

Oct. 24, 1939.

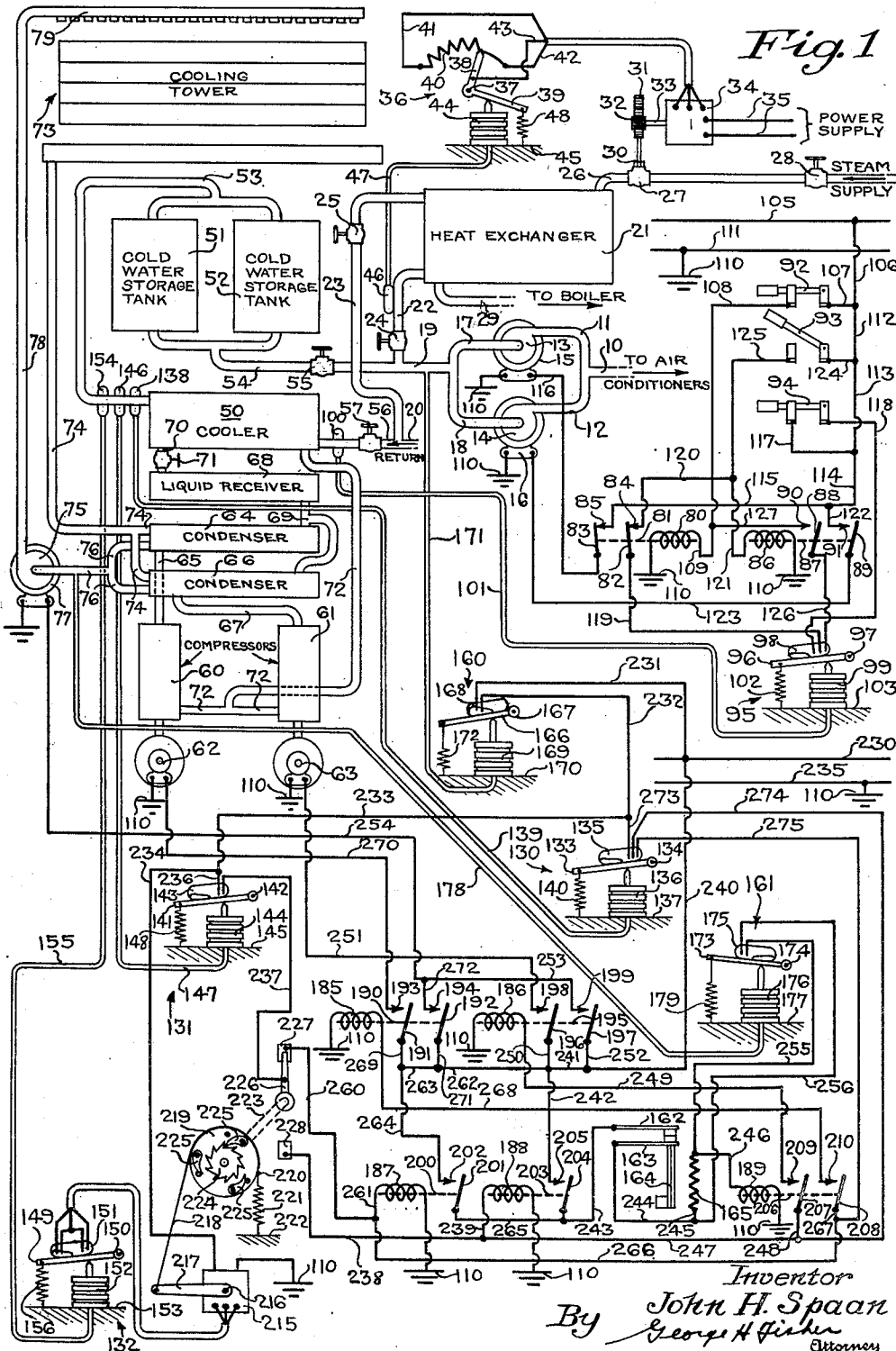
J. H. SPAAN

2,177,602

AIR CONDITIONING SYSTEM

Filed May 11, 1936

5 Sheets-Sheet 1



Oct. 24, 1939.

J. H. SPAAN

2,177,602

AIR CONDITIONING SYSTEM

Filed May 11, 1936

5 Sheets-Sheet 2

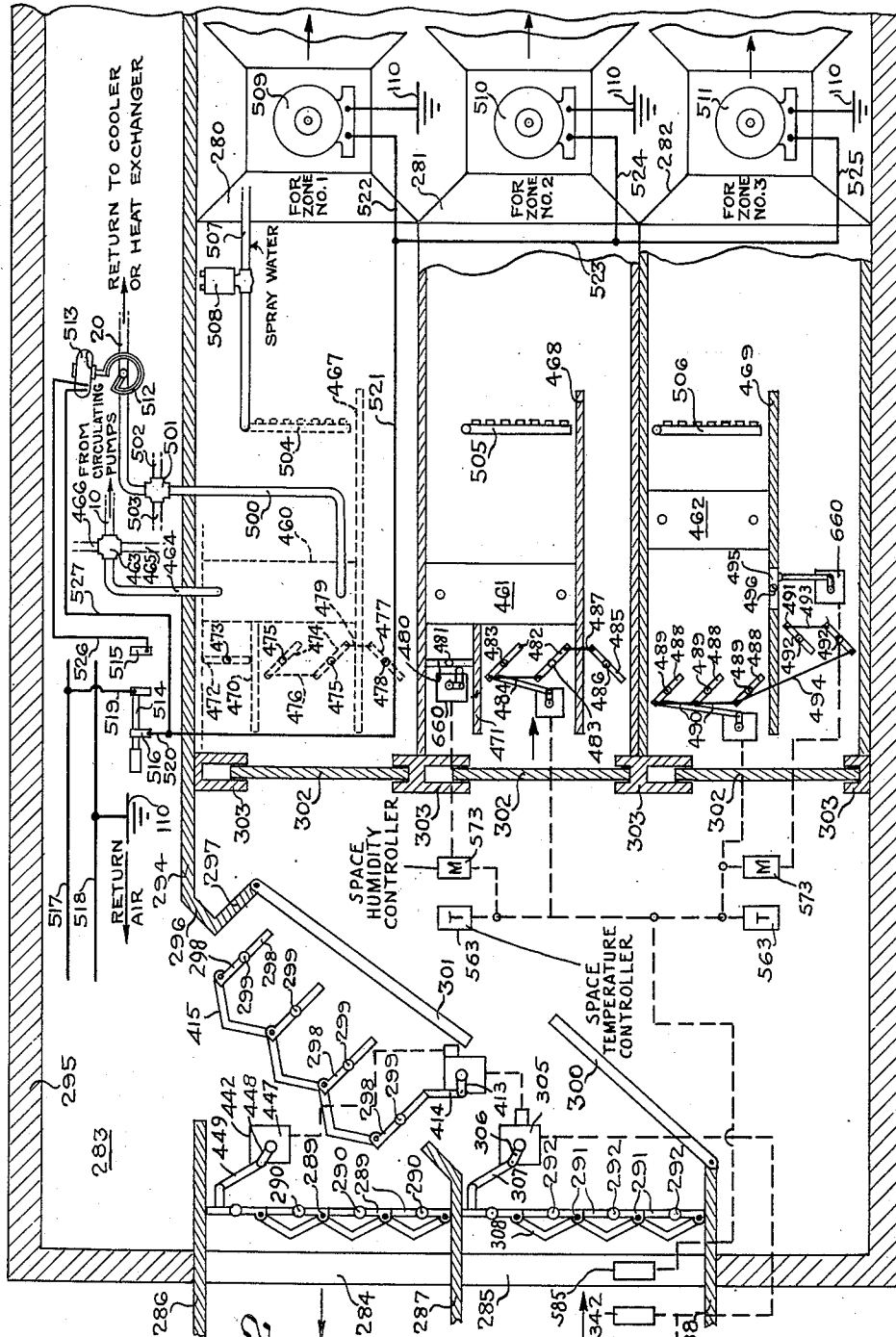


Fig. 2

Inventor
John H. Spaan
George H. Fisher
Attorney

Oct. 24, 1939.

J. H. SPAAN

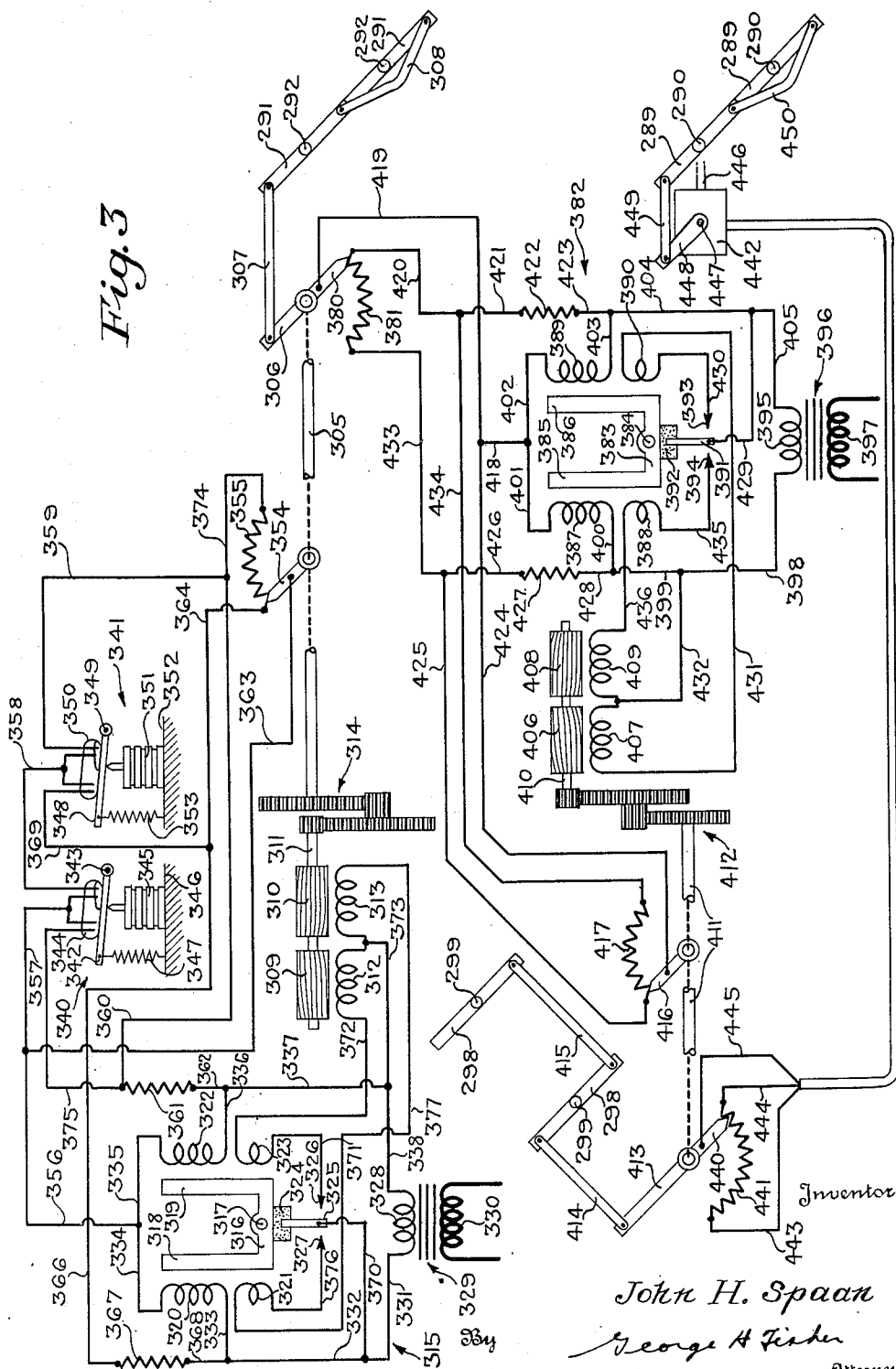
2,177,602

AIR CONDITIONING SYSTEM

Filed May 11, 1936

5 Sheets-Sheet 3

Fig. 3



Oct. 24, 1939.

J. H. SPAAN

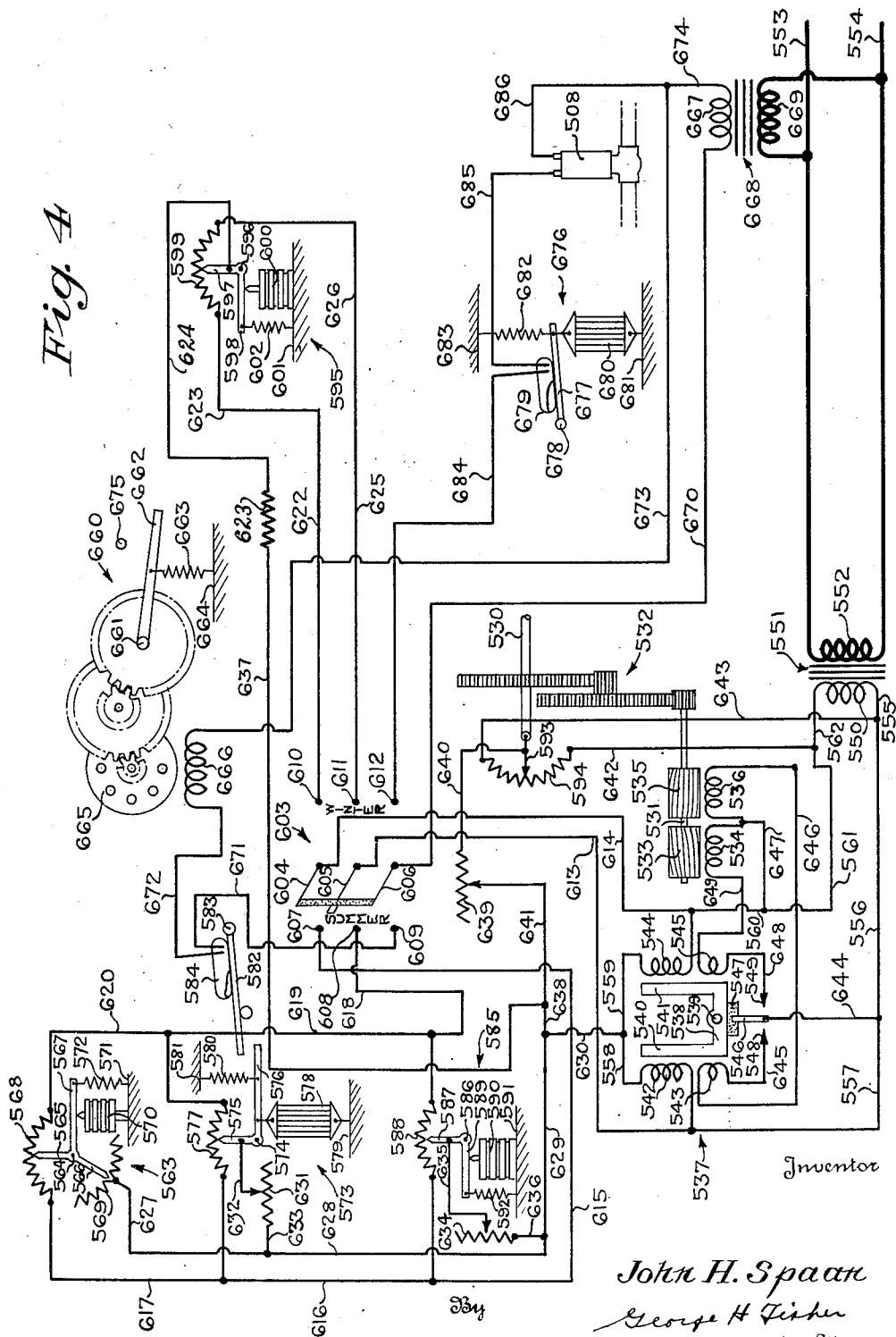
2,177,602

AIR CONDITIONING SYSTEM

Filed May 11, 1936

5 Sheets-Sheet 4

Fig. 4



Oct. 24, 1939.

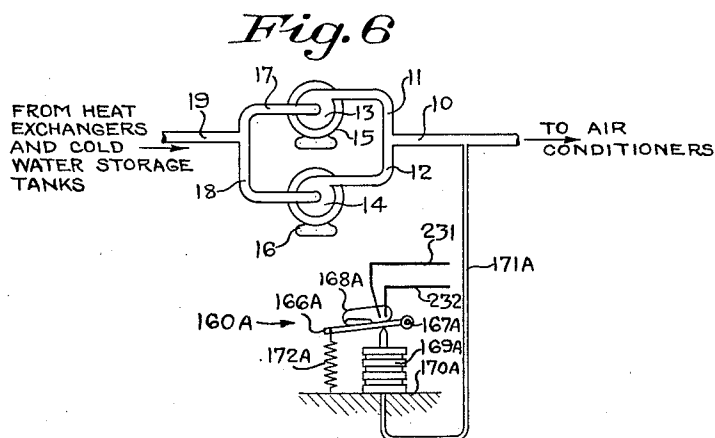
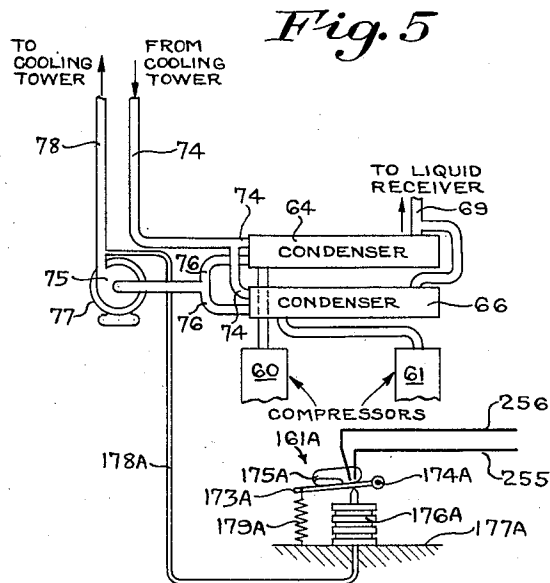
J. H. SPAAN

2,177,602

AIR CONDITIONING SYSTEM

Filed May 11, 1936

5 Sheets-Sheet 5



Inventor

John H. Spaan

By

George H. Fisher

Attorney

UNITED STATES PATENT OFFICE

2,177,602

AIR CONDITIONING SYSTEM

John H. Spaan, Oklahoma City, Okla., assignor to
Minneapolis-Honeywell Regulator Company,
Minneapolis, Minn., a corporation of Delaware

Application May 11, 1936, Serial No. 79,091

39 Claims. (Cl. 62-4)

The present invention relates to air conditioning systems by means of which the conditions in a space or a plurality of spaces may be controlled both in warm weather and in cold weather. The invention is directed not only to the specific manner of controlling the conditioning of the air itself but further relates to the combination of several such systems into a single large system in which the supplies of cooling and heating mediums are controlled in new and novel manners.

One of the objects of the present invention is the provision of an improved system of controlling the circulation of a temperature changing fluid, such as water, which is utilized to vary the temperature of air to be conditioned.

More specifically, the present invention has for an object the provision of a circulation controlling system in which any one of a plurality of circulating devices may be utilized to circulate a temperature changing fluid and providing means by which another of such circulating devices is placed in operation when the temperature of the circulating fluid returning from the devices to be heated or cooled thereby reaches a predetermined value.

Another object of the present invention is the provision of a cooling system for cooling a circulating medium in which the cooling apparatus cannot be placed in operation unless the fluid medium is in actual circulation.

More specifically, it is an object of the present invention to permit the operation of a cooling apparatus only in the event the pressure of a circulating medium which is cooled by the cooling apparatus changes from its static value thereby indicating that the fluid to be cooled is actually in circulation.

Another object of the invention is the provision of a cooling system of the type in which part of the cooling apparatus, such as the condenser of a mechanical refrigeration system, is cooled by means of the use of circulating a cooling fluid therethrough, such as circulating water through such a condenser, and in which the cooling apparatus is rendered inoperative after a time period if, in the meantime, the circulation of such cooling fluid has not commenced or, if during the operation of the cooling apparatus, the flow of the cooling liquid through the condenser is not maintained in sufficient volume to accomplish its purpose as a cooling liquid for the cooling apparatus.

More specifically, it is an object of the present invention to render the cooling apparatus of a mechanical refrigeration system inoperative in

the event the pressure of the condenser cooling water is not changed from a value equal to the static pressure.

A further object of the invention is the provision of a cooling system that includes a plurality of cooling apparatuses and arranging the system in such a manner that the cooling apparatuses are brought into operation alternately upon consecutive demands for cooling. In other words, upon a call for cooling, one of the cooling apparatuses is brought into operation and remains in operation until such call for cooling is satisfied and upon the next subsequent call for cooling the other cooling apparatus is brought into operation and remains in operation until the call for cooling is satisfied.

A further object of the invention is the provision of a cooling system in which a pair of cooling apparatuses are alternately brought into operation upon consecutive demands for cooling, and in which both cooling apparatuses are brought into operation upon an increased demand for cooling. Stated in another way, it is an object of this invention to provide a plurality of cooling apparatuses, both of which can be placed in operation at the same time in the event both cooling apparatuses are needed in order to obtain the desired cooling action, but in which if the demands for cooling are sufficiently small that only one cooling apparatus need be used then these cooling apparatuses are alternately operated upon consecutive demands for cooling.

Another object of the invention is the provision of an air conditioning system in which the supply of air to be conditioned to a plurality of conditioners is provided in a single large room or enclosure to which return air and fresh air is supplied.

Another object of the invention is the provision of a large room or enclosure to which return or fresh air is supplied under the control of suitable automatic controls, together with a plurality of air conditioning devices, each of which then receives its supply of air for conditioning from this central or single room or enclosure.

A further object of the invention is the provision of a novel electrical damper operating system wherein the dampers are too numerous or too heavy to be operated by a single electrical motorized mechanism wherefor a plurality of such mechanisms are necessary.

More specifically, it is an object of this invention to move a first damper from a first position to a second position by an electrical motor means which requires an appreciable time to so move

the first damper, and to have such motor means in turn operate mechanism which causes a second motor means that controls a second damper to exactly follow the motor of the first motor means.

5 In this manner, both dampers are operated substantially simultaneously by the use of commercial equipment available on the market.

A further object of the invention is to control dampers in an air conditioning system in such a manner that they are moved from a position permitting a maximum supply of air to pass therethrough to a position in which a minimum supply of air is allowed to pass therethrough and back to a position in which a maximum amount of air is allowed to pass therethrough as the outdoor temperature rises from a relatively low value, passes through an intermediate value, and then rises to an extreme or high value.

A further object of the invention is the provision of a combined cooling and dehumidifying system in which the dehumidifying action is obtained by decreasing the volume of air flowing through a cooling coil wherefor its speed of flow is reduced and it is cooled to a greater extent so as to remove more moisture therefrom.

More specifically, an object of the invention is the provision of an air conditioning system having a cooling coil only part of which is normally used for cooling purposes, a small amount of air being allowed to flow through the other portion thereof at a slow rate so as to obtain a high degree of cooling and dehumidification upon a demand for dehumidification.

Another object of the invention is the provision of an air conditioning system in which auxiliary damper means permits the flow of a small amount of air through a cooling coil upon a demand for dehumidification whereby such small amount of air moves at a slow rate and is cooled to a relatively great extent so as to remove a substantial amount of moisture therefrom.

A further object of the invention is the provision of an air conditioning system in which a plurality of air conditioners are supplied with a temperature changing fluid from a single source and in which the rate of flow of this temperature changing fluid to the various air conditioning devices is changed in accordance with changes in the temperature of the temperature changing fluid as it returns from all of the air conditioning devices.

Other objects of the invention include various combinations and sub-combinations to be disclosed hereinafter in detail, as well as various combinations of the features set forth above and will be found in the drawings, the detailed description and the appended claims.

For a better understanding of the invention, reference may be had to the following detailed description and the accompanying drawings, in which:

Fig. 1 is a diagrammatic showing of the manner in which the chilled and heated water is supplied for the complete air conditioning system and including the controlling apparatus therefor,

Fig. 2 is a diagrammatic showing of the general arrangement of the air conditioning devices and the manner in which a common supply of air to be conditioned is provided for all of the air conditioning apparatuses,

Fig. 3 is a diagrammatic showing of the control apparatus for that part of the apparatus shown in Fig. 2 by means of which the common supply of air to be conditioned is provided for the various air conditioning devices,

Fig. 4 is a diagrammatic showing of the control system utilized on each of the air conditioning devices shown in Fig. 2,

Fig. 5 is a modified showing of a portion of the apparatus of Fig. 1 and,

Fig. 6 is a modified showing of another portion of the apparatus of Fig. 1.

Turning now to the drawings, while a supply of chilled and heated water may be provided for the various air conditioning devices utilized in the present invention in any manner desired, the present invention includes a specific manner of providing such a supply of chilled and heated water. Referring first to Fig. 1 of the drawings, chilled or heated water is supplied to the air conditioning devices by means of a main delivery pipe indicated at 10. Connected to this main delivery pipe 10 is a pair of branch delivery pipes 11 and 12 which are respectively connected to the outlets of a pair of circulating pumps 13 and 14 which are respectively driven by electric motors 15 and 16. The inlets of the pumps 13 and 14 are respectively connected to branch inlet pipes 17 and 18 which in turn communicate with a main inlet pipe 19. After the heated or chilled water has passed through the various air conditioning devices in a manner to be explained hereinafter, it is returned by a main return pipe 20. The main inlet pipe 19 and the main return pipe 20 are respectively connected to the outlet and inlet of a heat exchanger 21 by means of pipes 22 and 23. Located in the pipe 22 is a manually operable shut-off valve 24 and a similar manually operable shut-off valve 25 is located in the pipe 23. It will be apparent that by opening these valves 24 and 25, the heat exchanger 21 can be placed in communication with the circulators 13 and 14 and with the main return pipe 20 and that by closing these valves 24 and 25 it is impossible for any water to flow to or from the heat exchanger and into or out of main inlet pipe 19 or the main return pipe 20.

The heat exchanger 21 is utilized to provide heated water or steam during cold weather. In the instant invention, this is accomplished by providing the heat exchanger 21 with a supply of steam through the medium of a steam supply pipe 26, under the control of a modulating or proportioning valve 27. This supply of steam may be obtained in any desirable manner either from an individually controlled boiler or from a central power station, and the pipe 26 may be further provided with a manually operable valve 28 for the purpose of preventing the flow of steam to the heat exchanger 21. After the steam has passed through the heat exchanger 21 it is returned to the individual boiler or disposed of in any desirable manner, as by permitting it to flow to a drain by means of a pipe 29.

Modulating or proportioning valve 27 may take any desired form and may be controlled in any desired manner. As herein shown, this valve includes a valve stem 30 which is connected to a rack 31. Cooperating with the rack 31 is a pinion 32 which is carried by the main operating shaft 33 of a motor mechanism 34. This motor mechanism 34 is supplied with power by means of line wires 35 and is controlled by a thermostatic mechanism generally indicated at 36.

The thermostatic mechanism 36 includes a bell crank pivoted at 37 and having a control arm 38 and an actuating arm 39. The control arm 38 cooperates with a control resistance 40 which is connected to the motor mechanism 34 by means of wires 41 and 42. The control arm 38 is

likewise connected to the motor mechanism 34 by means of a wire 43. The actuating arm 39 is positioned by a bellows 44, one end of which engages the actuating arm 39 and the other end of which is secured to a suitable support 45. Connected to the bellows 44 is a controlling bulb 46, the connection being by means of a connecting tube 47. The bellows, bulb and connecting tube are charged with a suitable volatile fluid, as is well known in the art, by means of which variable pressures are created in the bellows 44 in response to temperature changes at the controlling bulb 46. A coiled spring 48 has one of its ends attached to the actuating arm 39 and its other end attached to the support 45 and serves to oppose the variable pressures built up in the bellows 44.

This thermostat 36 may respond to any desired temperature and is herein shown as having its controlling bulb 46 located in heat exchange relationship with the pipe 22 which leads from the heat exchanger 21 and connects to the main inlet pipe 19 for the circulators 13 and 14. The arrangement of this thermostat is such that substantially 6° F. are required to cause the control arm 38 to completely traverse the control resistance 40 and the setting is such that this 6° temperature is from 132° F. to 138° F. The manner in which such a potentiometer type thermostat may control a motor mechanism such as the motor mechanism 34 to position a valve is now thought to be well known in the art. This mechanism may take the electrically balanced form as will be described hereinafter in connection with the control of certain other phases of the air conditioning system, or may be of the mechanical follow-up type such as disclosed in Lewis L. Cunningham Patent No. 1,989,972 granted February 5, 1935. In any event, the thermostat 36 variably positions the valve 27 through the medium of the motor mechanism 34 so as to maintain the temperature of the hot water leaving the heat exchanger between 132° F. and 138° F. With the parts in the position shown, the apparatus is operating on a cooling cycle, wherefor the manually operable valves 24 and 25 are closed as is the manually operable valve 28. Therefore, no steam is being supplied to the heat exchanger 21 and the temperature of the controlling bulb 46 corresponds to the surrounding atmosphere which, of course, would be lower than 132° F. As a result, the actuating arm 38 is engaging the extreme right-hand end of control resistance 40 and the proportioning valve 27 is completely open. However, since the manually operable valve 28 is closed no steam is flowing to the heat exchanger 21.

In order to supply chilled water to the air conditioning system, a tube and shell cooler 50 is provided. This cooler connects to a pair of cold water storage tanks 51 and 52 by means of pipes 53. These cold water storage tanks 51 and 52 in turn connect with the main inlet pipe 19 for the circulating pumps by means of a pipe 54 which is provided with a manually operable valve 55. The main return 20 is connected to the cooler 50 by a pipe 56 and a manually operable valve 57 is included in this pipe 56. As in the case of the heat exchanger 21, these manually operable valves 55 and 57 make it possible to valve off the cooling system or to place it in communication with the air conditioning devices. As indicated above, the system is operating under a hot weather cycle so as to provide chilled water wherefor the valves 55 and 57 are in their open

positions. The purpose of the cold water storage tanks 51 and 52 is to provide a relatively large supply of cold water which is capable of taking care of any sudden or unusual demands on the cooling system.

The water in the cooler 50 is adapted to be cooled by means of a mechanical refrigeration system which includes a pair of compressors 60 and 61 which are respectively driven by compressor motors 62 and 63. The hot gaseous refrigerant compressed by the compressor 60 is led to a condenser 64 by means of a pipe 65. Similarly, the hot gaseous refrigerant compressed by the compressor 61 is led to a condenser 66 by means of a pipe 67. The hot refrigerant is cooled and liquefied by these condensers in the usual manner and is then discharged into a liquid receiver 68 by means of connecting pipes 69. From this liquid receiver the refrigerant passes to the cooler 50 through a pipe 70 which is provided with an expansion valve 71. The refrigerant is expanded in the cooler 50 through the medium of the usual expansion coil and cools the water contained therein. The refrigerant then returns to the compressors 60 and 61 by means of pipes indicated at 72.

The condensers 64 and 66 are herein shown as being of the water cooled type to which water is delivered from a cooling tower 73 by means of pipes 74. The return water from the condensers 64 and 66 is led to a condenser water pump 75 by means of pipes 76. This pump is driven by a condenser pump motor 77 and the water is forced by this pump 75 through a pipe 78 which communicates with the spray 79 of the cooling tower 73.

The circulating pump motors 15 and 16 are electrically controlled by a system which will now be described. The motor 13 is controlled by a relay which includes a relay coil 80 that positions an armature 81 which in turn operates switch arms 82 and 83. Upon energization of the relay coil 80, the switch arms 82 and 83 are moved into engagement with contacts 84 and 85, respectively. In a similar manner, the circulating pump motor 16 is controlled by a relay that includes a relay coil 86 which operates an armature 87 that positions a pair of switch arms 88 and 89. Upon energization of the relay coil 86 the switch arms 88 and 89 are respectively moved into engagement with contacts 90 and 91.

The energization of these relay coils 80 and 86 is controlled by three manual switches 92, 93, and 94 by a thermostatic switch generally indicated at 95. The three manual switches 92, 93 and 94 are of the single-pole, single-throw type and need no further explanation. The thermostatic switch 95 includes a switch carrying arm 96 which is pivoted at 97 and carries a mercury switch 98. This switch carrying arm 96 is positioned by a bellows 99 which is connected to a controlling bulb 100 by means of a connecting tube 101. The bellows, bulb and tube are charged with volatile fluid wherefor variable pressures are created in the bellows 99 upon changes in the temperature at the controlling bulb 100. A spring 102 has one of its ends secured to the switch carrying arm 96 and its other end secured to a support 103 and serves to oppose the variable pressures created in the bellows 99. As shown, one end of bellows 99 engages the switch carrying arm 96 and its other end is secured to the support 103.

This thermostat 95 may respond to any desired temperature and is herein shown as responding

to the temperature of the water which is being returned to the cooler 50. In other words, this thermostat 95 responds to the temperature of the water as it leaves the various air conditioning devices. The arrangement is such that mercury switch 98 is in the open circuit position in which it is shown in Fig. 1. Whenever the temperature of this returned chilled water is at or below 41° F., and is moved to closed position whenever the temperature of this water rises to or above 43° F.

Either relay coil 80 or 86 can be energized by closing its associated manual switch 92 or 93. With the parts in the position shown in Fig. 1, the manual switch 92 is closed wherefor the relay coil 80 is energized by a circuit as follows: Line wire 105, wire 106, wire 107, manual switch 92, wire 108, wire 109, and relay coil 80, to ground 110, it being noted that the other line wire 111 is likewise connected to ground 110. Since relay coil 80 is energized, the switch arms 82 and 83 are engaged with contacts 84 and 85. Engagement of switch arm 83 with contact 85 energizes the circulating pump 15 by a circuit as follows: line wire 105, wire 106, wire 112, wire 113, wire 114, wire 115, contact 85, switch arm 83, wire 116, circulating pump motor 15 and ground 110. The circulating pump 15 is, therefore, in continuous operation. Now, in the event the manual switch 94 is also closed as shown in Fig. 1, then the thermostat 95 is operative to energize the other relay coil 86 if the temperature of the return water rises to 43° F., so as to close the mercury switch 98. Assuming that the return water temperature does rise to this value, then the relay coil 86 will be energized by a circuit as follows: Line wire 105, wire 106, wire 112, wire 113, wire 117, manual switch 94, wire 118, the left-hand electrode of mercury switch 98, the middle electrode thereof, wire 119, switch arm 82, contact 84, wire 120, wire 121, relay coil 86 and ground 110. Energization of relay coil 86 moves switch arms 88 and 89 into engagement with contacts 90 and 91 wherefor circulating pump motor 16 is energized as follows: Line wire 105, wire 106, wire 112, wire 113, wire 114, wire 122, contact 91, switch arm 89, wire 123, circulating pump motor 16, to ground 110. In this manner, when the temperature of the returned chilled water rises to some undesirable high value, such as 43° F., thereby indicating that the load on the air conditioning devices is relatively heavy, the other circulating pump is brought into operation in order to increase the flow of chilled water to the air conditioning devices whereby to take care of this excessive load. In the event the temperature of the returned chilled water drops to 41° F., mercury switch 98 returns to the position shown in Fig. 1 and the circuit for relay coil 86 is interrupted thereby causing deenergization of the circulating pump motor 16.

If the manual switch 92 be opened and the manual switch 92 be closed instead, then the relay coil 86 is continuously energized by a circuit as follows: Line wire 105, wire 106, wire 112, wire 124, manual switch 93, wire 125, wire 121, and relay coil 86 to ground 110. The circulating pump motor 16 is therefore continuously energized under these conditions. If the manual switch 94 is still closed and if the temperature of the return chilled water should rise to 43° F., then the relay coil 80 is energized as follows: Line wire 105, wire 106, wire 112, wire 113, wire 117, manual switch 94, wire 118, mercury switch 98, right-hand electrode thereof, wire 126, switch arm 88, contact 90, wire 127, and wire 109 to relay coil 80 and

ground 110. Such energization of relay coil 80 energizes the circulating pump motor 15 by the circuit set out above.

From the foregoing it is seen that either circulating pump motor 15 or 16 can be placed into continuous operation by means of closing either the manual switch 92 or the manual switch 93. In addition, in the event the manual switch 94 is closed, the other circulating pump motor will be energized whenever the temperature of the returned chilled water rises to 43° F., irrespective of which one of these motors is manually operated continuously. Also, if both manual switches 92 and 93 are closed then both circulating pump motors 15 and 16 are operated continuously irrespective of the temperature of the returned chilled water. This arrangement makes it possible to even up the wear and tear on both circulators by placing either of them in continuous operation and permitting the other to be automatically brought into operation. During cold weather it has been found that in this particular system sufficient hot water is supplied to the air conditioners irrespective of how cold it gets outside by only operating one circulator. Therefore, the manual switch 94 should be left open during the winter operation and the desired circulator can then be placed in operation by closing one or the other of the manual switches 92 or 93. In the event the switch 94 is left closed in the winter, during which time the cooler 50 is valved off by closing of the valves 55 and 57, it will be apparent that the temperature at the control bulb 100 will be that of the surrounding atmosphere which under all usual conditions would be above 43° F., wherefor both circulating motors 15 and 16 will be in continuous operation even though only one of the switches 92 or 93 is closed.

The compressor motors 62 and 63 are controlled, in a manner which will now be explained, in accordance with the temperature of the water leaving the cooler 50. In order to control these compressor motors in a particular manner, which will become clear hereinafter, three thermostats responsive to the temperature of the chilled water are provided. These thermostats are generally indicated at 130, 131, and 132.

The thermostat 130 includes a switch carrying arm 133 which is pivoted at 134 and supports a mercury switch 135. This switch carrying arm 133 is positioned by one end of a bellows 136, the other end of which is secured to a support 137. The bellows 136 communicates with a controlling bulb 138 through a connecting tube 139. The bellows, bulb and tube are charged with a suitable volatile fluid so that variable pressures are created in bellows 136 upon temperature changes at the bulb 138, and the variable pressures thus created at the bellows 136 are opposed by a coiled spring 140 which has one of its ends secured to the switch carrying arm 133 and its other end secured to the support 137.

The thermostat 131 is a substantial duplicate of the thermostat 130 and includes a switch carrying arm 141 which is pivoted at 142 and supports a mercury switch 143. This arm is positioned by a bellows 144 that has one of its ends secured to a support 145. The bellows 144 is connected to a controlling bulb 146 through a connecting tube 147, the bellows, bulb and tube being charged with a suitable volatile fluid. A coiled spring 148 opposes the variable pressures created in bellows 144 as a result of temperature changes in the bulb 146.

The thermostat 132 is likewise generally sim-

ilar to the thermostats 130 and 131. This thermostat includes a switch carrying arm 149 which is pivoted at 150 and supports a mercury switch 151. This switch carrying arm 149 is positioned by a bellows 152 which has one of its ends connected to a support 153. The bellows 152 communicates with a controlling bulb 154 through a connecting tube 155 and a coiled spring 156 opposes the variable pressures created in bellows 152 upon temperature changes at the bulb 154.

As indicated above, these three thermostats 130, 131, and 132 respond to the temperature of the chilled water and for this purpose the bulbs 138, 146 and 154 of these thermostats have been shown as positioned in heat exchange relationship with the pipe 53 which is connected to the outlet of the cooler 50. The thermostat 130 is arranged in such a manner that the mercury switch 135 thereof moves to closed circuit position whenever the temperature of the chilled water rises to or above 42° F., and moves to open position whenever the temperature of this cooled water falls to or below 34° F. The thermostat 131 is arranged so that its mercury switch moves to closed circuit position whenever the temperature of the chilled water rises to 39° and moves to open position whenever the temperature thereof falls to 35° F. The mercury switch 151 of the thermostat 132 is of the double circuit type which closes a circuit regardless of which way it is tilted. This mercury switch can operate at any temperature within the temperature limits of the thermostat 131 for reasons which will become apparent hereinafter. For the purpose of this explanation, it will be assumed that the mercury switch 151 is in the position shown in Fig. 1 in which its left-hand electrodes are closed whenever the temperature of the chilled water is at or below 36° F. Whenever the temperature of this water rises to or above 38° F. the mercury switch 151 is tilted to the opposite position in which its right-hand electrodes are closed.

The control system for the compressor motors 62 and 63 additionally includes certain safety controls in the form of a pressure responsive switch generally indicated at 160, a second pressure responsive switch generally indicated at 161, and a thermal cut-out switch. The thermal cut-out switch includes a pair of switch arms 162 and 163 which are normally in engagement and are so held in engagement by a bimetallic element 164. This bimetallic element 164 is adapted to be heated by an electrical heating element 165. The arrangement is such that if the heating element 165 is energized for a predetermined length of time the bimetallic element 164 is raised in temperature sufficiently that it goes far enough to the right to move out from under the end of switch arm 163. This permits switch arm 163 to separate from switch arm 162 to open the circuit therebetween. This circuit then can only be again completed by manually moving these switch arms 162 and 163 into engagement. Thermal switches of this type are well known in the oil burner art by the name of "safety switches" and the thermal switch of the present invention may well take the form shown in Frederick S. Denison Patent No. 1,958,081 granted May 8, 1934.

The pressure responsive switching mechanism 160 includes a switch carrying arm 166 which is pivoted at 167 and carries a mercury switch 168. This switch carrying arm 166 is positioned by a bellows 169 which is supported by a support 170. This particular pressure responsive switch-

ing mechanism 160 responds to the pressure in the main inlet pipe 19 to the circulating pumps 13 and 14. For this purpose the bellows 169 is connected to this pipe 19 by means of a pipe 171. The pressures to which the bellows 169 is thus subjected are opposed by a coiled spring 172. The purpose of this pressure responsive switching mechanism 160 is to determine whether or not either one of the circulators 13 and 14 is in operation. When neither of these circulators is in operation there will be a predetermined pressure in the pipe 19 or a static pressure which depends entirely upon the head of water in the system. In the particular system to which the present invention was applied this static head was substantially 42 pounds. Now, it will be evident that upon operation of either one of the circulators 13 and 14, there will be a decrease in pressure in the pipe 19 which is on the suction side of the pumps 13 and 14. The switching mechanism 160 is, therefore, so arranged that the mercury switch 168 thereof is in open circuit position whenever the pressure in pipe 19 is at or above the static head of the system and moves to closed position whenever the pressure in this pipe is reduced therebelow. It is, therefore, evident that the mercury switch 168 will be open whenever neither circulator is operating. Also, it will be apparent that mercury switch 168 will close in the event either of these circulators is operating. The mercury switch 168, therefore, by its position gives an indication as to whether or not the water is being circulated to the air conditioning devices.

The pressure responsive device 161 is similar to the device 160 and includes a switch carrying arm 173 which is pivoted at 174 and carries a mercury switch 175. This switch carrying arm 173 is positioned by a bellows 176 which has one end secured to a support 177. This bellows 176 responds to the pressure on the inlet or suction side of the condenser water pump 75 and is, therefore, connected to the pipe 76 by means of a pipe 178. The pressure thus produced in the bellows 176 is opposed by a coiled spring 179. In this particular system the static head of the condenser water circuit is substantially 50 pounds. This is slightly higher than the static head in the circulating system by reason of the cooling tower being at a higher point than are any of the air conditioning devices. The pressure responsive switching mechanism 161 is, therefore, arranged so that mercury switch 175 is in the open circuit position shown whenever the pressure on the inlet or suction side of the condenser water pump 75 is at or above 55 pounds, and is closed whenever this pressure is lowered. It will, therefore, be evident that mercury switch 175 is open unless the condenser water pump 75 is in operation.

The control system for the compressor motors 62 and 63 further includes five relays which respectively have operating coils 185, 186, 187, 188, and 189. The relay coil 185 operates an armature 190 which in turn controls switch arms 191 and 192. Upon energization of the relay coil 185 switch arms 191 and 192 are moved into engagement respectively with contacts 193 and 194. Similarly, the relay coil 186 controls an armature 195 which positions a pair of switch arms 196 and 197. Upon energization of the relay coil 186 these switch arms 196 and 197 respectively move into engagement with contacts 198 and 199. The relay coil 187 operates an armature 200 which moves a single switch arm 201 into engagement 75

with a single contact 202 when the relay coil 187 is energized. In a similar manner, the relay coil 188 controls an armature 203 which moves a single switch arm 204 into engagement with a single contact 205 upon energization of the relay coil 188. The relay coil 189 controls an armature 206 which positions switch arms 207 and 208 so as to move them into engagement with respective contacts 209 and 210 whenever the relay coil 189 is energized.

The thermostatic switching mechanism 132, which was explained in detail heretofore, operates a motor mechanism 215 which is provided with a main operating shaft 216 to which a crank 217 is secured. This motor mechanism 215 is of a type well known in the art which makes successive half revolutions of 180 degrees under the control of the mercury switch 151. Electrical power is furnished to this motor mechanism 215 in a manner which will be set forth in detail hereinafter. The crank 217 is connected to one end of a cable 218 which is partially wound about a disc 219 and is secured thereto as indicated at 220. A coiled spring 221 has one of its ends secured to the disc 220 and its other end secured to a suitable support 222 and serves to bias the disc 219 to the position shown. This disc 219 is loosely mounted upon a shaft 223 which carries a ratchet 224. Pivotaly carried on the disc 219 are a plurality of pawls 225 which are adapted to cooperate with the ratchet 224 so as to cause counter-clockwise rotation thereof upon counter-clockwise rotation of the disc 219. As is usual in such ratchet constructions, the ratchet 224 is not moved, but remains stationary, upon clockwise movement of the disc 219. The shaft 223 operates a contact arm 226 which is adapted to engage contacts 227 and 228. Assuming that power is available for the motor mechanism 215, and with the parts in the position shown in Fig. 1, if the mercury switch 151 of the thermostatic mechanism 132 is tilted to the opposite position in which its right-hand electrodes are bridged, then the crank 217 will be driven in a counter-clockwise direction through 180 degrees. As the crank arm 217 starts this counter-clockwise movement, it will pull upon the cable 218 and cause a counter-clockwise rotation of the disc 219. By properly correlating the radius of the disc 219 with the length of the crank arm 217, the disc 219 is moved a half revolution in counter-clockwise direction by the time arm 217 has moved through a quarter revolution, or is pointing in a downward direction. Such a half revolution of the disc 219 causes the shaft 223 to be driven through a half revolution by means of the pawls 225 and ratchet 224. This causes movement of switch arm 226 so that it disengages contact 227 and moves into engagement with contact 228. Now, as the crank 217 completes the other quarter of its half revolution, or goes from its downwardly pointing position to the horizontal position in which it points to the right, the spring 221 returns the disc 219 to the position shown in Fig. 1. During this movement of the disc 219 the shaft 223 remains stationary by reason of the ratchet and pawl connection between the shaft and the disc. It will thus be seen that an increase in the temperature to which the thermostat 132 responds to 38° F. causes switch arm 226 to disengage contact 227 and move into engagement with contact 228.

If the temperature now falls to 36° F. so that mercury switch 151 returns to the position shown in Fig. 1, then the motor mechanism 215 will

move crank 217 through another half revolution in counter-clockwise direction. During this half revolution of the crank 217, the disc 219 remains stationary since the only thing that happens is that slack is produced in the cable 218 until the crank is pointing upwardly. Rotation of disc 219 in a clockwise direction under the action of spring 221 at this time is prevented by a suitable stop (not shown). Upon the downward movement of crank 217, the slack is taken up by the time the crank 217 reaches the position shown in Fig. 1. On a subsequent rise in temperature to 38° F. the shaft 223 will move through another half revolution and move switch arm 226 back into engagement with contact 227. If the temperature then again falls to 36° F. the crank 217 will again return to its original position but the shaft 223 will remain stationary. In other words, the switching mechanism 226—227—228 is operated to a new position every time the temperature rises to 38° F. after it has fallen to 36° F. but is never operated upon temperature fall.

As has been brought out above, the circulator 13 is in operation by reason of the fact that manual switch 92 is closed. The pressure in pipe 19 should, therefore, be such that the mercury switch 168 is closed. The mercury switch 135 of the thermostat 130 is shown open, which indicates that the temperature of the chilled water is below 34° F. The mercury switch 143 of the thermostat 131 is therefore also open since this mercury switch opens when the temperature of the chilled water falls to 35° F. In addition, the mercury switch 151 of the thermostat 132 has its left-hand electrodes closed since they are closed when the temperature of the chilled water falls to 36° F. Chilled water is, therefore, being circulated to the various air conditioning devices or other apparatus and after a time period it is obvious that the temperature of the chilled water will rise due to the taking on of heat by the chilled water. When this temperature rises to 38° F. the mercury switch 151 will be tilted so as to close its right-hand electrodes whereupon the contact arm 226 will disengage contact 227 and engage contact 228 in the manner heretofore explained. This, however, does not cause operation of either of the compressors. As the temperature continues to rise, the mercury switch 143 of the thermostat 131 closes at 39° F. This causes operation of the compressor motor 63 provided the mercury switch 168 of the pressure responsive switching mechanism 160, which responds to the operation or non-operation of the circulating pumps, is closed. It should first be noted that power is always available for the motor mechanism 215 provided this mercury switch 168 is closed, by a circuit as follows: Line wire 230, wire 231, mercury switch 168, wire 232, wire 233, wire 234, motor mechanism 215, to ground 110, it being noted that the other line wire 235 is also connected to ground 110. Now, upon closure of the mercury switch 143 of the thermostat 131 due to a rise in the chilled water temperature to 39° F. and with the contact arm 226 now engaging the contact 228, relay coil 188 is energized as follows: Line wire 230, wire 231, mercury switch 168, wire 232, wire 233, wire 236, mercury switch 143, wire 237, contact arm 226, contact 228, wire 238, wire 239, and relay coil 188 to ground 110. It will be noted that this relay coil cannot be energized in the event the mercury switch 168 is in open circuit position. Energization of relay coil 188 moves arm switch 204 into engagement with contact 205 whereupon

electric heater 165 and relay coil 189, in series, are energized as follows: Line wire 230, wire 240, wire 241, wire 242, contact 205, switch arm 204, wire 243, switch arm 162, switch arm 163, wire 244, wire 245, electric heater 165, wire 246, relay coil 189 to ground 110. Energization of electric heater 165 starts heating the bimetallic element 164, as heretofore explained. Energization of relay coil 189 moves switch arms 207 and 208 into engagement with contacts 209 and 210. Engagement of switch arm 207 with contact 209 energizes relay coil 186 as follows: Line wire 230, wire 231, mercury switch 168, wire 232, wire 233, wire 236, mercury switch 143, wire 237, contact arm 226, contact 228, wire 238, wire 247, wire 248, switch arm 207, contact 209, wire 249, and relay coil 186 to ground 110. Energization of this relay coil 186 energizes the compressor motor 63 and the condensing pump motor 77. The circuit for compressor motor 63 is as follows: Line wire 230, wire 240, wire 241, wire 250, switch arm 196, contact 198, wire 251, and compressor motor 63 to ground 110. The circuit for condenser pump motor 77 is as follows: Line wire 230, wire 240, wire 252, switch arm 197, contact 199, wire 253, and wire 254, to condenser pump motor 77 and ground 110.

It will thus be seen that a rise in the temperature of the chilled water to 39° F. causes energization of the heating element 165 and operation of the compressor motor 63 and the condenser pump motor 77. It will be noted that none of these devices could be energized or placed in operation, as the case may be, if the mercury switch 168 were not in closed position. In other words, it is impossible to energize the compressor or the condenser water pump in the event neither of the circulating pumps 13 or 14 is in operation.

Operation of the condenser water pump 75 should cause circulation of the condenser water and reduce the pressure on the suction side of the pump 75. If this pump does operate and reduces this pressure, then the mercury switch 175 of the pressure responsive switching mechanism 161 will move to closed position. Closing of this mercury switch shunts the heating element 165 by a circuit as follows: From the upper end of heating element 165, wire 255, mercury switch 175, wire 256, and wire 245 to the lower end of heating element 165. Shunting of this heating element operatively deenergizes the same whereupon no further heat is delivered to the bimetallic element 164. It will, therefore, be apparent that if this pressure is reduced quickly enough after the initial energization of heating element 165 so as to prevent sufficient heating of bimetallic element 164, the switch arms 162 and 163 will not separate and the apparatus can remain in operation.

Assuming that the load on the apparatus is not particularly high at this time, the operation of compressor motor 63 will provide sufficient refrigeration to cool the chilled water down to 35° F. In so doing, the water will pass through a temperature of 36° F. whereupon mercury switch 151 of the thermostat 132 will return to the position shown in Fig. 1 and cause a further half revolution of the motor mechanism 215. As explained above, however, this will only serve to bring the motor mechanism 215 back to the position shown and the contact arm 226 will remain on the contact 228. When the temperature has thus been lowered to 35° F. the mercury switch 143 of the thermostat 131 opens so as to deenergize the various relays whereupon the compressor

motor 63 and the condenser pump motor 77 are deenergized. The parts are, therefore, in the position shown in Fig. 1 except that contact arm 226 is engaging contact 228.

Since no refrigeration is now being furnished to the chilled water, its temperature will gradually rise. When it rises to 38° F. mercury switch 151 will again be operated so that its right-hand electrodes close. The motor mechanism 215 goes through a further half revolution and this time moves contact arm 226 back into engagement with contact 227. Upon a still further rise to 39° F., mercury switch 143 will again close. This time, however, since the contact arm 226 is engaging the contact 227, the relay coil 187 will be energized instead of the relay coil 188. This circuit is as follows: Line wire 230, wire 231, mercury switch 168, wire 232, wire 233, wire 236, mercury switch 143, wire 237, contact arm 226, contact 227, wire 260, wire 261, and relay coil 187 to ground 110. It will again be noted that this relay coil cannot be energized unless the mercury switch 168 is in closed circuit position. Energization of relay coil 187 moves switch arm 201 into engagement with contact 202 to energize heating element 165 and relay coil 189 by a circuit as follows: Line wire 230, wire 240, wire 241, wire 262, wire 263, wire 264, contact 202, switch arm 201, wire 265, wire 243, switch arm 162, switch arm 163, wire 244, wire 245, heating element 165, wire 246 and relay coil 189 to ground 110. This causes movement of switch arms 207 and 208 into engagement with contacts 209 and 210. Engagement of switch arm 207 with contact 209 will not cause energization of relay coil 186 as it did formerly since contact 226 is disengaged from contact 228, but engagement of switch arm 208 with contact 210 does cause energization of relay coil 185 as follows: Line wire 230, wire 231, mercury switch 168, wire 232, wire 233, wire 236, mercury switch 143, wire 237, contact arm 226, contact 227, wire 260, wire 266, wire 267, switch arm 208, contact 210 and wire 268 to relay coil 185 and ground 110. Energization of relay coil 185 moves switch arms 191 and 192 into engagement with contacts 193 and 194 to energize compressor motor 62 and condenser pump motor 77. The circuit for compressor motor 62 is as follows: Line wire 230, wire 240, wire 241, wire 262, wire 263, wire 269, switch arm 191, contact 193, and wire 270 to compressor motor 62 and ground 110. The circuit for condenser pump motor 77 is as follows: Line wire 230, wire 240, wire 241, wire 262, wire 271, switch arm 192, contact 194, wire 272, and wire 254 to condenser pump motor 77 and ground 110. Operation of the condenser pump should cause a decrease in the pressure in pipe 76 as explained before to in turn cause closure of mercury switch 175. If this occurs in time, the heating element 165 is shunted before the switch arms 162 and 163 separate by reason of excessive heating of bimetallic element 164. It will be seen at this time, automatically, the compressor motor 62 has been energized instead of the compressor motor 63. In other words, consecutive demands for cooling have resulted in alternate operation of the compressors. It will be noted that irrespective of which compressor is in operation, the relay coil 189 is energized. If it should happen that a single compressor is not able to prevent the temperature of the chilled water from rising to 42° F., then the mercury switch 135 of the thermostat 130 will close. When this occurs, a circuit for relay coil 186 is established as follows: Line wire 230, wire

231, mercury switch 168, wire 232, wire 273, mercury switch 135, wire 274, wire 248, switch arm 207, contact 209, wire 249, and relay coil 186 to ground 110. Energization of relay coil 186 energizes compressor motor 63 as heretofore explained. Also, closure of this mercury switch 135 establishes an energizing circuit for relay coil 185 as follows: Line wire 230, wire 231, mercury switch 168, wire 232, wire 273, mercury switch 135, wire 275, wire 267, switch arm 208, contact 210, wire 268, and relay coil 185 to ground 110. Such energization of relay coil 185 energizes compressor motor 62 by the circuit set forth above. It is, therefore, seen that irrespective of which compressor may be in operation at the time, a rise in the chilled water temperature to 42° F. causes the other compressor to be placed in operation.

The two compressors are, of course, of such capacity as to lower the temperature of the cooling water regardless of the load. Since mercury switch 135 does not open until the temperature has fallen to 34° F., both of these compressors will continue to remain in operation even after mercury switch 143 moves to open position. Preferably, the mercury switches 135 and 143 should open at the same time but practically it is impossible to get this accurate a response in two different instruments, wherefor the mercury switch 135 has been indicated as opening at 34° F. and the mercury switch 143 as opening at 35° F.

From the foregoing, it will be seen that the system of Fig. 1 can be utilized to provide either heated water or chilled water for circulation to any desired point of use and particularly to air conditioning devices for summer and winter cooling and heating. The arrangement is such that the chilled water can be circulated at one of two speeds depending upon the temperature of the chilled water being returned from the point of use. Furthermore, these two speeds are accomplished by using two circulators, either of which can be placed into continuous operation and the other of which is automatically placed into operation upon such a rise of temperature of the returned chilled water. The system further prevents operation of the refrigeration system for cooling the water in the event neither of these circulators is in operation. In addition, the refrigeration system is caused to shut down if the condenser water pump does not come into operation within a predetermined time after the refrigeration system is placed in operation. This time delay is of particular utility where operation of the condenser water pump is measured by a change in the pressure of the condenser water due to the fact of its circulation. The system of Fig. 1 further provides an arrangement in which a plurality of refrigeration devices are utilized and in which both can be operated simultaneously, or in which they are separately operated alternately upon subsequent and consecutive demands for cooling.

Turning now to Fig. 2 of the drawings, while the supply of chilled and heated water which is provided by the apparatus described in connection with Fig. 1 can be used in any desired manner, I prefer to utilize it in connection with an air conditioning system which includes a plurality of air conditioning devices. Three of these air conditioning devices are indicated at 280, 281 and 282. These air conditioning devices are all located in a room 283 which is utilized as a mixing chamber or a controlling chamber by means of which fresh air

or return air is furnished to the various air conditioning devices 280, 281 and 282. This room 283 is provided with openings 284 and 285, which may be in the form of windows, for example. These openings 284 and 285 are defined by plates 286, 287 and 288. Located between the plates 286 and 287, and disposed within the room 283, are dampers 289. These dampers 289 are each rotatably mounted upon shafts 290 and these dampers comprise the exhaust dampers for exhausting air from the room 283 when the fresh air dampers are open. In a similar manner, dampers 291 are pivoted on shafts 292 and are disposed between the plates 287 and 288. These dampers comprise the fresh air dampers and permit the taking into the room 283 of fresh air when they are open. The plate 287 is provided with an angularly disposed extension 293. Also located within the room 283, is a partition 294 which runs substantially parallel to the ceiling 295 of the room. This partition 294 is provided with an extension 296 and a further extension 297. Disposed between the extension 296 of the partition 294 and the extension 293 of the plate 287 are dampers 298 each of which is pivotally mounted upon a suitable shaft 299. The space between the ceiling 295 and the partition 294 is utilized for returning air from the various spaces conditioned by the air conditioning devices 280, 281 and 282 and the dampers 298 control the flow of this return air into the inlet ends of these various conditioning devices. Suitable baffle plates 300 and 301 may be respectively pivotally connected to the plate 288 and the extension 297 and positioned in such a manner as to properly baffle the return air or fresh air, as the case may be. Located between these various sets of dampers and the air conditioning devices 280, 281 and 282 are suitable filters 302 which are supported by brackets 303 that permit the easy removal of these filters.

Referring now to both Figs. 2 and 3, the manner in which these various sets of dampers are controlled will now be explained. The fresh air dampers 291 are controlled by the main operating shaft 305 of a motor mechanism which may take any desired form. The connection between one of the fresh air dampers 291 and this main operating shaft 305 includes a crank 306 which is secured to the main operating shaft 305, and a connecting link 307 which connects this crank 306 to the damper. This damper and the other fresh air dampers are interconnected by links 308 by means of which all of the fresh air dampers are simultaneously moved in the same direction and to the same extent.

This main operating shaft 305 is operated by a reversible motor means which is herein shown as comprising a pair of motor rotors 309 and 310 which are secured to a common rotor shaft 311. Associated with the rotors 309 and 310 are field windings 312 and 313. The rotor shaft 311 is connected to the main operating shaft 305 through suitable reduction gearing indicated generally at 314.

Energization of the field windings 312 and 313 is controlled by a relay mechanism generally indicated at 315. This relay mechanism 315 includes an armature 316 which is pivoted at 317 and includes legs 318 and 319. Associated with the leg 318 is a main relay winding 320 and an auxiliary relay winding 321. In a similar manner, a main relay winding 322 and an auxiliary relay winding 323 are associated with the leg 319 of the armature 316. Secured to the armature 316, through the medium of a piece of insulating mate-

rial 324, is a switch arm 325 which is normally disposed intermediate a pair of contacts 326 and 327. Upon energization of the main relay winding 322 to a higher degree than that of main relay winding 320, armature 316 will be rotated counter-clockwise and switch arm 325 will move into engagement with contact 326. On the other hand, if the main relay winding 320 becomes more highly energized than the main relay winding 322, then armature 316 is rotated in a clockwise direction and switch arm 325 moves into engagement with contact 327.

The main relay windings 320 and 322 are connected in series across a source of power herein shown as the secondary 328 of a transformer 329 having a high voltage primary 330. This series circuit is as follows: Secondary 328, wire 331, wire 332, wire 333, main relay winding 320, wire 334, wire 335, main relay winding 322, wire 336, wire 337, and wire 338 to the other side of secondary 328. In order to energize one or the other of these main relay windings more highly than the companion relay winding, two thermostats generally indicated at 340 and 341 are arranged to substantially short-circuit one or the other of these main relay windings under certain conditions.

The thermostat 340 includes a switch carrying arm 342 which is pivoted at 343 and supports a mercury switch 344. This switch carrying arm 342 is positioned by one end of a bellows 345, the other end of the bellows being fastened to a suitable support 346. The bellows 345 is charged with a suitable volatile fluid wherefor variable pressures are created therein upon variations in the temperature at the bellows 345 and these variable pressures are opposed by a coiled spring 347 which has one of its ends secured to the switch carrying arm 342 and its other end secured to the support 346. Mercury switch 344 is of the double circuit type which has a pair of electrodes in either end so that one or the other of the pairs of electrodes is bridged by the mercury contained in the mercury switch. In other words, the mercury switch 344 comprises a single-pole, double-throw switch. This thermostat responds to the temperature of the outdoor atmosphere and the arrangement is such that a circuit is closed through the electrodes in its right-hand end whenever the outdoor temperature is at or above 60° F. Whenever the outdoor temperature falls below this value the mercury switch 344 is tilted in the opposite direction so that the circuit through the right-hand electrodes thereof is broken but a circuit is established through its left-hand electrodes.

The thermostatic switch 341 differs from the thermostatic switch 340 only in that it is set to operate at a different temperature. This thermostat 341 includes a switch carrying arm 348 which is pivoted at 349 and supports a mercury switch 350. This switch carrying arm 348 is positioned by one end of a bellows 351, the other end of which is secured to a suitable support 352. The bellows 351 is also charged with volatile fluid so that varying pressures are created therein upon temperature changes in the bellows and these variable pressures are opposed by a coiled spring 353 which has one of its ends secured to the switch carrying arm 348 and its other end secured to the support 352. This mercury switch 350 is also of the double circuit type. This thermostat likewise responds to the temperature of the outside air and the setting of the thermostat is such that the right-hand electrodes of the mercury switch are closed whenever the outside temperature is at or above 70° F. If the outside

temperature falls to a value below 70° F., the mercury switch 350 is tilted in the opposite direction and opens a circuit through the right-hand electrodes while closing a circuit through the left-hand electrodes.

As stated above, these two thermostats cooperate in controlling the relative energizations of the main relay windings 320 and 322. For the purpose of again equalizing the energizations of these two main relay windings, the main operating shaft 305 operates a balancing contact arm 354 which cooperates with a balancing resistance 355. With the parts in the position shown, the outside temperature is above 70° F., wherefor a circuit is closed through the right-hand electrodes of each of the mercury switches 344 and 350 of the thermostats 340 and 341. As a result, the main relay winding 322 is substantially short-circuited as follows: From the upper end of main relay winding 322, wire 335, wire 356, wire 357, the right-hand electrodes of mercury switch 344, wire 358, the right-hand electrodes of mercury switch 350, wire 359, wire 360, a protective resistance 361, wire 362 and wire 336 to the lower end of main relay winding 322. This short circuit of the main relay winding 322 would be complete were it not for the protective resistance 361. Also, with the parts in the position shown, the fresh air dampers are completely closed and the balancing contact arm 354 is engaging the extreme left-hand end of balancing resistance 355. Under these conditions, the main relay winding 320 is substantially short-circuited by a circuit as follows: From the upper end of main relay winding 320, wire 334, wire 356, wire 363, balancing contact arm 354, wire 364, wire 366, a protective resistance 367, wire 368 and wire 333 to the lower end of main relay winding 320. Here again, complete short-circuiting is prevented by reason of the protective resistance 367. Were it not for these protective resistances 361 and 367, it will be apparent that the secondary 328 of the transformer would be completely short-circuited. These protective resistances prevent such complete short-circuiting so that a small amount of current flows through the main relay windings 320 and 322. The two protective resistances are equal in value wherefor the main relay windings were equally energized. As a result, the armature 316 is in the intermediate position shown wherein switch arm 325 is disposed between contacts 326 and 327 and is not engaged with either of them.

Assuming that the outdoor temperature should fall below 70° F. but still remain above 60° F., it will be apparent that such outdoor air could well be used in the air conditioning devices since it is of an intermediate temperature. If this should occur, the mercury switch 344 remains in the position shown in Fig. 3 but the mercury switch 350 moves to its opposite circuit closing position wherein a circuit is completed through its left-hand electrodes. This change in circuit connections removes the substantial short-circuit for the main relay winding 322, which was traced above, and establishes an additional substantial short-circuit for the main relay winding 320. This new circuit is as follows: From the upper end of main relay winding 320, wire 334, wire 356, wire 357, right-hand electrodes of mercury switch 344, wire 358, left-hand electrodes of mercury switch 350, wire 369, wire 366, protective resistance 367, wire 368, and wire 333 to the lower end of main relay winding 320. The main relay winding 322 is now considerably more highly en-

energized than main relay winding 320 wherefor armature 316 is rotated in a counter-clockwise direction and switch arm 325 is moved into engagement with contact 326. Engagement of these parts sets up a series circuit through the auxiliary relay winding 323 and the field winding 312, which is as follows: Secondary 328, wire 331, wire 370, switch arm 325, contact 326, wire 371, auxiliary relay winding 323, wire 372, field winding 312, wire 373, and wire 338 to the other side of secondary 328. The energization of auxiliary relay winding 323 exerts an additional pull on the leg 319 of armature 316. In this particular apparatus this auxiliary winding is not necessary but the motor mechanism used herein is a standard one of general application which is normally controlled by a resistance type of control rather than by on and off switches and this auxiliary pull is utilized to increase the contact pressure upon light engagement of this switch arm and the contact 326 when the motor mechanism is variably controlled by such variable resistance controller. The energization of field winding 312 causes rotation of main operating shaft 305 in such a direction that the fresh air dampers 291 are moved towards open position and the balancing resistance 355 towards the right-hand end. As the balancing contact arm 354 moves along the balancing resistance 355, the original substantial short-circuit traced for main relay winding 320 is gradually removed by reason of the inclusion therein of part of the balancing resistance 355. However, this main relay winding 320 remains substantially short-circuited by reason of the second shunt circuit which was established upon movement of mercury switch 350 to its position wherein a circuit was completed through its left-hand electrodes. When the main operating shaft has been moved sufficiently far that balancing contact arm 354 engages the extreme right-hand end of balancing resistance 355, a substantially, complete short circuit for the main relay winding 322 is established as follows: From the upper end of main relay winding 322, wire 335, wire 356, wire 363, balancing contact arm 354, wire 374, wire 360, protective resistance 361, wire 362 and wire 336 to the lower end of main relay winding 322. The energization of these main relay windings are again thus equalized and the extra pull of auxiliary relay winding 324 is not sufficient to maintain switch arm 325 in engagement with contact 326. These parts, therefor, slightly separate and interrupt the circuit through the auxiliary winding 323 and the field winding 312. Deenergization of the auxiliary relay winding 323 enables switch arm 325 to move further from the contact 326. The main operating shaft 305 ceases rotating upon deenergization of the field winding 312 and remains in its new position. This position of the main operating shaft 305 wherein the balancing contact arm 354 engages the extreme right-hand end of balancing resistance 355 is such that the fresh air dampers 291 have been moved to a full open position.

If the outside temperature should again rise to above 70° F., the parts would be restored to the position shown in Fig. 3 wherein the fresh air dampers are completely closed. On the other hand, if the outside temperature should continue to drop and falls to below 60° F., then not only the mercury switch 350 would be tilted so that a circuit is closed through its left-hand electrodes, but the mercury switch 344 would also be tilted in a similar manner so that a circuit

is completed through its left-hand electrodes. Under these conditions the short circuit of winding 320 is opened, and a substantially complete short circuit for main relay winding 322 is established as follows: From the upper end of main relay winding 322, wire 335, wire 356, wire 357, left-hand electrodes of mercury switch 344, wire 375, protective resistance 361, wire 362, and wire 336 to the lower end of main relay winding 322. Main relay winding 320 is now more highly energized than main relay winding 322 wherefor armature 316 is rotated in a clockwise direction and switch arm 325 moves into engagement with contact 327. This establishes a series circuit through the auxiliary relay winding 321 and the field winding 313. This circuit is as follows: Secondary 328, wire 331, wire 370, switch arm 325, contact 327, wire 376, auxiliary relay winding 321, wire 377, field winding 313, wire 373, and wire 338 to the other side of secondary 328. The energization of auxiliary relay winding 321 exerts an additional pull on leg 318 of armature 316 so as to move switch arm 325 into more firm engagement with contact 327. Energization of field winding 313 causes rotation of main operating shaft 305 in a direction opposite to that in which it was rotated by the energization of field winding 312. In other words, fresh air dampers 291 are moved back towards their closed position and the balancing contact arm 354 moves along balancing resistance 355 towards its left-hand end. When the main operating shaft 305 has thus been rotated sufficiently far to move balancing contact arm 354 to the extreme left-hand end of balancing resistance 355, as shown in Fig. 3, the fresh air dampers will again be completely closed and the first mentioned substantially complete short circuit for the main relay winding 320 will again be established. The main relay windings 320 and 322 are, therefore, again equally energized and the pull of auxiliary winding 321 is not sufficient to maintain switch arm 325 in engagement with contact 327. These parts therefore separate, and deenergize the auxiliary relay winding 321 and the field winding 313. Deenergization of the auxiliary relay winding 321 enables a wider separation of the switch arm 325 and the contact 327. Deenergization of the field winding 313 causes main operating shaft 305 to cease its rotation.

As a practical matter, the limits of movement of main operating shaft 305 to fresh air damper open position and fresh air damper closed position would be obtained by the use of limit switches rather than through the balancing out process heretofore explained. The use of such limit switches is well known in the art and no further description thereof is thought necessary herein.

From the foregoing it will be seen that the fresh air dampers are closed whenever the outside air temperature is above a certain value or is below a lower predetermined value. These values, for the purposes of explanation, have been selected as 70° F. and 60° F.

Whenever the fresh air dampers are closed it is desired to have the return air dampers open and whenever the fresh air dampers are open it is desired to have the return air dampers closed. In other words, this invention contemplates that either fresh or return air will be furnished to the air conditioning devices 280, 281, and 282. In order to accomplish this, the main operating shaft 305 operates a variable resistance controller which in turn controls the return air dampers through a motor mechanism which will now be described.

This variable resistance controller comprises a control arm 380 which is operated by the main operating shaft 305 and which cooperates with a control resistance 381. The arrangement is such that the control arm 380 engages the extreme right-hand end of control resistance 381 when the main operating shaft 305 is in such position that the fresh air dampers are completely closed and engage the extreme left-hand end of this control resistance 381 when the main operating shaft 305 is in such position that the fresh air dampers are completely open.

This controller comprised by the control arm 380 and control resistance 381 controls a relay mechanism generally indicated at 382. This relay mechanism 382 is in all respects similar to the relay mechanism 315 heretofore described. In other words, it includes an armature 383 which is pivoted at 384 and is provided with legs 385 and 386. Cooperating with the leg 385 is a main relay winding 387 and an auxiliary relay winding 388. Likewise, a main relay winding 389 and an auxiliary relay winding 390 cooperate with the leg 386 of the armature 383. A switch arm 391 is secured to the armature 383 through the medium of a piece of insulating material 392. This switch arm is normally disposed between a pair of contacts 393 and 394. The main relay windings 387 and 389 are connected in series across any suitable source of power such as the secondary 395 of a step-down transformer 396 which is provided with a high voltage primary 397. This series circuit is as follows: Secondary 395, wire 398, wire 399, wire 400, main relay winding 387, wire 401, wire 402, main relay winding 389, wire 403, wire 404, and wire 405 to the other side of secondary 395.

This relay mechanism 382 controls the energization of a reversible motor means which is herein shown as comprising two oppositely acting motors. One of these motors comprises a rotor 406 and a cooperating field winding 407 and the other comprises a rotor 408 and a cooperative field winding 409. These two motor rotors are secured to a common rotor shaft 410 which is connected to a main operating shaft 411 through reduction gearing generally indicated at 412. This main operating shaft 411 operates a crank 413 which is connected to one of the return air dampers 298 by means of a link 414. The remaining fresh air dampers 298 are interconnected by links 415 so that all of these return air dampers move simultaneously in the same direction and to the same extent.

The controller comprised by the control arm 380 and the control resistance 381 is adapted to gradually vary the respective energizations of the main relay winding 387 and 389 in a manner which will be explained hereinafter. In order to rebalance the energizations of these main relay windings, whenever they are unbalanced, the main operating shaft 411 operates a balancing contact arm 416 which cooperates with a balancing resistance 417.

With the parts in the position shown, the control arm 380 is engaging the extreme right-hand end of control resistance 381 wherefore main relay winding 389 is substantially completely short-circuited by a circuit as follows: From the upper end of main relay winding 389, wire 402, wire 418, wire 419, control arm 380, wire 420, wire 421, a protective resistance 422, wire 423, and wire 403 to the lower end of main relay winding 389. The main relay winding 387 is also substantially completely short-circuited by a circuit

as follows: From the upper end of main relay winding 387, wire 401, wire 418, wire 424, balancing contact arm 416, wire 425, wire 426, a protective resistance 427, wire 428, and wire 400 to the lower end of main relay winding 387. These two protective resistances are equal so it will be apparent that under these conditions the main relay windings 387 and 389 are equally energized. The switch arm 391 is therefore disposed intermediate contacts 393 and 394 and is not engaging either of them. The main operating shaft 411 is stationary and in such position that the return air dampers 298 are all in open position.

If the fresh air dampers 291 should now start to move towards open position by reason of proper rotation of main operating shaft 305 as a result of change in outdoor temperature as explained above, control arm 380 will begin to move along control resistance 381 towards its left-hand end. Such movement of the control arm 380 gradually inserts all of the control resistance 381 in the shunt circuit just traced for the main relay winding 389. This renders the short circuit for the main relay winding 389 less complete so that less current flows through the short circuit or shunt and more flows through the main relay winding 389. When this increased current flow through the main relay winding 389 becomes sufficiently high the armature 383 will be rotated in a counter-clockwise direction far enough to bring switch arm 391 into contact with contact 393. When this occurs, the auxiliary winding 390 and field winding 407 are energized in series by a circuit as follows: Secondary 395, wire 405, wire 429, switch arm 391, contact 393, wire 430, auxiliary relay winding 390, wire 431, field winding 407, wire 432 and wire 398 to the other side of secondary 395. This energization of field winding 407 causes rotation of main operating shaft 411 in such direction that the balancing contact arm 416 moves towards the right-hand end of balancing resistance 417 and the return air dampers 298 are moved towards closed position. The initial engagement of switch arm 391 with contact 393 was very light, but the energization of the auxiliary relay winding 390 created an additional pull on the leg 386 of armature 383 by means of which switch arm 391 is held more firmly in engagement with contact 393.

This movement of balancing contact arm 416 towards the right-hand end of balancing resistance 417 gradually inserts part of the balancing resistance 417 into the short circuit or shunt circuit for the main relay winding 387. As a result, more current flows through the main relay winding 387 but at the same time the control arm 380 is continuing to move along control resistance 381 towards its left-hand end so that at all times the main relay winding 389 is energized more highly than the main relay winding 387. When the control arm reaches the center of control resistance 381 and the balancing contact arm 416 reaches the center of balancing resistance 417 these main relay windings will be energized at the highest value that they are ever energized. As these two arms continue their movements the energization of these main relay windings thereupon decreases but the main relay winding 389 is always more highly energized than the main relay winding 387 until a limiting position is reached. By the time the fresh air dampers have been completely opened, the control arm 380 has reached the extreme left-hand end of control resistance 381. When this occurs, a new substantially complete short circuit for main relay wind-

ing 387 is established as follows: From the upper end of main relay winding 387, wire 401, wire 418, wire 419, control arm 380, wire 433, wire 426, protective resistance 427, wire 428, and wire 400 to the lower end of main relay winding 387. Main relay winding 389 remains more highly energized than main relay winding 387 until the main operating shaft 411 has moved balancing contact arm 416 into engagement with the extreme right-hand end of balancing resistance 417. When this occurs, a new substantially complete short circuit is established for the main relay winding 389 which is as follows: From the upper end of main relay winding 389, wire 402, wire 418, wire 424, balancing contact arm 416, wire 434, wire 421, protective resistance 422, wire 423 and wire 403 to the lower end of main relay winding 389. The main relay windings 387 and 389 are now equally energized and the pull exerted by the auxiliary winding 390 is not sufficient to maintain switch arm 391 into engagement with contact 383. These parts, therefore, separate and interrupt the series circuit through the auxiliary winding 390 and the field winding 407. Deenergization of the auxiliary relay winding 390 permits the switch arm 391 to move further away from the contact 393. Further rotation of main operating shaft 411 ceases, of course, upon deenergization of field winding 407. Under these conditions, the return air dampers 298 are completely closed.

Whenever the outdoor conditions change again so as to close the fresh air dampers 291 the control arm 380 will begin moving away from the left-hand end of control resistance 381 and will move towards its right-hand end. This will increase the energization of main relay winding 387 in respect to the energization of main relay winding 389, in a manner which should now be apparent. Armature 383, therefore, rotates in a clockwise direction and switch arm 391 will engage contact 394. This establishes a circuit through the auxiliary relay winding 388 and the field winding 409 as follows: Secondary 395, wire 405, wire 429, switch arm 391, contact 394, wire 435, auxiliary relay winding 388, wire 436, field winding 409, wire 432 and wire 398 to the other side of the secondary 395. Main operating shaft 411 is now rotated in the opposite direction so that return air dampers 298 begin moving towards open position and the balancing contact arm 416 begins moving away from the right-hand end of balancing resistance 417 and towards its left-hand end. Energization of the auxiliary relay winding 388 increases the contact pressure between the switch arm 391 and contact 394 as previously explained in connection with contact 393. The main operating shaft 411 will continue rotating in this new direction until the parts return to the position shown in Fig. 3 wherein the control arm 380 is engaging the extreme right-hand end of control resistance 381 and the balancing contact 416 is engaging the extreme left-hand end of balancing resistance 417. When these positions are again assumed the main relay windings 387 and 389 will again be equally energized and the switch arm 391 will disengage contact 394 to deenergize the auxiliary relay winding 388 and the field winding 409. Further movement of the main operating shaft 411 ceases and the return air dampers are now again in their full open position.

As in the case of the motor mechanism which controls the fresh air dampers 291 these end or

limit positions would be obtained in actual practice by the use of limit switches.

Whenever the fresh air dampers open and the return air dampers close, it is desirable to open the exhaust dampers 289 in order that the air returning from the air conditioning devices may be exhausted to the atmosphere. This is accomplished by having the main operating shaft 411 operate a control arm 440 which cooperates with a control resistance 441. These parts are connected to a motor mechanism 442 by means of wires 443, 444 and 445. Power is supplied to this motor mechanism 442 by line wires 446. This motor mechanism 442 is provided with a main operating shaft 447 which operates a crank 448. This crank 448 is connected to one of the exhaust dampers 289 by means of a link 449. All of the exhaust dampers 289 are interconnected by means of links 450 so that all of them move in the same direction and to the same extent. In view of the foregoing description of the manner in which the return air dampers are controlled, it is now thought that it will be obvious how the movement of control arm 440 in respect to the control resistance 441, as a result of rotation of the main operating shaft 411, controls the motor mechanism 442 so as to open and close the exhaust dampers 289 upon closing and opening of the return air dampers 298.

From the foregoing it will be seen that whenever the outside air temperature is above 70° F., the fresh air dampers and the exhaust dampers are closed and the return air dampers are open. This means that the air being taken out of the spaces to which conditioned air is being supplied will be returned to the air conditioning devices for reconditioning. If the outdoor temperature falls below 70° F. but remains above 60° F., the fresh air dampers and the exhaust dampers are opened and the return air dampers are closed. This means that fresh air is delivered to the air conditioning devices and the air being withdrawn from the spaces being conditioned, instead of returning to the air conditioning devices for reconditioning, is exhausted into the outside atmosphere. If the outdoor temperature continues to drop so that it falls below 60° F., then the parts are returned to the position shown wherein the return air dampers are open so that return air is again used for conditioning purposes instead of fresh air.

It will be noted that although these dampers are all controlled in an on and off manner, motor mechanisms of the type which generally give a modulating or variable movement have been utilized. The reason for this arrangement is that the ordinary commercial two-position motor mechanisms are provided with auxiliary switches that are only operated when the motor mechanism reaches an extreme position. In this instance, it would mean that the fresh air dampers would have to completely open before the motor mechanism for operating the return air dampers would be placed in operation. In turn, the return air dampers would have to completely close before the exhaust dampers would begin to open. These motor mechanisms necessarily operate relatively slowly in order to develop the necessary force and if ordinary two-position motors were utilized and equipped with auxiliary switches so that one was operated by another then it will be obvious that a considerable delay would obtain between a demand for a change between the position of one of the dampers and the time when all of them would be so changed.

On the other hand, it is desirable to use this

so-called "dual control" wherein one motor mechanism causes a second motor mechanism to operate in a manner similar to which the first motor mechanism has been operated in that only one set of control thermostats is necessary, it often being impossible to use one set of controlling thermostats to directly control a plurality of motor mechanisms by connecting them up in parallel since many of the standard motor mechanisms on the market cannot be hooked up in parallel. A relay would, therefore, have to be interposed to use such a system. Again, if the motor mechanism could be hooked up in parallel it is possible that the placing of such a large number of motor mechanisms under the control of a single set of controlling thermostats would require so much power as to exceed the rating of the thermostats. In the present arrangement, motor mechanisms of the proportioning or modulating type are used which are ordinarily provided with auxiliary potentiometers in order to give a "dual control". As pointed out in the above explanations, as soon as the motor mechanism which controls the fresh air dampers begins to operate the fresh air dampers, it also begins to operate the dual potentiometer. This means that the return air dampers begin to move to their new position as soon as the fresh air dampers begin to move. In turn, the exhaust dampers also begin to move just as soon as the return air dampers begin to move. The present system, therefore, makes it possible to have all of these sets of dampers moving at the same time wherefor the time delay between a demand for a shift in damper position and the time such shift actually occurs in all of the dampers is greatly reduced. Of course, in smaller systems, wherein the number of dampers is less and wherein they are of less weight and therefore require less power, a single motor mechanism can be used and mechanically interconnected to all of the dampers in such a manner as to give the desired results, but the present system, as will be seen, is concerned with a large installation wherein the dampers are numerous and are heavy and by this system substantially simultaneous movement of all of the dampers can be obtained, although a plurality of motor mechanisms are employed and this is obtained without the utilization of a plurality of sets of controlling thermostats or the interposition of a relay between a single set of thermostats and the plurality of motor mechanisms.

Returning now to Fig. 2 of the drawings, each of the air conditioners 280, 281 and 282 is provided with a combined heating and cooling coil, these coils being indicated at 460, 461 and 462. The pipe 10 which delivers the heated or chilled water from the circulating pumps 13 and 14 is connected to each of these combined heating and cooling coils in any desired manner. In this diagrammatic showing of the invention, the pipe 10 is shown connected to a four-way connection 463 from which pipes 464, 465 and 466 lead. The pipe 464 connects to the cooling and heating coil 460 and the pipes 465 and 466 are adapted to be connected to the cooling and heating coils 461 and 462. In the case of each of these conditioners, the combined heating and cooling coil does not extend all the way to the bottom of the conditioner but only extends to partitions indicated at 467, 468 and 469. These partitions form two passage ways through each conditioner, the lower passage of each of which comprises a by-pass passage. In the case of the conditioners 280 and 281, an additional partition in each, which are

indicated at 470 and 471, provides for the passage of a relatively large amount of air through the combined heating and cooling coils and also provides auxiliary passages by means of which a relatively small amount of air can pass through the heating and cooling coils. Located in this auxiliary passage of the conditioner 280 is a damper 472 which is pivoted upon a shaft 473. Located in the main passage of this conditioner are face dampers 474 which are pivoted on shafts 475. These dampers 475 are interconnected by means of a link 476 so that they both move in the same direction and to the same extent. Located in the by-pass passage is a by-pass damper 477 which is pivoted on a shaft 478. The damper 477 is connected to one of the dampers 474 by means of a link 479, the arrangement being such that the damper 477 moves to the same extent as the dampers 474 but in an opposite direction. In other words, as the face dampers 474 move towards open position the by-pass damper 477 moves towards closed position and vice versa.

As indicated above, the air conditioner 281 is exactly the same as the air conditioner 280 and it includes an auxiliary damper 480 which is mounted in the auxiliary passage thereof and is pivoted on a shaft 481. It also includes a pair of face dampers 482 which are located in the main passage-way and are pivoted on shafts 483. These face dampers are interconnected by a link 484 in such a manner that they move in the same direction and to the same extent. Located in the by-pass passage is a by-pass damper 485 which is pivoted on a shaft 486. This by-pass damper 485 is connected to one of the face dampers 482 by a link 487, the arrangement being such that the by-pass damper 485 moves to the same extent as the face dampers 482 but in the opposite direction.

Located in the main passage of the air conditioner 282 are a plurality of face dampers 488 which are pivoted on shafts 489. These face dampers are interconnected by links 490 in such manner that they move in the same direction and to the same extent. Also located in the by-pass chamber are by-pass dampers 491 which are pivoted on shafts 492. These dampers are interconnected by a link 493 and one of them is connected to one of the face dampers 489 by a link 494 in such manner that the face dampers and the by-pass dampers move the same amount but in opposite directions. The partition 469 of this conditioner 282 is provided with an opening in which is located a normally closed auxiliary damper 495 that is pivoted upon a shaft 496.

The heated or chilled water, after flowing through the combined heating and cooling coil 460, passes by way of a pipe 500 to a four-way connection 501. Similarly, the water passing out of the combined heating and cooling coils 461 and 462 also return to this same four-way connection 501 by means of pipes 502 and 503. The main return pipe 20 is also connected to this four-way fitting 501.

Each conditioner is provided with a water spray for the purpose of raising the humidity of the air being conditioned in the winter as will be explained hereinafter. These sprays are indicated at 504, 505 and 506. The spray 504 is shown connected to a spray water pipe 507 which includes an electrically operated valve 508 by means of which the supply of spray water may be turned on and off. The sprays 505 and 506 should be similarly provided with a supply of spray water and a controlling valve. These

three conditioners are respectively provided with fans which are operated by fan motors 509, 510 and 511. These fans serve to pull air through their associated conditioners, which air will be either return air or fresh air as determined by the outdoor thermostats as explained in connection with Fig. 3, and deliver this air to various zones or spaces to be conditioned. These fans are controlled under certain conditions by a thermostat having an element 512 which responds to the temperature of the water leaving all of the various air conditioning devices and is herein shown as applied to the main return pipe 20. This thermostatic element 512 operates a mercury switch 513 and moves the same to open circuit position whenever the temperature of the return water falls below 90° F. For all temperature values above 90° F. this switch is closed. This switch is used during cold weather operation when the apparatus is utilizing hot water and it will be obvious that during summer operation when cold water is used the mercury switch 513 will be continuously open. The various fans are also controlled by a single-pole, double-throw switch which includes a switch arm 514, a winter contact 515 and a summer contact 516. Power is supplied by line wires 517 and 518, the latter being connected to ground 110. The switch arm 514 is shown engaging the summer contact 516 and under these conditions all of the fan motors are continuously energized by circuits as follows: Line wire 517, wire 519, switch arm 514, summer contact 516, wire 520 and wire 521, at which point the circuit branches and goes in three directions. The first branch goes by way of wire 522 to the fan motor 509 and to ground 110. The second branch goes by way of wire 523 and wire 524 to fan motor 510 and to ground 110. The third branch goes by way of wire 523 and wire 525 to fan motor 511 and ground 110. It will, therefore, be seen that during summer operation all of the fans of the various air conditioners are in continuous operation.

For winter operation the manual switch 514 is moved into engagement with winter contact 515. A new circuit is then established for the various fan motors which is operative to energize these fan motors only in the event the temperature of the return water is above 90° F. It will be noted that this circuit goes from line wire 517, wire 519, switch arm 514, winter contact 515, wire 526, mercury switch 513 and wire 527 back to wire 521, at which point the circuits for the various fan motors are as described above. As a result, during the winter the fan motors are only in operation provided the temperature of the return water is above 90° F. Under ordinary circumstances, the temperature of this water will always be above 90° F. and the purpose of this mercury switch 513 is for shutting down the fans under extraordinary conditions.

As noted above, the air conditioners 280 and 281 are exactly the same. It will be noted that the air conditioner 282 differs somewhat from these other two air conditioners. However, the control systems for the air conditioners are exactly the same and the results obtained by these two types of air conditioners are substantially the same although they are accomplished in different manners.

Referring now to both Figs. 2 and 4, the manner in which these air conditioners are controlled will now be explained. The face and by-pass dampers are operated by a motor mechanism that includes a main operating shaft 530 which

is coupled to a rotor shaft 531 through suitable reduction gearing indicated generally at 532. This rotor shaft is operated by a reversible motor means which herein takes the form of two oppositely acting motors, one of which comprises a rotor 533 and associated field winding 534 and the other of which comprises a rotor 535 and an associated field winding 536. Energization of these field windings is controlled by a relay mechanism generally indicated at 537 which includes an armature 538 that is pivoted at 539 and is provided with a pair of legs 540 and 541. Associated with the leg 540 is a main relay winding 542 and an auxiliary relay winding 543. In a similar manner, a main relay winding 544 and an auxiliary relay winding 545 are associated with the leg 541 of the armature 538. Secured to this armature 538 is a switch arm 546 which is secured thereto through the medium of a block of insulating material 547. This switch arm 546 is normally disposed intermediate a pair of contacts 548 and 549 but does not normally engage either of them. The main relay windings 542 and 544 are connected in series across a suitable source of power indicated herein as the secondary 550 of a transformer 551 having a high voltage primary 552, which is connected to suitable line wires 553 and 554. This circuit is as follows: Secondary 550, wire 555, wire 556, wire 557, main relay winding 542, wire 558, wire 559, main relay winding 544, wire 560, wire 561, and wire 562 back to the other side of secondary 550. In the absence of any other electrical circuits it will be obvious that these two main relay windings will be equally energized at all times so that the armature 538 will assume the position shown in Fig. 4 wherein switch arm 546 is disposed intermediate contacts 548 and 549 but is not engaging either one of them.

The energizations of these main relay windings 542 and 544 are primarily unequalized or unbalanced by a space temperature responsive thermostat generally indicated at 563. This thermostat can respond to the space temperature of the particular space which is being conditioned by an air conditioner to which the control system of Fig. 4 is applied or could respond to the temperature of the air being withdrawn from such space. This thermostatic mechanism 563 includes a bell crank pivoted at 564 and which is provided with a control arm 565, a corrector arm 566 and an actuating arm 567. The control arm 565 cooperates with a control resistance 568 and the corrector arm 566 cooperates with a corrector resistance 569. One end of a bellows 570 engages the actuating arm 567 and its other end is secured to a suitable support 571. The bellows 570 is charged with a suitable volatile fluid so that variable pressures are created therein upon temperature changes and these variable pressures are opposed by a coiled spring 572 which has one of its ends secured to the actuating arm 567 and its other end secured to the support 571.

The energization of these main relay windings 542 and 544 are also additionally varied by a space relative humidity responsive device generally indicated at 573. This device includes a bell crank pivoted at 574 which is provided with a control arm 575 and an actuating arm 576. The control arm 575 cooperates with a compensating resistance 577. A relatively humidity responsive element 578 has one of its ends secured to the actuating arm 576 and its other end secured to a suitable support 579. A coiled spring 580 has one of its ends secured to the actuating

arm 576 and its other end secured to a suitable support 581 and serves to maintain the relative humidity responsive element 578 under proper tension at all times. This relative humidity responsive device 573 also includes an auxiliary on and off switch. This is indicated as being constituted by a switch carrying arm 582 which is pivoted at 583 and which carries a mercury switch 584. In operation, when the value of the relative humidity to which the element 578 responds rises to such a degree that the control arm 575 moves to the extreme left-hand end of compensating resistance 577, the actuating arm 576 engages the switch carrying arm 582 and lifts the same about its pivot 583 so as to tilt mercury switch 584 to a position opposite that shown in Fig. 4, wherefor a circuit is closed therethrough.

The energization of these main relay windings 542 and 544 are additionally modified by an outside temperature responsive controller generally indicated at 585. This controller includes a bell crank pivoted at 586 which includes a control arm 587 and a compensating resistance 588 with which such control arm is associated. The bell crank further includes an actuating arm 589 which is positioned by one end of a bellows 590, the other end of which is secured to a suitable support 591. The bellows 590 is charged with a suitable volatile fluid so that variable pressures are created therein upon temperature fluctuations and these variable pressures are opposed by a coiled spring 592 which has one of its ends secured to the actuating arm 589 and its other end secured to the support 591. This outdoor temperature responsive thermostat can be located out of doors or could be located in any other suitable position so that it responds to outdoor temperature changes.

Regardless of the manner in which the energizations of these main relay windings 542 and 544 are unbalanced, they are adapted to be rebalanced by means of a balancing potentiometer which includes a balancing contact arm 593 that is driven by the main operating shaft 530 and which cooperates with a balancing resistance 594.

During the winter operation, the energizations of these main relay windings 542 and 544 are adapted to be varied by a space temperature responsive thermostat generally indicated at 595. This thermostat includes a bell crank pivoted at 596 which is provided with a control arm 597 and an actuating arm 598. The control arm 597 cooperates with a control resistance 599. The actuating arm is positioned by a bellows 600, one end of which engages the actuating arm 598 and the other end of which is secured to a suitable support 601. The bellows 600 is charged with a suitable volatile fluid and the variable pressures created therein upon temperature change are opposed by a coiled spring 602 which has one of its ends secured to the actuating arm 598 and its other end secured to the support 601.

In order to selectively place this thermostat 595 in control of the relay mechanism 537 or to place the two thermostats 563 and 585 and the relative humidity responsive device 573 in control thereof, a triple-pole, double-throw switch is utilized which is generally indicated at 603. This switch is herein shown as manually operated, although it will be understood that it could be automatically operated if desired. This switch includes three switch arms 604, 605 and 606. When the switch is placed in summer position the switch arms 604, 605 and 606 respectively engage contacts 607, 608 and 609. When it is placed

in winter position, the switch arms respectively engage contacts 610, 611 and 612. Only two of the switch arms of this switching mechanism 603 are utilized for varying the control of the relay mechanism 537 and the other switch arm thereof is utilized to control certain other portions of the system which will be described later.

The lower end of main relay winding 542 is connected to the switch arm 605 by a wire 613 and the lower end of main relay winding 544 is similarly connected to the switch arm 604 by a wire 614. The summer contact 607 which cooperates with the switch arm 604 is connected to the left-hand end of each of the resistances 588, 577 and 568 by wires 615, 616 and 617. The summer contact 608 which cooperates with the switch arm 605 is connected to the right-hand end of each of these resistances by means of wires 618, 619 and 620. The winter contact 610 is connected to the left-hand end of the control resistance 599, by means of a wire 622. Likewise, the winter contact 611 is connected to the right-hand end of this control resistance 599, by a wire 625. The center of corrector resistance 569 is connected to the junction of wires 558, and 559, and, therefore, connected intermediate the main relay windings 542 and 544, by means of wires 627, 628, 629 and 630. The control arm 575 is likewise connected intermediate these main relay windings by being connected to the junction of wires 627 and 628, through a rheostat 631, by means of wires 632 and 633. The control arm 587 is similarly connected to the junction of wires 628 and 629, through a rheostat 634, by means of wires 635 and 636. The control arm 597 is directly connected intermediate these main relay windings by being connected to the junction of wires 629 and 630, through a protective resistance 623 by wires 624, 637 and 638. The balancing contact arm 593 is connected to the junction of wires 637 and 638, through a rheostat 639, by means of wires 640 and 641. The opposite ends of the balancing resistance 594 are connected across the secondary 550 by a wire 642 which connects to the junction of wires 561 and 562 and by a wire 643 which connects to the junction of wires 555 and 556.

Assume that the switch 603 is in its summer position. Also, assume that the indoor temperature responsive device 563 has a range of 75° F. to 90° F., that the outdoor temperature responsive mechanism 585 has a range of from 75° F. to 105° F. and that the relative humidity responsive control 573 has a range of from 30 per cent to 60 per cent. With the parts in the position shown, the temperature of the space being controlled is substantially 82½° F., the outside temperature is substantially 90° F., and the relative humidity of the space is substantially 45 per cent. The control arms of the three controllers are, therefore, engaging the center of their associated resistances and, in order to maintain the main relay windings 542 and 544 equally energized, the balancing contact arm is in the middle of balancing resistance 594 wherefor the main operating shaft 530 is intermediate its limits of motion.

If the inside temperature should rise, the control arm 565 will move along control resistance 568 towards its left-hand end. Such movement of this control arm will reduce the energization of main relay winding 544 in respect to the energization of main relay winding 542 whereupon armature 538 will be rotated in a clockwise direction and switch arm 546 will gradually move towards contact 548. When this rise in space

temperature has been sufficient, this switch arm 546 will lightly engage contact 548 whereupon a circuit for the auxiliary winding 543 and the field winding 536 is established as follows: Secondary 550, wire 555, wire 556, wire 644, switch arm 546, contact 548, wire 645, auxiliary relay winding 543, wire 646, field winding 536, wire 647, wire 561, and wire 562 to the other side of secondary 550. Energization of the auxiliary winding 543 exerts an additional pull on leg 540 of armature 538 and pulls the switch arm 546 into firm engagement with contact 548 thus preventing chattering between these parts. Energization of the field winding 536 drives the main operating shaft 530 in such a direction that the balancing contact arm 593 moves upwardly along the balancing resistance 594. Such movement of the balancing contact arm gradually equalizes the energizations of the main relay windings 542 and 544 and when they are substantially equal the switch arm 546 will just separate from contact 548. This deenergizes the auxiliary relay winding 543 and the field winding 536. Deenergization of the auxiliary relay winding 543 removes the additional pull on leg 540 of armature 538 wherefor switch arm 546 separates more widely from contact 548 so as to give a substantial break between these parts. Further rotation of main operating shaft 530 ceases, of course, upon deenergization of field winding 536.

On the other hand if the temperature of the space being controlled should fall, control arm 565 will move along control resistance 568 towards its right-hand end. This causes the energization of main relay winding 542 to become less than that of main relay winding 544, whereupon armature 538 is rotated in a counter-clockwise direction so as to move switch arm 546 towards contact 549. When this fall in the temperature of the space becomes sufficiently great, switch arm 546 will lightly engage contact 549 whereupon a series circuit through the auxiliary winding 545 and the field winding 534 is established as follows: Secondary 550, wire 555, wire 556, wire 644, switch arm 546, contact 549, wire 648, auxiliary relay winding 545, wire 649, field winding 534, wire 647, wire 561, and wire 562 to the other side of secondary 550. Energization of the auxiliary relay winding 545 increases the contact pressure between the switch arm 546 and contact 549. Energization of the field winding 534 causes rotation of main operating shaft 530 in the opposite direction so that balancing contact arm 593 moves downwardly along balancing resistance 594. Such movement gradually equalizes the energizations of main relay winding 542 and 544 and when they are substantially equally energized the switch arm 546 will barely separate from contact 549. This deenergizes the auxiliary relay winding 545 and the field winding 534. Deenergization of the auxiliary relay winding 545 allows switch arm 546 to separate more widely from contact 549. Further rotation of main operating shaft 530 ceases, of course, upon deenergization of field winding 534.

The arrangement is such that only a relatively small part of the movement of the main controller 563 is required to cause the main operating shaft 530 to move from one of its extreme positions, wherein the balancing contact arm 593 engages one end of the balancing resistance 594, to its other extreme position, wherein the balancing contact arm 593 engages the other extreme end of balancing resistance 594. The function of the humidity responsive controller 573 and the

outdoor temperature responsive controller 585 is to vary that portion of the main controlling resistance 568 which will be effective to move the main operating shaft 530 from one of its extreme positions to its other extreme position. Referring first to the humidity responsive controller 573, a rise in relative humidity causes its control arm 575 to move towards the left-hand end of the associated compensating resistance 577. The effect of such movement is to reduce the energization of the main relay winding 544 in respect to the main relay winding 542 so as to cause a movement of the main operating shaft 530 in the same direction as is caused by a rise in temperature of the space being controlled. This means that for the main operating shaft 530 to again assume its central position, the temperature of the space being controlled must drop. On the other hand, if the relative humidity falls so that the control arm 575 moves towards the right-hand end of compensating resistance 577, the energization of main relay winding 542 is reduced in respect to the energization of the main relay winding 544. This causes a movement of main operating shaft 530 in the same direction as would a fall in the temperature of the space being controlled. Therefore, in order for the main operating shaft 530 to again assume a central position between its extreme limits of movement the temperature of the space being controlled must rise. In other words, a rise in the relative humidity of the space being controlled lowers the control point of the space temperature responsive controller so that a lower space temperature will be maintained therein, and a fall in relative humidity raises the control point of the space temperature responsive thermostat so that a higher temperature will be maintained therein. As is well known in the art, the effective result of these changes of control point of the space temperature responsive thermostat upon fluctuations in relative humidity provides a substantially constant effective temperature control if the adjustments are properly picked and this is taken care of by the range of the controls set out above.

If the outdoor temperature should rise, the control arm 587 will move towards the right-hand end of the compensating resistance 588. This produces a movement of main operating shaft 530 such as would be produced by a fall in space relative humidity or a fall in space temperature. In other words, the value of the temperature being maintained in the space being controlled will be raised upon a rise in outdoor temperature. On the other hand, this value will be lowered upon a fall in outdoor temperature. These three controllers, therefore, which respond to the temperature of the space being controlled, the relative humidity of the space being controlled, and the outdoor temperature, operate to give a substantially constant effective temperature in the space being controlled so long as the outdoor temperature remains constant and this effective temperature in turn is raised or lowered as the outdoor temperature rises or falls. Since the range of the inside temperature responsive controller is from 75° F. to 90° F., whereas the range of the outside temperature responsive controller is from 75° F. to 105° F., the temperature of space will be raised one degree for each 2 degree rise in outside temperature wherefor a variable differential between these two temperatures is maintained.

The corrector resistance 569 of the space tem-

perature responsive controller 563 has two functions. First, it gradually inserts resistance in the circuit connection between the main relay windings 542 and 544 whenever this controller moves from its central position. This means that although the controller moves to either of its extreme positions, neither of the main relay windings can be completely short-circuited so that these main relay windings always are energized to at least a small extent and never lose complete control of the armature 538. The other function of this corrector resistance 569 is to make it necessary that there be substantially equal temperature changes in order to move the main operating shaft 530 from one of its extreme positions to its other extreme position regardless of whether the control point of this controller be near the middle of its range or near either extreme thereof. The function of the rheostats 631 and 634 is to limit the effect of the relative humidity responsive controller 573 and the outdoor temperature responsive controller 585 upon the energizations of the main relay windings 542 and 544 to such an extent that the space temperature responsive controller 563 always has dominating control of the system. The function of the rheostat 639 is to determine the amount of movement necessary by the main operating shaft 530 and, therefore, necessary by the balancing contact arm 593 to rebalance the energizations of main relay windings 542 and 544 upon a given movement of the main controller. By adjusting this rheostat the amount of movement of this main controller 563 to cause a complete movement of the main operating shaft 530 from one of its extreme positions to its other extreme position can be determined. By always maintaining a small amount of the resistance 639 in circuit, a complete short-circuit of either one of the main relay windings 542 and 544 is prevented even though the balancing contact arm 593 moves to either of its extreme positions in respect to the balancing resistance 594.

Applicant does not claim any novelty in this compensated effective temperature control system per se since this invention is disclosed in an application of John E. Haines, Serial No. 38,946, filed September 3, 1935, to which reference may be had for a more detailed description of the exact operation of such systems.

In the winter operation, the switch 603 is thrown to the opposite position. It will then be noted that the left-hand end of the control resistance 599 of the winter controller 595 is connected to the wire 614 which is the same wire to which the left-hand end of the control resistance 568 of the summer controller 563 is connected. Such operation of this switch 603 also connects the right-hand end of this winter control resistance to the same wire that the right-hand end of the summer control resistance is connected during the summer operation, but it will be noted that the left-hand end of the winter control resistance is the low temperature value hereof, while the left-hand end of the summer control resistance is its high value. It, therefore, will be obvious that the winter controller 595 moves the main operating shaft 530 in a direction opposite to that in which it is moved by the summer controller 563. Now, this winter controller may have any desired temperature limits which, for instance, may be from 68° F. to 72° F. This means that the main operating shaft 530 moves from one of its extreme positions to its other extreme position when the temperature of the

space being controlled rises from 68° F. to 72° F. The resistance of this winter controller is such that the controller must completely traverse the control resistance 599 in order to cause movement of the main operating shaft 530 from one extreme position to the other extreme position.

The summer portion of the control system additionally includes a motor mechanism 660 which is diagrammatically shown as including a main operating shaft 661 that operates a crank arm 662 which is biased to the position shown by means of a coiled spring 663 which has one of its ends secured to the crank 662 and its other end secured to a suitable support 664. This main operating shaft 661 is driven by a suitable motor through reduction gearing. This motor is shown herein as comprising a rotor 665 and a field winding 666. As will be evident from the foregoing description, normally no attempt is made to control the relative humidity of the space being controlled during the summer operation. However, if the relative humidity rises to the extreme value of 60 per cent, then, as explained in connection with the operation of the humidity responsive controller 573, mercury switch 584 is moved to closed position. When this occurs, the field winding 666 is energized from a source of power herein shown as the secondary 667 of a transformer 668 having a high voltage primary 669 which is connected to the line wires 553 and 554. This energizing circuit for the field winding 666 is as follows: Secondary 667, wire 670, switch arm 606, summer contact 609, wire 671, mercury switch 584, wire 672, field winding 666, wire 673, and wire 674 to the other side of secondary 667. Energization of this field winding causes rotation of main operating shaft 661 in a counter-clockwise direction whereupon the right-hand end of the crank 662 is moved upwardly against the bias of the spring 663. When the crank 662 has thus been raised to a predetermined extent it can rise no further by reason of any suitable stop means herein diagrammatically shown as a pin 675. The motor then stalls and maintains the crank 662 in this upraised position. Upon a fall in relative humidity in the space being controlled, the mercury switch 584 will immediately open and deenergize the field winding 666 whereupon the crank 662 will return to the position shown in Fig. 4 under the influence of spring 663. Such types of power failure motors are well known in the art and any well known type can be utilized.

The winter control also includes means for controlling the spray valves of the various air conditioners, one of which is indicated at 508. This spray valve is controlled by a relative humidity responsive controller generally indicated at 676 which includes a switch carrying arm 677 that is pivoted at 678 and carries a mercury switch 679. A relative humidity responsive element 680 has one of its ends secured to the switch carrying arm 677 and its other end secured to a suitable support 681. A coiled spring 682 has one of its ends secured to the relative humidity responsive element 680 and its other end secured to a suitable support 683 and serves to keep the element 680 under proper tension at all times. The adjustment of this device is such that the mercury switch 679 is in open circuit position when the relative humidity of the space is above 40 per cent. Remembering that the conditions assumed in connection with the summer operation was a relative humidity of 45 per cent, it will be seen that the mercury switch 679 is in open posi-

tion as shown in Fig. 4. If the relative humidity should fall below 40 per cent, at any time during the winter operation, the spray valve 508 is energized by a circuit as follows: Secondary 667, wire 670, switch arm 606, winter contact 612, wire 684, mercury switch 679, wire 685, spray valve 508, wire 686 and wire 674 to the other side of secondary 667. This admits water to the spray of the associated air conditioner which water is picked up by the air passing therethrough and operates to raise the relative humidity thereof.

Referring again to Fig. 2 of the drawings, it was stated above that the control system of Fig. 4 was utilized with each of the conditioners 280, 281 and 282 and that this control system was the same even though the conditioner 282 is of a somewhat different type than the conditioners 280 and 281. When this system is connected to the conditioner 281, the main operating shaft 530 is connected to one of the face or by-pass dampers thereof and the crank 662 is connected to the auxiliary damper thereof. During summer operation, therefore, the auxiliary damper is normally closed. With the conditions assumed, the face dampers and the by-pass damper are each half-way open so that half of the air passing to the conditioner passes through the combined heating and cooling coil and is cooled, and the other half by-passes the same. If the space temperature rises, the face dampers are moved to a more wide open position and the by-pass damper is moved to a more nearly closed position so that more air is cooled and less is by-passed. A rise in relative humidity will bring about the same result as will a fall in outdoor temperature. In the case of a fall in inside temperature, a fall in relative humidity or a rise in outside temperature, the face dampers are moved towards closed position and the by-pass damper is moved towards open position so that less air is conditioned or cooled and more air is by-passed around the combined cooling and heating coil. In this manner, the face and by-pass dampers are controlled so as to maintain a substantially constant effective temperature for constant outside temperature and one which is raised and lowered as the outdoor temperature rises and falls. In connection with the conditioners 280 and 281, it will be noted that generally only a portion of the combined cooling and heating coil is utilized. If the relative humidity should become excessive, then the crank 662 opens the auxiliary damper 472 of the conditioner 280 or 480 of the conditioner 281 which allows part of the air to flow through the remaining portion of the combined heating and cooling coil. Assuming that we have a condition wherein the outside air is relatively cool but very humid, outside air will be furnished to the conditioners and this may cause the inside relative humidity to become excessive although the inside temperature is relatively low. Under these conditions, all of the air would be by-passing the combined heating and cooling coil were it not for the auxiliary damper. This provides a cooling of some of the air and removal of moisture therefrom. On the other hand, suppose the face dampers are part way open. Then, if the auxiliary damper is open there is a larger passageway for the air to pass through the combined heating and cooling coil wherefore its velocity therethrough will be decreased and, since it is moving more slowly, it will be called to a further extent wherefore more moisture will be removed therefrom than if this auxiliary damper had not been opened.

During the winter operation of the conditioners

280 or 281, the auxiliary dampers thereof will be closed at all times and the face and by-pass dampers will be operated in a manner to permit more air to be heated when the space temperature becomes low and less air to be heated when the space temperature becomes high.

In connection with the conditioner 282 all of the heating and cooling coil is utilized at all times. In this type of conditioner, if the relative humidity becomes excessive so that crank 662 is operated in the manner set out above, the auxiliary damper 495 is open. If at this time the face dampers are completely open, then some of this air will pass down through the auxiliary damper 495 and into the by-pass passageway so that less air is passing through the combined cooling and heating coil which will slow up its motion to a certain extent thereby permitting it to be cooled to a further degree so as to remove more moisture than would otherwise be removed. While the total amount of dehumidification done will not be increased to a great extent, due to the fact that the by-passed air is not dehumidified, the opening of damper 496 will nevertheless decrease the amount of cooling done without corresponding decrease in dehumidification, thereby permitting dehumidification without overcooling the space. On the other hand, if the face dampers are closed by reason of a cool inside temperature but an excessive relative humidity causes opening of this auxiliary damper, this will allow a relatively small amount of air to pass through this cooling and heating coil. This small amount of air has a large passageway through which to pass and it will, therefore, move very slowly so that it will be cooled to a great extent and a large amount of moisture will be removed therefrom. During the winter this auxiliary damper 495, of course, remains closed at all times and the amount of air passing over the heating and cooling coil is increased and decreased as the space temperature falls and rises.

Regardless of which type of conditioner is used, when the relative humidity becomes too low during the winter, the associated water spray valve opens so as to add water to the air passing through the conditioner.

From the foregoing it will be seen that the present invention provides a novel manner of supplying cooled or heated water to a plurality of air conditioners, the provision of this water being controlled in a manner set forth in detail in the first part of this description. The various conditioners are all provided with fresh or return air from a single source under the control of a single controlling system. Further, the fans of the conditioner are operated continuously in the summer and under the control of a return water temperature controller in the winter. The conditioners are arranged in a manner such that upon excessive relative humidity conditions, either a small or relatively small amount of air is permitted to flow through a cooling coil, or the flow area for the air through the cooling coil is increased wherefore it flows through the cooling coil at a relatively slow rate and is cooled to a relatively great extent so as to remove a substantially great amount of moisture therefrom. Although the two types of conditioners are specifically different, they both function in substantially the same manner in this dehumidifying action. The present invention also contains many features of novelty which have been pointed out in detail hereinbefore.

Reverting to the apparatus of Fig. 1, the pres-

sure responsive switching mechanism 160 thereof, which determines whether or not chilled water is being circulated, is connected to the suction side of pumps 13 and 14 by being connected to the pipe 19. Similarly, the pressure responsive switching mechanism 161, which determines whether or not the condenser water for the refrigeration apparatus is circulating, is connected to the suction side of the condenser pump 75. Both of these pressure responsive switching mechanisms therefore respond to a lowering in pressure in order to give the desired control functions. It will be obvious that these switching mechanisms could operate upon an increase in pressure instead of a decrease in pressure and be connected to the outlet side of the respective pumps.

Turning to Fig. 5, the switching mechanism 161A is identical with the switching mechanism 161 except that the mercury switch 175A thereof is reversed so that it moves to closed circuit position upon an increase in pressure rather than upon a decrease in pressure. The tube 178A which connects to the actuating bellows 176A is connected to the pipe 78 which in turn is connected to the outlet side of the pump 75. It will be apparent that upon operation of the pump 75, the pressure in the pipe 78 will increase wherefore mercury switch 175A will close to connect wires 255 and 256 so as to give the same result as the switching mechanism 160 of Figure 1.

Similarly, in Fig. 6, the switching mechanism 160A is identical with the switching mechanism 160 of Fig. 1 except that the mercury switch 168A is reversed so that it closes a circuit between wires 231 and 232 upon an increase in pressure. The actuating bellows 169A is connected to the outlet side of pumps 13 and 14, by being connected to the main outlet pipe 10, through a connecting tube 171A. Here again, it will be obvious that upon operation of either of the pumps 13 or 14, the pressure in pipe 10 will increase so as to move mercury switch 168A to complete a circuit between wires 231 and 232 in the same manner that the mercury switch 168 of Fig. 1 closes a circuit between these wires upon a decrease in pressure.

Regardless of which type of responsive mechanism is utilized, the result is to indicate the operation or non-operation of the particular pump involved and it is to be understood that either manner of determining whether or not these various pumps are in operation can be used.

While a specific modification of the invention has been disclosed herein, it will be readily apparent that numerous changes can be made in the various details without departing from the spirit of the invention. I intend, therefore, to be limited only by the scope of the appended claims.

I claim as my invention:

1. A refrigeration system of the class described, comprising, in combination, a refrigerating device including a water cooled condenser, means to circulate water through said condenser, means to place the refrigerating device and said condenser water circulating means into operation, time delay means to render said refrigerating device inoperative after a time period, and means responsive to a change in the condenser water pressure as a result of actual circulation thereof to prevent operation of said time delay device whereby the refrigerating device remains in operation in the event the condenser water is actually circulated to the condenser.

2. A refrigeration system of the class described, comprising, in combination, a refrigerating device including a water cooled condenser, means to circulate water through said condenser, means to place the refrigerating device and said condenser water circulating means into operation, time delay means to render said refrigerating device inoperative after a time period, and means responsive to an increase in the condenser water pressure as a result of actual circulation thereof to prevent operation of said time delay device whereby the refrigerating device remains in operation in the event the condenser water is actually circulated to the condenser.

3. A refrigeration system of the class described, comprising, in combination, a refrigerating device including a water cooled condenser, means to circulate water through said condenser, means to place the refrigerating device and said condenser water circulating means into operation, time delay means to render said refrigerating device inoperative after a time period, and means responsive to a decrease in the condenser water pressure as a result of actual circulation thereof to prevent operation of said time delay device whereby the refrigerating device remains in operation in the event the condenser water is actually circulated to the condenser.

4. A temperature changing system of the class described, comprising, in combination, a supply of temperature changing fluid, a plurality of circulating devices to circulate said temperature changing fluid, a temperature changing device to which the temperature changing fluid is circulated, means to place any one of said circulating devices in operation, and means responsive to the temperature of the circulating fluid as it returns from said temperature changing device to place another of said circulating devices into operation irrespective of which of the circulating devices is already in operation.

5. A cooling system of the class described, comprising, in combination, a cooling device, a supply of cooling fluid therefor, a pair of circulating devices to circulate the cooling fluid to said cooling device, means to place either of said circulating devices into operation, means responsive to the temperature of the circulating fluid as it leaves said cooling device to place the other of said circulating devices into operation upon a rise in the temperature of such fluid irrespective of which of the circulating devices is already in operation, refrigeration system means including a pair of actuating devices, said refrigeration system means requiring cooling water and operative to lower the temperature of the cooling fluid, means responsive to a rise in the temperature of the cooling fluid to place one of said actuating devices into operation and to place the other of said actuating devices into operation upon a subsequent rise in the temperature of the cooling fluid after the temperature thereof has been lowered by the operation of the first actuating device whereby consecutive demands for cooling of the fluid cause alternate operation of the actuating devices, means responsive to a further rise in the temperature of the cooling fluid to place both of said actuating devices in operation regardless of which one thereof is operating at the time, means to circulate cooling water to said refrigeration system means when either of said actuating devices is placed in operation, means to prevent operation of said actuating devices a timed period after either of them is placed in operation, and means responsive to a change in

pressure of the cooling water as a result of circulation thereof to prevent operation of said last named means.

6. A cooling system of the class described, comprising, in combination, a cooling device, a supply of cooling fluid therefor, a pair of circulating devices to circulate the cooling fluid to said cooling device, means to place either of said circulating devices into operation, means responsive to the temperature of the circulating fluid as it leaves said cooling device to place the other of said circulating devices into operation upon a rise in the temperature of such fluid irrespective of which of the circulating devices is already in operation, refrigeration system means including a pair of actuating devices, said refrigeration system means requiring cooling water and operative to lower the temperature of the cooling fluid, means responsive to a rise in the temperature of the cooling fluid to place one of said actuating devices into operation and to place the other of said actuating devices into operation upon a subsequent rise in the temperature of the cooling fluid after the temperature thereof has been lowered by the operation of the first actuating device whereby consecutive demands for cooling of the fluid cause alternate operation of the actuating devices, means responsive to a further rise in the temperature of the cooling fluid to place both of said actuating devices in operation regardless of which one thereof is operating at the time, means to circulate cooling water to said refrigeration system means when either of said actuating devices is placed in operation, means to prevent operation of said actuating devices a timed period after either of them is placed in operation, means responsive to a change in pressure of the cooling water as a result of circulation thereof to prevent operation of said last named means, and means responsive to the actual circulation of the cooling fluid to prevent operation of either of said actuating devices in the event such fluid is not being circulated.

7. An air conditioning system of the class described, comprising, in combination, a plurality of air conditioners, common means for supplying fresh and return air to said air conditioners, said common means comprising damper means to selectively supply fresh air or return air to all of said conditioners, a first motor means in control of part of said damper means and movable from a first position to a second position in a substantial period of time, control means in control of said first motor means to move the same from its first position to its second position, a second motor means in control of another portion of said damper means and movable from a first position to a second position in a substantial period of time, a controller associated with said second motor means to cause the same to assume a number of positions between its first and second positions, and connections between said first motor means and said controller by which said controller is gradually moved from its one extreme position to its other extreme position as the first motor means moves from its first position to its second position whereby the second motor means is caused to follow the movements of said first motor means.

8. A combined cooling and dehumidifying system comprising, in combination, a cooling and dehumidifying chamber through which air to be conditioned is adapted to flow, said chamber being provided with a main passageway and a by-pass, a cooling coil located in said main pas-

sageway, damper means to control the flow of air through the main passageway and the by-pass, means responsive to demands for cooling in control of said damper means, additional damper means operable to provide communication between the main passageway and by-pass on the upstream side of the cooling coil, and means responsive to relative humidity conditions in control of said additional damper means.

9. In an air conditioning system, in combination, an air conditioning chamber, a cooling coil located therein, means to cause air to flow through the air conditioning chamber, means responsive to the effective temperature of the air to be controlled in control of said cooling coil for placing said cooling coil in operation when the effective temperature of the air rises to a predetermined value, a controller for controlling the flow of air through said cooling coil, and means responsive to relative humidity for controlling said controller in a manner to decrease the air flow upon increase in relative humidity and to increase the air flow upon decrease in relative humidity.

10. A cooling system of the class described, comprising, in combination, a source of fluid to be cooled, means to circulate the cooled fluid to a point of use, a plurality of cooling devices to cool the fluid, means responsive to an initial demand for cooling of the fluid to place one of said devices in operation and responsive to a subsequent demand for cooling after said initial demand has been satisfied to place the other of said devices in operation whereby said devices are alternately operated upon subsequent demands for cooling, and means responsive to the actual circulation of said cooled fluid to prevent operation of either of said cooling devices if such circulation is not taking place.

11. A cooling system of the class described, comprising, in combination, refrigeration system means including a plurality of actuating devices operative to cool a supply of cooling fluid, means responsive to temperature demands to place the first of said devices into operation upon an initial demand for cooling and to place another of said devices into operation upon a subsequent demand for cooling after said first demand has been satisfied, said refrigeration system means including a portion which requires the removal of heat therefrom, means to circulate heat removing fluid to said portion, and means responsive to the circulation of said heat removing fluid and to the circulation of said cooling fluid to prevent operation of any of said actuating devices if both of said fluids are not being circulated.

12. A temperature changing system of the class described, comprising, in combination, a temperature changer for varying the temperature of a supply of temperature changing fluid, a plurality of circulating devices to circulate said temperature changing fluid, means to place any one of said circulating devices into operation, means responsive to temperature changing demands to place another of said circulating devices into operation irrespective of which circulating device is already in operation, and means responsive to the actual circulation of said temperature changing fluid to prevent operation of said temperature changer in the event the temperature changing fluid is not being circulated.

13. A temperature changing system of the class described, comprising, in combination, temperature changing means for changing the tem-

perature of a supply of temperature changing fluid, said temperature changing means including a plurality of actuating devices, a plurality of circulating devices to circulate said temperature changing fluid to a point of use, means to place any one of said circulating devices into continuous operation, means to automatically place another of said circulating devices into operation upon a demand for a larger rate of flow of temperature changing fluid irrespective of which of the circulating devices is already in operation, and means responsive to demands to place one of said actuating devices into operation upon an initial demand and to place another of said actuating devices into operation upon the next subsequent demand after said first demand has been satisfied.

14. A temperature changing system of the class described, comprising, in combination, temperature changing means for changing the temperature of a supply of temperature changing fluid, said temperature changing means including a plurality of actuating devices, a plurality of circulating devices to circulate said temperature changing fluid to a point of use, means to place any one of said circulating devices into continuous operation, means to automatically place another of said circulating devices into operation upon a demand for a larger rate of flow of temperature changing fluid irrespective of which of the circulating devices is already in operation, means responsive to demands to place one of said actuating devices into operation upon an initial demand and to place another of said actuating devices into operation upon the next subsequent demand after said first demand has been satisfied, and means responsive to the actual circulation of said temperature changing fluid to prevent operation of any of said actuating devices if said temperature changing fluid is not being circulated.

15. A cooling system of the class described, comprising, in combination, means to cool a supply of temperature changing fluid, and including a portion requiring the removal of heat therefrom, a plurality of circulating devices to circulate said temperature changing fluid to a point of use, means to place any one of said circulating devices into continuous operation, means responsive to an increased demand for circulation of said temperature changing fluid operative to place another of said circulating devices into operation irrespective of which one of said circulating devices is already in operation, means to circulate a heat removing fluid to said portion of said cooling means, and means to prevent operation of said cooling means responsive to the non-circulation of said heat removing fluid.

16. A cooling system of the class described, comprising, in combination, a cooling device for cooling a supply of temperature changing fluid and including a portion which requires the removal of heat therefrom, a plurality of circulating devices to circulate the temperature changing fluid to a point of use, means to place any one of said circulating devices into continuous operation, means responsive to an increased demand for circulation of said temperature changing fluid to place another of said circulating devices into operation irrespective of which one of said circulating devices is already in operation, means to circulate a heat removing fluid to said portion of the cooling device, and means responsive to the circulation of said heat removing

fluid and to the circulation of said temperature changing fluid operative to prevent operation of said cooling device unless both of said fluids are being circulated.

17. An air conditioning system, comprising, in combination, a plurality of air conditioning devices adapted to have air to be conditioned passed therethrough, common means for supplying fresh and return air to all of said air conditioning devices, said common supply means including damper means to control the flow of fresh air and return air, a cooling coil in each of said air conditioning devices, other damper means in control of the flow of air in heat exchange relationship with said cooling coil, means responsive to demands for cooling in control of said other damper means, and means responsive to a demand for dehumidification also in control of said other damper means to retard the rate of air flow in contact with said cooling coil whereby the air is cooled to a greater extent so as to remove more moisture therefrom.

18. An air conditioning system, comprising, in combination, a plurality of air conditioning devices adapted to have air to be conditioned passed therethrough, common means for supplying fresh and return air to all of said air conditioning devices, said common supplying means including damper means to control the flow of fresh air and return air, a cooling coil in each of said air conditioning devices, other damper means in control of the flow of air in heat exchange relationship with said cooling coil, means responsive to demands for cooling in control of said other damper means, means responsive to a demand for dehumidification also in control of said other damper means to retard the rate of air flow in contact with said cooling coil whereby the air is cooled to a greater extent so as to remove more moisture therefrom, a plurality of refrigerating devices to cool a supply of cooling fluid for all of said cooling coils, and means responsive to an initial demand for cooling of said fluid to place one of said refrigerating devices into operation and responsive to a subsequent demand for cooling to place another of said refrigerating devices into operation.

19. In a system of the class described, in combination, means for supplying gaseous refrigerant under pressure, a condenser for condensing the compressed refrigerant, means including a pump for circulating a cooling medium through said condenser, means for selectively placing said gaseous refrigerant supplying means out of operation or for conditioning said supplying means for operation, and means actuated by the pressure on the inlet side of said circulating pump for actuating said control means in a manner to place said gaseous refrigerant supplying means out of operation when the pressure of said cooling medium increases, and to condition said supplying means for operation when the pressure of said cooling medium decreases.

20. In a system of the class described, in combination, compressing means for raising the pressure of a gas, a condenser for condensing the compressed gas, means including a pump for causing flow of cooling medium through said condenser, control means for simultaneously starting said compressing means and said pump, and means for placing said compressing means out of operation upon failure of flow of said cooling medium.

21. In an air conditioning system, in combination,

nation, a conditioning chamber, means for causing air to be conditioned to flow through said conditioning chamber, means in said chamber for cooling and dehumidifying the air passing therethrough, a by-pass passage for air around said cooling and dehumidifying means, damper means for controlling the relative volumes of air passed through said cooling and dehumidifying means and through said by-pass passage, temperature responsive means for controlling said damper means in a manner to increase the volume of air passed through said cooling and dehumidifying means upon an increase in cooling load, and moisture responsive means for controlling said damper means in a manner to decrease the volume of air passed through said cooling and dehumidifying means upon an increase in humidity.

22. In an air conditioning system, in combination, a conditioning chamber, means for causing air to be conditioned to flow through said conditioning chamber, means in said chamber for cooling and dehumidifying the air passing therethrough, a by-pass passage for air around said cooling and dehumidifying means, damper means for controlling the relative volumes of air passed through said cooling and dehumidifying means and through said by-pass passage, temperature responsive means for controlling said damper means for determining the relative volumes of air passed through said cooling and dehumidifying means and through said by-pass passage, and means including moisture responsive means for varying the flow area for the air through said cooling and dehumidifying means in accordance with changes in humidity.

23. In an air conditioning system, in combination, a conditioning chamber, means for causing air to be conditioned to flow through said conditioning chamber, means in said chamber for cooling and dehumidifying the air passing therethrough, damper means for varying the volume of air passed through said cooling and dehumidifying means, temperature responsive means for controlling said damper means, and means responsive to humidity for also controlling said damper means in a manner to increase the volume of air passed through said cooling and dehumidifying means upon decrease in humidity, and to decrease said volume upon increase in humidity.

24. In a system of the class described, a refrigeration system including a pair of heat exchangers and actuating means connected to said heat exchangers for causing transfer of heat from one of said heat exchangers to the other, means for circulating heat exchange fluid through one of said heat exchangers, control means for placing said actuating means and said circulating means into operation, time delay means for rendering said actuating means inoperative after a time period, and means responsive to the flow of said heat exchange fluid for rendering said time delay means inoperative for maintaining the actuating means in operation in the event that the heat exchange fluid is actually circulated.

25. In a system of the class described, a refrigeration system including a pair of heat exchangers and actuating means connected to said heat exchangers for causing transfer of heat from one of said heat exchangers to the other, means for circulating heat exchange fluid through one of said heat exchangers, control means for starting said actuating means irrespective of the cir-

ulation of heat exchange fluid, and means for placing said actuating means out of operation upon failure to circulate of said heat exchange fluid.

26. A system of the class described, comprising in combination, flow control means for a stream of fluid comprising a plurality of flow controlling sections, a first motor means in control of one of said sections and movable from a first position to a second position in a substantial period of time, control means in control of said first motor means to move the same from its first position to its second position, a second motor means in control of another of said flow controlling sections, and movable from a first position to a second position in a substantial period of time, a controller associated with said second motor means to cause the same to assume a number of positions between its first and second positions, and connections between said first motor means and said controller by which said controller is gradually moved from its one extreme position to its other extreme position as said first motor means moves from its first position to its second position whereby said second motor means is caused to follow the movements of said first motor means.

27. In an air conditioning system, in combination, an air conditioning chamber, means for supplying fresh and return air to said chamber, damper means for controlling the flow of fresh air into said chamber, reversible electric motor means for moving said damper means from one position to another, temperature responsive means for controlling said motor means, said temperature responsive means including a first switching means for causing operation of said motor means from a position providing a maximum flow of fresh air towards closed position as the temperature varies from a predetermined intermediate value in one direction, and second switching means controlled by said temperature responsive means for causing operation of said motor means in the same direction when said temperature varies in the opposite direction from said predetermined intermediate value.

28. In a control system, in combination, a device to be controlled, reversible electric motor means for actuating said device from one position to another, a control circuit for said motor means, electric current controlling means interposed in said control circuit for controlling the position assumed by said motor means, condition responsive means for actuating said electric current controlling means, said condition responsive means and said electric current controlling means being arranged with respect to said motor means in a manner to cause operation of said motor means to drive said device to be controlled from one end of its normal range of movement towards the other end as the condition to which the condition responsive means responds varies from a predetermined intermediate value in one direction, and for causing operation of said motor means in the same direction when the condition varies in the opposite direction from said predetermined intermediate value.

29. A combined cooling and dehumidifying system, comprising in combination, a cooling and dehumidifying chamber through which air to be conditioned is adapted to flow, said chamber being provided with a main passageway and a by-pass, a cooling coil located in said main passageway, damper means to control the flow of air through said main passageway and said by-pass, 75

additional damper means to provide communication between said main passageway and said by-pass on the upstream side of said cooling coil, means responsive to the demand for cooling in control of one of said damper means, and means responsive to relative humidity conditions in control of the other of said damper means.

30. An air conditioning system, of the class described, in combination, a cooling and dehumidifying chamber through which air to be conditioned is adapted to flow, cooling and dehumidifying means in said chamber, a by-pass around said cooling and dehumidifying means, damper means for controlling the relative volumes of air passed through said cooling and dehumidifying means and through said by-pass, other damper means for varying the flow area for the air through said cooling and dehumidifying means, means responsive to the demand for cooling for controlling one of said damper means, and means responsive to the demand for dehumidification for controlling the other of said damper means.

31. An air conditioning system of the class described, in combination, a cooling and dehumidifying chamber through which air to be conditioned is adapted to flow, cooling and dehumidifying means in said chamber, means for passing air to be conditioned through said cooling and dehumidifying means, flow control means for varying the quantity of air passed through said cooling and dehumidifying means, means responsive to the demand for cooling for controlling said flow control means, other flow control means for varying the flow area for the air through said cooling and dehumidifying means, and means responsive to the demand for dehumidification for controlling said other flow control means.

32. An air conditioning system of the class described, in combination, a cooling and dehumidifying chamber through which air to be conditioned is adapted to flow, cooling and dehumidifying means in said chamber, means for passing air to be conditioned through said cooling and dehumidifying means, flow control means for varying the quantity of air passed through said cooling and dehumidifying means, a second flow control means for varying the flow area for the air through said cooling and dehumidifying means, means responsive to the demand for cooling for controlling one of said flow control means, and means responsive to the demand for dehumidification for controlling the other of said flow control means.

33. An air conditioning system for conditioning a space, in combination, cooling and dehumidifying means through which air to be conditioned is adapted to be passed, damper means for increasing or decreasing the flow area for the air through said cooling and dehumidifying means without substantially varying the quantity of air passed through said cooling and dehumidifying means, and means responsive to the demand for dehumidification for controlling said damper means.

34. An air conditioning system for conditioning a space, in combination, cooling and dehumidifying means through which air to be conditioned is adapted to be passed, damper means for increasing or decreasing the flow area for the air through said cooling and dehumidifying means without substantially varying the quantity of air passed through said cooling and dehumidifying means, and means influenced by a

condition of the air within said space for controlling said damper means.

35. A control system of the class described, comprising, in combination, a plurality of devices which it is desired to operate simultaneously from a first position to a second position, a separate motor means for each device which requires a substantial period of time to move such device from said first position to said second position, a controller for one of said motor means, said controller being of the type assuming only either a first position or a second position, connections between said one motor means and said controller for causing said one motor means to assume its first position when said controller assumes its first position and for causing said one motor means to assume its second position when said controller assumes its second position, a controller for another of said motor means, said last mentioned controller being of the graduating type and connected to said other motor means in a manner to cause said other motor means to assume intermediate positions in accordance with the position of said last mentioned controller, said last mentioned controller being actuated by said one motor means to thereby cause said other motor means to follow the movements of said one motor means.

36. In combination, refrigeration system means including a pair of actuating devices and condensing means associated therewith, said condensing means requiring condenser water for cooling the same, means to place one of said actuating devices into operation upon demand for cooling, means to place the other of said actuating devices into operation upon a subsequent demand for cooling after said first demand has been satisfied, whereby said actuating devices are alternately operated upon consecutive demands for cooling, means to place both of said actuating devices into simultaneous operation upon an increased demand for cooling irrespective of which actuating device is operating at such time, condenser water pumping means for circulating cooling water to said condensing means and placed into operation upon operation of either of said actuating devices, time delay means to prevent further operation of said actuating devices after a time period, and means responsive to a change in pressure of the cooling water as a result of circulation thereof to prevent shutting down of said actuating devices by said time delay device.

37. In a system of the class described, in combination, compressing means for raising the pressure of a gas, a condenser for condensing the compressed gas, means for passing cooling medium through the condenser, means for controlling the flow of cooling medium, means for actuating said cooling medium flow control means to cause flow of cooling medium, means for starting said compressing means irrespective of flow of cooling medium, and means responsive to the flow of cooling medium for placing said compressing means out of operation upon failure to flow of said cooling medium.

38. An air conditioning system for conditioning a space, in combination, a cooling and dehumidifying means through which air to be conditioned is adapted to be passed, thermostatic means responsive to the temperature of said space for controlling said means in a manner to maintain a predetermined temperature in said space, damper means for increasing or decreasing the flow area for the air through said cool-

ing and dehumidifying means without substantially varying the quantity of air passed through said cooling and dehumidifying means, and means influenced by the humidity in said space for controlling said damper means.

39. An air conditioning system for conditioning a space, in combination, a cooling and dehumidifying means through which air to be conditioned is adapted to be passed, thermostatic means responsive to the temperature of said space for controlling said means in a manner to maintain a predetermined temperature in

said space, damper means for blocking off a portion only of said cooling and dehumidifying means to flow of air for thereby varying the flow area for the air through said cooling and dehumidifying means, and means influenced by humidity of the air for operating said damper means in a manner to reduce the flow of air through said portion upon fall in humidity, while increasing the flow through said portion upon rise in humidity.

JOHN H. SPAAN.