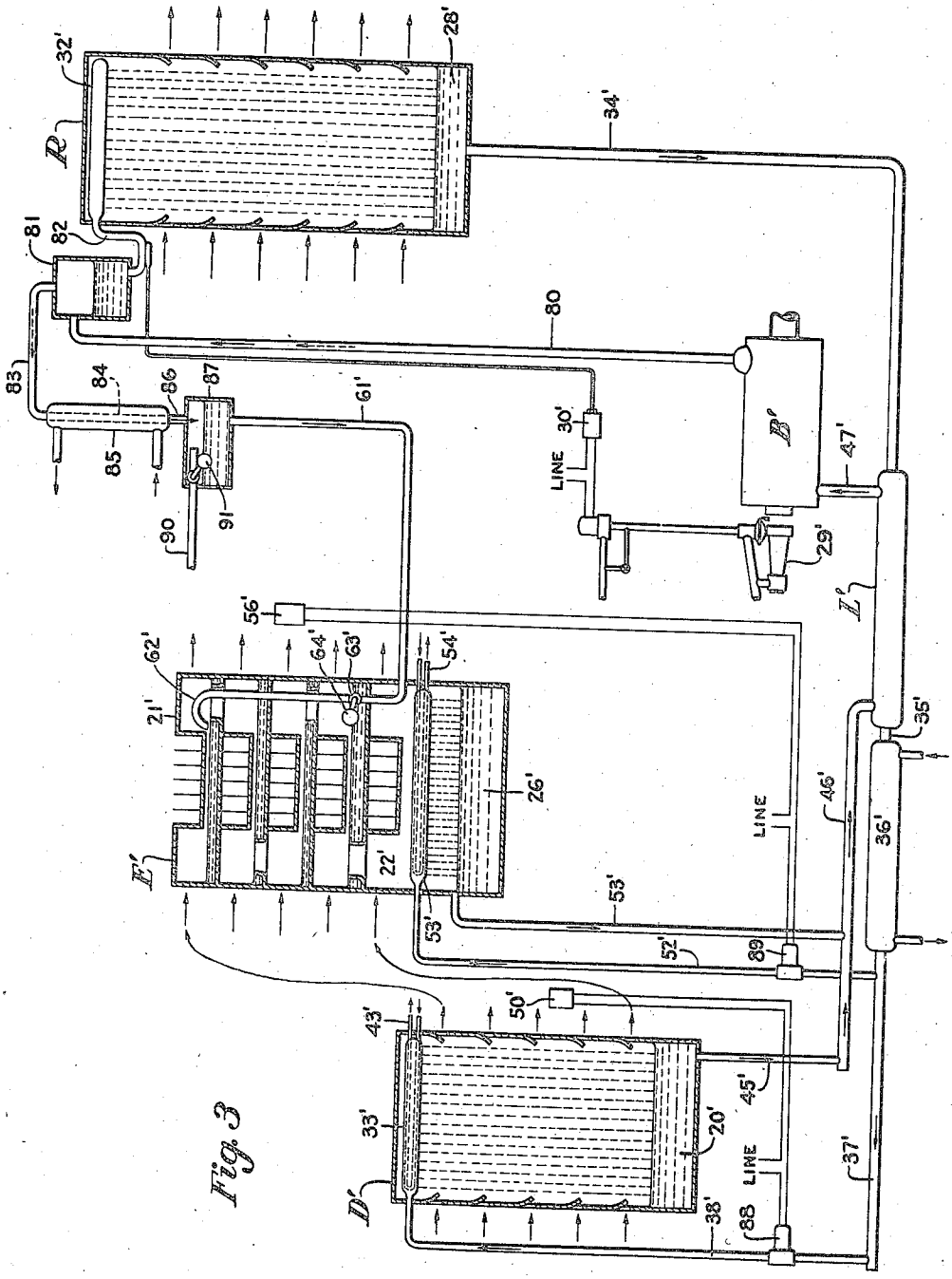


Fig. 3

INVENTOR
Otis B. Sutton
BY
Harry S. Ducas
ATTORNEY

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REFRIGERATION

Otis B. Sutton, North Canton, Ohio, assignor to The Hoover Company, North Canton, Ohio, a corporation of Ohio

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9 Claims. (Cl. 62—6)

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This invention relates to the art of refrigeration and more particularly to an air conditioning apparatus involving a novel method of air conditioning and a novel refrigerating apparatus for dehumidifying and conditioning the air.

It is a particular object of the invention to provide a refrigerating and air conditioning apparatus using a refrigerating and dehumidifying apparatus of the absorption type adapted to be operated by low grade heat, where available, and in which the absorbent fluid is brought into direct contact with the air to be conditioned for the purpose of dehumidifying the air and is also utilized to cause evaporation of a volatile fluid in heat exchange relationship with the air to be conditioned whereby the air is both dehumidified and cooled.

It is a further object of the invention to provide a system in which an absorbent material circulates in contact with the air to be conditioned in heat exchange relation with the air to be conditioned and in contact with vapor of refrigerant to dehumidify and cool the air and in which the absorbent material is regenerated by passing the same in heated condition in direct contact with outside air in order to reject absorbed moisture from the system.

Other objects and advantages of the invention will become apparent as the description proceeds when taken in connection with the accompanying drawings, in which—

Figure 1 is a diagrammatic representation of the system.

Figure 2 is a diagrammatic view on a small scale showing the relationship of the principal vessels of the system to the air undergoing conditioning, and

Figure 3 is a diagrammatic representation of a modified form of the invention.

Referring to Figure 2 the apparatus comprises a space to be conditioned F which is connected with a dehumidifying chamber D by a duct 1 and with a cooling chamber E by a duct 2 which also includes a circulating fan unit 3 which is driven by an electrical motor 4. The dehumidified air is conducted from the chamber D to the cooling unit E by a duct 5. If desired, a fresh air duct 6 may be connected to the duct 1 and the proportion of fresh and recirculated air controlled by a damper 7. The regenerating chamber R receives outside air through a duct 8 and discharges the same through a duct 9 which includes a circulating fan 10 which is driven by an electrical motor 11. In this figure only the major vessels and their associated air ducts are shown.

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The various fluid circuits forming the cooling and dehumidifying system are illustrated in detail in Figure 1 and will be described in connection therewith.

In Figure 1 the air ducts and air circulating fans have been eliminated in order to facilitate illustration and understanding of the cooling and dehumidifying systems per se as well as the internal structure of the various major vessels forming the conditioning and cooling system.

The dehumidifying chamber D consists simply of a spray chamber, the bottom portion of which acts as a sump as is indicated at 20.

The cooling chamber E consists of an upper evaporating portion 21 and a lower absorbing portion 22. The evaporator portion is provided with a plurality of air ducts 23 extending therethrough and each air duct is provided with a plurality of heat conducting fins as indicated at 24. The bottom portion of the cooling unit E acts as a sump as is indicated at 26.

The regenerating unit R consists simply of a spray chamber, the bottom portion of which forms a sump as is indicated at 28.

The apparatus will be charged with a suitable absorbent, such as lithium chloride or a similar salt which has the property of absorbing water. The lithium chloride is heated in the boiler B to an extent sufficient to cause the same to give up water readily when brought in contact with atmospheric air. The boiler B may be heated in any suitable manner as by an electrical heater, a combustible fuel burner, waste furnace gas, or a steam or hot water coil, particularly where waste heat is available. The heating means which is indicated generally at 29 will be controlled by a thermostatic mechanism indicated at 30 which is responsive to the temperature of the salt solution discharging through the pipe 31.

The pipe 31 terminates in a spray head 32 which is positioned in the upper portion of the regenerator R. The hot solution flows downwardly in a widely dispersed spray through the regenerator R and in contact with atmospheric air which is circulating therethrough. The hot solution readily gives up water to the air which also cools the solution and the cooled concentrated solution collects in the sump 28. The concentrated solution is conveyed from the sump 28 to the spray head 33 of the dehumidifier D by means of a conduit 34, the inner path of the heat exchanger L, the conduit 35, the inner path of the water cooler 36, a conduit 37 and conduit 38 which terminates in the spray head 32. A suitable solution circulating pump 40 is included in the con-

duit 38 and is driven by an electrical motor 41. The spray head 33 is provided interiorly thereof with a water cooling coil indicated at 43. The cooled concentrated solution discharges in a widely dispersed spray and falls through the dehumidifier D in contact with air to be conditioned which is circulated through the conditioned space F. The moist air entering the chamber D is dried as the concentrated solution has a great affinity for water and dry air is discharged from the chamber D. The solution which collects in the sump 20 is then returned to the boiler by means of the conduit 45, conduit 46, the outer path of the heat exchanger L and the conduit 47, thus completing the circuit for the absorbing solution which passes through the dehumidification chamber.

The motor 41 is controlled by a humidostat indicated generally at 50 which is in the path of the air discharged from the chamber D and is preferably of the modulating type so as to drive the motor 41 at varying speeds to supply varying amounts of absorbent to the dehumidifier D to maintain desired relative humidity in the air discharged therefrom.

A portion of the concentrated solution in the pipe 37 is withdrawn by a conduit 52 and is conveyed to the spray head 53 which is located in the chamber 22 of the cooling unit E. The spray head 53 is cooled by a water cooling coil 54 so that the solution discharging from the spray head is concentrated and cooled. The solution falls in a widely dispersed spray and collects in the sump 26 of the vessel E from which point it is returned to the conduit 46 by the conduit 51 from which it ultimately returns to the boiler mixed with the solution withdrawn from the dehumidification chamber.

A pump 58 driven by a variable speed motor 59 is inserted in conduit 52 to pump concentrated solution to the spray head 53. The motor 59 is regulated by a modulating control mechanism indicated at 56 which is responsive to the temperature of the cool air and serves to maintain the air at a desired temperature value by varying the motor speed and hence the quantity of solution supplied to spray head 53 per unit of time.

The upper walls of each of the air ducts 23 extend entirely across the cooling chamber E to provide trays 57 and are provided with openings defined by upwardly turned flanges 55 so as to form liquid containing vessels above and in heat transfer relationship with air ducts 23. The openings are staggered as is clearly discernible in Figure 1. The lowermost tray 57 is above the lowest air duct 23 and has a deeper flange 55 than those provided on the higher trays 57. Water is supplied to the uppermost tray 57 from a water reservoir or other source of supply 60 and a conduit 61 which enters the lower portion of the element E and terminates in a gooseneck 62 which discharges into the uppermost tray 57. A float valve 63 is positioned in the conduit 61 and is arranged to be actuated by a float 64 resting in the water supported by the lowermost tray 57. The apparatus is so arranged that the float valve will shut off when the water in the lowermost tray 57 reaches a predetermined depth, which is insufficient to allow the same to overflow the flange 55 and thus to fall into the absorption chamber 22. In this way all the trays 57 will be completely filled with water at all times as water cannot reach the lowermost tray 57 except by progressive overflow through the upper trays 57.

The lithium chloride spray and pool of lithium chloride in the lower portion of the chamber 22 has a great affinity for water vapor, as a result of which the vapor pressure above the pools of water in the trays 57 is maintained at a low value which promotes rapid evaporation of the water. This evaporation of water is accompanied by a reduction in the temperature thereof and thus cools the air due to the direct heat transfer path formed between the pools of water in the trays 57 along the top walls of the air duct 23 and also the heat conducting path formed between the cold water vapor, which surrounds the side and bottom wall of the air duct 23.

Weakened solution formed in the dehumidification chamber D and the cooling chamber E returns to the boiler, is heated and then flows through the spray in the regenerator R where the water vapor taken up in the elements D and E is liberated into outside air circulating through the regenerator.

It is thus apparent that air from the space to be conditioned and fresh air, if any is admixed therewith, is caused to circulate through the dehumidification chamber wherein it is dehumidified by direct contact with the absorbent solution and then through the air duct in the cooling chamber E wherein it is cooled by heat transfer relationship with evaporating water, the evaporation of which is produced by absorption of water vapor in a concentrated solution of the absorbent. The concentrated solution is divided into two streams which absorb water from different sources and is then re-united for regeneration in the regenerator R.

The vapor pressure of water with respect to the cooled absorbent in the dehumidifier is less than the vapor pressure of water in the air to be conditioned. The vapor pressure of water in the cooling chamber is greater than the vapor pressure of water of the cooled absorbent in the cooling chamber. The vapor pressure of water in the atmospheric air circulating through the regenerator is less than the vapor pressure of water with respect to the heated absorption solution. Consequently, the solution absorbs water vapor in the dehumidifier and cooling chambers and expels water in the regenerator.

Referring now to Figure 3 there is disclosed a modified form of the invention. The apparatus of Figure 3 differs only in certain respects to be enumerated hereinafter from the apparatus of Figures 1 and 2 and the arrangement of the major vessels and of the air ducts is identical with that arrangement illustrated in Figure 1. Portions of the apparatus of Figure 3 which are identical with portions of the apparatus heretofore described in connection with Figures 1 and 2 are given the same reference characters primed.

In this form of the invention the boiler B' is positioned at an elevation relatively low with respect to the elevation of the cooling unit E' and of the dehumidifying unit D' and of the rectifying unit R'. The solution flows into the boiler through the conduit 47' and is elevated through a vapor lift conduit 80 by the vapor formed in the boiler into a gas separation chamber 81. The hot concentrated solution collects in the lower portion of the chamber 81 and is conveyed therefrom through the conduit 82 to the spray head 32' of the regenerator R' where the hot solution is brought into contact with atmospheric air and further moisture is removed therefrom which results in additional concentration of the solution. The vapor liberated in the gas separation chamber 81 is conveyed by a conduit

83 to a condenser 84 which is cooled by the water jacket 85. The condensate is discharged through the conduit 86 into the condensate reservoir 87 from which it is conveyed into the evaporating chamber 21' by the conduit 61'.

Due to the fact that the solution is elevated by heat applied to the boiler the regenerating chamber R' will be at an elevation above the spray heads 33' and 53' which, as illustrated, are at substantially the same elevation. The solution flows by gravity through the conduit 34', solution heat exchanger L', conduit 35', cooler 36' and conduits 37', 38' and 52' through the spray heads 33' and 53', respectively. Due to the gravity flow of solution in this form of the invention the motor pump units which are provided in Figure 1 are here replaced by modulating valves 88 and 89 in the conduits 38' and 52', respectively. These valves as illustrated are controlled in the manner in which the motors are controlled in the form of the invention illustrated in Figure 1, otherwise this form of the invention is identical with that illustrated in Figure 1.

In this form of the invention the water supplied to the space 21' of the cooling unit E' is taken from the solution which is supplied to the boiler B'; that is, in effect water is evaporated in the space 21', is absorbed in the space 22' into the solution, the water is driven out of the solution in the generator B', is recondensed in the condenser 84 and is returned to the evaporating space 21' in this form of the invention. The water added to the solution in the dehumidification chamber D' is returned to the outside air in the regenerating chamber R'. In this way the need for makeup water can be substantially eliminated. However, provision may be made for makeup water as by placing a connection 90 to the city water supply which is governed by a float valve 91 for supplying makeup water in the event that the balance of the system is disturbed.

In both forms of the invention an absorbing solution is concentrated by being brought into contact in heated condition with atmospheric air. The concentrated solution is then divided, one part being brought into contact with air to be conditioned with resulting dehumidification of the air and weakening of the absorption solution, while the balance of the solution is utilized to create a low vapor pressure over a plurality of bodies of water in heat exchange relation with the air to be conditioned as a result of which the air is cooled and the solution is weakened. The weakened solution from the cooling and dehumidification chambers is then returned to the generator where it is again heated and returned to the regenerator, thus completing the solution cycle.

The type of system herein disclosed is particularly well adapted to air conditioning purposes as the production of refrigerant by absorption of water vapor will produce refrigerating temperatures in a range desirable for air conditioning purposes with a relatively high thermodynamic efficiency and with a relatively small expenditure of energy. Additionally, the system is ideally adapted to use waste heat such as low grade steam where such is available.

While the invention has been illustrated and described herein in considerable detail, various changes may be made in the arrangement, construction and proportions of parts without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. That improvement in the art of air conditioning which includes the steps of dehumidifying air to be conditioned by passing such air in contact with a body of an absorbent for water, subsequently cooling said air by passing it in heat exchange relation with a body of evaporating water, promoting the evaporation of said water by absorbing water vapor above said water in another body of said absorbent, uniting said bodies of absorbent and absorbed water vapor and removing water vapor from said absorbent by passing the absorbent in contact with air.

2. In an air conditioning apparatus, a dehumidifier, a cooler, a boiler, a regenerator, means for flowing air to be conditioned through said cooler and said dehumidifier, means for passing air through said regenerator, means for supplying water to said cooler for evaporation in heat exchange relation with said air to be conditioned, means for conducting a heated absorbent from said boiler and for passing the absorbent into contact with air in said regenerator, means for conducting separate bodies of the absorbent to said dehumidifier and to said cooler, and means for returning absorbent and absorbed water vapor from said dehumidifier and said cooler to said boiler.

3. In an air conditioning apparatus, a dehumidifier, a cooler, a boiler, a regenerator, means for flowing air to be conditioned through said cooler and said dehumidifier, means for passing air through said regenerator, means for supplying water to said cooler for evaporation in heat exchange relation with said air to be conditioned, means for conducting a heated absorbent from said boiler and for passing the absorbent into contact with air in said regenerator, means for conducting separate bodies of the absorbent to said dehumidifier and to said cooler, means for returning absorbent and absorbed water vapor from said dehumidifier and said cooler to said boiler, and means for governing the quantities of solution supplied to said dehumidifier and to said cooler.

4. That improvement in the art of air conditioning which includes the steps of passing air to be conditioned in contact with an absorbent for water vapor to dehumidify the air, passing said dehumidified air in heat exchange relation with water, while cooling said water by absorbing the vapor thereof in an absorbent for water vapor, applying heat to said absorbent for water vapor to expel a portion of the absorbed water vapor therefrom, condensing the expelled vapor and returning the condensate into heat exchange relation with air to be conditioned, and further removing water vapor from said absorbent by passing hot absorbent from which the water vapor has been partially expelled in contact with atmospheric air.

5. In an air conditioning apparatus, a dehumidifier, a cooler, a regenerator, a boiler, a condenser, said dehumidifier being constructed and arranged to provide contact between air to be conditioned and an absorbent for water vapor, said cooler being constructed and arranged to provide heat exchange between air to be conditioned and water and to provide contact between vapor of said water and an absorbent for water vapor, said regenerator being constructed and arranged to provide contact between atmospheric air and absorbent for water vapor, a vapor lift pump including a vapor separation chamber connected to said boiler, means con-

necting said condenser to receive vapor from said vapor separation chamber and to supply water from said condenser to said cooler, means for conveying absorbent from said separation chamber to said regenerator, and means for conveying absorbent from said regenerator to said dehumidifier and to said cooler.

6. In an air conditioning apparatus a dehumidifier, a cooler, a boiler, a regenerator, means for flowing air to be conditioned through said cooler and said dehumidifier, means for passing air through said regenerator, the lower part of said regenerator serving as a sump for absorbent and being positioned above the lower portions of said dehumidifier and said cooler, means for flowing absorbent by gravity from said regenerator to said dehumidifier and said cooler, means for flowing absorbent by gravity from said dehumidifier and said cooler to said boiler, a heat operated vapor lift pump arranged to elevate heated absorbent partially deprived of absorbent water vapor to the upper portion of said regenerator, and means for condensing vapor of water discharged by said vapor lift pump and for supplying the condensed water to said cooler.

7. In an air conditioning apparatus a dehumidifier, a cooler, a boiler, a regenerator, means for flowing air to be conditioned through said cooler and said dehumidifier, means for passing air through said regenerator, the lower part of said regenerator serving as a sump for absorbent and being positioned above the lower portions of said dehumidifier and said cooler, means for flowing absorbent by gravity from said regenerator to said dehumidifier and said cooler, means for flowing absorbent by gravity from said dehumidifier and said cooler to said boiler, a heat operated vapor lift pump arranged to elevate heated absorbent partially deprived of absorbent water vapor to the upper portion of said regenerator, means for condensing vapor of water discharged by said vapor lift pump and for supplying the uncondensed water to said cooler, means including a humidostat which is responsive to the humidity of said air for governing the supply of absorbent to said dehumidifier, and means including a thermostat which is responsive to the temperature of said air for governing the supply of absorbent to said cooler.

8. In an air conditioning apparatus, a chamber for dehumidifying the air to be conditioned, a chamber for cooling the air to be conditioned, means for maintaining an evaporating body of water in heat exchange relationship with the air undergoing cooling in said cooling chamber, means for flowing a first body of hygroscopic material through said dehumidifying chamber in contact with the air to be conditioned, means for flowing a second body of hygroscopic material through said cooling chamber in contact with vapor produced by the evaporation of water therein, means for withdrawing said bodies of hygroscopic material and absorbed water vapor from said chambers, means for mixing said bodies of hygroscopic material and for raising the water vapor pressure of said bodies of hygroscopic material higher than the water vapor pressure of the atmosphere, means for passing said bodies of hygroscopic material at said raised water vapor pressure into contact with atmospheric air to reduce the water content thereof, and means for returning said bodies of hygroscopic material to said chambers subsequent to said reduction in the water content thereof.

9. In an air conditioning apparatus, a chamber for dehumidifying the air to be conditioned, a chamber for cooling the air to be conditioned, means for maintaining an evaporating body of water in heat exchange relationship with the air undergoing cooling in said cooling chamber, means for flowing a first body of hygroscopic material through said dehumidifying chamber in contact with the air to be conditioned, means for flowing a second body of hygroscopic material through said cooling chamber in contact with vapor produced by the evaporation of water therein, means for withdrawing said bodies of hygroscopic material and absorbed water vapor from said chambers, means for mixing said bodies of hygroscopic material and for raising the water vapor pressure of said bodies of hygroscopic material higher than the water vapor pressure of the atmosphere, means for condensing water vapor released from said hygroscopic material in said water vapor pressure raising means, means for conducting said condensed water vapor to said cooling chamber, means for passing said bodies of hygroscopic material at said raised water vapor pressure into contact with atmospheric air to reduce the water content thereof, and means for returning said bodies of hygroscopic material to said chambers subsequent to said reduction in the water content thereof.

OTIS B. SUTTON.