PUBLISHED

MAY 18, 1943.

BY A. P. C.

E. ALTENKIRCH

AIR CONDITIONING

Filed Jan. 6, 1938

Serial No

183,581

6 Sheets-Sheet 1

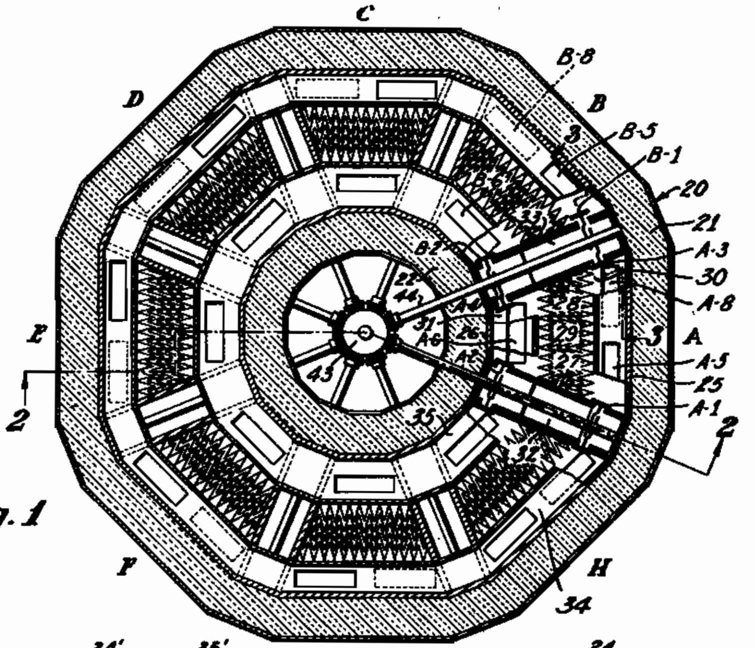

Fig. 1

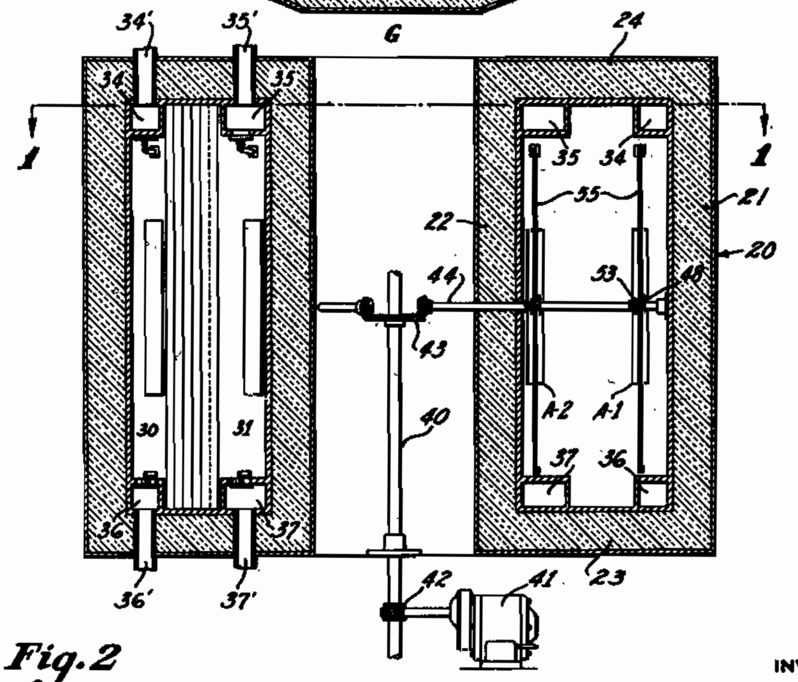

Fig. 2

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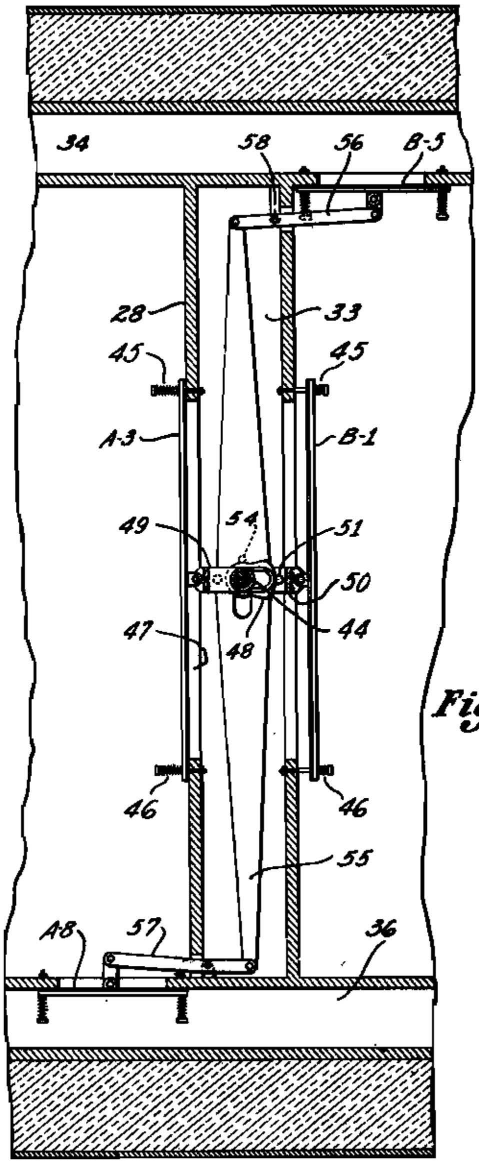


Fig. 3

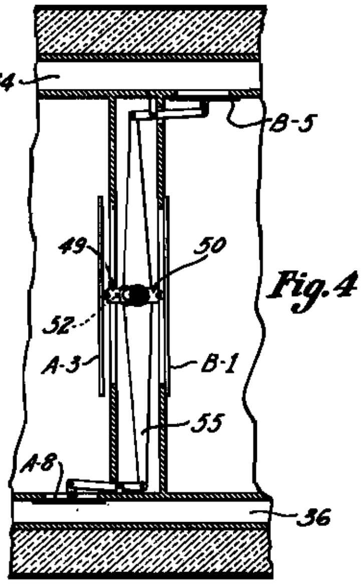


Fig. 4

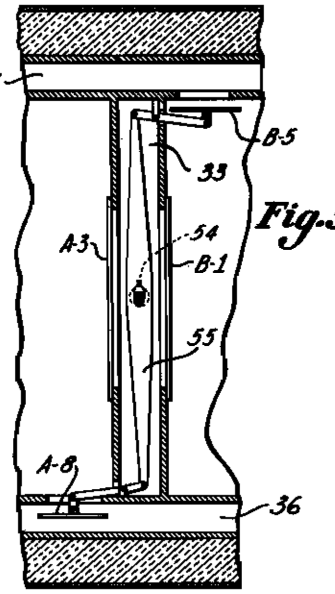
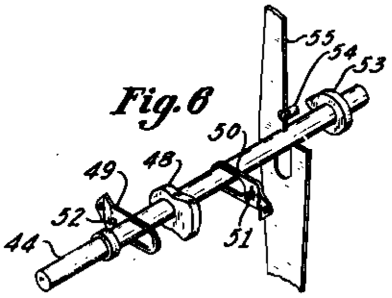


Fig. 5

Fig. 6



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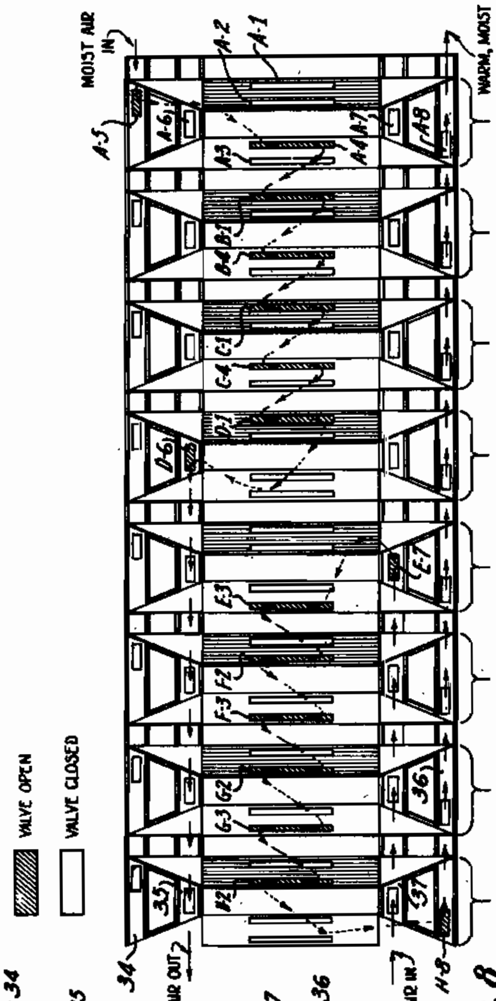

Fig. 8

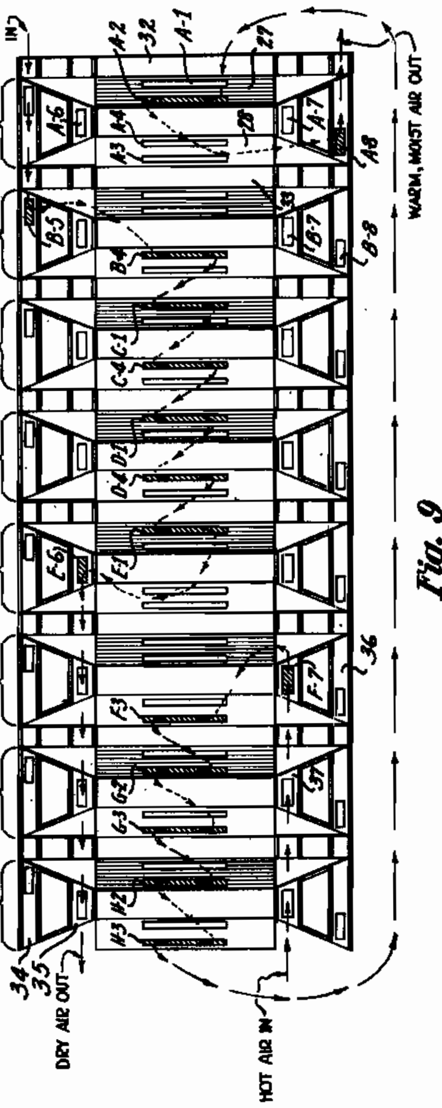

Fig. 9

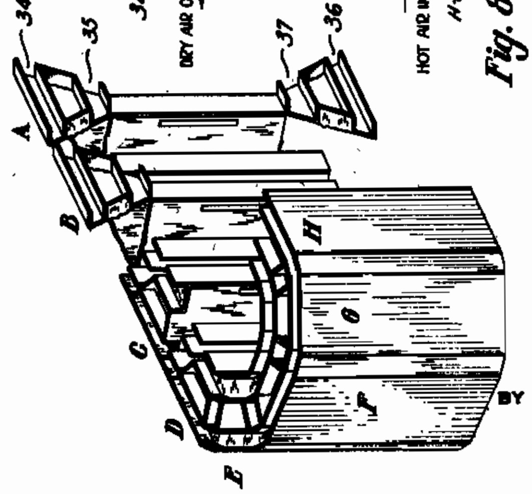

Fig. 7

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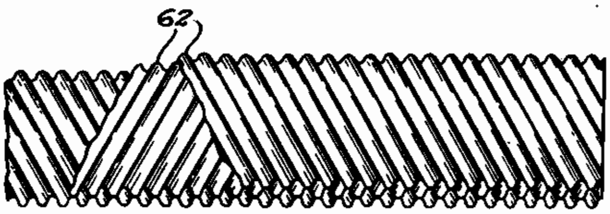

Fig. 10

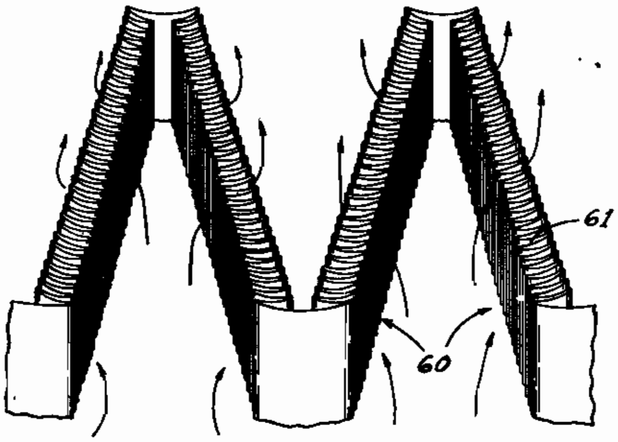

Fig. 11

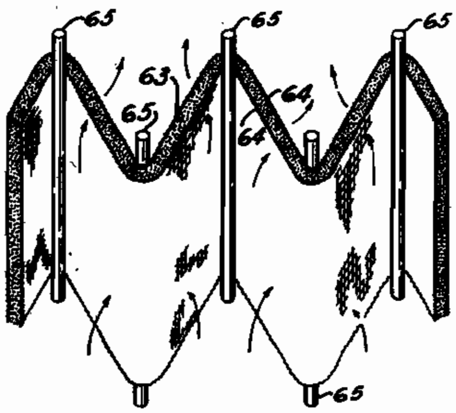

Fig. 12

Fig. 13

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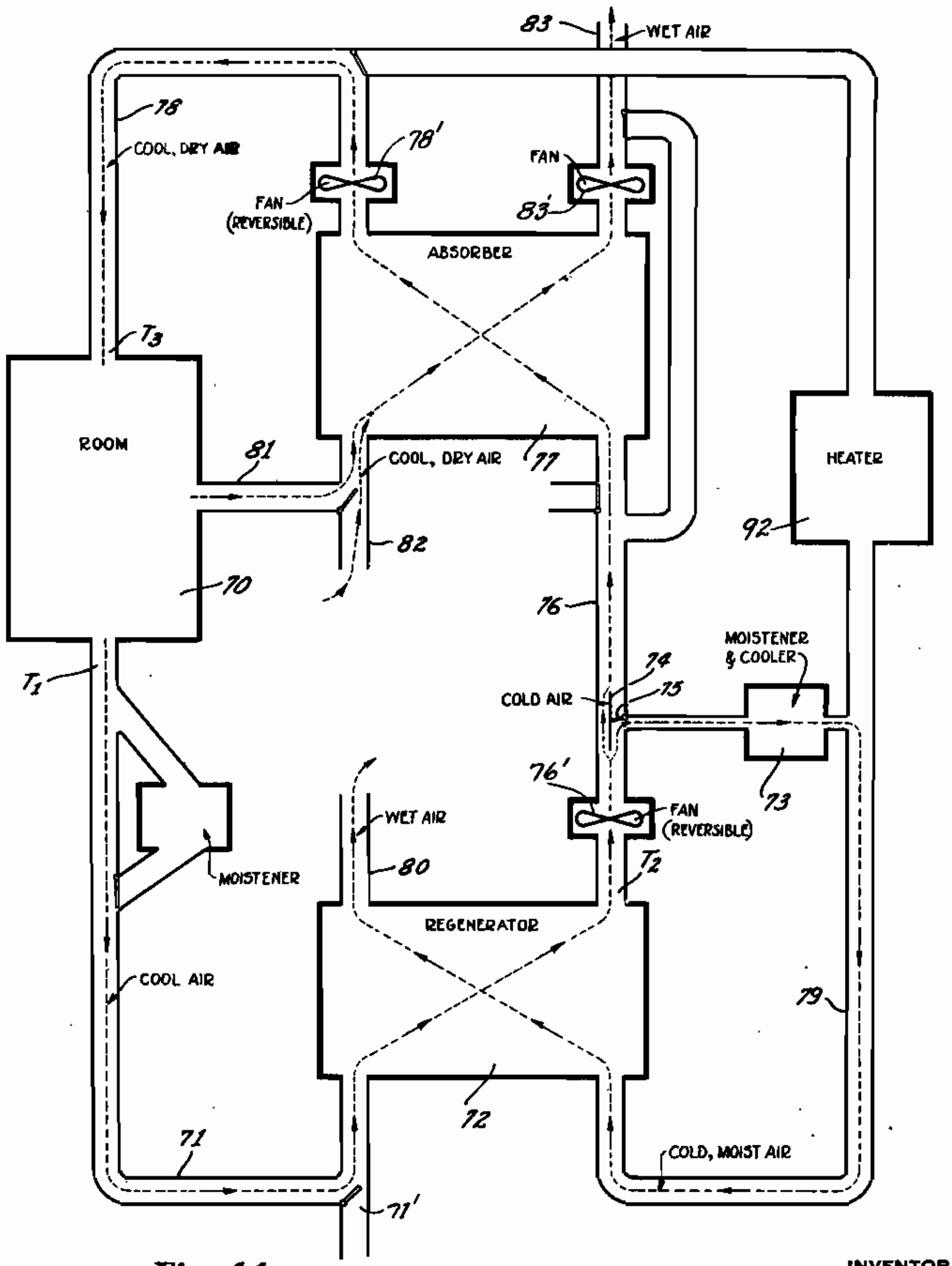

Fig. 14

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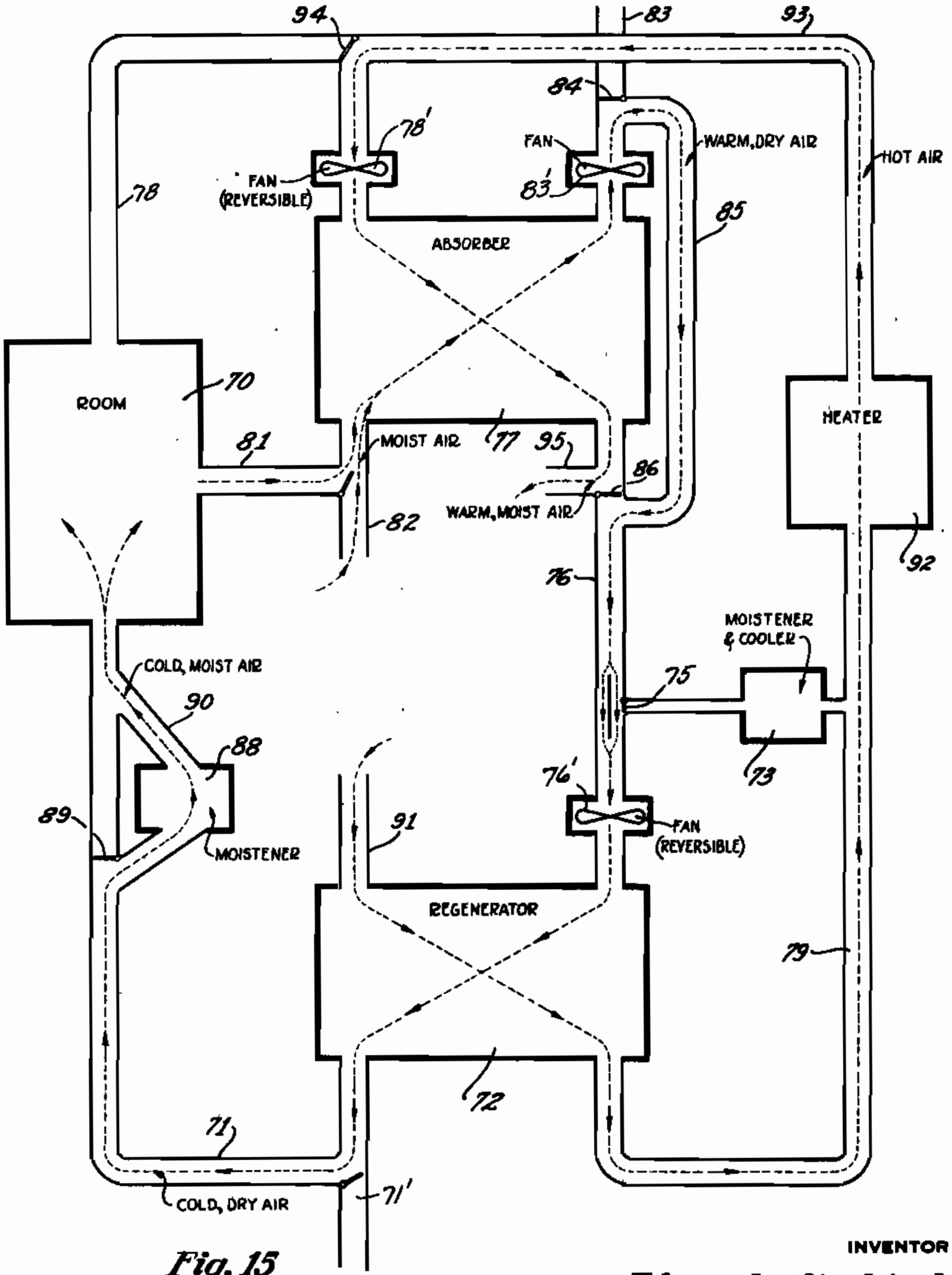

Fig. 15

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ALIEN PROPERTY CUSTODIAN

AIR CONDITIONING

Edmund Altenkirch, Neuenhagen, near Berlin, Germany; vested in the Alien Property Custodian

Application filed January 6, 1938

This invention relates to an air conditioning apparatus and method of conditioning air having many novel features not heretofore known.

By means of the air conditioning apparatus disclosed in the accompanying specification, I am enabled to perform several steps in the conditioning of air and other gases in an especially simple and expedious manner wherein the cost of the energy required is maintained at a minimum. In general, the invention involves the use in a novel manner of two series of chambers containing air conditioning bodies in which one series of chambers serves to condition air while the conditioning bodies of the other series is being reconditioned to supplant the first series after the effectiveness thereof in conditioning the air has been reduced.

Heretofore, it has been the practice to employ this general method of conditioning air, but the apparatuses have been very large, heavy and inefficient. More particularly, it has been necessary to either actually exchange the positions of the bodies newly activated and those to be activated, or to exchange the stream of air being conditioned with that used to reactivate the bodies of material. The former type of apparatus necessitates a complex construction and a large source of power for bodily moving the greater part or all of the apparatus periodically. The latter type avoids this very considerable disadvantage but exhibits other disadvantages which are common to both types. For example, in both types of conditioner, the condition of the air delivered by the apparatus varies constantly due to the fact the condition of the material over which the air flows is continually changing from one of maximum effectiveness to one of minimum effectiveness. This follows from the fact that the active and inactive bodies of material are interchanged periodically as a group.

According to this invention, I propose to arrange the conditioning material in a plurality of chambers connected to operate consecutively in two banks. Moreover, the two banks are so arranged and controlled that there are always bodies of conditioning material in each one thereof of varying degrees of effectiveness. Thus, in one bank, there are bodies of material of varying degrees of effectiveness in conditioning air. Likewise, there are bodies of material in the other bank in varying stages of reactivation.

Another disadvantage of prior art devices of the general class in which the present invention may be grouped is that in some constructions part of the air being conditioned passes over newly reconditioned material while another part passes only over material which is practically ineffective in conditioning the air. Obviously, the resultant stream of air is only partially conditioned.

According to this invention however, the air or gas being conditioned is passed over all bodies of material capable of conditioning the air in any degree. Hence, the resultant stream of gas delivered by my apparatus is conditioned to the maximum degree possibly limited only by the effectiveness of the material within the conditioning bank. And, of course, all portions of the stream are uniformly conditioned.

A still further undesirable characteristic of prior constructions is that the conditioning bodies are so arranged that it is necessary to employ large fans operating under high pressures in order to circulate the air over and through the conditioning material. According to my invention, the conditioning material is arranged in an especially novel and advantageous manner whereby a very large surface area of the material is exposed to the air stream in a minimum of space and in such a way that the pressure gradient through the material is only a fraction of that common to known constructions.

Another feature of my invention is that the same housing and valve mechanism can be utilized either as a regenerative heater, or as a gas separator or dryer depending upon the type of conditioning material with which the gas treating chambers are charged. Thus, if the chambers are charged with material having a high heat capacity, the apparatus may be employed as a regenerative heater as is advantageously done where hot gases are available which can not be used directly to heat a space or some object. Likewise, if the treating chambers are charged with absorbent material, then the apparatus may be used to separate gases provided one of the gases is not absorbable by that particular material.

And of course one of the particularly advantageous applications of the invention is in air conditioning a room or other enclosure by the conjoint use of one of the apparatuses charged to act as a regenerative heater and another of the apparatuses charged to act as an absorber or dryer. In this event it is possible to condition an enclosure without the expenditure of energy other than that necessary to operate the valve mechanism. However, if the relative humidity of the air to be conditioned is greater than fifty per cent it is desirable to supply some energy in the form of heat in order that the apparatus may operate with the greatest efficiency as will appear more closely from the detailed description of the invention.

It is accordingly an object of this invention to provide an air conditioner which is chargeable to act as a gas separator or a regenerative heater. Another object of the invention is the use of both a regenerative heater and a gas separator along with certain auxiliary devices connected in such a way as to condition air in a very efficient and inexpensive manner. It is likewise an object of the invention to provide connections and control means between the various parts of the apparatus and the auxiliary devices whereby only so many of the latter may be employed as is necessary to obtain the desired degree of air conditioning with a minimum expenditure of materials and energy.

It is also an object of the invention to provide an air conditioner wherein the only moving parts are the valve mechanisms and the actuating means therefor.

Another object of the invention is the provision of an air conditioner apparatus operating continuously. More particularly, it is an object of the invention to provide an apparatus which supplies a continuous stream of air uniformly conditioned.

A further object of the invention is to construct and position the conditioning material within the apparatus in such a way as to expose a maximum surface area of the material to the gases with a minimum pressure drop between the air inlet and the air outlet.

Another object is to provide a novel arrangement of multiple valves and actuating mechanism therefor so constructed as to actuate all of the valves in a predetermined, time relationship.

Still other objects of the invention will become apparent from the following detailed description of a preferred manner of practicing the invention as illustrated in the accompanying drawings wherein:

Figure 1 is a horizontal sectional view on the line 1—1 of Figure 2 showing one of the conditioner units according to this invention;

Figure 2 is a vertical sectional view along line 2—2 of Figure 1;

Figure 3 is a vertical sectional view along line 3—3 of Fig. 1 showing one of the valve operating assemblies in one operative position;

Figure 4 is a view of one of the valve assemblies with the valves in a second operative position;

Figure 5 is a view of one of the valve assemblies in a third operative position;

Figure 6 is a fragmentary view in perspective of one of the valve operating shafts and associated cams;

Figure 7 is a perspective view of one of the conditioner units showing how the apparatus has been unfolded for purposes of illustration in Figs. 8 and 9.

Figure 8 is a developed view of one of the units unfolded in the manner indicated in Figure 7, and showing the positions of the various valves and the gas circuits under one set of operating conditions;

Figure 9 is a view similar to Figure 8 but showing the positions of the valves and the gas circuits under the next operative set of conditions after that shown in Figure 8;

Figure 10 is a perspective view of one way of arranging the conditioning material of high heat capacity for use in the regenerative heater;

Figure 11 is a fragmentary perspective view of one manner of arranging the absorbent material in the apparatus;

Figure 12 is a fragmentary view of an alternative method of arranging loose absorbent material in the apparatus;

Figure 13 is a fragmentary view of a third way of arranging absorbent material, such as crepe paper, in the apparatus.

Figure 14 is a diagrammatic view showing how a gas separator and a regenerative heater may be connected to an enclosure to condition the same when the relative humidity of the air to be conditioned is not too high;

Figure 15 is a view similar to Fig. 14 but showing how the various valves may be positioned for most efficient operation when the humidity is relatively high.

A preferred form of the invention is shown in Figures 1 and 2 as encased in an octagonal prism housing **20** having an outer heat insulating wall **21** and an inner heat insulating wall **22**. As will be seen in Figure 2, rings **23** and **24** of heat insulating material serve to close the top and bottom ends of walls **21** and **22** and cooperate therewith to form an annular air conditioning chamber.

Within the annular shaped air treating chamber are located eight individual conditioning chambers A, B, C, D, E, F, G and H which are circumferentially spaced from one another by air passages. Each of the air conditioning chambers or cells is similar in construction and manner of operation, and consequently detailed description of one of these chambers will suffice for all.

Referring to chamber A, for example, it will be seen that this chamber consists of an outer wall **25**, an inner wall **26**, and two diverging side walls **27** and **28**. Any desired conditioning material such as nested corrugated sheets **29** may be arranged to extend between the side walls **27** and **28**, and is spaced from the inner and outer walls **26** and **25** as indicated in Figure 1. The particular manner in which this material is arranged in each of the chambers will be described in detail hereinafter.

As will be observed from Figure 1, the conditioning material **29** is spaced from both the outer wall **25** and the inner wall **26** to provide air entrance and exit passageways **30** and **31**. There are a plurality of air passageways which may be placed in communication with passageways **30** and **31**. For instance, each of these passages can be connected with each of the radially extending air passages on either side of section A of the apparatus, the one being formed in the part by wall **27** being designated **32** and the one adjacent wall **28** being designated **33**.

Communication between passages **30** and **31** and radial passages **32** and **33** is controlled by four valves A**1**, A**2**, A**3**, and A**4** interconnected in a manner to be described to open and close in a certain order. Valves A**1** and A**2** are located on wall **27**, while valves A**3** and A**4** are located on wall **28**. At this point it may be stated that these valves are so operated that air entering a conditioning section from one of the radial passages must pass through conditioning material **29** before it can reach the other radial passage. Moreover, air entering a section from one radial passage cannot flow back into the other end of the same radial passage but must flow into the radial passage on the opposite side of the section.

As will be seen from Figure 2, there is also an annular passageway in each corner of the annular chamber formed by the insulating walls 21, 22, 23 and 24. These passageways have been designated 34, 35, 36 and 37 for reference purposes and extend completely around the apparatus. Each of the annular passageways has a conduit 34′, 35′, 36′ and 37′, respectively, leading to the exterior of the apparatus. As in the case of the radially extending passages, each of the annular passages is in communication optionally with each of the air conditioning chambers. Thus, passageway 34 communicates with the outer air passageway 30 within conditioning chamber A by means of valve A5. Also passageway 35 is in communication with inner passageway 31 through valve A8. Directly beneath valve A6 is another valve A7 controlling the communication between passageways 37 and 31. Likewise, there is a valve A8 between passageways 36 and 36. It will also be understood that air may be lead into or withdrawn from either passageway 30 or 31 of each conditioning chamber through any one of the passageways 34, 35, 38, and 37, since each section of the apparatus is similar to section A in all respects.

From the foregoing it will be evident that two streams of air may be passed through the conditioning chambers at different times in any one of four directions. Thus, air may flow from radial passageway 32 through valve A1 into passage 38, through material 29 into passageway 31, and past valve A4 into radial passage 33. On the other hand, air may flow from passageway 33 through valve A3 into passageway 30, then through material 29 into passageway 31, and into chamber 32 through valve A2. Likewise, an entirely different stream of air may be passed through the conditioning chamber in either direction. For example, the air might flow from passageway 34 through valve A5 into passage 39 and through the material 29 into passage 31 and through valve A7 into passageway 37. In order to pass air in the opposite direction, it would flow from passageway 35 through valve A8 into passage 31, through material 29 into passage 30 and then through valve A6 into passage 38. In other words, gases may pass diagonally through each of the treating chambers A, B, C, D, E, F, G or H from the four opposite corners in both the horizontal and the vertical planes.

It will also be understood that the air might be caused to flow through the conditioning chambers in other manners according to the setting of the various valves.

In order to accomplish the purposes of this invention, it is important that the various valves controlling communication between each of the conditioning chambers and the air passageways communicating therewith be controlled in a very definite manner. The mechanisms which are proposed to accomplish this will now be described.

It will be understood of course that each of the chambers A, B, C, D, E, F, G, and H are identical in construction. Moreover, each of the chambers is provided with identical valve control mechanisms. As will be apparent from Figure 1, this valve mechanism is largely located in the radially extending passageways between the conditioning chambers. All valves are operated by shafts extending radially from the center of the apparatus. Located at the axis of the apparatus is a power shaft 40 driven by means of a motor 41 through speed reducing gears 42. Secured to this shaft is a bevel gear 43 positioned to drive each one of the eight shafts extending radially to the valve mechanisms. Thus, shaft 44 extends to the valve mechanism located between sections A and B. Valves A3, A4, B1, B2, A7, A8, B5 and B8 are all operated from shaft 44. The manner in which A3, B1, A8 and B5 are operated will now be described in detail.

Referring to Figures 3 to 6 wherein valves A3, A8, B1 and B5 are shown as they appear from a view taken on line 3—3 of Figure 1, it will be seen that each of the valves consists of a flat plate adapted, when closed, to lie flat against a wall separating the radial air passages from the conditioning material. For example, A3 is supported by partition 28 and is spring pressed by means of springs 45 and 48 against this partition to close the opening 47 therethrough. Valves A3 and B1 move in a plane parallel to the supporting partitions when opening and closing. Valves A8 and B5 may open in the same manner as valves A3 and B1.

Valves A3 and B1 are actuated by a cam 46 rigidly mounted on shaft 44. This operation is accomplished when the high portion of the cam strikes pins 51 and 52 secured to link members 50 and 49, respectively. Thus, as will be seen from Figure 3, the high portion of cam 48 is positioned beneath pin 51 on link 58 so as to move valve B1 to open position against the action of springs 45 and 46. In Figure 4 it will be seen that cam 48 has revolved 180 degrees to contact pin 52 on link 49 and thus move valve A3 to open position. Meanwhile, and before A3 opened, the springs on valve B1 have urged it to closed position. As will be observed from the drawings, the high surface of the cam 48 is appromixately 90 degrees in arcuate extent. Hence, each of the valves is open for one-quarter revolution of shaft 44.

The mechanism for operating valves A8 and B5 is similar to that just described in connection with valves A3 and B1. These valves are operated by means of a second cam 53 attached to shaft 44 and positioned to contact a pin 54 on a motion transmitting member 55 extending vertically in air passageway 33. The upper end of member 55 is connected through a linkage 58 to valve B5, while the lower end is connected through a similar linkage 57 to valve A8. When the high portion of cam 53 contacts pin 54, arm 55 is carried upwardly to move linkage 58 about pivot 58 in such a manner as to open valve B5. At the same time valve A8 is also opened in a similar manner. At this point, attention is called to the fact that valves A8 and B5 are always operated simultaneously to either closed or opened position. On the other hand, valves A3 and B1 are never operated simultaneously, and one always remains closed. Attention is further called to the fact that the high portion of cam 53 is much shorter in arcuate extent than the high portion of cam 48. Also note that valves A8 and B5 are only open when valves A3 and B1 are closed (see Figure 5).

Valves A4, B2, A7 and B6 are operated by a mechanism identical with that just described. However, the cams for operating these valves corresponding to cams 48 and 53, are positioned to operate the valves in a different timed sequence than that just described in connection with valves A3, B1, B8 and A8.

A preferred manner of operating the numerous valves of my apparatus in timed sequence will now be described. In order to permit of a clear understanding of the valves and the order in which the same operate, the apparatus of Figures 1 and 2 has been illustrated in an exploded development view in Figures 7, 8 and 9. Figure 7 indicates the manner in which the apparatus has been unfolded to bring all valves into a single plane. Thus, it will be noted that the side walls, top and bottom of the apparatus has been unrolled. Then the top portion of the apparatus has been folded upwardly, and the bottom has been folded downwardly. Figure 9 is identical with Figure 8 except that a second position of the valves and the resulting modified gas circuits are there indicated. Note that the shaded rectangles indicate open valves, while the unshaded rectangles indicate closed valves.

Assuming that it is desired to condition a body of air by removing excess moisture therefrom, the apparatus which has just been described may be operated in the following manner. Moist air, as from the atmosphere, is conducted into the annular passageway 34 through the inlet 34'. This air stream passes along passageway 34 until it comes to open valve A5 in the first drying section A. (At this time attention is called to the fact that no more than one valve is ever open in any one of the annular passages 34, 35, 36 and 37). This moist air then passes through the absorbent material in section A into passageway 31. The only exit from this chamber is provided through open valve A4, since valves A1, A2 and A3, as well as valves A6, A7 and A8 are closed as shown in Figure 8. The partially dried air which flows out through valve A4 is led into the next conditioning chamber B through the open valve B1. The air is again led through the conditioning material in this chamber and exits therefrom through valve B4 in a still dryer condition. In like manner, the air to be conditioned passes through chambers C and D. However, in chamber D it will be noted that all valves except D1 and D6 are in closed position. Valve D6 is located in the annular passageway 35 in the top of the apparatus. Hence, the air, which by this time has been fully dried, passes along passageway 35 to exit conduit 35'.

It will be noted that the air to be conditioned has only passed through four of the eight air conditioning chambers. The other four chambers will have been saturated with moisture from previous use in conditioning air, and will be in need of reactivation. To this end, warm air from any convenient source is led into passageway 37 through opening 37', and passes therealong until it reaches the open valve E7 in section E. The conditioning material in this section will be substantially saturated with water vapor. The hot air passing through this material and out through the only open valve E3 into the air passageway between sections E and F and drives off a part of the moisture. This hot air containing some moisture from the material in section E then passes through each of the sections F, G and H in the manner indicated by the arrows in Figure 8. Upon reaching section H, the air passes through the material in this chamber, and since all valves except the valve H8 are in closed position, the air passes into passageway 36 and therealong until it reaches outlet conduit 36'.

It will therefore be seen that while four of the conditioning chambers are being employed to dry air, the remaining four chambers are being reactivated by hot gases for subsequent use in conditioning air. In order that the air may be conditioned in a continuous manner, it is of course desirable to introduce periodically a dry body of absorbent material in the air drying cycle, and to remove saturated absorbent material to the reactivating cycle. This operation is automatically accomplished without actually transferring the absorbent material, as has been customary heretofore, simply by operating the various valves described hereinabove. At the end of a predetermined period of time, as dictated by experience, the cams 48 and 53 on the eight motor-driven shafts similar to shaft 44 are brought into position to change the condition of certain of the valves. This operation is indicated in Figure 9. Referring to this figure, it will be seen that the moist air entering the apparatus no longer enters section A, because valve A5 is now in closed position. The only valve in passageway 34 which is open is valve B5 in section B. Consequently, the moist air now flows through sections B, C, D and E. As will be seen from Figure 8, section E was previously in the activation cycle, but has now been placed in the drying cycle by reason of the operation of the valves. After the air has passed through section E, it passes into passageway 35 through open valve E6 and is conducted from the apparatus to the space to be conditioned. Likewise, the hot air employed to recondition the absorbent material first passes into section F, and from there to sections G and H. From this point the air next passes through section A which has just been saturated with moisture in the drying cycle. From this point the air, which is now substantially saturated with moisture and is therefore no longer effective in reactivating absorbent material, passes into passageway 36 and out into the atmosphere.

The apparatus continues to operate in this same manner, and it will be appreciated that the air to be conditioned is always led through four chambers, and that hot air is always being passed through the remaining four chambers to reactivate the material therein. It will also be observed that a freshly conditioned drying section is always periodically added to the end of the stream of air being conditioned, and also that the wettest and least effective of the drying chambers is periodically added to the end of the reactivating air stream to be reconditioned. Due to this fact, the air being dried always passes through freshly dried absorbent material immediately before passing from the apparatus and is therefore dried to a minimum degree. By the same token, a body of saturated absorbent material is added to the reactivating cycle at the entrance end thereof where the hot air is the warmest and driest and remains in the reactivating air stream for a maximum period of time.

It is of course obvious that the apparatus can be used to condition air in other ways than that of drying it. If it is desired to heat a body of air by means of hot gases which are unsuitable for use in the space to be heated, this same apparatus may be utilized simply by replacing the absorbent material by some material having high heat capacity. For example, aluminum foil may be substituted for the absorbent material in the conditioning chambers of the apparatus. In this event, the air to be conditioned is passed through four sections of the apparatus in the same manner as the moist air in the above described drying operation. At the same time a stream of hot air or other hot gases is passed through the remaining four sections of the apparatus in the manner just described in connection with the reactivating air stream. Under these circumstances, the apparatus functions according to the well known regenerative principle of heating a cold stream of fluid indirectly from a hot stream of fluid. Referring to Figure 8 (assuming that the conditioning chambers are now filled with material of high heat capacity) it will be seen that the hot air passes through sections E, F, G and H and thereby heats the aluminum foil to a high temperature. After the material in these chambers has been heated for a period of time, the valves are operated to the position shown in Figure 9. Cold air to be conditioned by heating is now passed through sections B, C, D and E. The air will be partially heated by passing through section E, but after the apparatus has been in operation for a period of time, all of the four sections through which the air to be heated passes will have been previously heated by the hot gas stream and will be in condition to heat the cold air stream. Not only is the air conditioned by heating during this operation, but the relative humidity of the air is also reduced by reason of the heating so that the resultant air stream is much warmer and drier than the original cold and moist air stream.

In order that an air conditioning device of the type herein disclosed be compact, efficient in operation, and offer a minimum resistance to the passage of gases therethrough, it is essential that the material selected for the conditioning chambers have certain characteristics and that it be specially arranged in the apparatus. Not only should the material be so arranged as to offer a minimum resistance to the flow of air through the device, but it should also be so arranged as to present a maximum surface area to the air stream. If the material is intended to remove moisture from the air, then it is important to select a material which has the property of absorbing and liberating moisture with very slight changes in temperature. If the conditioning material is intended for use in the regenerative heater, then it is important that the material have a very great heat capacity and good heat conductivity so that the material may absorb a large amount of heat quickly from the air stream and give up the stored heat quickly to a stream of air to be heated. As will appear more fully hereinbelow, I have designed an air conditioning device incorporating all of the foregoing desirable characteristics along with many others which will become apparent from the following detailed description.

I have found that ordinary wood, paper, and other cellulose products are especially efficient materials for use in an air conditioning device. It will of course be understood that this invention is not limited to the use of wood and paper as absorbent materials, but that these materials are employed in the preferred form of the invention due to the ease with which these materials may be placed in the conditioning chambers, the rapidity with which these materials absorb and liberate moisture, the slight temperature difference required to cause the material to act either as an absorbent body or as a moisture liberating body, as well as the cheapness and availability of these materials. If wood or paper of sufficient thickness to have some rigidity is employed, I have found that sheets thereof may be arranged entirely across the conditioning chambers in the direct path of the air stream without unduly hindering the flow of the air through the chamber. In other words, the material has been found to be sufficiently porous to permit the air to filter therethrough in spite of the absence of any preformed perforations in the sheets. However, if desired, the sheets of wood or paper may be perforated to permit a greater quantity of air to pass, although I have found that this is quite unnecessary.

In order to decrease the resistance to the air flow further and to present a greater surface area of the conditioning material to the air stream, I find it advantageous to arrange the sheets of material in zigzag fashion across the air stream. This arrangement not only increases the surface area of the material several times in a given cross sectional area of air duct, but also increases the number of pores through which the air may filter several fold. As is indicated in Figure 1, any desired number of sheets of absorbent material may be nested together in slightly spaced relationship across each of the conditioning chambers, but it is desirable and quite feasible in my apparatus to place only a small number of sheets in each chamber and recycle the apparatus oftener. Any convenient way of supporting the sheets of absorbent material in the chambers may be employed, as for example, wire rods located in the constricted portions or apices of the corrugations. It will be noted from section A of Figure 1 for example, that all of the air entering passageway **30**, for instance, must flow through each of the sheets of absorbent material **29** in order to reach passageway **31**. Due to the tremendous surface area of the absorbent material presented to the air stream, it is only necessary that the air filter slowly through a given section of the material in order that a stream of considerable volume reach passageway **31**. Moreover, all of the air must come in contact with absorbent material, and as a result the moist air is quickly stripped of its moisture.

In order to still further increase the surface area of the sheets of absorbent material, the sheet may be preformed as shown in Figure 11. In addition to the large corrugation **60** corresponding to the corrugations in the sheets of Figure 1, the side walls of the large corrugation **60** are also corrugated with small indentations **61**. Both the large corrugation **60** and the small corrugation **61** are V-shaped. Therefore, regardless of whether the air flows in the direction indicated by the arrows of Figure 11, or in the reverse direction, the air stream entering either the large corrugation **60** or the small corrugation **61** enters at a point of maximum cross sectional area. As the air stream proceeds into the corrugation, the cross sectional area gradually decreases in accordance with the diminishing quantity of air which has not yet filtered through the sheet.

If it is desired to employ the conditioner as a heat regenerator, I have found that a most advantageous way of arranging the material of high heat capacity is in the manner indicated in Figure 10. A particularly desirable material to use for this purpose is aluminum foil. This material is relatively inexpensive and easily worked into any desired form. Moreover, it is not affected by moisture or other materials ordinarily present in air to be conditioned, or in the hot gases available as a source of heat. It also has a very high heat capacity and excellent heat conductivity.

In order to present as large a surface area of this material as possible to the gas stream in a minimum of space, and without providing too much resistance to the flow of the gases, the foil may be cut in relatively narrow strips 62 and corrugated at an angle to a longitudinal side of the strip in the manner indicated in Figure 10. The corrugated strips are then laid one on top of the other with the corrugations of adjacent strips running at an angle to one another as clearly shown in the drawings. This arrangement results in the spacing of the strips without the use of separate spacers and prevents the nesting of the strips. This mode of assembly is continued to provide units of convenient height, and then the units are inserted crosswise of the conditioning chambers—that is, in a direction transversely of the air stream flowing between passages 30 and 31, for instance. A number of such units may be located across the conditioner chamber parallel to one another as in the case of the sheet absorbent material, if desired, or the strips of foil may be originally cut sufficiently wide to extend from the inner to the outer air passages 30 and 31 of the conditioning chambers. As is true of the absorbent material, the air stream passing through the treating chamber does not flow rapidly, but gradually filters from the inlet passage to the outlet passage in contact with the material of high heat capacity. If the air stream is highly heated, then the foil will also become heated in a very short period of time. After the hot air has passed over the foil for a sufficient period to heat the material to substantially the temperature of the hot gas stream, the hot air stream is directed to another treating chamber to heat that, and a stream of air to be heated is passed in the opposite direction over the aluminum foil and quickly becomes heated from the foil.

Still another method of arranging the absorbent material in the apparatus is illustrated in Figure 12. According to this arrangement, loose absorbent material, such as fuller's earth or silica gel 63, may be supported in a thin layer between two sheets 64 of wire mesh, fabric or other suitable material. The resulting laminated sheet may be corrugated in the manner hereinabove described in connection with Figures 1 and 11. As was the case with these arrangements, it is desirable to provide supports such as rods 65 in the troughs of at least certain of the corrugations in order to support the sheets in a vertical and rigid position. However, use of the rods 65 may be dispensed with in certain cases as where wire mesh 64 is employed provided the two opposing layers of mesh are secured together at intervals by suitable ties not shown.

Still another manner in which the conditioning chambers may be charged with absorbent material is illustrated in Figure 13. According to this form of the invention, the units of absorbent material are formed from layers of crepe paper cut in a zigzag manner as shown. The individual strips of crepe paper are then placed directly on top of one another until a unit of convenient size is obtained. It is important, of course, that the grain or crepe of the paper extend crosswise of the strips in the manner indicated in the drawings. The crepe paper units are placed crosswise of the conditioning chambers in the same manner as sheet 29 in Figure 1, and as many units may be placed parallel to one another as is found desirable. The individual units should not extend too far vertically without some means of supporting the units as otherwise the weight of the paper will cause the lower layers to become packed too tightly to permit the air to filter therethrough readily. So long as the individual sheets do not become packed together too tightly, the air will filter through the units in a very satisfactory manner. If moist air is being passed therethrough, the moisture will be absorbed by the crepe paper provided the temperature of the air is low enough for absorption to take place. However, if the temperature of the air is raised slightly, then the moisture contained in the crepe paper will be liberated into the air, and the paper will become reactivated.

Referring now to Figures 14 and 15 which are diagrammatic representations of the manner in which one absorber and one regenerator of the type described hereinabove may be interconnected with an enclosure to be conditioned and with certain auxiliary devices to condition air in a continuous and highly efficient manner. By reason of the use of the regenerative heater in connection with my absorber, it is entirely practical to condition a room with little or no expenditure of energy other than the small amount required to operate the valve mechanisms of the two conditioners, and the small amount of auxiliary energy desirable under certain conditions to supplement and assist the functioning of the absorber and regenerative heater. If the relative humidity of the air to be conditioned is below forty or fifty per cent, it is unnecessary to use any of the auxiliary devices with the possible exception of a simple means for passing a part of the air through a water spray or other moistening device to cool the air by evaporative cooling. Under these circumstances the absorber and regenerative heater may be connected to a space to be conditioned and to the outside atmosphere in the manner illustrated in Figure 14.

It will be understood that the absorber and regenerative heater are identical in construction except that the conditioning chambers of the absorber are charged with absorbent material, and the regenerator is charged with material of high heat capacity. Both units are constructed as described hereinabove. It is therefore thought sufficient if the discussion of Figures 14 and 15 is restricted to a description of the manner in which the apparatus illustrated operates to condition air when the relative humidity is below a predetermined value, and also when the relative humidity is above this same value.

Referring first to Figure 14, it will be seen that air to be conditioned, as from the room 70, may be led through conduit 71 to regenerator 72. Approximately one-quarter of the air delivered from the regenerator is then by-passed through a suitable moistening device 73, where it is cooled by the evaporation of water thereinto. In view of this fact, it may be desirable to add make-up air to the main air stream to prevent influx of unconditioned air to the room. This may be accomplished by adding the required amount of air by means of the adustable valved inlet 71' leading into conduit 71. Consequently the main room air stream plus the make-up air is conditioned as it passes through the regenerator. As previously stated, a certain portion of the air stream discharged from the regenerator is diverted through the moistening and cooling device 73, of any suitable construction, by means of the dividing partition 74 and valve 75 located in conduit 76. The remaining portion of the air discharged from the regenerator is led through conduit 78 into the absorber 77 wherein the moisture contained in the air is absorbed or separated from the air by the absorbent material. The resulting cool, dry air is then led back to the room through conduit 78. The body of air passing through the regenerator between conduits 71 and 76 is cooled by means of the portion of the air cooled in cooler 73, since this air is led through conduit 78 to the regenerator. After giving up its heat to the main air stream in the regenerator, this air is discharged to the atmosphere through conduit 80.

The absorber is reconditioned by means of the warm air derived from either room 70 or the atmosphere, or from both sources. The air from the room is led to the absorber through conduit 81, and air from the atmosphere is mixed with this air through conduit 82. The relative proportions of room and atmospheric air may be regulated at will by means of the valve at the junction of conduits 81 and 82. This air passes through the absorber in the manner indicated by the dotted line, and passes back to the atmosphere through conduit 83.

It is of course necessary to provide some means of circulating the various air streams just described through the apparatus and to the space being conditioned. As shown in Figure 14, three fans may be utilized and disposed as indicated, although it will be understood that other arrangements may be employed and the fans may be disposed in other locations to satisfy the requisites of a given situation. As shown, a fan 76' is located in conduit 76 between the regenerator and diversion valve 75. Fan 76' is preferably driven by a reversible motor, not shown, and is so designed as to cause air flow in either direction in conduit 76. Also inserted in the same air stream is a second similar fan 78' which is intended to assist and supplement fan 76' in circulating air from room 70 through the regenerator and absorber, and back to the room. If desired, another reversible fan may be located in conduit 79 or 80 to assist fan 76' in circulating the smaller air stream through cooler 73 and the regenerator. A third fan 83' which need not be of the reversible type, is shown in conduit 83 for circulating reactivating air through the absorber and discharging the same to the atmosphere.

From the foregoing description, it will be seen that the air leaves the room at a temperature of T_1, which is too high for human comfort. After the air has passed through the regenerator it will have been cooled to a temperature T_2, which is much lower than T_1. This cooled air is then led to the absorber where it is dried, and consequently warmed somewhat by the heat of absorption. Therefore, the temperature T_3 of the air being returned to the room through conduit 78 is intermediate T_1 and T_2. Moreover, in addition to the fact that the temperature has been reduced, it will also be appreciated that the air is much drier then it was upon leaving the room. Therefore, by reason of the operation of the apparatus, the temperature, relative humidity, and absolute humidity of the air have been modified without the expenditure of any energy other than that contained in the atmospheric air and that expended to operate the control valves of the apparatus. Moreover, this operation may be carried out continuously without any attention whatsoever and in a very efficient manner.

If the relative humidity of the air in the space to be conditioned, or from any other source, has a relative humidity above approximately forty or fifty percent, it may become desirable to supply auxiliary energy to the apparatus in order to obtain the most effective and efficient results. This may be done by the same apparatus illustrated in Figure 14 provided certain valves in the interconnecting conduits are modified to change the circulation of the various air streams so as to include an auxiliary source of heat. Figure 15 accordingly shows the same apparatus as Figure 14, but with the valves in the new position. Fans 78' and 78' are now reversed by a suitable means, while fan 83' continues to operate in the same direction, and new air circuits are established as indicated by the dotted lines in Figure 15. The air flows in the direction indicated by the arrows. By reason of the operation of the fans, it will be observed that moist air from either room 70 or the atmosphere may be conveyed directly to the absorber 77 through conduits 81 and 82. This air stream passes through the absorber where it is dried and warmed somewhat by the heat of absorption. Valve 84 in conduit 83 is now positioned to direct the warm, dry air through conduit 85 into conduit 76. Valve 86 which was previously adjusted to a vertical position in Figure 14 is now in a horizontal position and directs the warm dry air stream downwardly through conduit 76, past valve 75, which is now closed, into the regenerator. As a result, the warm dry air stream is cooled and led from the regenerator by conduit 71 into an air moistening device 88, in the event additional cooling is desired. It will be understood that moistener 88 may be of any desirable type in which cooling is obtained by the evaporation of a liquid, such as water. The air in conduit 71 is diverted through moistener 88 by means of valve 89, and, after being further cooled and moistened somewhat, is conveyed through conduit 90 back to room 70 in a cooled, moderately moist condition.

In order to obtain cooling of the conditioned air stream in the regenerator, cool atmospheric air may be led into the regenerator through conduit 91 wherein this air stream will be heated somewhat by the heat stored in the aluminum foil through which the conditioned air stream has just passed. This warm atmospheric air stream may then be further heated if desired in the artificial heater 92, after which it is led through conduit 93 to the absorber 77 for the purpose of reactivating the previously saturated absorbent material therein. The hot air stream is caused to flow into the absorber by reason of the new position of valve 94 in conduit 93. After passing through the absorber, the warm air carrying the moisture liberated from the absorbent material is discharged back to the atmosphere through conduit 95.

The supplemental heat added to the air in conduit 79 and heater 92 may be derived from any convenient source. For instance, if hot products of combustion or other waste warm gases are available, these may be passed through heater 92 in heat exchange relation with the air from conduit 79 in any convenient manner. Obviously, heater 92 may be heated in any other known manner, as by employing solid, liquid, or gaseous fuel.

It will therefore be appreciated that I have provided an air conditioning device functioning in accordance with an entirely new and novel principle, and deriving by far the major portion of the energy required from the heat contained in atmospheric air or the air to be conditioned. It has long been known that atmospheric air contained an enormous quantity of energy, and by the use of the apparatus just described I am enabled to employ this energy advantageously to condition other air. I have also provided auxiliary devices for supplementing and augmenting the energy available from the atmosphere whenever this may be desirable in order to increase the general efficiency and effectiveness of my apparatus.

Furthermore, I have not only provided an air conditioning apparatus incorporating and comprising a novel arrangement of an absorber and a regenerator, but I have also devised both a new absorber and a new regenerator incorporating many novel features not heretofore known or used. And while I have described what I consider a preferred manner of constructing and operating both the individual units and a combination thereof, yet it will be obvious that the various valves and other component elements may be assembled and operated in other manners, each of which has particular advantages in certain applications and under the special conditions then prevailing. It is also obvious that my invention may be practiced by various modifications not herein shown and described without departing from the spiirt of the invention or of the annexed claims.

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