

June 16, 1942.

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2,286,604

AIR CONDITIONING SYSTEM

Filed June 25, 1938

2 Sheets-Sheet 1

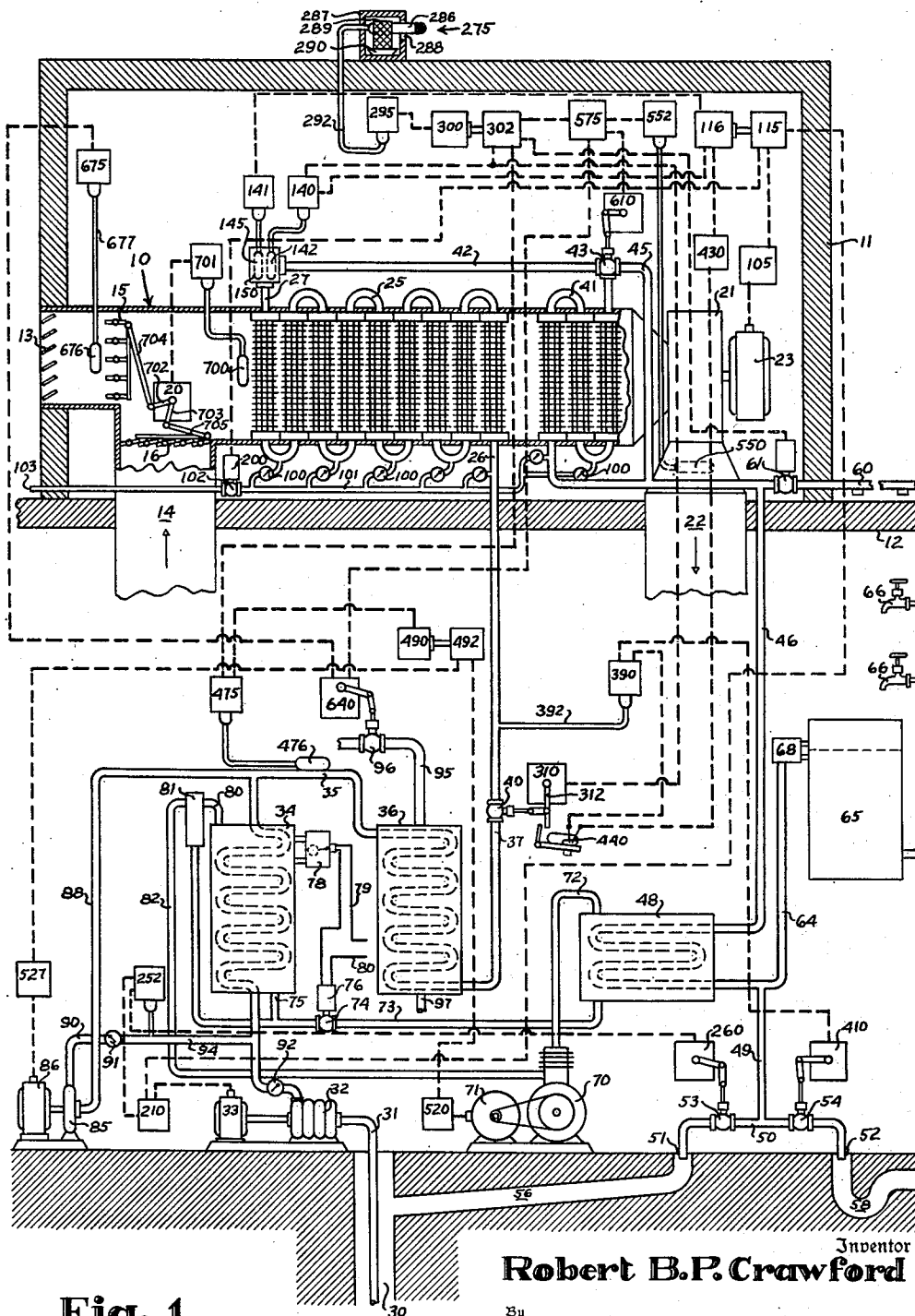


Fig. 1

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2,286,604

AIR CONDITIONING SYSTEM

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Application June 25, 1938, Serial No. 215,805

30 Claims. (Cl. 257—3)

This invention relates to an air conditioning system and more particularly to an air conditioning system wherein a supply of water such as well water is utilized for heating or cooling a building.

In accordance with my invention I provide an air conditioning chamber provided with suitable heat exchanger coils through which water is circulated, this water coming from a suitable source of supply such as a well with means for further heating or cooling the water in accordance with the heating or cooling demand of the building. The invention is more particularly concerned with the provision of suitable control means for controlling the temperature and rate of flow through the heat exchanger coils and for maintaining a suitable pressure within the coils so as to insure a suitable heat exchange condition within the coils.

It is therefore an object of my invention to provide a novel air conditioning system for a space to be conditioned.

More particularly it is an object of my invention to provide an air conditioning system of the type utilizing water from a suitable source of supply such as a well for heating or cooling the air to be conditioned with means for regulating the temperature and the rate of flow of water to the air conditioning unit in accordance with the heating or cooling demand on the system.

A further object of my invention is the provision of means for preventing the freezing of the water in the coils during the winter-time by providing automatic means for draining the water from the coils should the temperature of the water leaving the coils drop to a dangerously low value.

A further object of my invention is the provision of suitable control means for a system of the class described for controlling the temperature and rate of flow of the cooling fluid in such a manner as to insure economical operation thereof and to prevent exhausting of the source of supply without unduly heating or cooling the source of supply as the case may be when the source of supply is adequate.

Other objects and advantages of my invention will become apparent upon a study of the specification, claims, and appended drawings wherein like reference characters represent like parts in the two views, and wherein

Figure 1 is a schematic diagram of an air conditioning system embodying my invention, and

Figure 2 is a wiring diagram of the control system illustrated in Figure 1.

Referring more particularly to Figure 1 an air conditioning chamber is represented generally by the reference character 10 and is illustrated as being located within a chamber or penthouse 11 located upon a roof 12 of the building to be conditioned. While the air conditioning chamber is illustrated as being located on the roof of a building it will be understood that this chamber may be otherwise suitably located. The chamber 10 includes a fresh air inlet 13 and a return air inlet 14 which communicates with the interior of the building to be conditioned. The flow of air through the fresh air inlet 13 and the return air inlet 14 may be controlled by suitable dampers 15 and 16 which are suitably connected to a motor 20 operating in a manner to be hereinafter described. A fan 21 is provided for drawing air into the chamber 10 and exhausting it through the outlet 22 which communicates with the interior of the building being conditioned. A motor 23 is provided for driving the fan 21 and this motor is illustrated in Figure 2 as being a multi-speed motor.

Located within the chamber 10 is a heat exchanger coil 25 having an inlet at 26 and an outlet at 27. Water or other cooling medium is caused to flow through the coil 25 in counterflow relationship with respect to the flow of air by the fan 21. Water may be supplied to the coil 25 from a well 30 or any other suitable source of supply, the water being drawn through the pipe 31 by means of the pump 32 driven by a motor 33 and forced through a heat exchanger unit 34. The water flows from the upper portion of the unit 34 through a pipe 35 to a second heat exchanger unit 36 from which it flows through a pipe 37 to the inlet 26 of the coil 25, the flow of water to the coil being controlled by a valve 40 operated in a manner to be described. A second heat exchanger 41 is located in the air conditioning chamber 10 downstream of the heat exchanger unit 25, this unit 41 serving as a reheater in the cooling season. The water leaving the unit 25 flows through a pipe 42 to a three-way valve 43 which valve controls the flow of water to the reheater 41 and the water may also flow through a pipe 45 which by-passes the reheater 41, the amount of water flowing through the reheater and by-passing the reheater depending upon the setting of the valve 43 which is operated in a manner to be set forth.

From the reheater 41 and the by-pass 45 the water flows through a pipe 46 through a heat exchanger 48 which forms a condenser of a refrigeration system to be described and from the

condenser 48 the water flows through pipe 49 to a pipe 50 provided with outlets 51 and 52. Valves 53 and 54 control the flow of water to the outlets 51 and 52, respectively, these valves being controlled in a manner to be henceforth set out. The outlet 51 communicates with a subterranean channel 56 which in turn communicates with the well 30. The outlet 52 empties into a waste pipe 58 by means of which the water may be led to a sewer or may be otherwise disposed of. Located above the roof 12 is a spray 60 which communicates by means of a valve 61 with the outlet of the heat exchanger 41 and the by-pass 45. The outlet from the condenser 48 also communicates by means of a pipe 64 with a tank 65 for providing water for domestic purposes to suitable faucets 66, etc. Communications between the pipe 64 and the tank 65 may be controlled by a float valve 68 of suitable well known construction and the upper portion of the tank may be provided with air under pressure to cause the water from the tank 65 to rise to the faucets 66 when these faucets are opened.

For cooling the water leading to the coil 25, I have illustrated a refrigeration system of any suitable construction the system herein disclosed comprising a compressor 70 driven by a motor 71 which is controlled in a manner to be set forth. The outlet of the compressor 70 communicates by means of a pipe 72 with the condenser 48 and from the condenser the refrigerant flows by means of a pipe 73 and a valve 74 to the inlet 75 of the heat exchanger 34 which serves as the evaporator of the refrigeration system. The valve 74 is illustrated as being a solenoid type valve, this valve including a solenoid 76 which is controlled by means of a suitable float switch 78 so that when the level of refrigerant in the evaporator 34 drops to a predetermined value the solenoid will be energized by means of conductors 79, switch 78, and conductor 80, it being understood that conductors 79 and 80 are connected to a suitable source of power (not shown). From the evaporator 34 the refrigerant flows through a pipe 80, a trap 81, and a pipe 82 back to the inlet of the compressor 70. Liquid refrigerant is prevented from getting back to the compressor since this refrigerant is caught in the trap 81 and is returned to the evaporator 34. It will now be understood that when the compressor 70 is in operation the refrigerant surrounding the coil through which water flows in the evaporator 34 will reduce the temperature of the water therein so that the water will be supplied to the coil 25 in the air conditioning chamber 10 at a temperature which is lower than the temperature of the water in the well 30 or other source of supply.

In order to increase the heat transfer within the evaporator 34 the water is caused to circulate through the coil therein at an increased rate by means of a pump 85 driven by means of a motor 86 controlled in a manner to be described. The inlet of the pump 85 communicates by means of a pipe 88 with the outlet of the coil in the evaporator 34 and the water flows from the pump 85 through a pipe 90 which communicates with the inlet of the coil in the evaporator 34. A check valve 91 is provided in the pipe 90 to prevent water flowing from the pump 32 to the outlet of the pump 85 and a second check valve 92 is provided in the outlet of the pump 32 to prevent flow of water by the pump 85 back to the outlet of the pump 32.

For the purpose of heating the water leading

to the heat exchanger 25 when outside conditions require, the heat exchanger 36 is provided and steam is admitted to this heat exchanger by means of a pipe 95 controlled by a valve 96 which is controlled in a manner to be described, the steam leaving the heat exchanger 36 through a pipe 97.

The bottom loops of the coils 25 and 41 communicate by means of check valves 100 with a pipe 101 which serves to drain the temperature of the water from the coils when the water in the outlet of the coil 25 drops to a dangerously low value. The flow of water through the pipe 101 is controlled by a valve 102 and when the valve 102 is opened in a manner to be described the water flows from the coils through the pipe 101 to the outlet 103 which may empty onto the roof or be connected to a suitable waste pipe.

Referring now to Figure 2 the means for controlling the operation of the fan motor 23 will be described. This motor is connected by means of a suitable starter box 105 which is in turn connected by means of conductors 106, 107, and 108 with a suitable source of power (not shown). It will be understood that this starter box includes suitable windings which control the speed of the motor 23 but since the construction of this starter unit forms no part of the present invention the details thereof are not being illustrated. When the terminals 109 and 110 are connected together the fan motor runs at low speed, when terminals 109 and 111 are connected together the motor runs at a higher speed and when terminals 109 and 112 are connected together the fan runs at a still higher speed. A suitable step controller indicated generally by the reference character 115 is provided for controlling the speed of the motor 23. This controller includes a motor 116 which may be a proportioning motor of the type illustrated in Patent 2,028,110 issued to D. G. Taylor on January 14, 1936. This motor carries on its shaft 117 a plurality of cams designated by the reference characters 118, 119, 120, and 121. These cams control the positions of mercury switches 122, 123, 124, and 125 as is apparent from the drawings. When the cams rotate in a counter-clockwise direction the switch 125 will first be moved to open position followed by the opening of the switch 124 which is in turn followed by the simultaneous opening of the switch 123 and moving of the switch 122 to open the contacts which are illustrated as being closed and to bridge the opposite set of contacts. With the switches in the positions illustrated it will be apparent that the terminal 109 of the starter unit 105 is connected to the terminals 110, 111, and 112 so that the motor 23 is operating at its highest speed and the fan 21 driven thereby is causing a maximum flow of air through the air conditioning chamber 10. The terminals 110, 111, and 112 are connected by conductors 130, 131, and 132 to the switches 123, 124, and 125, respectively. The terminal 109 is connected by means of the conductors 133, 134, and 135 to the mercury switches 123, 124, and 125, respectively. A manual switch 140 controls the connection between the terminal 109 and all the mercury switches so that the motor 23 may be stopped at any time by operation of the manual switch 140.

The operation of the motor 116 is controlled by the controllers 140 and 141. The controller 140 includes a bulb 142 connected by means of the capillary tube 143 to a bellows 144, this tube, bulb, and bellows being provided with a suitable volatile fluid so that the bellows 144 will be

caused to expand or contract in accordance with variations in temperature affecting the bulb 142. The controller 141 similarly includes a bulb 145 connected by means of a capillary tube 146 to a bellows 147, this tube, bulb, and bellows also being provided with a suitable volatile fill. As will be noted upon reference to Figure 1 the bulbs 142 and 145 are mounted in a chamber 150 which comprises the connection between the outlet 27 of the heat exchanger 25 and the pipe 42. The bulbs 142 and 145 are therefore subject to the temperature of the water leaving the heat exchanger unit and accordingly the bellows operated thereby will expand or contract in accordance with changes in temperature of the water leaving the unit 25.

The controller 140 also includes a bell crank lever pivoted at 152, one arm 153 of this lever being biased by means of a spring 154 into engagement with the upper portion of the bellows 144 and the other arm 155 being arranged to sweep across a potentiometer resistance 156. A link 157 provided with an insulated portion 158 is connected to a control arm 160 pivoted at 161 and arranged to sweep across the potentiometer resistance 165. As the bellows 144 expands or contracts the arms 155 and 160 will be caused to move in unison as will be understood across their respective resistances. The resistances are so arranged that the arm 155 will move to the right end of its resistance before the arm 160 will start to move across its resistance 165. The arm 160 and resistance 165 form the main control elements for the proportioning motor 116 of the step controller 115. The upper terminal of the motor 116 designated B is connected to the left end of the resistance 165 by means of a conductor 170. The terminal W of the motor 116 is connected by means of a conductor 172, the adjustable resistance 173 and conductors 174 and 175 to the right end of the resistance 165. The center terminal R of the motor 116 is connected to the control arm 160 by means of a conductor 178, a switch arm 179, contact 180, and conductor 181. Power may be supplied to the motor 116 by means of conductors 185 and 186 to a suitable source of power (not shown). Upon reference to the above mentioned Taylor patent it will be understood that the shaft 117 driven by the motor 116 will assume positions corresponding with the position of arm 160 with respect to resistance 165. In the position illustrated with the arm 160 at the extreme right end of the resistance 165 the shaft 117 has been rotated by the motor 116 to one extreme position. When the temperature of the water leaving the unit 25 drops to a low enough value which may be 75° F., the contraction of the bellows 144 will cause the arm 160 to start moving across the resistance 165 towards the right. When this happens the shaft 117 will start moving the cams carried thereby in a counter-clockwise direction so that as the temperature of the water leaving the unit 25 drops the speed of the motor 23 will be reduced in a step by step manner. The provision of the resistance 173 in the circuit to the terminal W of the motor 116 prevents the motor from moving far enough to open the mercury switch 123 under the influence of the controller 140.

The controller 145 controls the position of a mercury switch 190 carried by a lever 191 biased by means of a spring 192 into engagement with the upper portion of the bellows 147. This mercury switch 190 is arranged to short-circuit the resistance 173 when the switch is moved to closed

position, this short-circuiting taking place by means of conductors 193 and 194 connected to opposite ends of the resistance 173. Thus when the temperature at the bulb 145 which is at the outlet of the heat exchange unit 25 drops to a sufficiently low value such for example as 34° F., the mercury switch 190 will be moved to closed position through shunting out the resistance 173 whereupon the motor 116 will cause clockwise movement of the cams 118 and 119 so that the switches controlled thereby will be tilted in the opposite direction from that illustrated. When this happens the motor 23 stops operating so that no air is drawn through the air conditioning chamber 10 by the fan 21. A spring arm 198 is positioned to hold the lever 191 in the position it assumes when the switch 190 is tilted to closed position regardless of a subsequent rise in temperature at the bulb 145 so that it will require manual attention to permit the switch 190 to move back to its open position and thus breaking the shunt around the resistance 173.

The valve 102 which permits the water to drain from the coils 25 and 41 is controlled by the switch 122 operated by the cam 118 of the step controller 115. A solenoid 200 is provided for opening the valve 102 when the solenoid is energized. When the switch 122 is tilted to its opposite position by reason of a drop in temperature at the outlet of the coil 25 the solenoid 200 is energized through the conductor 201, switch 122, conductor 202 to the solenoid 200 and conductor 203, the conductors 201 and 203 being connected to a suitable source of power (not shown).

From the foregoing it will be understood that the speed of the fan 21 is controlled by the controller 140 so that as the temperature of the water leaving the heat exchanger unit 25 drops from a value of say 75° F. to 70° F., the speed of the fan will be reduced in a step by step manner from a maximum speed to a minimum speed. Whenever the temperature of the water leaving the unit 25 is sufficiently high so that the arm 160 is at the extreme left of the resistance 165 the fan will operate at its maximum speed. Should the temperature of the water leaving the unit 25 drop to a sufficiently low value as for example to 34° F., indicating that upon a further drop there might be danger of freezing the coils 25 and 41 the controller 141 interrupts the operation of the fan and opens the drain valve 102 thus permitting the water to drain from the coils and stopping the flow of air thereof by the fan 21.

The motor 33 for operating the pump 32 which pumps water from the well 30 to the heat exchangers in the air conditioning chamber is shown as being controlled by means of a relay designated by the reference character 210. This relay includes a relay coil 211, an armature 212 and switch arms 213, 214, 215, and 216 operatively connected to the armature 212. Power is supplied to the motor 33 by means of conductors 217, 218, and 219 and it will be understood that when the relay 210 is energized and the arms 213, 214, and 215 move into engagement with their cooperating contacts the motor 33 will be energized and water will be pumped from the well by means of the pump 32 to the coils 25 and 41 in the air conditioning chamber 10. The relay 210 is designed to be manually energized by means of a normally open switch 224. When this switch is depressed current will flow through the relay coil 211 as follows: from the conduc-

tor 219 through conductors 226, 227, switch 224, conductor 228, relay coil 211, conductor 229, the mercury switch 122, it being assumed that this switch is in the position illustrated and conductor 230 to the conductor 218 connected to the source of power. The relay is now energized and upon movement of arm 216 into engagement with its cooperating fixed contact a holding or maintaining circuit for the relay 211 which is independent of the manual switch 224 is established this maintaining circuit for the relay 210 is as follows: from the conductor 219 through conductors 226, 235, the switch arm 216, conductor 236, a switch member 238, conductor 239, a normally closed mercury switch 240, conductor 241, relay coil 211, conductor 229 through the mercury switch 122 in the step controller 115 and conductor 230 to the conductor 218 connected to the source of power. It will now be understood that the energization of relay 210 is not dependent upon the manual normally opened switch 224 remaining in its closed position. The provision of the switch 238 permits manual deenergization of the relay coil 211 when desired. Since the maintaining circuit for the relay 210 includes the mercury switch 122 in the step controller 115 it will be apparent that when the temperature of the water leaving the conditioning unit 25 drops to such a low value that the switch 122 is moved to its other position and the fan motor 23 is deenergized and drain valve 102 is opened, the relay 210 will simultaneously be deenergized whereupon the motor 33 which drives the pump 32 will stop so that water will no longer be supplied to the coils in the air conditioning chamber 10. In this manner whenever the temperature of the water leaving the coil 25 becomes dangerously low indicating the inadvisability of pumping more water thereto the pump 32 stops operating.

The maintaining circuit for relay 210 also includes a mercury switch 240 and this switch is carried by an arm of a lever 250. One arm of this lever is biased by means of a spring 251 into engagement with the upper portion of a bellows 252 which has its interior in communication with the pipe 94 which is in communication with the outlet of the pump 32. As the pressure of the water in the outlet of the pump 32 varies the bellows 252 will be caused to expand or contract and thus control the position of the lever 250 as will be apparent. This lever also includes an arm 255 which is arranged to sweep across a potentiometer resistance 256. The arm 255 and resistance 256 form the control potentiometer for a motor 260 which includes an arm 261 connected by means of a link 262 to the stem 263 of the valve 53 which controls the flow of water from the outlet of the coils 25 and 41 to the channel 56 leading to the well 30. The motor 260 may be a proportioning motor similar to the motor 116 of the step controller 115 and the position of the valve 53 will therefore depend upon the position of the arm 255 with respect to the resistance 256. As the arm 255 moves towards the right in response to a drop in pressure at the outlet of the pump 32 the valve 53 will move towards open position a proportionate amount. A drop in pressure at the outlet of the pump may be an indication that the supply of water in the well 30 is becoming depleted and it is therefore advisable to send the water back to the well instead of allowing it to go to waste. When there is sufficient water in the well however it may be advisable to permit the water to go to waste so that the water

in the well will not become too warm during the cooling season, for example, or will not become too cold during the heating season. Obviously if the water is raised in temperature in the air conditioning chamber and then recirculated back to the well the supply of water in the well will increase in temperature. By sending the water through the subterranean channel 56 before it reaches the well it will tend to assume the temperature of the water in the well. It is preferable however when there is an ample supply of well water to not recirculate this water but when the supply is becoming depleted as evidenced by a drop in the pressure at the outlet of the pump 32 then the water should be returned thereto and this is readily done by controlling the valve 53 in the manner set forth above. Should the pressure drop to a sufficiently low value indicating that the supply of water in the well is so low that it is useless to run the pump 32, the switch 240 carried by the lever 250 will be moved to open position thus interrupting the maintaining circuit for the relay 210 so that the operation of the motor 32 is interrupted and the pump 32 will not continue to operate.

Situated above the penthouse 11 is a control device indicated generally by the reference character 275. This control device may include a bulb 286 having a portion thereof located within a small insulated casing 287 but having its interior subject to the outside temperature and humidity conditions by means of the aperture 288. That portion of the bulb 286 located within the casing 287 is subject to the wet bulb temperature of the air, this portion being provided with a suitable wick or the like 289 having a portion located in a pan of water 290 as is conventional in the art. The extreme outer portion of the bulb 286 may be blackened so that it will respond to radiant heat and the portion to the left of this blackened portion will be subject to the dry bulb temperature of the air. The bulb 286 is connected by means of a capillary tube 292 to a bellows 294, this tube, bulb, and bellows being provided with a suitable volatile fill whereupon the bellows will expand or contract in response to variations in the dry bulb temperature of the outside air as well as variations in the wet bulb temperature and radiant heat. Accordingly the bellows will respond to variations in the actual external cooling load on the building.

The bellows 294 form a portion of a control device 295, this control device also including a lever 296 having an arm biased by means of a spring 297 into engagement with the top of the bellows. The arm 298 of the lever 296 moves over the resistance 299 as the bellows expands and contracts. The arm 298 and resistance 299 form a control potentiometer for a proportioning motor 300 which operates the step controller 302. The shaft 303 of the motor 300 moves between two extreme positions in response to movement of the arm 298 between the ends of the resistance 299.

Carried by the shaft 303 of the step controller 302 is an arm 304 which is arranged to sweep over a potentiometer resistance 305, this arm moving in a clockwise direction upon an increase in the total heat at the control device 275 and upon a decrease in this total heat the arm 305 moves in a counter-clockwise direction. The arm 305 may be arranged to move from the extreme left of resistance 305 to the extreme right as the integrated temperature equivalent at the controller 275 varies from 77° to 100° approximately

although these so-called resultant temperatures will depend of course upon the radiant heat as well as the humidity.

The potentiometer 305 forms one of the control devices for a motor 310 which may also be a proportioning motor similar to the motor 116 and this motor is provided for controlling the position of the valve 40 which controls the flow of water to the heat exchanger unit 25. An arm 312 carried by the motor 310 is connected by means of a link 313 to the stem 314 of the valve 40. The extreme left end of the resistance 305 is connected to the B terminal of the motor 310 by means of conductors 316 and 318 whereas the lower terminal marked W is connected to the opposite end of resistance 305 by means of conductors 320, 317, and 321. The arm 304 is connected to the center terminal of the motor 310 by means of a conductor 325, an adjustable resistance 326, conductors 327, 328, a mercury switch 330, and conductor 331. When the mercury switch is in the position illustrated the position of the motor 310 will be controlled by the position of the arm 304 with respect to the resistance 305 and as the arm 304 moves to the left the valve 40 will tend to move towards open position and vice versa, but at the same time the controller 142 will tend to move the valve towards open position as explained below.

The operation of the motor 310 is also controlled by the controller 140 which is responsive to the temperature of the water leaving the unit 25. The center terminal R of the motor 310 is connected to the control arm 155 of the controller 140 by means of conductors 331, the mercury switch 330, conductors 328, 340 and the center tapped resistance 345. The upper terminal B of the motor 310 is connected by means of conductors 318 and 345 to the left end of the resistance 156 while the opposite end of this resistance is connected by means of conductors 346 and 320 to the bottom or W terminal of the motor 310. Since the circuit to the arm 304 of the controller 302 includes the resistance 326 this controller is less sensitive than the controller 140. In other words, if movement of arm 304 from one extremity to the other of the resistance 305 is required to cause movement of the valve 40 from open to closed position a similar movement will be imparted to the motor upon movement of the arm 155 through a small distance as indicated at X. The effect of the controller 304 is therefore to adjust the control range of the controller 140 on the motor 310. Thus as the load on the cooling system rises and arm 305 moves toward the right, the control range X of the controller 140 will be moved toward the left so that a higher temperature of the water leaving the coil 25 in the air conditioning chamber will be maintained and in the end more water will be circulated through valve 40. The provision of the center tapped resistance 345 in the controller 140 insures that the control range will always be of the same magnitude regardless of the position of this control range with respect to the resistance 156. The arrangement is such that the temperature of the water leaving the heat exchanger unit 25 during the cooling season will be maintained at very nearly the temperature of the air entering the air conditioning chamber so that the maximum cooling capacity of the water will be utilized.

To summarize the operation of the valve 40, the main control of this valve is by the controller 140 which positions the valve in accord-

ance with the temperature of the water leaving the coil 25, and the temperature which is maintained at the outlet of the coil is varied as the outside cooling load varies so that as the cooling load increases, the temperature of the water leaving the coil will be increased to cause the water to have a temperature nearly as high as the temperature of the air entering the air conditioning chamber. The result is that the valve 40 is operated to permit an increased supply of water to the coil 25 as the cooling load increases and vice versa. While the controller 275 responding to the cooling load tends to move the valve towards closed position as the cooling load increases, the temperature of the water leaving the coil will simultaneously increase as the cooling load increases and since the main control over the valve is by the controller 140, the net result is that an increase in the cooling load means an increase in the amount of water entering the coil 25 and an increase in the temperature of the water leaving the coil, and vice versa.

Provision is also made for positioning the valve 40 in a fixed partially open position during the wintertime so that regardless of the temperature of the outside air there will be a fixed flow of water to the heat exchanger units in the air conditioning chamber 10. For this purpose the mercury switch 330 in the step controller 302 is utilized. When the outside temperature drops to a certain low value the cam 360 carried by the shaft 303 of the motor 300 is rotated in a counter-clockwise direction until the switch 330 operated thereby is tilted in the opposite direction from that illustrated. The R and W terminals of the motor 310 are now connected together as follows: from the R terminal through conductor 331, the mercury switch 330, conductor 362, a variable resistance 363, and conductors 364, 317, and 320 to the W terminal of the motor 310. This will cause the motor 310 to move the valve 40 to a minimum open position, the position of the valve being determined by the setting of the resistance element 326. Before the valve is moved by the switch 330 to this minimum open position during the heating season it will have been moved to entirely closed position by the controllers 305 and 140 at an outside temperature of, say 77° F., since the control range of the arm 155 will be shifted to the extreme right end of the resistance 156 and when the water temperature drops to 75° F. for example, the R and W terminals of the motor will be directly connected together and the valve will be entirely closed but as the temperature continues to drop and the switch 330 is moved to its opposite position the placing of the resistance 363 in the circuit to the W terminal of the motor will cause this motor to open the valve to a predetermined position.

The step controller 302 also includes a cam 370 which controls the operation of the valve 61 for admitting water to the spray 60 located on the roof of the building being conditioned. The valve 61 may be operated by a motor 375 connected by conductors 376 and 377 to line wires 378 and 379. When the terminals R and B of the motor 375 are connected together the motor will cause the valve to move to open position for supplying water to the spray 60. It will be noted that with the cam 370 in the position illustrated the switch 380 controlled thereby closes a circuit through conductors 381 and 382 connected to the R and B terminals of the motor 365, respectively,

so that the valve 61 is in its open position and water is supplied to the spray 60 for additionally cooling the building. If the cooling load on the building should decrease the motor 300 will be operated by the controller 275 to move the cam 370 in a counter-clockwise direction and after the load drops to a predetermined value the switch 380 will be tilted in the opposite direction and close a circuit through the conductors 381 and 383 which are connected to the R and W terminals of the motor 375 so that this motor now causes the valve 61 to move to closed position and stop the flow of water to the spray 60.

It is intended to supply water to the spray 60 only when the cooling load is quite heavy since when the cooling load is not sufficiently great it is advisable to cause the water to flow either to the outlet 51 or the outlet 52 to take advantage of the syphonic action to reduce the load on the pump 32. If this syphonic action is great enough however the pressure within the coils 25 and 41 may be so reduced that the rate of heat exchange at the coils 25 and 41 may drop and reduce the efficiency of these units. In order to overcome this difficulty the pressure responsive device 390 is provided. This device includes a bellows 391 connected by cams of a pipe 392 to the pipe leading to the inlet 26 of the heat exchanger unit 25, between this unit and the valve 40. A lever 395 carries a mercury switch 396 on one arm thereof and this arm is biased by means of a spring 397 into engagement with the upper portion of the bellows. A second arm 398 of this lever is arranged to sweep over a potentiometer resistance 400, this arm and resistance forming a control potentiometer for a motor 410 which is connected to the valve 54 controlling the flow to the outlet 52. It will be understood that upon a drop in pressure between the valve 40 and the coil 25 the bellows 391 will contract and move the arm 398 towards the right and upon an increase in pressure the arm 398 will be moved toward the left. Conductors 412 and 413 connect the right and left hand ends of the resistance 400 with the B and W terminals of the motor 410, and the R terminal of this motor is connected by the conductor 415 to the control arm 398 of the controller 390.

The arm 418 of the motor 410 is connected by means of a link 419 to the valve stem 420 of the valve 54. Upon a decrease in pressure of the water the movement of arm 398 of the controller 390 towards the right will cause the valve 54 to be moved towards closed position by the motor 410 so as to reduce the rate of flow from the outlet 52 and build up a back pressure in the system or reduce the syphonic action so that the pressure of the water in the units 25 and 41 will be high enough to insure efficient operation thereof. When the pressure becomes too high in these units the valve 54 is opened to a greater extent so as to prevent the pressure from becoming excessive. Valve 54 may be placed in line 49 if the characteristics of the pump 32 and well 30 are such that they do not allow this pressure building to take place in the manner described.

Provision is also made for interrupting the operation of the fan 21 and the pump 32 should the pressure in the system become abnormally low. This is advisable since if the pressure is sufficiently low between the valve 40 and the coil 25 it indicates that sufficient fluid is not being pumped through the coil to affect any appreciable heating or cooling of the air in the chamber 10 as the case may be so that continued operation of the

fan 21 would result in circulating unheated air through the space to be conditioned in the wintertime or hot air through the space in the summertime. For this purpose the relay 430 is provided. This relay includes relay coil 431, an armature 432, the arm 179 positioned thereby co-operating with the fixed contact 180 and contact 434. When the relay coil 431 is deenergized the arm 179 is maintained in engagement with the fixed contact 180 under the influence of gravity or any suitable biasing means (not shown) and upon energization of the coil 431 the arm 179 is moved into engagement with the fixed contact 434. The energization of the relay 430 is controlled by the mercury switch 396 operated by the pressure responsive controller 390 and by a second mercury switch 440 carried by the arm 441 of a bell crank lever having its other arm 442 situated in the path of movement of the arm 312 operated by the motor 310 which controls the position of the valve 40. The arm 441 is normally in engagement with a stop 445 but whenever the valve is moved to its fully closed position the bell crank lever is tilted to a position wherein the switch 440 is tilted in its other position. When the valve 40 is positioned in its fixed minimum open position during the wintertime the switch 440 will be in the position illustrated and it should be understood that this switch is moved to its other position only during the summertime when the valve 40 is in full or nearly fully closed position.

When the pressure between the valve 40 and the coil 25 becomes sufficiently low that the mercury switch 396 of the controller 390 is tilted to its closed position and with the switch 440 in the position illustrated the relay coil 431 of the relay 430 will be energized as follows: from the line wire 379 through conductors 450, 451, mercury switch 396, conductor 454, mercury switch 440, conductor 456, the relay coil 430 and conductor 457 to the line wire 378. It will now be understood that the relay 430 is energized only when the valve 40 is at least partially open and the pressure between this valve and the coil 25 drops sufficiently. The energization of the relay 430 causes arm 179 thereof to be moved into engagement with the contact 434 whereupon the R and W terminals of the motor 116 of the step controller 115 are directly connected together as follows: from the R terminal of the motor through conductor 178, arm 179, contact 434, conductors 460 and 172 to the W terminal of the motor. The motor 116 is now operated to move the various cams controlled thereby in a counter-clockwise direction to a position wherein the mercury switches 122 to 125 are tilted in their other positions. The circuit to the fan motor 23 is now interrupted at the mercury switch 123, the circuit to the motor 33 driving the pump 32 is interrupted at the mercury switch 122 and at the same time the motor 200 for the drain valve 102 is energized. It will now be seen that when the pressure of the water entering the coil 25 drops sufficiently the circulation of air through the air conditioning chamber is stopped, the main pump motor 33 is stopped, and the water is drained from the heat exchanger units. It is advisable to drain the water from the heat exchanger units particularly in the wintertime since otherwise all of the water in these coils might freeze up and to avoid this danger the water is drained therefrom at the same time that the pump 32 and fan 21 are stopped. It may often happen in the summertime that the valve 40 will be positioned

in very nearly closed position but the system is operating properly to give the necessary cooling effect to the air passing through the chamber 10. With the valve 40 in this very nearly closed position the pressure of the water between the valve and the coils 25 may become very low but it is not advisable at this time to shut the system down since this drop in pressure may result from this minimum opening of the valve 40. When this happens therefore the switch 440 will be moved to open position by the arm 312 of the motor 310 so that the relay 430 cannot be energized and the system will not therefore shut down.

During the summer cooling season the temperature of the well water may not be low enough to give the necessary cooling to the air being conditioned and the refrigeration system including the compressor 70, the condenser 48, and the evaporator 34 is provided. The operation of the compressor is controlled by a controller 475, this controller including a bulb 476 mounted in engagement with the pipe 35 through which the water is flowing, this bulb being connected by a capillary tube 478 to a bellows 480, the tube, bulb, and bellows being provided with a suitable volatile fill so that expansion and contraction of the bellows will take place in accordance with variations in the temperature. An arm 481 of a bell crank lever is biased by means of spring 482 into engagement with the upper portion of the bellows 480 and the other arm 485 of this lever is arranged to sweep across a potentiometer resistance 486 in accordance with variations in pressure within the bellows 480. The potentiometer 486 controls the operation of a motor 490 of a step controller 492 which controls the operation and speed of the compressor motor 71. The right end of resistance 486 is connected by means of conductor 494 to the B terminal of motor 490 and the opposite end of the resistance is connected by means of conductors 496 and 497 to the W terminal of the motor 490. The arm 485 is connected by means of a conductor 499, mercury switch 500 and conductor 501 to the R terminal of the motor 490. The mercury switch 500 is operated by a cam 502 of the step controller 302 and this switch will be in the position illustrated whenever the cooling load on the system is sufficiently high. When the outside temperature drops to a low enough value however, the switch 500 will be tilted in its other position for a purpose to be set forth.

The step controller 492 for controlling the operation of the compressor motor 71 includes cams 505, 506, and 507 which control the position of mercury switches 508, 509, and 510, respectively. These cams are moved by the motor 490 in a clockwise direction in response to an increase in temperature at the bulb 476 and as the temperature of the water decreases and the control arm 485 of the controller 475 moves to the left decreasing the resistance between the R and W terminals of the motor 490 the cams of the step controller 492 will move in a counter-clockwise direction to sequentially open the mercury switches. In the position illustrated the mercury switches 508 and 509 are closed and the switch 510 is open. The switch 508 controls the low speed operation of the compressor motor 71, this switch closing a circuit between the terminals 515 and 516 of the control box 520 of the compressor motor 71 as follows: from the terminal 515 through conductor 521, the switch 508 and conductor 522 to the terminal 516. Conductors 523 are

provided for connecting the control box 520 to a suitable source of power (not shown). It will accordingly be seen that when the temperature outdoors is high enough so that mercury switch 500 of the step controller 302 is in the position illustrated and the temperature of the water is sufficiently high so that mercury switch 508 is in closed position the compressor motor 71 will operate at low speed to cool the water flowing through the evaporator 34 to further increase the cooling effected by the coil 25 in the air conditioning chamber.

If the temperature of the water affecting the bulb 476 is still too high the mercury switch 509 of the step controller 492 will be in closed position and this will cause the energization of the motor 86 driving the pump 85. The terminals 525 and 526 of the control box 527 for the motor 86 will be connected together through the mercury switch 509 by means of the conductors 530 and 531. The pump 85 will therefore operate to recirculate some of the water through the evaporator 34 thus increasing the amount of heat exchange in the evaporator so as to further reduce the temperature of the water flowing through the pipe 35 and to the heat exchanger 25.

Should the temperature of the water in the pipe 35 still be too high the motor 490 will be operated by the controller 475 to rotate cam 507 to a position wherein the switch 510 is in closed position thus closing a circuit between the high speed terminals 516 and 517 of the starter box 520 as follows: from the terminal 516 through conductor 522, mercury switch 508 will still be in its closed position, the conductor 540, switch 510, and conductor 541 to the terminal 517 of the control box 520. The compressor will now operate at high speed to increase the flow of refrigerant through the evaporator and to further reduce the temperature of the water flowing to the coil 25.

It will now be seen that the system for cooling the water being supplied to the coil 25 first causes the operation of the compressor 71 at low speed, then causes the operation of pump 85 to increase the amount of heat exchange in the evaporator 34 and if this is not sufficient to reduce the temperature of the water the necessary amount the compressor is then operated at high speed so that the water will be delivered to the heat exchanger 25 at the proper temperature. When the outdoor temperature or cooling load becomes sufficiently low the cam 502 of the step controller 302 rotates to a position wherein the switch 500 is tilted in the opposite direction. The R and W terminals of the motor 490 of the step controller 492 will now be directly connected together as follows: from the R terminal through conductor 501, mercury switch 500, conductors 545 and 497 to the W terminal of the motor 490. The motor 490 will now operate to move the cams 505, 506, and 507 in a counter-clockwise direction to an extreme position wherein all the mercury switches controlled thereby are in open positions. The operation of the compressor motor 71 will now be interrupted as will the operation of pump 85 since the cooling load on the system is sufficiently low that no auxiliary cooling of the cooling water is necessary. Since the cooling water will be of approximately the same temperature at all times the various controls can be so adjusted that the auxiliary cooling means for the cooling water can be shut off as the cooling load de-

creases and the valve 40 which controls the flow of water to the cooling coils will be sufficient to control the amount of cooling effected thereby.

Located in the discharge outlet from the fan 21 is the bulb 550 of a controller 552. The bulb 550 is connected by means of a capillary tube 553 to a bellows 554, this tube, bulb, and bellows being provided with a suitable volatile fill so that the bellows will expand or contract in accordance with variations in temperature at the fan discharge. A bell crank lever 555 has an arm 556 biased by means of a spring 557 into engagement with the upper portion of the bellows 554 and the arm 558 of this lever is arranged to sweep over a potentiometer resistance 560. As the temperature of the air leaving the air conditioning chamber drops the arm 558 will move to the right and upon an increase in this discharge temperature the arm will be moved toward the left over the resistance 560. This controller 552 controls the position of the valve 43 by means of which the amount of water leaving the heat exchanger 25 and passing through the reheater 41 may be effectively controlled. The controller 552 is arranged to control the operation of the valve 43 in accordance with the discharge temperature during the cooling season only but during the heating season this valve will be moved to a position wherein all the water will be caused to flow through the by-pass 45. This valve might also be controlled by a humidostat in the space to be treated.

For this purpose a relay indicated generally by the reference character 575 is provided, this relay including a coil 576, an armature 577, and switch arms 580, 581, 582, 583, and 584. When the relay is deenergized the arm 580 is in engagement with the contact 590 and the arms 582, 583, and 584 are in engagement with contacts 592, 593, and 594, these arms being moved to these positions under the influence of gravity or any suitable biasing means (not shown). Upon energization of the relay 75 the switch arms will all be moved toward the left, the arm 580 being moved out of engagement with the contact 590 and the remaining switch arms being moved into engagement with the fixed contacts 596, 597, 598, and 599, respectively. The energization of the relay 575 is controlled by the step controller 302 and more particularly by means of the cam 600 thereof. The mercury switch 601 is controlled by the cam 600 of this step controller and during the cooling season this switch will be in open position as illustrated. When the outside temperature is sufficiently low however and the cams are moved in a counter-clockwise direction to their extreme positions the switch 601 will be moved to closed position and will energize the relay coil 576 as follows: from the line wire 379 through conductor 605, switch 601, conductor 606, relay coil 576, and conductor 607 to the line wire 378. It will therefore be seen that when the outside temperature is sufficiently low the relay coil 576 will be energized and the various switch arms operated thereby will be moved to the left into engagement with their respective contacts.

Assuming that the outside temperature is sufficiently high so that the relay 575 is deenergized and the system is being used for cooling the air supplied to the building the motor 610 for controlling the position of the three-way valve 43 will be operated in accordance with the discharge temperature from the fan 21. The B terminal of the motor 610 is connected to the

right end of resistance 560 of the controller 552 by means of the conductor 612, the switch arm 584, and conductor 613. The W terminal is connected to the opposite end of this resistance by means of conductor 615, contact 592, switch arm 582, and conductor 616. The control arm 558 of the controller 552 is connected to the R terminal of the motor 610 by means of conductor 615, switch arm 583, contact 593, and conductor 621. The motor 610 is connected to the valve 43 by means of the link 625 connecting the movable arm 626 of the motor with the valve stem 627. This motor 610 may be a proportioning motor similar to the motor 116 and it will be understood that the position of arm 626 of the motor and accordingly the position of the valve 43 will vary proportionately with the position of the control arm 558 of the controller 552 with respect to the resistance 560 or in other words, will vary in accordance with the temperature of the air leaving the air conditioning chamber 10. As the discharge temperature drops the valve will move to a position wherein more of the water is caused to flow through the reheater 41 and a lesser amount by-passes this reheater. Therefore the controller 552 acts to prevent the temperature of the air entering the space being conditioned from dropping below a predetermined value by utilizing the relatively warm water leaving the coil 25 for reheating the air as may often be necessary, particularly where the outside relative humidity is high and the coil 25 is being utilized for removing latent heat from the air by reducing the temperature of the air below its dew-point.

During the heating season it is desirable to use only the heat exchanger 25 for heating purposes since the temperature of the water leaving the coil 25 might be considerably lower than the temperature of the air leaving the coil 25 by reason of the counterflow relationship, and it is therefore desirable to cause all of the water leaving the coil 25 to flow through the by-pass 45. Accordingly the valve 43 is positioned so that all the water will have to flow through the by-pass 45. When the outside temperature drops sufficiently low so that the mercury switch 601 of the controller 302 is moved to closed position and the relay 575 is energized the R and W terminals of the motor 610 will be directly connected together so that the valve will be moved to the position wherein all the water will by-pass the coil 41, the connection between these terminals being as follows: from the R terminal through conductors 621, 631, contact 596, arm 581, conductors 632 and 615 to the W terminal of the motor 610. Accordingly when the relay 575 is energized due to a drop in outside temperature the controller 552 will have no effect whatever upon the valve 43 which will be maintained in the position wherein all the water flows through the by-pass 45.

In order to heat the water during the wintertime the heat exchanger 36 through which the water flows on the way to the air conditioning chamber is provided and steam is admitted to this heat exchanger through the pipe 95, the flow of steam being controlled by the valve 96. A proportioning motor 640 may be provided for controlling the position of the valve 96, the arm 641 of this motor being connected to the valve by means of a link 642. The motor 640 is controlled primarily by the controller 552 in the wintertime but during the cooling season the valve 96 may be maintained in its fully closed position by the motor 640. When the relay 575 is deenergized the R and W terminals of the motor 640 are

directly connected together and the valve 96 is maintained in its closed position. The connection between the R and W terminals at this time is as follows: from the R terminal through conductors 644, 645, contact 590 of the relay 575, arm 580, conductors 648, 656, 649, a mercury switch 650 whose function will be hereinafter set forth but which will be in closed position during the heating season and conductors 652 and 653 to the W terminal of the motor 640. The controller 552 will therefore have no effect upon the motor 640 during the summertime but during the heating season when the relay 575 is energized the controller 552 will control the operation of the motor 640 and determine the position of the valve 96. With the relay 575 energized the W terminal of motor 640 will be connected to the left end of resistance 560 by means of conductors 653, 652, mercury switch 650, conductors 649, 656, 657, contact 597 of relay 575, arm 582, and conductor 616 whereas the opposite end of resistance 560 will be connected by means of conductor 660, arm 584, contact 599 of relay 575, and conductor 661 to the B terminal of motor 640. The R terminal of the motor will be connected by means of conductors 644, 662, contact 599, arm 583, and conductor 615 to the control arm 558 of the controller 552. Accordingly upon a decrease in temperature at the bulb 550 the arm 558 will be moved toward the right decreasing the resistance between the R and B terminals of the motor 640 and thus opening the steam valve to heat the water flowing to the air conditioning chamber.

In order to further safeguard the coils 25 and 41 against freezing during cold weather provision is made for causing valve 96 to be opened to at least a minimum position when the outside temperature is sufficiently low and for this purpose the controller 675 is provided. The controller 675 includes a bulb 676 located in the fresh air inlet and connected by means of a capillary tube 677 to the bellows 678, this tube, bulb, and bellows being provided with a suitable volatile fill so that the bellows 678 will expand or contract in accordance with variations in the fresh air temperature. The mercury switch 650 is carried by a lever 680 biased by means of a spring 681 into engagement with the upper portion of the bellows and when the fresh air temperature drops sufficiently low the contraction of the bellows 678 will cause the switch 650 to move to open position. The connection between the W terminal and motor 640 and the left end of resistance 560 of the controller 552 now includes the variable resistance 690 which was previously shunted out by the conductor 652 and the mercury switch 650 when this switch was closed. The circuit between the W terminal of the motor and the controller 552 is now as follows: through the conductor 653, 691, variable resistance 690, conductors 692, 656, 657, contact 597 of relay 575, arm 582, and conductor 616. Accordingly regardless of the discharge temperature at the fan 21 if the outside temperature is sufficiently low there will always be a certain resistance between the R and W terminals and motor 640 will cause the valve 96 to be opened a predetermined amount, this resistance being variable so that the minimum opening of the valve may be varied at will. Accordingly when the outside temperature drops to a sufficiently low value a certain amount of heat will at all times be supplied to the water entering the heat exchanger units 25 and 41 to further safeguard these units against freezing.

Positioned just ahead of the heat exchanger unit 25 is the bulb 700 of a controller 701 which may be of a construction similar to the construction of the controller 552 and this controller is suitably connected to a proportioning motor 20 so that this motor operates in accordance with the temperature of the mixture of fresh and return air passing through the air conditioning chamber prior to being conditioned. Arms 702 and 703 operated by this motor are connected by means of links 704 and 705 to the dampers 15 and 16, respectively. This controller forms a further means to safeguard the coils within the chamber 10 against freezing and is adapted to start closing the fresh air damper 15 and open the return air damper 16 when the temperature of the air passing over the coil 25 drops below a predetermined value of say 36° F. As the fresh air dampers 15 start to close and the return air dampers 16 start to open the fresh air entering at 13 will mix with the relatively warm return air and thus prevent the passage of extremely cold air over the units 25 and 41. The dampers 15 and 16 will be caused to assume positions by the controller 701 so that the temperature of the air passing over the air conditioning units will be at all times high enough to prevent freezing of the coils. If desired these dampers may be so arranged that the dampers 15 in the fresh air inlet are never moved to fully closed position so that there will always be a certain amount of fresh air taken into the system for ventilating purposes. These dampers function as a safety feature to avoid the danger of freezing of the air conditioning units and also serve to reduce the heating load during the wintertime when the outdoor temperature becomes abnormally low. If desired, however, these dampers might be omitted and a fixed amount of fresh air taken into the system at all times, the controller 141 operating as a safety device to prevent freezing of the coils 25 and 41. However, if the dampers are also used and controlled in the manner described then the danger of freezing is very unlikely by reason of the two devices which safeguard the coils 25 and 41.

Operation

The operation of the system should be apparent from the preceding description thereof but may be summarized as follows: during the cooling season the flow of water to the coil 25 will be controlled by the valve 40 and this valve is controlled by the controller 140 responsive to the temperature of the water leaving the coil and this controller will be compensated by the controller 275 which measures the total cooling load on the system since this controller responds to the wet bulb temperature of the air, the dry bulb temperature of the air, and the radiant heat of the air. It should be understood however that this controller 275 may be of any conventional form for measuring the total cooling load on the system. The temperature of the water leaving coil 25 will be maintained at a value only slightly below the temperature of the air so that the maximum cooling effect of the water being circulated therethrough may be utilized. When the cooling load is sufficiently high the auxiliary cooling system for the cooling water will be placed into operation to maintain the temperature of the water entering the coil 25 at a predetermined value by means of the controller 475 controlling the operation of the compressor 70 and the circulating pump 85. As the water tem-

perature increases the compressor will first be operated at low speed, the pump 85 will then be put into operation and upon a further increase in the water temperature the compressor 70 will operate at high speed.

The water is returned to the source of supply only when the source is becoming depleted as evidenced by a drop in pressure at the controller 252 and when this pressure drops the valve 53 is opened a corresponding amount to return the water to the source by way of the subterranean temperature leveling channel 56. When the pressure at 252 is sufficiently high indicating an ample supply of cooling water at the source 30 the valve 53 will be closed and the water will go to waste through the drain 58. The valve 54 controlling the flow to the drain 58 will be operated in accordance with the pressure of the water between the valve 40 and the coil 25 in a manner to insure that the pressure of the water in this coil will be sufficiently high to insure a high rate of heat exchange. Should the pressure between the valve 40 and the coil 25 drop the pressure responsive controller 390 will move valve 54 towards closed position to increase the back pressure on the coils 25 and 41. When the cooling load is sufficiently high the valve 61 is opened so that the water leaving the air conditioning units may be sprayed on to the roof of the building by way of the spray 60 to further cool the building. This spray is not utilized however except when the cooling load is excessively high since the system may be more economically operated by allowing this water to pass through the drain 58 or to the well 30 so that the syphonic action of the water will assist the pump 32 in circulating the water through the cooling coils and thus relieve the load on this pump.

The temperature of the air entering the space being conditioned will not be allowed to fall below a predetermined value, the controller 552 which responds to the discharge air operating the valve 43 to cause the water leaving the coil 25 to pass through the reheater 41 by an amount which will reheat the air sufficiently to prevent this discharge air temperature from dropping below a predetermined value.

During the heating season, the control of the valve 43 will be taken away from the controller 552 through the operation of the relay 575 and this valve will be maintained in a position wherein all the water will flow through the by-pass 45. The steam valve 96 controlling the flow of steam to the heat exchanger 36 will be operated in the wintertime by the controller 552 so that the temperature of the air entering the space will be maintained at a predetermined value whereas in the summertime this steam valve will be maintained in a closed position. The valve 40 controlling the flow of water to the coil 25 will be maintained in a fixed predetermined position during the wintertime. During the summertime the speed of the fan 23 will be controlled in accordance with the temperature of the water leaving the coil 25 and as the temperature of this water drops from say 75° F. to 70° F. the fan speed will be reduced in a step by step manner from high speed to low speed. During the wintertime this fan will operate at a low speed at all times during the normal operation of the system.

The dampers 15 and 16 will operate during extremely cold weather to prevent the temperature of the air passing to the coil 25 from dropping below a predetermined value to avoid the

danger of freezing the water in the coils. As a further safeguard against freezing of the water in the coils the controller 141 which responds to the temperature of the water leaving the coil 25 operates when this temperature drops below a safe value such as 34° F. to open the drain valve 200, thus draining the water from the coils 25 and 41 and also stops the fan 23 and the pump 32 so that cold air will not be admitted to the space being conditioned and so that water will not be supplied to the coil 25.

Whenever the pressure of the water entering the coil 25 becomes sufficiently low and this pressure drop is not due to the valve 40 being in closed position or substantially closed position during the cooling season it is an indication that the supply of water at the source is becoming so depleted that the system should be shut down or it may be an indication that the pump 32 is not operating properly. The controller 390 accordingly will stop the pump 32 and the fan 23 since it is not desirable to circulate air over the coils 25 when these coils are not being properly supplied with a conditioning fluid. The drain valve 102 will also be opened at this time since it would be inadvisable to leave the coils full of water particularly if the outside temperature was low and this forms an additional safety feature for the system.

During the heating season the supply of steam to the coils is controlled as previously disclosed by the discharge air temperature but the controller 675 additionally controls the supply of steam to insure a predetermined supply of steam thereto when the outside temperature drops sufficiently low to further insure the system against freezing during severely cold weather. It will thus be seen that there are many safeguards against the possibility of the coils 25 and 41 freezing so that should anyone of these safeguards fail to operate for any particular reason the other safeguards will operate to prevent the system from freezing.

The water leaving the coils 25 and 41 is effectively utilized for the domestic water supply through the medium of the tank 65 containing a fixed supply of water under pressure, this supply being controlled by the float valve 68.

Having described the preferred form of my invention many modifications may become apparent to those skilled in the art and it should be understood that my invention is limited only by the scope of the appended claims.

I claim as my invention:

1. In an air conditioning system, an air conditioning chamber, a heat exchanger in said air conditioning chamber, means for circulating air over said heat exchanger, means for circulating a cooling fluid through said heat exchanger, valve means controlling the flow of cooling fluid to said heat exchanger, means for controlling said valve means so as to maintain the temperature of the fluid leaving said heat exchanger at a given value, means responsive to the outside temperature for varying the temperature at which said fluid is maintained, and means responsive to a drop in outside temperature to a predetermined value for maintaining said valve means open a predetermined amount.

2. In an air conditioning system, a heat exchanger, means for circulating a cooling fluid through said heat exchanger, means for circulating air over said heat exchanger in counterflow relationship with respect to the flow of cooling fluid, a reheating coil over which the air being

conditioned is circulated, valve controlled means for conducting fluid from the outlet of said heat exchanger through said reheating coil, means responsive to the temperature of the air leaving said reheating coil in control of said valve means, valve means controlling the flow of cooling fluid to said heat exchanger, and means responsive to the temperature of the fluid leaving said heat exchanger and to a psychrometric condition of the outdoor air in control of said valve means.

3. In a system of the class described, heat exchanger means, means for circulating a fluid through said heat exchanger means, said heat exchanger means being located above said fluid circulating means, conduit means connected to said heat exchanger means and having an outlet positioned below said heat exchanger means whereby the siphonic action produced by the fluid flowing from the heat exchanger means lessens the load on the circulating means, valve means controlling the flow of fluid to said heat exchanger means, condition responsive means in control of said valve means, second valve means controlling the flow of fluid from said conduit means, and means responsive to the pressure of the fluid between said first valve means and said heat exchanger means in control of said second valve means to maintain a predetermined pressure of the fluid in said heat exchange means.

4. In an air conditioning system, an air conditioning chamber, means for circulating outside air through said air conditioning chamber and through a space to be conditioned, heat exchanger means in said chamber in the path of the flow of air, a source of cooling fluid, means for circulating said cooling fluid through said heat exchanger means, means conducting the fluid leaving the heat exchanger back to the source of supply or to waste, valve means controlling the flow of the fluid to waste, valve means controlling the flow of fluid back to the source of supply, means responsive to the pressure at the inlet of the heat exchanger means in control of said first named valve means, and means responsive to the pressure at the outlet of the cooling fluid circulating means in control of said last named valve means.

5. In an air conditioning system, an air conditioning chamber, means for circulating outside air through said air conditioning chamber and through a space to be conditioned, heat exchanger means in said chamber in the path of the flow of air, a source of cooling fluid, means for circulating said cooling fluid through said heat exchanger means, means for controllably conducting the cooling fluid leaving the heat exchanger means back to the source of supply, means responsive to a drop in pressure at the outlet of the fluid circulating means for increasing the flow of fluid back to the source of supply, and means responsive to a drop in pressure at the outlet of the fluid circulating means to a predetermined value for interrupting the operation of the fluid circulating means.

6. In an air conditioning system, an air conditioning chamber, means for circulating outside air through said air conditioning chamber and through a space to be conditioned, heat exchanger means in said air conditioning chamber in the path of air flow therethrough, a source of cooling fluid, means for circulating fluid from said source through said heat exchanger means, valve means controlling the flow of fluid to said

heat exchanger means, means for operating said valve means so as to maintain the temperature of the fluid leaving the heat exchanger means at a value which bears a definite relationship with a psychrometric condition of the outside air, means for reducing the temperature of the cooling fluid before it reaches the heat exchanger means, and means responsive to a predetermined psychrometric condition of the outside air for initiating operation of the temperature reducing means.

7. In an air conditioning system, an air conditioning chamber, means for circulating outside air through said air conditioning chamber and through a space to be conditioned, heat exchanger means in said air conditioning chamber in the path of air flow therethrough, a source of cooling fluid, means for circulating fluid from said source through said heat exchanger means, valve means controlling the flow of fluid to said heat exchanger means, means for operating said valve means so as to maintain the temperature of the fluid leaving the heat exchanger means at a value which bears a definite relationship with a psychrometric condition of the outside air, means for reducing the temperature of the cooling fluid before it reaches the heat exchanger means, means responsive to a predetermined psychrometric condition of the outside air for initiating operation of the temperature reducing means, and means responsive to the temperature of the cooling fluid leaving the temperature reducing means for controlling the cooling capacity of the temperature reducing means.

8. In an air conditioning system, an air conditioning chamber, means for circulating outside air through said air conditioning chamber and through a space to be conditioned, heat exchanger means in said air conditioning chamber in the path of air flow therethrough, a source of fluid, means for circulating fluid from said source through said heat exchanger means, a second heat exchanger means through which fluid leaving the first heat exchanger means may flow, valve means controlling the flow of fluid through said second heat exchanger means, means for heating the fluid entering the first heat exchanger means, means responsive to the temperature of the air leaving said air conditioning chamber in control of said valve means and said heating means, and changeover means for selectively placing said last named means in control of said valve means or said heating means.

9. In an air conditioning system, an air conditioning chamber, means for circulating outside air through said air conditioning chamber and through a space to be conditioned, heat exchanger means in said air conditioning chamber in the path of air flow therethrough, a source of fluid, means for circulating fluid from said source through said heat exchanger means, a second heat exchanger means through which fluid leaving the first heat exchanger means may flow, valve means controlling the flow of fluid through said second heat exchanger means, means for heating the fluid entering the first heat exchanger means, means responsive to the temperature of the air leaving said air conditioning chamber in control of said valve means and said heating means, changeover means for selectively placing said last named means in control of said valve means or said heating means, means causing said heating means to remain inoperative when the valve means is under

the control of said temperature responsive means, and means causing said valve means to remain in a position preventing flow of fluid through said second heat exchanger means when the heating means is under the control of said temperature responsive means.

10. In a system of the class described, an air conditioning chamber, heat exchanger means in said air conditioning chamber, means for circulating air over said heat exchanger means and through a space to be conditioned, means for circulating fluid through said heat exchanger means so as to change the temperature of the air passing over said heat exchanger means, valve means for draining fluid from said heat exchanger means, and means responsive to a low predetermined temperature at the outlet of the heat exchanger means for opening said valve means.

11. In a system of the class described, an air conditioning chamber, heat exchanger means in said air conditioning chamber, means for circulating air over said heat exchanger means and through a space to be conditioned, means for circulating fluid through said heat exchanger means so as to change the temperature of the air passing over said heat exchanger means, valve means for draining fluid from said heat exchanger means, means for changing the temperature of the fluid being circulated through said heat exchanger means, means responsive to the temperature of the air leaving said air conditioning chamber in control of said temperature changing means, means responsive to the temperature of the fluid leaving the heat exchanger means in control of the amount of air circulated by the air circulating means, and means responsive to a drop in temperature of the fluid at the outlet of the heat exchanger means to a low predetermined value to open said valve means and to interrupt operation of said air circulating means.

12. In an air conditioning system, an air conditioning chamber, means for circulating outside air through said air conditioning chamber and through a space to be conditioned, first and second heat exchanger means in said air conditioning chamber in the path of air flow therethrough, means for circulating a conditioning fluid through said first heat exchanger means, means responsive to the temperature of the air entering said space for controlling the flow of fluid from said first heat exchanger means through said second heat exchanger means, and means responsive to a predetermined low outside temperature for causing all of the fluid to by-pass said second heat exchanger means.

13. In an air conditioning system, an air conditioning chamber, means for circulating outside air through said air conditioning chamber and through a space to be conditioned, first and second heat exchanger means in said air conditioning chamber in the path of air flow therethrough, means for circulating a conditioning fluid through said first heat exchanger means, means responsive to the temperature of the air entering said space for controlling the flow of fluid from said first heat exchanger means through said second heat exchanger means, means responsive to a predetermined low outside temperature for causing all of the fluid to by-pass said second heat exchanger means, and means responsive to an outdoor psychrometric condition for controlling the flow of fluid to said first heat exchanger means.

14. In an air conditioning system, an air conditioning chamber, means for circulating outside air through said air conditioning chamber and through a space to be conditioned, first and second heat exchanger means in said air conditioning chamber in the path of air flow therethrough, means for circulating a conditioning fluid through said first heat exchanger means, means responsive to the temperature of the air entering said space for controlling the flow of fluid from said first heat exchanger means through said second heat exchanger means, means responsive to a predetermined low outside temperature for causing all of the fluid to by-pass said second heat exchanger means, and means responsive to the load on the air conditioning system for varying the rate of flow and the temperature of the fluid to said first heat exchanger means.

15. In a system of the class described, a source of cooling fluid, means for reducing the temperature of the fluid, said means including a heat exchanger through which the fluid is circulated, means for circulating a refrigerant through said heat exchanger to reduce the temperature of the fluid, and condition responsive means for sequentially causing circulation of refrigerant at a low rate, for causing recirculation of the cooling fluid through said heat exchanger, and for causing circulation of refrigerant at a high rate.

16. In an air conditioning system, a source of cooling fluid, means for reducing the temperature of the fluid, said means including a heat exchanger through which the cooling fluid and a cold fluid are circulated in heat exchange relationship, means for circulating the cold fluid through said heat exchanger at different rates of flow, means for causing a recirculation of said cooling fluid through said heat exchanger, and means responsive to the temperature of the cooling fluid leaving said heat exchanger for controlling the rate at which said cold fluid is circulated through said heat exchanger and for controlling the operation of the recirculation causing means.

17. In an air conditioning system, a source of conditioning fluid, means for reducing the temperature of the conditioning fluid, said means including a heat exchanger through which said fluid is circulated, said heat exchanger including an evaporator of a refrigeration system, a variable capacity compressor means for circulating a refrigerant through said evaporator, means responsive to an increase in the load on the air conditioning system to a predetermined value to initiate operation of the compressor means at low capacity, means responsive to a rise in temperature of the conditioning fluid leaving said evaporator above a predetermined value while the load on the air conditioning system is high to increase the rate of flow of the conditioning fluid through said evaporator, and means responsive to a further rise in temperature of the cooling fluid leaving the evaporator to cause operation of the compressor means at high capacity.

18. In an air conditioning system, a conditioning chamber, means for passing air through said conditioning chamber, a heat exchanger in said chamber, said heat exchanger comprising a plurality of serially connected passages for cooling fluid, said passages being disposed in series with respect to air flow, means for passing cooling fluid through said heat exchanger for cooling and dehumidifying the air, said last named means causing the cooling fluid to pass through

the heat exchanger in counter flow relationship with the air flow whereby the temperature of the cooling fluid leaving the heat exchanger is warmer than the temperature of the air leaving the heat exchanger, a reheater downstream of the heat exchanger for reheating the air, means for passing cooling fluid from the outlet of said heat exchanger through said reheater, a by-pass for the fluid around said reheater, valve means for varying the proportions of the fluid passed through and by-passed around said reheater, means for controlling said valve means in accordance with the demand for reheat, valve means controlling the flow of fluid through said heat exchanger, and means responsive to the temperature of the fluid leaving said heat exchanger and to a temperature condition which is a measure of the load on the system in control of said last-named valve means.

19. In an air conditioning system, a conditioning chamber, means for passing air through said conditioning chamber, a heat exchanger in said chamber, said heat exchanger comprising a plurality of serially connected passages for cooling fluid, said passages being disposed in series with respect to air flow, cooling means for cooling the cooling fluid, said cooling means comprising a refrigeration system including a condenser, means for passing the cooled cooling fluid through said heat exchanger for cooling and dehumidifying the air, said last named means causing the cooling fluid to pass through the heat exchanger in counter flow relationship with the air flow whereby the temperature of the cooling fluid leaving the heat exchanger is warmer than the temperature of the air leaving the heat exchanger, a reheater downstream of the heat exchanger for reheating the air, means for passing cooling fluid from the outlet of said heat exchanger through said reheater, and means for conveying the fluid from the reheater to the condenser for cooling the same.

20. In an air conditioning system, a conditioning chamber, means for passing air through said conditioning chamber, a heat exchanger in said conditioning chamber for cooling and dehumidifying the air, a supply of fluid for the heat exchanger means for reducing the temperature of said fluid before it passes to the heat exchanger including a refrigeration system having a condenser, a reheater for reheating the air passing from the heat exchanger, means for supplying the fluid leaving said heat exchanger to said reheater, and means for then passing the fluid leaving the reheater through the condenser, thereby utilizing the cooling effect of the air being reheated for partially cooling said condenser.

21. In a system of the class described, heat exchanger means, means for circulating a fluid through said heat exchanger means, conduit means connected to the outlet of said heat exchanger means, valve means controlling the flow of fluid from said conduit means, and motor means influenced by the pressure of the fluid on the inlet side of said heat exchanger means for variably positioning said valve means in a manner to maintain a predetermined pressure within said heat exchanger means to insure an efficient heat exchange relationship therein.

22. In a system of the class described, heat exchanger means, means for circulating a fluid through said heat exchanger means, conduit means connected to the outlet side of said heat exchanger means, valve means on the inlet side

of said heat exchanger means controlling the flow of fluid to said heat exchanger means, condition responsive means in control of said valve means for variably positioning the same, and pressure operated valve means for restricting the flow of fluid from the conduit means in a manner to maintain a predetermined pressure within the heat exchanger means to insure an efficient heat exchange relationship therein.

23. In a system of the class described, a heat exchanger, a source of supply of heat exchange medium, means including conduit means for delivering medium from said source to said heat exchanger, conduit means for normally delivering heat exchange medium from said heat exchanger to a location other than said source, other conduit means for returning heat exchange medium from said heat exchanger to said source, control means for normally preventing substantial flow of heat exchange medium through said other conduit means, and means actuated upon shortage of heat exchange medium at said source for controlling said control means in a manner to cause return of the heat exchange medium to said source upon the occurrence of such shortage.

24. In a system of the class described, a heat exchanger, a source of supply of heat exchange medium, means including conduit means for delivering medium from said source to said heat exchanger, conduit means for normally delivering heat exchange medium from said heat exchanger to a location other than said source, other conduit means for returning heat exchange medium from said heat exchanger to said source, control means for normally preventing substantial flow of heat exchange medium through said other conduit means, flow control means for varying the flow of heat exchange medium through said heat exchanger in accordance with the demand for heat exchange, and means influenced by the relationship between the rate of supply of heat exchange medium from said source and the demand for heat exchange medium by said flow control means for actuating said first control means in a manner to return heat exchange medium to the source when the supply of heat exchange medium falls below the demand therefor.

25. In an air conditioning system utilizing water from a well or the like for conditioning the air in a space, a heat exchanger in heat exchange relationship with air for a space, means including a pump for causing water from the well to flow through said heat exchanger, conduit means for conveying water from the heat exchanger to a location other than the well, return conduit means for returning water from the heat exchanger to the well, valve means for normally preventing return of water from the heat exchanger through said return conduit means, and means responsive to pressure varied by said pump for controlling said valve means in a manner to operate said valve means for returning the water to the well upon fall in said pressure.

26. In a system of the class described, an air conditioning chamber, heat exchanger means in said air conditioning chamber, means for circulating air over said heat exchanger means and through a space to be conditioned, means for circulating fluid through said heat exchanger means so as to change the temperature of the air passing over said heat exchanger means, valve means for draining fluid from said heat exchanger means, and means responsive to a low predeter-

mined temperature at the outlet of the heat exchanger means for interrupting delivery of fluid to said heat exchanger means and for opening said valve means.

27. In an air conditioning system, an air conditioning chamber, cooling means in said chamber, means for causing a circulation of fresh outside air through said air conditioning chamber in contact with said cooling means and into a space to be conditioned, means for varying the capacity of said cooling means and said air circulating means, and a single means responsive to the wet bulb temperature of the outside air, the dry bulb temperature of the outside air and the radiant heat of the outside air in control of said varying means for increasing the capacity of the cooling means and of the air circulating means as the total outside cooling load on the air conditioning system increases.

28. In an air conditioning system, an air conditioning chamber, a heat exchanger in said air conditioning chamber, means for circulating air over said heat exchanger, means for circulating heat exchange fluid through said heat exchanger, flow control means controlling the flow of fluid through said heat exchanger, means for controlling said flow control means so as to vary the temperature of the fluid leaving the heat exchanger according to the load on the system, and means actuated in response to the load on the system for controlling said flow control means so as to maintain a predetermined flow of fluid

when the load on the system lies within a predetermined range of values.

29. In a heat exchange system, in combination, a source of heat exchange fluid, means for changing the temperature of said fluid including a heat exchanger through which said fluid flows, means for controlling said temperature changing means to operate the same at varying rates, means for causing a recirculation of said heat exchange fluid through said heat exchanger, and means responsive to the temperature of the heat exchange fluid leaving the heat exchanger for controlling the rate at which said temperature changing means is operated and for controlling the operation of the recirculation causing means.

30. In a heat exchange system, in combination, a source of heat exchange fluid, means for changing the temperature of said fluid including a heat exchanger through which the fluid and a temperature changing medium are circulated in heat exchange relationship, means for circulating the medium through the heat exchanger at different rates of flow, means for causing a recirculation of said heat exchange fluid through said heat exchanger, and means responsive to the temperature of the heat exchange fluid leaving said heat exchanger for controlling the rate at which said temperature changing medium is circulated through said heat exchanger and for controlling the operation of the recirculation causing means.

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