July 8, 1952 G. C. COLLISON 2,602,307

AIR-CONDITIONING METHOD AND APPARATUS THEREFOR

Filed Oct. 31, 1949 3 Sheets-Sheet 1

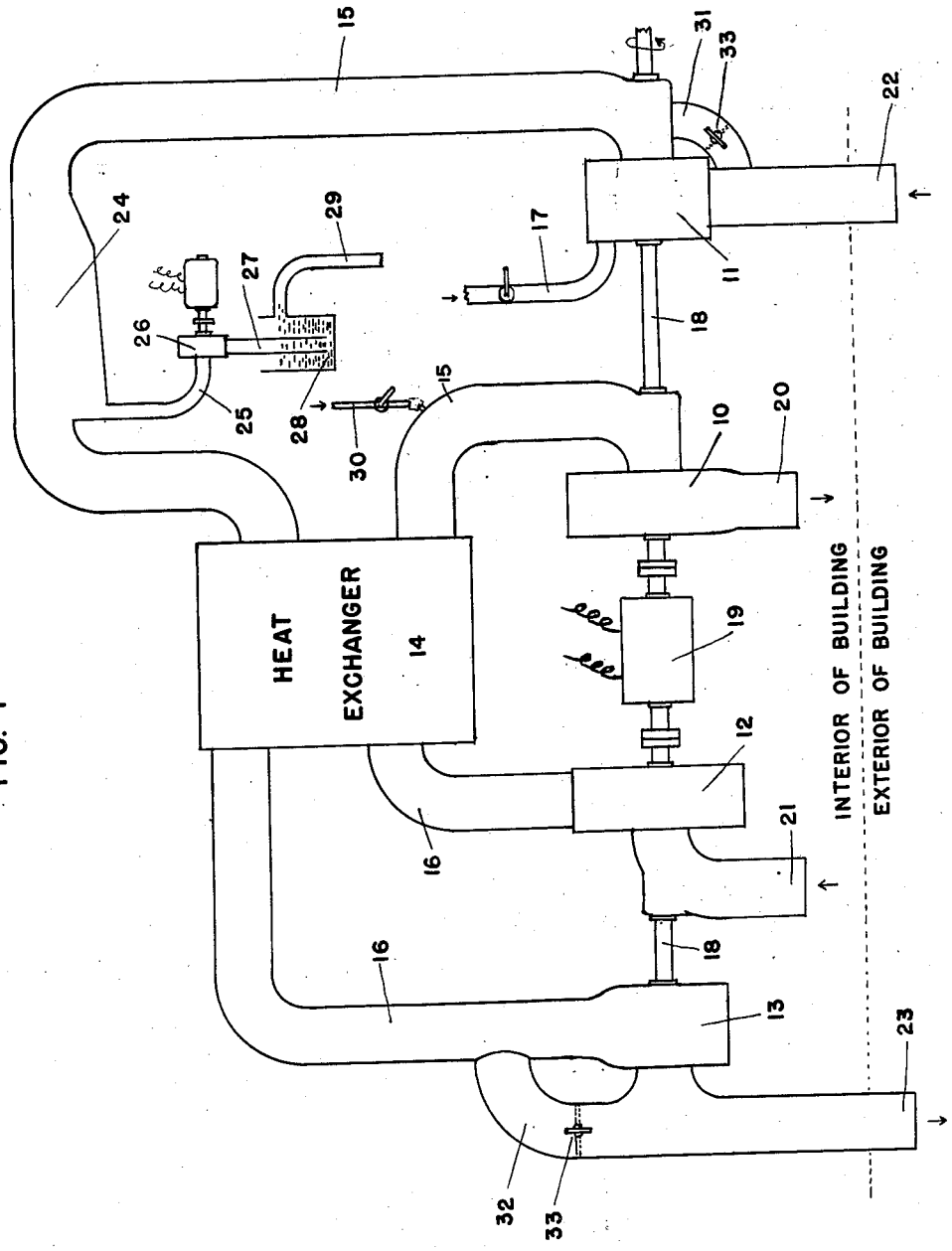


FIG. 1

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FIG. 2

HEAT EXCHANGER 14

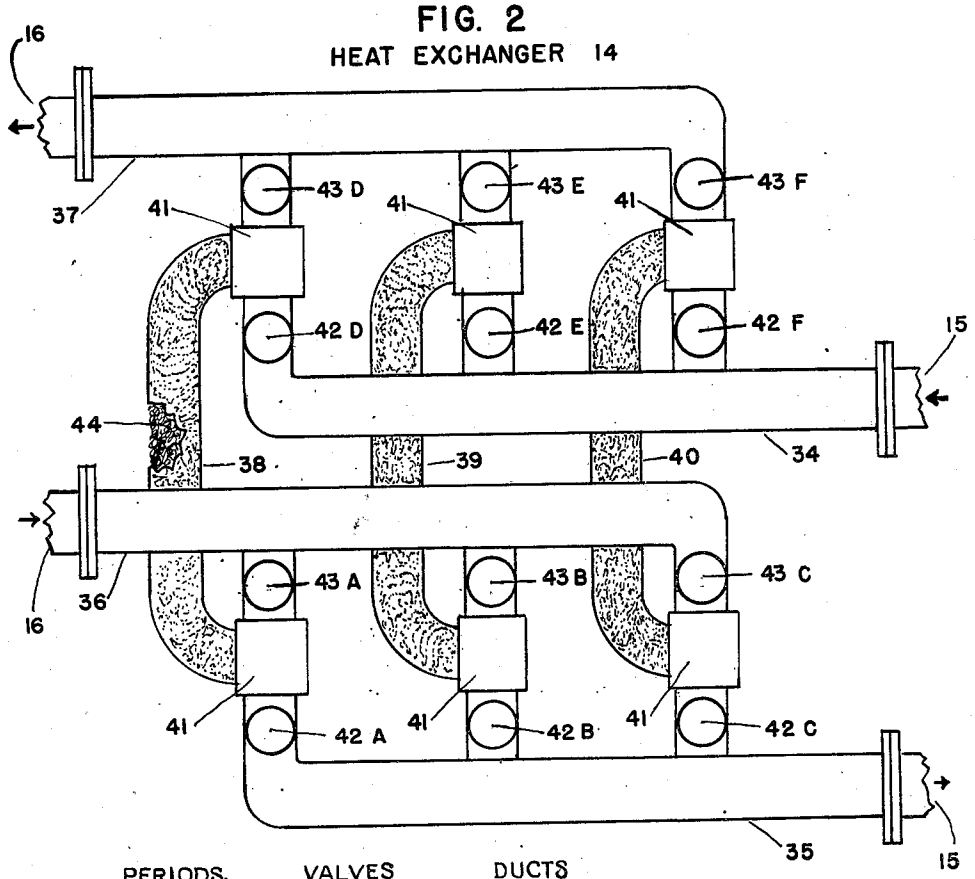
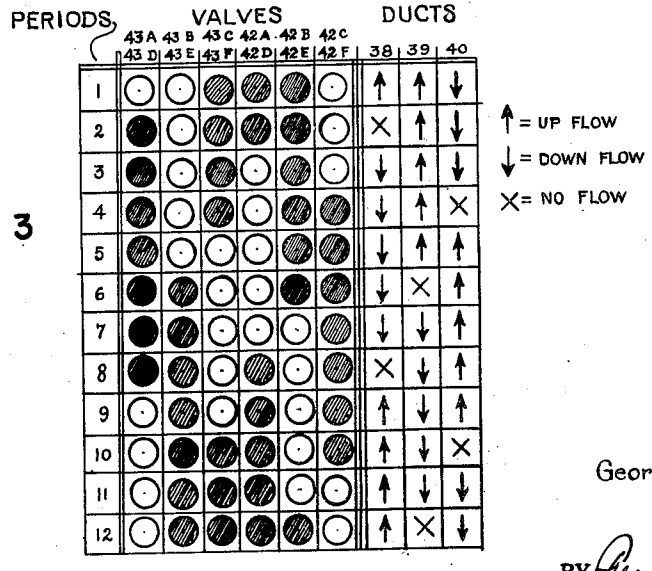


FIG. 3



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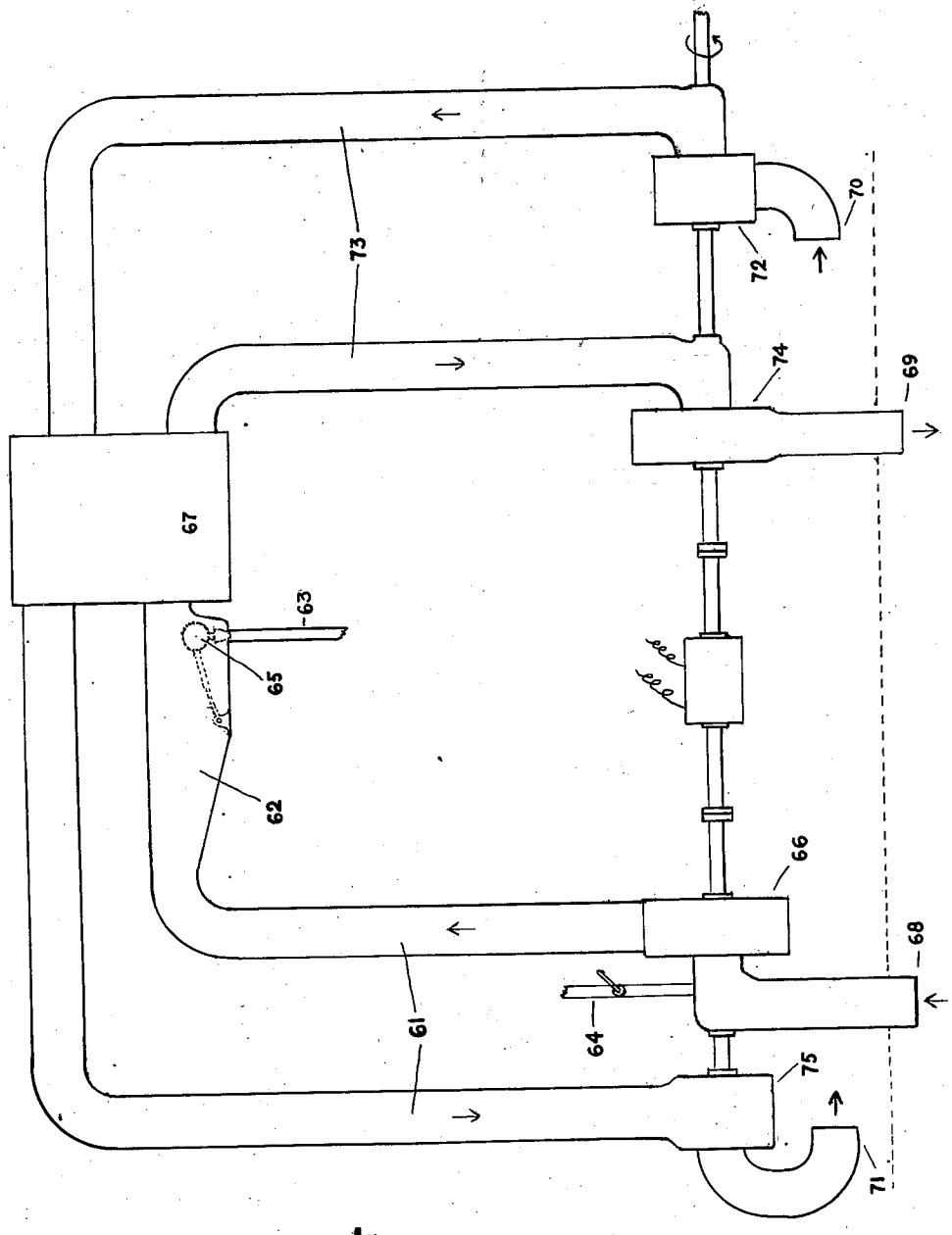


FIG. 4

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2,602,307

AIR-CONDITIONING METHOD AND APPARATUS THEREFOR

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Application October 31, 1949, Serial No. 124,661

11 Claims. (Cl. 62—136)

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The object of the invention is to provide a method and means for treating the interior air of habitable structures, so that the temperature in the latter may be economically maintained at a degree comfortable to the occupants, or so treating air in other inclosures as to economically increase its heat content where heat is a consideration in the use of the inclosure; to provide a method and means for the indicated purpose in which, when heat is desired, it may be obtained from sub-surface earth, or at times from the outside air where, at moderate temperatures, it is inexhaustible; to provide a thermo-dynamic air heating apparatus having a high coefficient of performance; to provide a method and means for himidity control, and for changing the air with sufficient rapidity to constitute, not only ample ventilation, but effective air cleaning as well; to provide a method and means to cool the air when desired; and generally to provide an apparatus for the purpose specified, which is composed of conventional parts, comparatively few in number, and which is therefore susceptible of cheap manufacture, operation and maintenance.

With this object in view, the invention consists of a construction and combination of parts, and a method of operation therefor, of which a preferred embodiment is illustrated in the accompanying drawings, in which:

Figure 1 is a diagrammatic view showing the assembly of parts necessary to practice the invention;

Figure 2 is a similar view of the heat exchanger;

Figure 3 is a chart of the valve movements (for one cycle) in the heat exchanger; also of the corresponding flows through the heat-absorption ducts, for each of the twelve periods of valve operation.

Figure 4 is a diagrammatic view, similar to Figure 1, showing the assembly of parts necessary for the invention to function as a means for super-cooling.

The apparatus employed for practicing the invention with a high coefficient of performance consists of the blower 10 and its smaller, but otherwise almost identical counterpart 11, which latter functions, however, not strictly as a blower, but as a retarding turbine; a similar blower 12, and its similar counterpart, the turbine 13; a heat exchanger 14; a tubular conductor 15, connecting the axial intake of blower 10 with the axial discharge of turbine 11; a like conductor 16, connecting the peripheral discharge of blower

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12 with the peripheral intake of turbine 13; and means, such as the valve controlled pipe or conductor 17, for admitting a heat-carrying medium (water from sub-surface earth, for example) into the conductor system 15.

The two blowers and the two turbines, for purposes of clarity, are shown in the accompanying drawings as consisting merely of a single stage each. The turbines, except for the smaller circumference of the rotors, the direction in which the vanes or impellers are cupped, and the peripheral intake and center exhaust are similar to the blowers. Preferably the two blowers and the two turbines are actuated in synchronism. Toward that end, the impellers or vanes of each pair are mounted on a shaft 18 common to the two, the two shafts being axially aligned and coupled to that of the driving motor 19.

In the embodiment shown, the blowers are of the center-intake peripheral-discharge type, while the smaller turbines take in at the periphery and discharge at the center. The shaft and duct connections between each blower and its peripherally slower turbine are such that the corresponding air current, produced by the blower and forced through the turbine, tends to rotate the vanes of the latter at a rate faster than the speed of the shaft will allow. This constitutes a retardation of the air flow which has two results. The first result is the maintenance, within the conductor connecting the blower with its corresponding turbine, of either a sub-atmospheric pressure, depending on which blower (and its corresponding turbine) is currently considered. The second result is a rotative effort by the turbine that is cumulative rather than opposing; thus the turbine tends to return to the shaft a modicum of the power consumed or absorbed by its corresponding blower, and in consequence, the required demand on motor 19 is, with due allowance for frictional and other losses, approximately the difference between the combined power rating of the two blowers and the combined power rating of the two turbines, rather than the sum of those two quantities.

As the blower 10 and its turbine 11 are connected, they produce a sub-atmospheric pressure in the duct 15 connecting them; blower 12 and its turbine 13, as connected, produce a super-atmospheric pressure in the duct 16 connecting them. The ducts 22 and 23 are, respectively, the ultimate intake and discharge of the system, and are exterior to the equipped building. The ducts 20 and 21 are, respectively, the delivery outlet

of the heated (or otherwise conditioned) air, and the exhausting outlet for used or vitiated air. Both of these outlets terminate within the building, and ordinarily would be coupled directly to the conventional air conditioning system of ducts within the building.

The volumetric space within the conductor **15** (between its blower **10** and its turbine **11**) and the volumetric space within the conductor **16** are respectively referred to herein as the expansion and compression chambers by reason of the functions of their respective blower-turbine couples, and these two chambers are in heat transfer relation within the heat exchanger **14**, as explained in detail hereinafter.

While sub-atmospheric air in the expansion chamber **15** may be heat treated from any available source, it is proposed, as a practical expedient, to do so from water drawn from subsurface earth and, as hereinbefore stated, this is admitted through the pipe or conductor **17**, and preferably through the turbine **11**, the vanes of which break it up into small drops. After its heat is abstracted by the air, this water must be withdrawn, wherefore the conductor **15**, at a point adjacent its entry into the heat exchanger, is formed with a trap **24**, from the lowest point of which a pipe **25** conducts its water content to the intake of a small motor-driven pump **26**, the discharge **27** of which is submerged in the contents of a vessel **28**, with tis outlet below the level of the discharge **29** of the latter. By this means a water-seal is provided to prevent the entrance of exterior air into the expansion chamber through the pump.

One of the functions of which the apparatus is susceptible calls for the admission of moisture into the conductor **15**, and such moisture is admitted through the valve-controlled pipe **30** which is connected to an appropriate water supply.

When used for air conditioning purposes, where reduced temperatures and/or humidity are desired, as in summer time, no useful function can be performed by turbine **13**, therefore it is shunted with the by-pass **32**, this by-pass being provided with a valve or shut-off damper **33** which, when opened, affords passage of air around the turbine **13**, thus voiding the effect (the compression within chamber **16**) that it would otherwise produce. Thus the functions of the whole compression side of the apparatus would be reduced to that of merely maintaining its normal current of air. A similar though modified by-pass **31** is provided around turbine **11**. This by-pass, when its valve **33** is opened, substantially voids the sub-atmospheric pressure within the expansion chamber. However, in order that the chamber may still operate to treat the air with water, this by-pass is formed cross-sectionally smaller than the duct **15**, which results in a slight residual sub-atmospheric pressure in the expansion chamber, even though the valve **33** of this by-pass is fully open. The slight sub-atmospheric pressure within the expansion chamber facilitates the normal entry, through the turbine **11**, of water from pipe **17** into the expansion chamber.

The heat exchanger which establishes the heat transfer relation between the conductors **15** and **16** consists (Fig. 2) of low pressure manifolds **34** and **35**; the high pressure manifolds **36** and **37**; the three heat-absorption ducts **38**, **39** and **40**; the headers **41**, constituting in pairs the terminals of the three heat-absorption ducts; the valves **42** and **43** controlling communication between the several manifolds and the several headers.

The ducts **38**, **39** and **40** enclose each a loose filler **44**, preferably of metal wool, which absorbs heat from high pressure air passing through the ducts and gives it up to the low pressure air later passing therethrough.

As shown in Figure 1 of the drawings, the tubular conductor **15** is separated between the trap **24** and the blower **10**, and the terminals thus provided are connected to the manifolds **34** and **35**. Similarly, the manifolds **36** and **37** are included in the tubular conductor **16**. Thus the two sides of the heat exchanger become elements of the expansion and compression chambers, the interior space of tthe conductors **15** and **16**.

The valves **42** and **43** may be specimens of any conventional valve adapted to intermittent opening and closing, and the present organization calls for the co-ordinated operation of the full complement of valves in such manner that at no time will both the valves **42** and **43** of the same duct be open at the same time. But while this latter is a requirement, it is also required that, where the valves **42** of one duct have been opened, the corresponding valves of another duct shall be opened before the first set close. This requirement applies also to the valves **43** and is necessary (first) to avoid any interruption in the air currents flowing in the low pressure manifolds **34—35** and high pressure manifolds **36—37**, and (second) to avoid the intermingling of the high pressure and the low pressure currents. This prescribed co-ordinated valve movement may be accomplished by any of a number of available conventional means.

But while all the valves **42** and **43** as a set are coordinated, the corresponding valves for each duct are synchronized, that is, they are simultaneously opened or closed.

The operation may be best understood by reference to Figure 3 of the drawings showing one cycle of operations divided into twelve periods. During the first period, with the valves **43A** and **43D**, **43B** and **43E**, and **42C** and **42F** open as shown, air in the low pressure chamber **15** will flow from the manifold **34**, down through duct **40**, into manifold **35**, and air from the high pressure chamber **16** will flow from the manifold **36**, up through ducts **38** and **39**, into manifold **37**. All the other valves being at this instant closed, low pressure air will be excluded from ducts **38** and **39**, and high pressure air will be excluded from duct **40**. But in the next period, valves **43A** and **43D** close, which changes the previously described air paths only to the extent of excluding high pressure air from duct **38**. At the beginning of the third period, the valves **42A** and **42D** are opened, and low pressure air begins to flow from manifold **34**, down through duct **38**, in multiple with the flow of low pressure air downward through duct **40** (as above described). At the beginning of the fourth period, the downward flow of low pressure air through duct **40** is shut off by the closing of the valve pair **42C** and **42F**, and the duct remains inert during the remainder of this period, at the end of which it becomes a conductor for a reverse flow (upward) of high pressure air, upon the opening of valve pair **43C** and **43F**.

It will be seen, by following the full cycle of operations charted in Figure 3, that each pair of valves is open during five periods in the cycle and closed during seven periods; that in every cycle, each duct is subjected to upflow of compressed

air for a sequence of five periods and to downflow of expanded air for a sequence of five periods, with the sequences overlapping in such wise that, during the changeover of one duct from upflow to downflow (or vice versa), there is no interruption to flow in either of the other two ducts. Moreover, at no time will any path be open to permit flow from the high pressure side of the apparatus to the low pressure side.

The heat exchange function is performed by the fillers **44** with which each duct is charged. These fillers, presenting a comparatively extensive area to the high pressure air when the same traverses the ducts, absorb the heat therefrom and conduct it to the low pressure air when the ducts are conductors, in counterflow, for the latter.

While the heat exchanger and compression side of the apparatus are not indispensable to the successful practice of the invention, they do materially increase its efficiency and raise its co-efficient of performance. The expansion side, however, is essential, and without more is susceptible of a highly useful function. By placing the intake **22** of turbine **11** within the inclosure to be heated, the expansion side of the apparatus, divested of the heat exchanger and the compression side, constitutes in itself a complete heating system, adaptable also to summer cooling. Air to be heated, drawn normally from the colder parts of the building, enters expansion chamber **15** through turbine **11**, where the air undergoes expension, due primarily to the exhausting action of blower **10**, and secondarily to the retarding action of turbine **11**. Coincident with its expansion, the current of air is subjected to intimate contact with water drawn from sub-surface earth or other available heat source, the water being fed by pipe **17** directly into the intake side of turbine **11**, where it is dashed into small particles by the rotor of the turbine. Thus the expansion of the air will be nearly isothermal, or at least its temperature drop will be limited to practically the temperature of the copious supply of water fed from pipe **17**. Therefore the otherwise normal thermo-dynamic cooling of the air will be offset by the heat abstracted from the water. When recompression takes place (that is, when the rarefied air in the expansion chamber is forced into the atmosphere against the superior pressure of the latter, and consequently gains or regains that higher pressure) as when the air is discharged from outlet **20** into the equipped inclosure, such recompression will be accomplished adiabatically, with resultant thermo-dynamic heating. This continued process of (nearly) isothermal expansion and adiabatic re-compression results in the addition of substantial increments of heat until the interior air is finally of the desired temperature. Moreover, it is possible to accomplish this result with but moderate air pressure difference, a differential that is within the practical range of rotary types of air-moving machinery.

As the water with which the air is initially saturated is dissipated therefrom, it accumulates, as before explained, in the trap **24** from which it is withdrawn by the pump **26** and discarded or returned to its original source. Since the sub-atmospheric pressure in the chamber **15** must be maintained, the possibility of its loss through the pump **26** is insured against by the contents of the vessel **28** which is always available for pump priming purposes.

In the above mentioned apparatus consisting of the expansion side acting alone as an air conditioning system, ventilation can be effected by dividing inlet **22** into two multiple branches, one of which is extended outside the building. This branch should be valve or damper controlled, so as to regulate the proportion of outside air admitted into turbine **11**.

In providing the compression side of the apparatus and establishing a heat exchange relation between it and the expansion side, the time for attaining the desired temperature in the treated air is materially reduced, as is also the work of maintaining that temperature. A further advantage is, that with two pressure differentials (one for the expansion side and one for the compression side), their degree can be reduced to about one half of the pressure difference required for the expansion side working alone. These two lowered pressure differences are therefore as effective, in their sum, as the single greater pressure difference, and there is a consequent advantage due to the peculiar suitability of rotary air-moving machinery to low pressure and high volume.

As air is discharged into the equipped building or inclosure from the blower **10**, an approximately equal volume of air hitherto therein is removed therefrom by the blower **12**, which it enters through the intake **21** and passes into the conductor (chamber) **16**. But the turbine **13** tends to retard its discharge from the chamber, and the result is compression of the air content of the chamber **16**, but with movement of the same air towards the turbine **13**, and out through the discharge **23**. While under compression (and consequent thermo-dynamic heating), the air in chamber **16** is, as before explained, subjected to contact with the fillers **44**, to which it transfers its heat by conduction, and this heat is picked up in like manner by the expanded air in chamber **15**, as a result of the operation of the heat exchange mechanism hereinbefore explained.

After having its heat abstracted while under compression, the air in the compression chamber **16** passes on, and its impingement on the rotor of turbine **13** effects a drop in pressure (re-expansion) to approximately atmospheric pressure, as the air is discharged through outlet **23**, outside the building into the atmosphere.

It is obvious that the improved apparatus provides for a constant change of air in the equipped building, and that this is accomplished substantially without loss of heat, since the stale air, upon its passage through the compression chamber, has what heat it then contains (heat at temporarily augmented temperature due to the thermo-dynamic heating by compression) abstracted and transferred to expanded air which later undergoes further warming (by thermo-dynamic heating) when it is re-compressed and ejected into the atmosphere within the building.

When exterior air is taken into the expansion chamber and is mixed with the finely divided water therein, its relative humidity approaches 100%. However, after the expanded air has absorbed heat in the heat exchanger, its relative humidity is materially reduced, and upon recompression, as it is discharged through outlet **20**, the relative humidity is still further reduced. No lower relative humidity than that due to the second reduction would be desirable, hence any call for humidity change would be an increase, which may be accomplished by admitting moisture into chamber **15** in the form of spray entering the conductor **15** between the heat exchanger and the blower **10**, and supplied through the valve-controlled pipe **30**.

While the invention, with all parts functioning, is designed primarily for winter use, it is equally effective for cooling and humidity control in the summer time. It is to provide for this latter function that by-passes 31 and 32 are incorporated. When the valve 33 of by-pass 31 is opened, turbine 11 is substantially shunted so that the sub-atmospheric pressure in chamber 15 is correspondingly substantially voided, leaving only a small residuum of reduced pressure, the purpose of which is to facilitate entry of water from pipe 17, through turbine 11 into chamber 15. The relatively smaller cross sectional area of by-pass 31 exerts enough constrictive effect to produce the slightly-lower-than-atmospheric pressure in chamber 15. Operating thus at practically atmospheric pressure, conductor 15 therefore serves simply as a chamber in which the current of warm air is treated with water freshly drawn from sub-surface earth. The result of such treatment is, (1) the reduction of the sensible heat of the air so treated, and (2), if the dew point of the air is higher (as is often the case) than the temperature of the water, the reduction of the humidity of that air.

When valve 33 of by-pass 32 is opened, turbine 13 is shunted so that the otherwise super-atmospheric pressure in chamber 16 is voided. Chamber 16 therefore acts only as a conductor through which air is moved by blower 12 in such wise as to maintain its part of the desired system of circulation of air. This system of circulation comprises the following:

Outside air enters through intake 22, flows through chamber 15, where it undergoes water treatment; it is then expelled within the building, through discharge 20. Inside air enters intake 21, flows through chamber 16 and is expelled outside the building through discharge 23.

For super-cooling, which is desirable in sub-tropical and tropical areas, but slight modification of the structure of Figure 1 is necessary; but such modification is shown in Figure 4.

In the modification the air is untreated on the expansion side but water treated on the compression side which latter consists of the turbine 75 and blower 66 whose peripheral intake and peripheral discharge respectively are connected by the conductor 61 which enters the heat exchanger 67, as in the form shown in Figure 1. But adjacent the heat exchanger the conductor 61 is provided with a trap 62 from which extends a water discharge 63, controlled by a float valve 65, water being injected into the compression side through a valve control pipe 64.

The center discharge 71 of the turbine 75 is interior to the enclosure to be cooled while the center intake 68 to the blower 66 is exterior to the enclosure.

On the expansion side, the turbine 72 and blower 74 have their center discharge and center intake respectively connected by a conductor 73 which enters the heat exchanger 67, as in the form shown in Figure 1; but the peripheral intake to the turbine is interior to the enclosure while the peripheral discharge of the blower is exterior thereto.

In operation, inside air is drawn through the intake 70 and turbine 72 into the conductor 73, the interior space of which functions as an expansion chamber. This air is ejected by the blower 74 through the discharge 69 and, just as in the structure of Figure 1, such air as is in the chamber 73 is expanded. Under expansion, this air is cooled thermo-dynamically and, passing throught he heat exchanger, it absorbs heat prior to discharge through the blower 74 Coincident to this operation, outside air enters through intake 68 and blower 66 into conductor 61, the interior space of which functions as a compression chamber. Water being admitted through the supply pipe 64, the air in the compression chamber has its heat abstracted by such water. De-humidification ensues under appropriate conditions, even when the water is comparatively warm. The air is then further cooled by heat exchange with the expanded air in expansion chamber 73, and passing to the turbine 75, is re-expanded to atmospheric pressure with consequent further cooling and is then discharged into the enclosure.

It is obvious that because of structural similarity of the two embodiments shown in Figures 1 and 4, both functions can easily be incorporated in a single apparatus which may be provided with conventional simple means to allow for alternate operation either for heating, or for super-cooling.

The invention having been described, what is claimed as new and useful is:

1. A method for heating enclosures which comprises repeating in cycles the successive steps of first expanding atmospheric air in the presence of media of high thermal capacity, then recompressing it to its original pressure and delivering it to the enclosure, then withdrawing it and compressing it to superatmospheric pressure while in heat conductive relation to air undergoing the expansion step, and finally discharging it exteriorly of the enclosure.

2. A method for the temperature control of air in habitable enclosures which comprises repeating in cycles the successive steps of first expanding atmospheric air and then reducing it to its original pressure, and second, compressing it to super-atmospheric pressure while in heat-conductive relation to air undergoing expansion, and finally discharging it into the enclosure at atmospheric pressure after subjecting it to one of said steps while discharging it from the enclosure after subjecting it to the other of said steps.

3. Apparatus for the purpose specified which comprises a conductor constituting an expansion chamber, a pair of synchronously driven air displacing units of different capacities connected to the remote ends of said conductor whereby air may be taken in through the smaller unit, expanded, and recompressed and discharged through the larger unit, means for admitting a heat carrying agent of high thermal capacity into the conductor in the presence of the expanded air therein and consisting of a valve controlled water pipe leading from a water source of moderate heat content and discharging on the moving element of the smaller unit for dashing into spray, and a valve controlled by-pass shunting the smaller unit.

4. Apparatus for the purpose indicated which comprises a pair of synchronously driven air displacing units of different capacities, a conductor so connecting the same that air may be taken thereinto through the smaller unit, expanded, and recompressed and discharged through the larger unit, a second pair of synchonously driven air units of different capacities, a conductor so connecting the same that air may be drawn thereinto by the larger unit, compressed, and re-expanded and discharged

through the smaller unit, a heat exchanger in heat conductive relation to both conductors, and means for admitting a heat carrying agent of high thermal capacity into the first said conductor in the presence of the expanded air.

5. Apparatus for the purpose indicated which comprises a pair of synchronously driven air displacing units of different capacities, a conductor so connecting the same that air may be taken thereinto through the smaller unit, expanded, and recompressed and discharged through the larger unit, a second pair of synchronously driven air units of different capacities, a conductor so connecting the same that air may be drawn thereinto by the larger unit, compressed, and re-expanded and discharged through the smaller unit, a heat exchanger in heat conductive relation to both conductors, and a valve-controlled water pipe leading from a water supply source of moderate heat content and discharging into the first said conductor at the smaller unit connected thereto.

6. Apparatus for the purpose indicated which comprises a pair of synchronously driven air displacing units of different capacities, a conductor so connecting the same that air may be taken thereinto through the smaller unit, expanded, and recompressed and discharged through the larger unit, a second pair of synchonously driven air units of different capacities, a conductor so connecting the same that air may be drawn thereinto by the larger unit, compressed, and re-expanded and discharged through the smaller unit, a heat exchanger in heat conductive relation to both conductors, and a valve-controlled water pipe leading from a water supply source of moderate heat content and discharging into the first said conductor on the moving element of the smaller unit connected thereto.

7. Apparatus for the purpose indicated which comprises a pair of synchronously driven air displacing units of different capacities, a conductor so connecting the same that air may be taken thereinto through the smaller units, expanded, and re-compressed and discharged through the larger units, a second pair of synchronously driven air units of different capacities, a conductor so connecting the same that air may be drawn thereinto by the larger units, compressed, and re-expanded and discharged through the smaller units, a heat exchanger in heat conductive relation to both conductors, and means for admitting a heat carrying agent of high thermal capacity into the first said conductor in the presence of the expanded air, and a valve-controlled by-pass shunting the smaller units of each pair.

8. A heat exchanger comprising a plurality of filler charged ducts, manifolds connected to the remote ends of said ducts and designed for connection to fluid carrying conductors whose contents are at different heat levels, and co-ordinated valves controlling communication between the manifolds and the ducts, whereby the fillers in the latter are alternately subjected to contact with the fluids in the different conductors.

9. A method for the temperature control of air in habitable enclosures which comprises repeating in cycles the successive steps of first compressing atmospheric air in the presence of media of high thermal capacity, then expanding it to its original pressure and delivering it to the enclosure, then withdrawing it and expanding it to sub-atmospheric pressure while in heat conductive relation to air undergoing the compression step and finally discharging it exteriorly of the enclosure.

10. Apparatus for the purpose indicated which comprises a pair of synchronously driven air displacing units of different capacities, a conductor so connecting the same that air may be taken thereinto through the smaller unit, expanded and recompressed and discharged through the larger unit, a second pair of synchronously driven air displacing units of different capacities, a conductor so connecting the same that air may be drawn thereinto by the larger unit, compressed and re-expanded and discharged through the smaller unit, and a heat exchanger in heat conductive relation to both of said conductors.

11. Apparatus for the purpose indicated which comprises a pair of synchronously driven air displacing units of different capacities, a conductor so connecting the same that air may be taken thereinto through the smaller unit, expanded and recompressed and discharged through the larger unit, a second pair of synchronously driven air displacing units of different capacities, a conductor so connecting the same that air may be drawn thereinto by the larger unit, compressed and re-expanded and discharged through the smaller unit, a heat exchanger in heat conductive relation to both of said conductors, and means for admitting a heat abstracting agent of high thermal capacity into the second said conductor in the presence of the compressed air therein.

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