Nov. 4, 1941. F. F. BAHNSON 2,261,103

AIR CONDITIONING METHOD AND APPARATUS

Filed Aug. 4, 1938 2 Sheets-Sheet 1

Fig. 1.

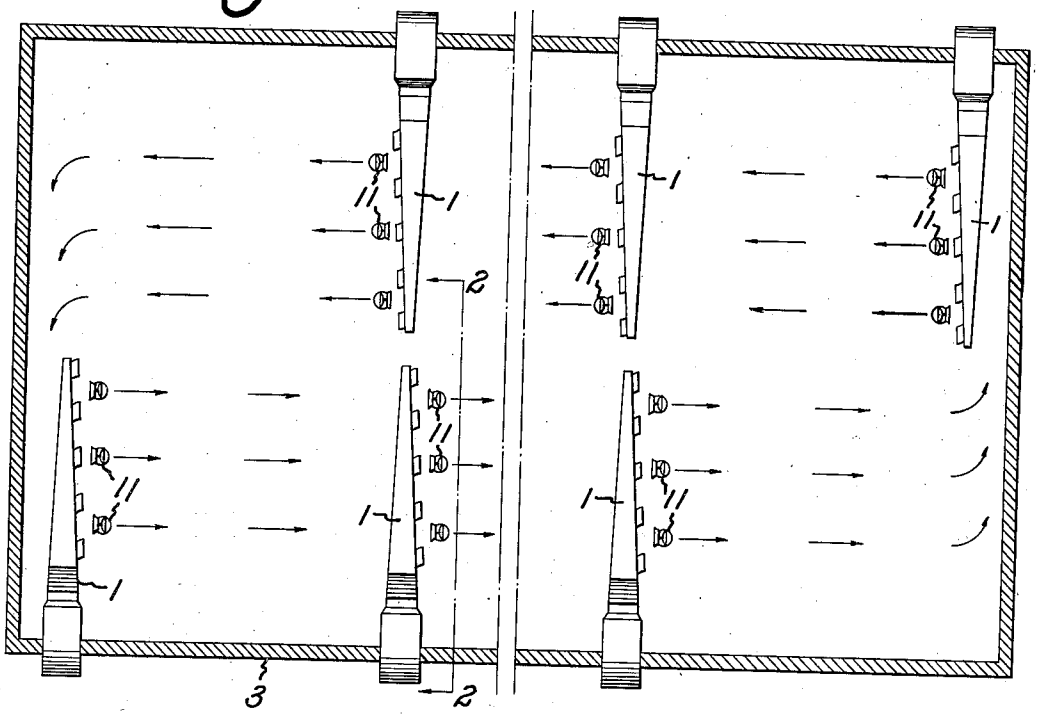
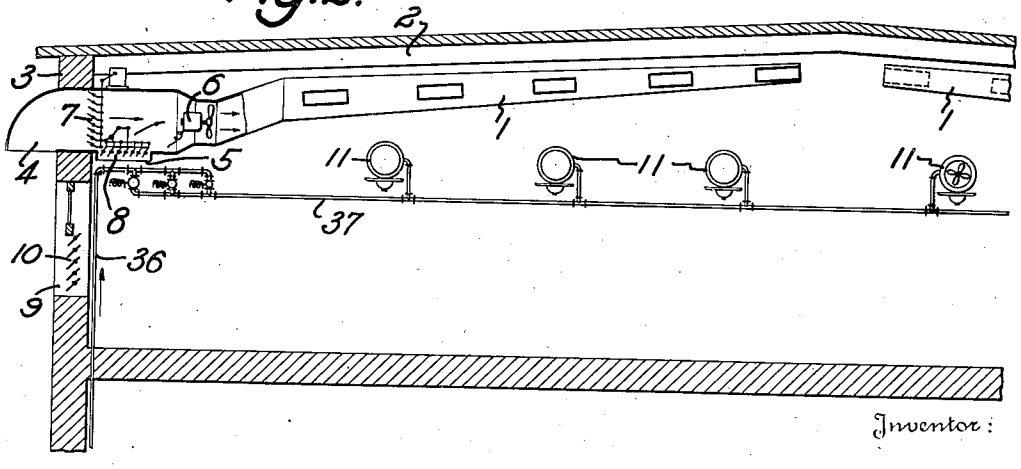


Fig. 2.



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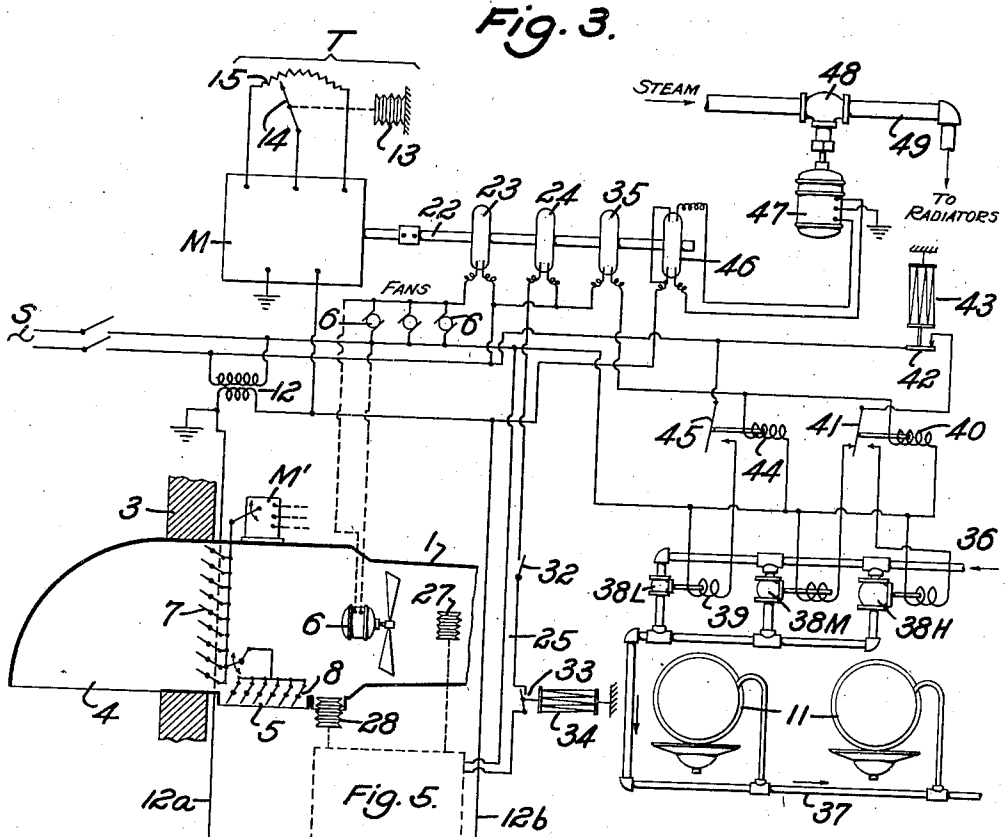
Attorneys.

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AIR CONDITIONING METHOD AND APPARATUS

Filed Aug. 4, 1938 2 Sheets-Sheet 2

Fig. 3.



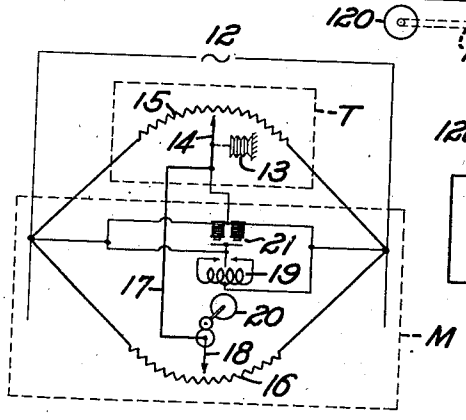


Fig. 4.

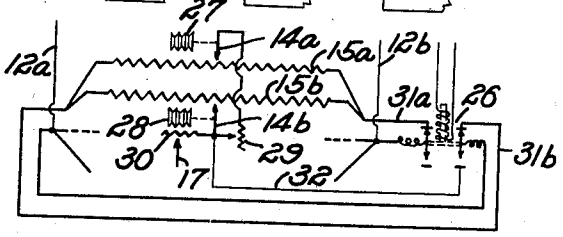


Fig. 5.

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UNITED STATES PATENT OFFICE

2,261,103

AIR CONDITIONING METHOD AND APPARATUS

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Application August 4, 1938, Serial No. 223,132

15 Claims. (Cl. 236—44)

This invention relates to air conditioning methods and apparatus, and particularly to methods and apparatus for ventilating a room and for humidifying the air therein by moisture introduced into the room air.

The invention is particularly applicable to, but not restricted to, the combined ventilating, humidifying and cooling of large work rooms, for example spinning mills, printing shops and the like. Various systems have been used which are characterized by passing air in a closed circuit that includes the room and a conditioning chamber located outside of the room. The cooling and humidifying of the air can be accomplished more efficiently and more uniformly by introducing fresh air and evaporating water at a number of places in the room to be cooled.

The latent heat of evaporation of water at ordinary room temperatures is about 1000 B. t. u. per pound of water, and therefore any humidifier which evaporates water directly into the room acts as a cooling device for the room air. When water is evaporated in any room, with no addition or removal of heat by means other than the evaporation, the ultimate condition is saturation or 100% relative humidity at the temperature of the wet-bulb at which the run started. Since practically no industry can operate at 100% relative humidity, cooling by evaporation only is definitely limited by the permissible humidity which often is less than 60%. But additional cooling may be effected by introducing into the room air with a dew point lower than that within the room. The introduced air may be saturated, as on a cold rainy day, but will require additional moisture or humidification when transferred to a warmer region, as the weight of moisture per cubic foot of air for any given relative humidity doubles for each rise in temperature of approximately 20° F. The cold damp air therefore has a direct cooling action and a further cooling action due to its additional moisture requirements.

Objects of this invention are to provide methods and apparatus for air conditioning which are characterized by the evaporation of water within the room to be cooled, and the circulation of the air in a continuous, closed horizontal path. Objects are to provide methods and apparatus, as stated, in which air is withdrawn from a relatively low level of the room, and air is re-introduced at a higher level, the introduced air being the withdrawn air, fresh air or mixtures of the same in accordance with the existing room and outside temperature and humidity conditions.

These and other objects and advantages of the invention will be apparent from the following specification when taken with the accompanying drawings in which:

Fig. 1 is a fragmentary sectional view of a room provided with an air conditioning system which embodies this invention, the section being taken on an approximately horizontal plane at the ceiling of the room;

Fig. 2 is a fragmentary vertical section on line 2—2 of Fig. 1;

Fig. 3 is a schematic view of the control system, the inlet end of one ventilating duct being shown in vertical section;

Fig. 4 is a circuit diagram of a typical modulating bridge circuit for the control of a motor unit; and

Fig. 5 is a fragmentary circuit diagram of the dew point control system.

The drawings illustrate an application of the invention to the ventilating, cooling and humidifying of the air in a large room, such as the one floor level of a shop or mill. The air is circulated in an approximately oval-shaped path, as indicated by the arrows of Fig. 1, by the discharge of air from the outlets of a plurality of ducts 1 that are located at or adjacent the ceiling 2 of the room. The inlet end of each duct is at an outside wall 3 of the building, and the ducts extend approximately to the center of the room to discharge air longitudinally of the room, the outlets being presented in opposite directions at the opposite sides of the room to establish the circulating air stream. Each duct has an inlet 4 for admitting fresh air and an inlet 5 for withdrawing air from the main air current within the room. Air is forced through the ducts by fans 6 and the ratio of fresh air to re-circulated air which enters the ducts is determined by louvers 7, 8 in the fresh air and re-circulated air inlets 4, 5, respectively. Some air must be vented from the room when fresh air enters at the ducts, and the vent openings 9 are preferably at a relatively low level to impart a vertical component to the air stream. An automatic venting system is readily provided at an appropriate level by replacing the lower sections of several windows with sets of light metal vanes 10. The vanes are pivotally mounted to swing open when the air pressure within the room is a few ounces above the exterior air pressure and to swing to closed position when the

outside air pressure is higher than the pressure within the room.

A plurality of humidifier units 11 are located at the outlet side of each duct, and below the level of the duct outlets. Atomizer heads may be used but preferably, as shown, the humidifiers are of the type described in Bahnson Patent No. 1,891,133 and Simpson Patent No. 1,966,872, as the fans of these humidifiers accelerate the circulation of the air around the room. The relatively dry air from the ducts moves downwardly through the humidifying zone as air travels around the room, and the air is humidified and thereby cooled when it reaches the level of the operators and the machines. The fan motors of the humidifiers preferably operate continuously when the room is occupied and the humidity control system regulates the supply of water to the humidifiers.

The horizontal circulation of the room air in a closed path equalizes conditions at the different regions of the room, and the vertical component of circulation prevents stratification of the air into layers of different temperatures and moisture values. The location of the humidifiers below the duct outlet level promotes the rapid evaporation of a large quantity of water in the air stream that is slowly moving downwardly as it travels around the room. Water mist and vapor tend to rise, but the downward air currents overcome this tendency and the air is at lowest temperature and highest moisture content as it approaches the level of the machines and the workmen.

A combined thermal and hygrometric system for automatically controlling the ventilating fans and humidifiers is shown diagrammatically in Fig. 3. The illustrated control system is of the "modulating" or continuously variable type but it is to be understood that an on-off type of control may be used.

The power for operating the equipment may be the customary alternating current power line, indicated at S, across which a step-down transformer 12 is connected to supply a lower voltage circuit for operating the modulating motors of the control system.

The temperature control unit T is located at some convenient point of average temperature conditions in the room and includes a Sylphon bellows 13 for displacing a contact arm 14 along the resistance 15. As shown in Fig. 4, the resistance 15 and a resistance 16 form the four side arms of a Wheatstone bridge, the conjugate arms being the secondary of the transformer 12 and a lead 17 that connects the contact arm 14 to the slider 18 of the resistance 16. Current flow to the field windings 19 of reversible motor 20 is controlled by a relay 21 to operate the motor when the bridge is unbalanced by a displacement of the contact arm 14, and the motor is geared to and actuates the slider 18 to rebalance the bridge at the new position of the contact arm 14. The direction and the extent of the angular displacement of the motor shaft is thus controlled by the displacement of the contact arm 13 of the temperature control unit T.

This modulating type of motor control is well known but a brief description of the method of operation is included here to facilitate an understanding of the operation of some of the control elements of the air conditioning system. The motor 20 and its associated elements are usually manufactured as a complete unit, indicated by the rectangle M, which can be mounted in any convenient point and the parts 13—15 are manufactured as a separate unit.

The motor 20 of the control unit M actuates the shaft 22 which carries a plurality of switches. The switches may be of the mercury type and preferably are mounted on brackets that may be angularly adjusted on the shaft. Switch 23 controls the power supply to the fans 6 in the ventilating ducts and the switch is so positioned on shaft 22 that the fans are turned on when the room temperature rises to a predetermined point.

Switch 24 supplies current through leads 25 to a relay 26 which exercises a master control upon the regulating system for the dampers in the duct inlets 4, 5; and switch 24 is set to close simultaneously with the switch 23 of the ventilating fan circuit. The damper regulating system is designed to introduce the maximum amount of fresh air for cooling that can pass through the ducts without chilling the ducts below the dew point of the room. A thermostat 27 within a duct 1 responds to the temperature of the mixture of fresh and recirculated air, and a thermostat 28 is positioned in an inlet to the duct to measure the temperature of the recirculated air. As shown in Fig. 5, these thermostats control contact arms 14*a*, 14*b*, respectively, of the resistances 15*a*, 15*b* that are connected in parallel. Contact arms 14*a*, 14*b* are connected through an adjustable resistance 29, and arm 14*b* is connected to cross-arm 17 of the bridge circuit through an adjustable resistance 30.

The leads 12*a*, 12*b* from the transformer 12 are connnected directly to the lower arms of the bridge but are connected to the bridge arms 15*a*, 15*b* through leads 31*a*, 31*b* and the upper contacts of relay 26 when the latter is energized. A back contact of the relay is connected by lead 32 to the sliders 14*a*, 14*b* of the resistance arms, and the open-circuit position of the relay thus connects these sliders to the transformer lead 12*a*. This simulates an adjustment of the sliders 14*a*, 14*b* to the extreme left of the resistances 15*a*, 15*b* and corresponds to an abnormally low temperature in the duct.

The control network of Fig. 5 is indicated in Fig. 3 by the block diagram marked "Fig. 5." The motor 120 of this unit has a shaft 121 which carries a series of contact arms 114 that are displaced along resistances 115 to control the damper motors M' that actuate the dampers 7, 8 of the several ventilating ducts. It is to be noted that these potentiometers 114, 115 correspond to the temperature-actuated potentiometer T of the control system illustrated in Fig. 4. The motor 120 may be, and preferably is, the motor element of one of the damper motors M' but, for clearness of illustration, no damper connection is shown for the motor shaft 121.

The method of operation of the Fig. 5 control bridge of Fig. 5 will be apparent from an inspection of the simpler bridge circuit of Fig. 4. The balance of the bridge is determined jointly by the sliders 14*a*, 14*b* in accordance with the temperature of the air mixture in the duct 1 and the temperature of the recirculated component of that air mixture. Increasing room temperature results in a displacement of slider 14*b* towards the right end of resistance 15*b*, and the resulting unbalance of the bridge circuit energizes the motor 120 to restore a balance, thus actuating shaft 121 to adjust potentiometers 114, 115 to effect an opening of the fresh air dampers 7 and a closing of the recirculated air dampers 8. This

control of the damper setting by thermostat 28 and slider 14a is operative only so long as the duct temperature, as measured by the thermostat 27, does not drop below the room temperature by more than a predetermined value. The permissible temperature difference that will not be accompanied by condensation upon the ducts 1 is determined by relative humidity and the room temperature. There is an approximately constant temperature differentiation between the dew point and room temperature at a predetermined relative humidity when the room temperature varies over a comparatively limited range. The temperature differential may be set by an adjustment of the resistance 29, Fig. 5, and the sensitivity of the control of the dampers by temperature changes at thermostat 28 may be adjusted by the resistance 30.

When the relay 26 is de-energized, the electrical connection of the sliders 14a, 14b to lead 12a creates a condition corresponding to abnormally cold air in the duct 1 and thus results in a complete closing of the fresh air dampers 7. The circuit to relay 26 is opened by switch 24 simultaneously with the opening of switch 23 which controls the ventilating fans 6. A manually operated switch 32 is preferably included in the leads 25 to permit a closing of the dampers 7 while the fans 6 are in operation. An additional switch 33 controlled by an "overrun" hygrostat 34 may also be included in the leads 25. This is a safety feature to prevent the introduction of fresh air when the relative humidity of the outside air is so high that, under special conditions, its introduction would create an excess humidity within the room. This condition could arise when the plant is shut down over a week end, the heat generation within the room being a minimum as the production machinery is not in operation, but the temperature conditions being such that the controls call for an introduction of fresh air for cooling.

Reverting to Fig. 3, the shaft 22 of motor M carries a third mercury switch 35 for adjusting the pressure of the water supplied to the humidifiers 11 in accordance with the room temperature. As explained in Bahnson Patent 1,657,362, the quantity of water which must be supplied to correct a given deficiency in relative humidity increases with the room temperature, and a temperature control of water pressure is therefore desirable. The patent describes a progressive control of pressure but a step-by-step control is indicated in Fig. 3.

A high pressure water line 36 is connected to the humidifier supply pipes 37 through a plurality of pressure regulating valves 38L, 38M and 38H. The valves are of any known type and have the characteristic of a check valve when the outlet pressure exceeds the pressure at which the valve is set to open. As indicated by their relative sizes, valve 38L is set to close at a low back pressure, valve 38M at a medium pressure and valve 38H at a high pressure. The valves may be actuated by motors or, as illustrated, by solenoids 39. Solenoid 39 of the medium pressure valve 38M is connected between one side of the power line from source S and the back contact of a relay 40 that is energized when the switch 35 is closed. The contact arm 41 of relay 40 is connected through switch 42 of the master hygrostat 43 to the opposite side of the power line. The solenoids of valves 38L and 38H are connected to the active contacts of relays 40, 44, respectively, and contact arm 45 of relay 44 is returned directly to the power line. Hygrostat 43 and switch 42 therefore control the intermediate pressure reducing valve 38M when the switch 35 is open and relays 40, 44 are de-energized, and control the higher pressure valve 38H when switch 35 closes to energize relays 40, 44.

The low pressure valve 38L acts as a by-pass around the high pressure valve 38H when the system is in operation at temperatures that require the higher pressure water supply. The large volume of fresh air introduced by the ventilating fans would produce a quick drop in relative humidity if the water supply to the humidifiers were completely closed, and the high pressure valve 38H would open and close at short intervals if the water supply to the humidifiers were controlled solely by the high pressure valve. The valve 38L remains closed so long as high pressure valve 38H is open, but valve 38L opens automatically to supply the humidifiers with a limited quantity of water when the relative humidity reaches the desired value and the valve 38H is closed. This limited quantity will not prevent a drop in the relative humidity, but it does decrease the rate of change of humidity and thus prevents a "hunting" of the control system when the room temperature is high and a large volume of fresh air is introduced into the room.

The air conditioning system of Fig. 3 includes means for heating the room when the temperature falls below a predetermined point. The control switch 46 of the heating system is a single pole, double throw mercury switch on the shaft 22 of the motor M. The switch selectively connects the windings of a reversible motor 47 to transformer 12 to actuate the valve 48 in the steam line 49 to radiators, not shown. The angular adjustment of switch 46 on motor shaft 22 is such that the steam valve 48 will be opened when the room temperature drops several degrees below the point at which the ventilating fan switch 23 is opened.

The operation of the system is as follows. The room temperature may be so low at an early morning hour that the main temperature control T, M brings shaft 22 into position to close the "starting" contacts of the heat control switch 46. Steam valve 48 is opened by motor 47, and heat is supplied to the room. The humidity control switch 42 is connected to solenoid 39 of the intermediate pressure reducing valve 38M since switch 35 is open and relay 40 is not energized. Water will be supplied to the humidifiers at a relatively low rate through valve 38M when the switch 42 is closed by the hygrostat 43. The ventilating fans are not operating and the fresh air dampers are completely closed since switches 23 and 24 are open.

Increasing temperature at control unit T actuates the motor unit M to tilt switch 46 to reverse motor 47 and close the heating valve 48. A further rise in temperature results in the actuation of motor shaft 22 to close switch 23 of the ventilating fan circuit and switch 24 of the damper control system. The closing of switch 24 energizes relay 26 and its contacts move into the positions shown in Fig. 5. The circuit through lead 32 is thus broken and the control of the motor 120 is thus returned to the temperature-actuated sliders 14a, 14b. Motor 120 is immediately energized to shift the arms 114 on the resistances 115 to effect movement of the damper regulator motors M' to some intermediate posi-

tion to open the fresh air dampers 7 and to shift the recirculated air dampers 8 to closed or partially closed position. The settings of the dampers 7, 8 will be adjusted in accordance with the temperature at thermostat 28 so long as the temperature within the duct, at thermostat 27, remains above the point at which moisture will condense on the ducts. The duct temperature cannot drop below the dew point as the temperature-difference network of Fig. 5 is so adjusted that thermostat 27 shifts slider 14b on resistance 15b to effect a partial closing of the fresh air dampers when the duct temperature drops below the room temperature by a predetermined value. Any failure of the master humidity control which tends to produce excessive humidity causes the overrun hygrostat 34 to open the switch 33, thus opening the circuit to relay 26. Sliders 14a, 14b are thereby connected to the "cold" end of resistances 15a, 15b by the lead 32, and this actuates the motor 120 to shift the damper control potentiometers to close the fresh air dampers.

The increasing room temperature requires an increased evaporation of water to maintain the relative humidity, and switch 35 on motor shaft 22 is closed at or somewhat above the room temperature at which the ventilating fans were started. Relays 40, 44 are thus energized to shift the humidity control circuit to solenoid 39 of the high pressure valve 38H, and to connect the solenoid of low pressure valve 38L across the power line. The humidity control 42, 43 now operates on the high pressure valve and, when the latter is closed, the low pressure valve 38L opens automatically to prevent rapid changes in the relative humidity.

It will be apparent that the described embodiment is illustrative of the invention and that many changes may be made in the design, construction and relation of the various control members without departing from the spirit of my invention as set forth in the following claims.

I claim:

1. Process of conditioning the air within a room which comprises impelling said air in the direction of a substantially horizontal closed path to set up a circulation thereof within the room, withdrawing air from the room at a relatively low level thereof, returning the withdrawn air to the room at a plurality of points at a higher level than that at which it is withdrawn and introducing moisture into the circulating air at a plurality of points at a level not higher than that at which the withdrawn air is returned to the room.

2. The process as claimed in claim 1, wherein the moisture is introduced into the circulating air within the room at a level substantially above the floor and below the level at which air is returned to the room.

3. The process of conditioning the air within a room which comprises setting substantially the entire body of air within the room into circulation in the direction of a closed substantially horizontal path, withdrawing air from the room at a relatively low level thereof and returning the withdrawn air to the room at a plurality of points at higher level, and introducing moisture into the circulating air at a plurality of spaced points located between said withdrawal and return levels.

4. The process of conditioning the air within a room which comprises establishing a circulation of substantially the entire body of air within the room in the direction of a closed substantially horizontal path introducing moisture into the circulating air at a plurality of spaced points at a level substantially above the floor of the room, withdrawing air from the room at a level below that of moisture introduction, and returning the withdrawn air to the room at a level above that of moisture introduction and with a horizontal component to assist in the circulation of the air.

5. The process as claimed in claim 4, in combination with the step of admixing with the returned air a quantity of fresh air of lower moisture content than the air within the room.

6. In an air conditioning system, the combination with side walls, floor and ceiling defining a room, of means within the room for setting the air therein into circulation in the direction of a closed substantially horizontal path, a plurality of ducts extending from certain of said side walls towards the center of the room, said ducts having outlets for delivering air into the room in the direction of flow of said circulating air, inlets for admitting room and outside air into said ducts, fan means for forcing air through said ducts and outlets into the circulating air, dampers in said inlets, and humidifier means for introducing moisture into the circulating air below the outlets from said ducts.

7. Apparatus as claimed in claim 6, the combination with said dampers, of means for automatically adjusting said dampers to control the proportions of room and of outside air passing through said ducts to prevent moisture condensation on the outside of said ducts.

8. In apparatus for conditioning the air within a room of rectangular plan, the combination with the side walls of the room, of ducts extending inwardly from the side walls towards the center of the room, said ducts having outlets, the outlets of the ducts at opposite sides of the room being oppositely directed, means for forcing air from said ducts into said room with a horizontal component tending to set the room air into circulation in the direction of a horizontal closed path, inlets for admitting into said ducts room air from a level below the duct outlets, inlets for admitting outside air into said ducts, and means for introducing moisture into the room air at a level below said duct outlets.

9. Apparatus as claimed in claim 8, in combination with means for regulating the relative quantities of room air and of outside air entering said ducts, and means controlled jointly by the room air temperature and the air mixture temperature for adjusting said regulating means to maintain the temperature of the air mixture within the ducts above its dew point.

10. In an air conditioning system of the type in which moisture is introduced directly into the room, a plurality of humidifying devices within said room, a high pressure water line, a plurality of pressure reducing valves connected between said water line and said humidifiers, said valves being set to pass water at different pressures, hygrostatic means for controlling the opening of a valve to admit water to said humidifiers, and temperature-controlled means for determining the valve which is actuated by said hygrostatic means.

11. An air conditioning system as claimed in claim 10, wherein a valve set to pass water at a relatively low pressure is rendered operative by said temperature-controlled means when the latter selects one of the higher pressure valves for actuation by said hygrostatic means, whereby said low pressure valve opens automatically to admit a limited supply of water to said humidifiers when said higher pressure valve is closed.

12. An air conditioning system for adjusting the temperature and moisture content of the air within a room, said system including means for setting the air into circulation in the direction of a closed substantially horizontal path, means for introducing moisture into said circulating air at a plurality of points, means for withdrawing air from the room at a low room level and for returning the same at a higher room level, means for admixing fresh air with the returned room air, temperature-controlled means for regulating the ratio of returned room air to fresh air, and hygrometric means for preventing the introduction of fresh air when the relative humidity within the room rises to a predetermined value.

13. An air conditioning system as claimed in claim 12, in combination with temperature-controlled means for admitting heat to said room when the room temperature falls to a predetermined value.

14. An air conditioning system as claimed in claim 12, wherein said means for introducing moisture are located at a level below that at which air is returned to the room and above the level at which air is withdrawn from room.

15. Apparatus for conditioning the air within a room comprising means for setting said air into circulation in the direction of a closed substantially horizontal path, a plurality of ducts having outlets directed to deliver air horizontally in the direction to assist the circulation of the air, inlets for admitting air from the room into said ducts at a level below that of said outlets, fresh air inlets for said ducts, fan means for forcing air from said ducts through said outlets and into the circulating air, and means for introducing moisture directly into the circulating air within said room at a level intermediate the duct outlets and the room air inlets thereof.

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