Aug. 7, 1945. S. W. E. ANDERSSON 2,381,427

AIR CONDITIONING

Filed Aug. 14, 1941 6 Sheets-Sheet 1

Fig. 1.

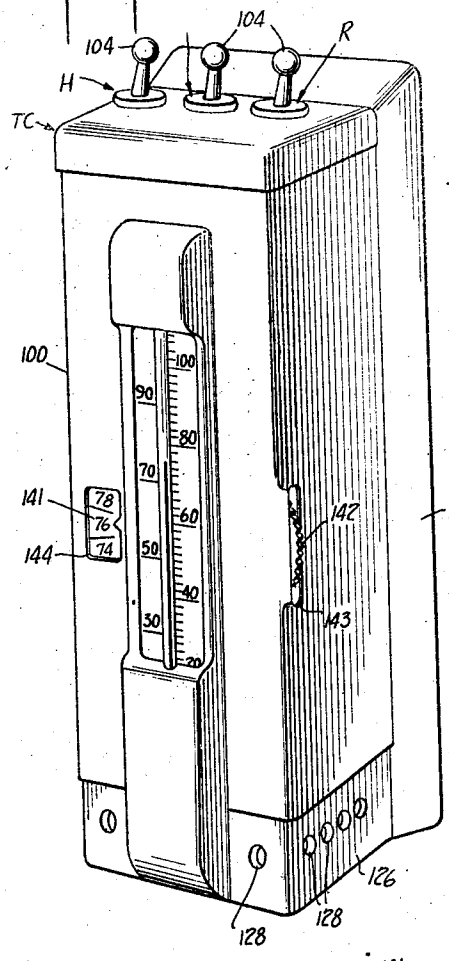
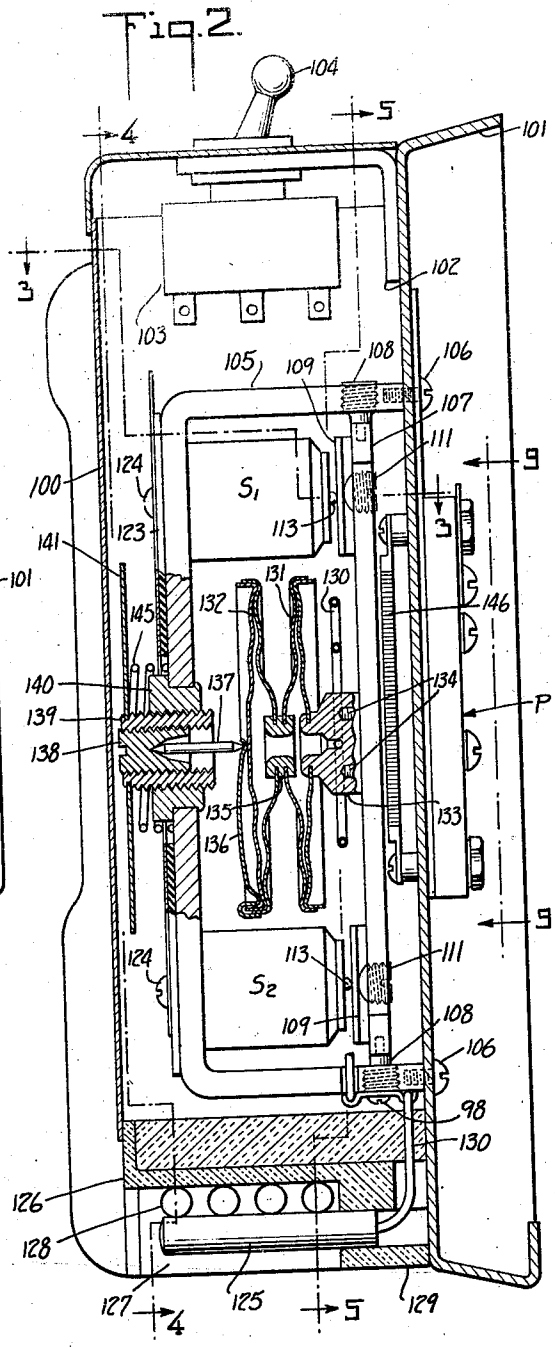


Fig. 2.



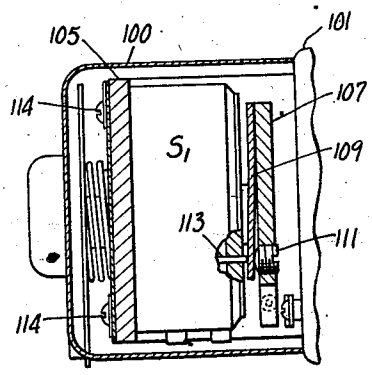


Fig. 3.

INVENTOR.

BY Sven W. E. Andersson

Ellsworth Alexander Jr. ATTORNEY

Aug. 7, 1945. S. W. E. ANDERSSON 2,381,427

AIR CONDITIONING

Filed Aug. 14, 1941 6 Sheets-Sheet 2

Fig. 4.

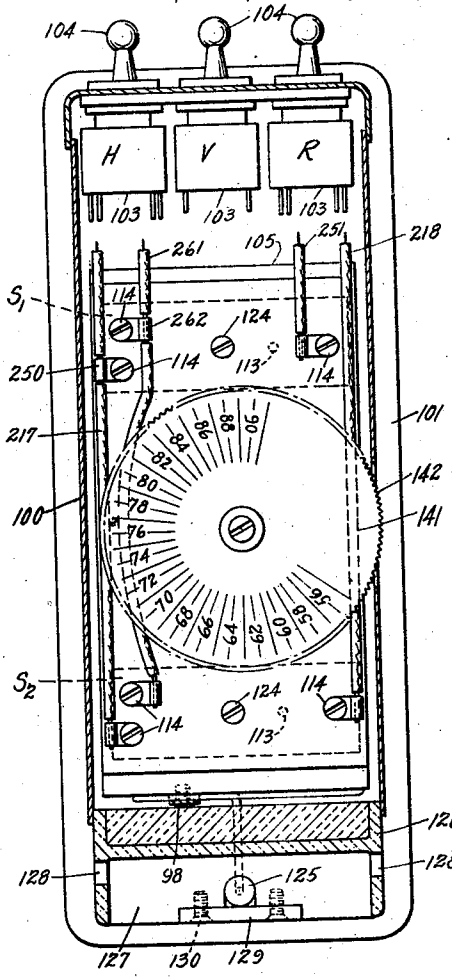


Fig. 5.

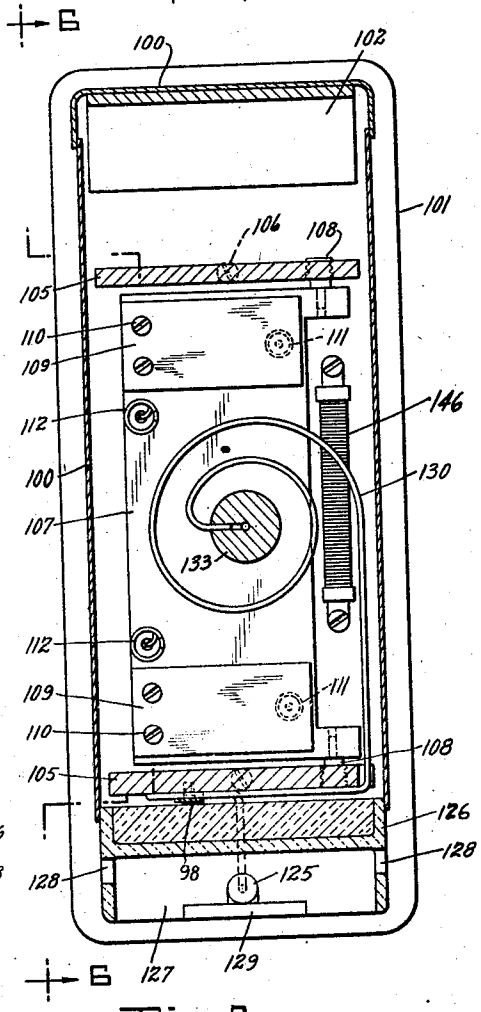


Fig. 7.

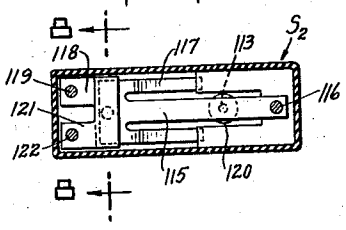
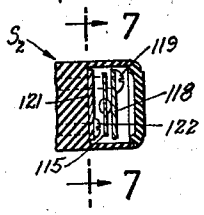


Fig. 8.



INVENTOR.

Sven W. E. Andersson

BY

Ellfelander

his ATTORNEY

Aug. 7, 1945. S. W. E. ANDERSSON 2,381,427

AIR CONDITIONING

Filed Aug. 14, 1941 6 Sheets-Sheet 3

Fig. 6.

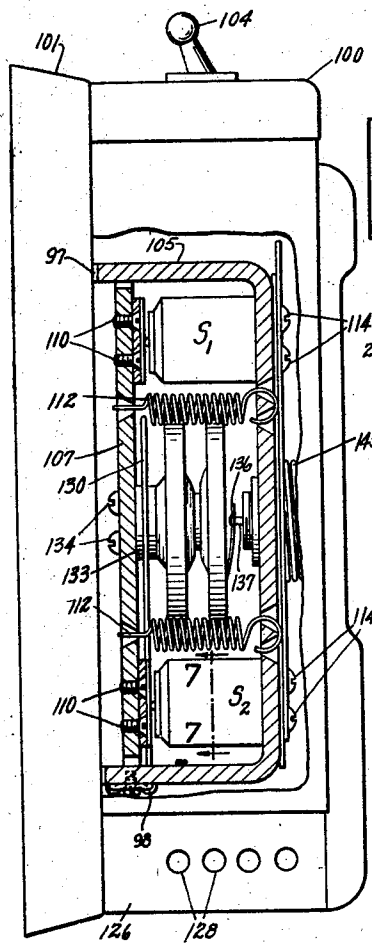
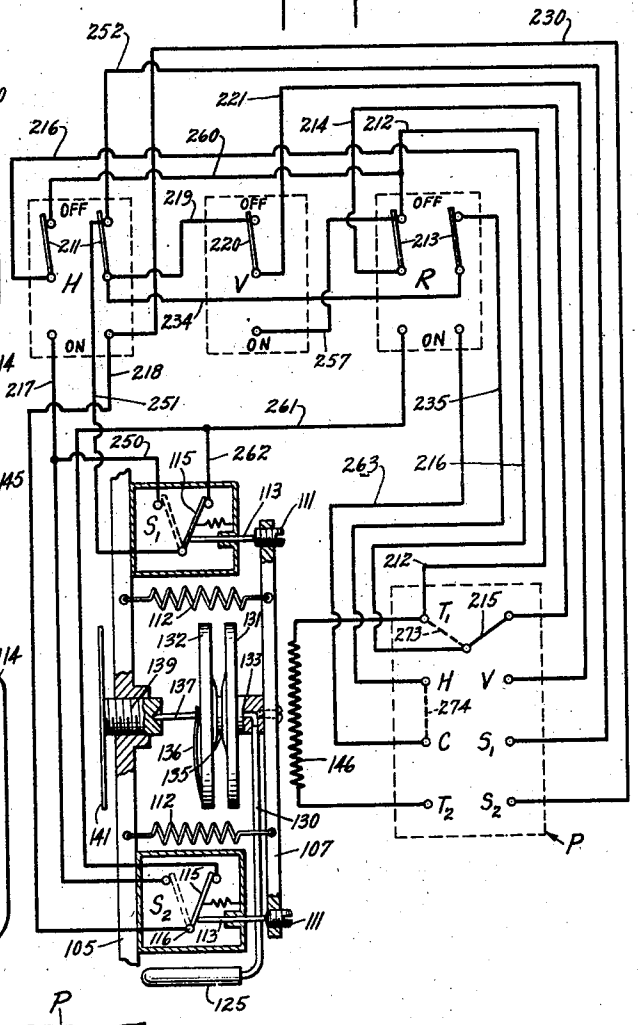


Fig. 10.



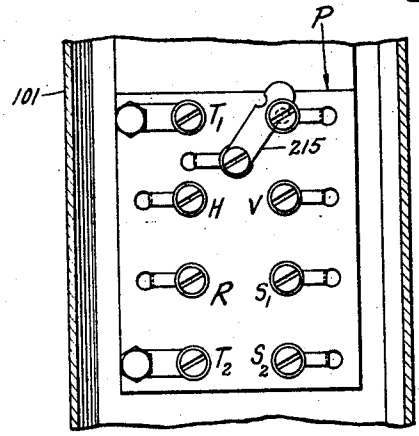


Fig. 9.

INVENTOR.

BY Sven W. E. Andersson

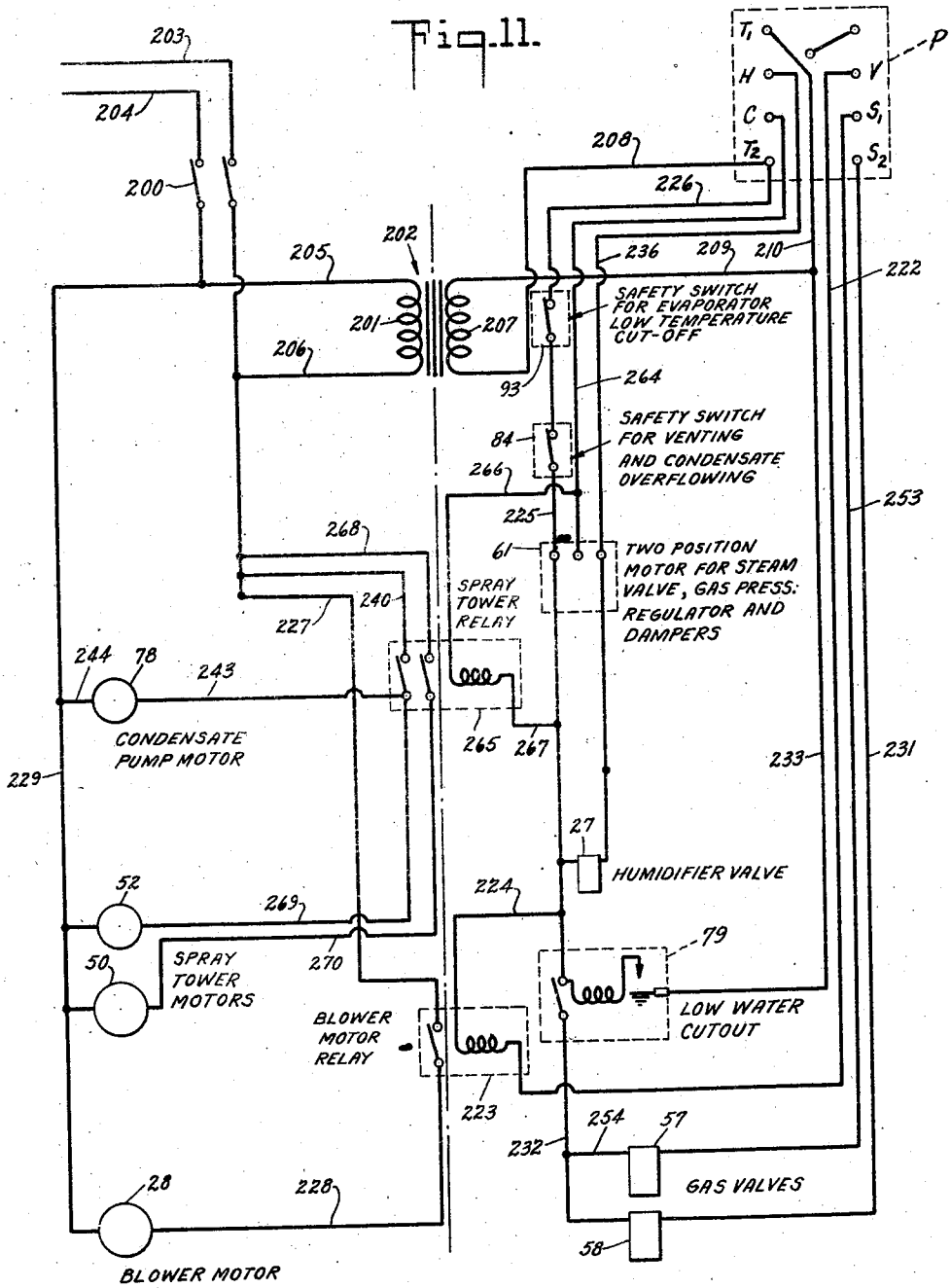
Ellsworth Flounder his ATTORNEY

Aug. 7, 1945. S. W. E. ANDERSSON 2,381,427

AIR CONDITIONING

Filed Aug. 14, 1941 6 Sheets-Sheet 4

Fig. 11.



INVENTOR.
Sven W. E. Andersson

BY Ed Fernander his ATTORNEY

Aug. 7, 1945. S. W. E. ANDERSSON 2,381,427

AIR CONDITIONING

Filed Aug. 14, 1941 6 Sheets-Sheet 5

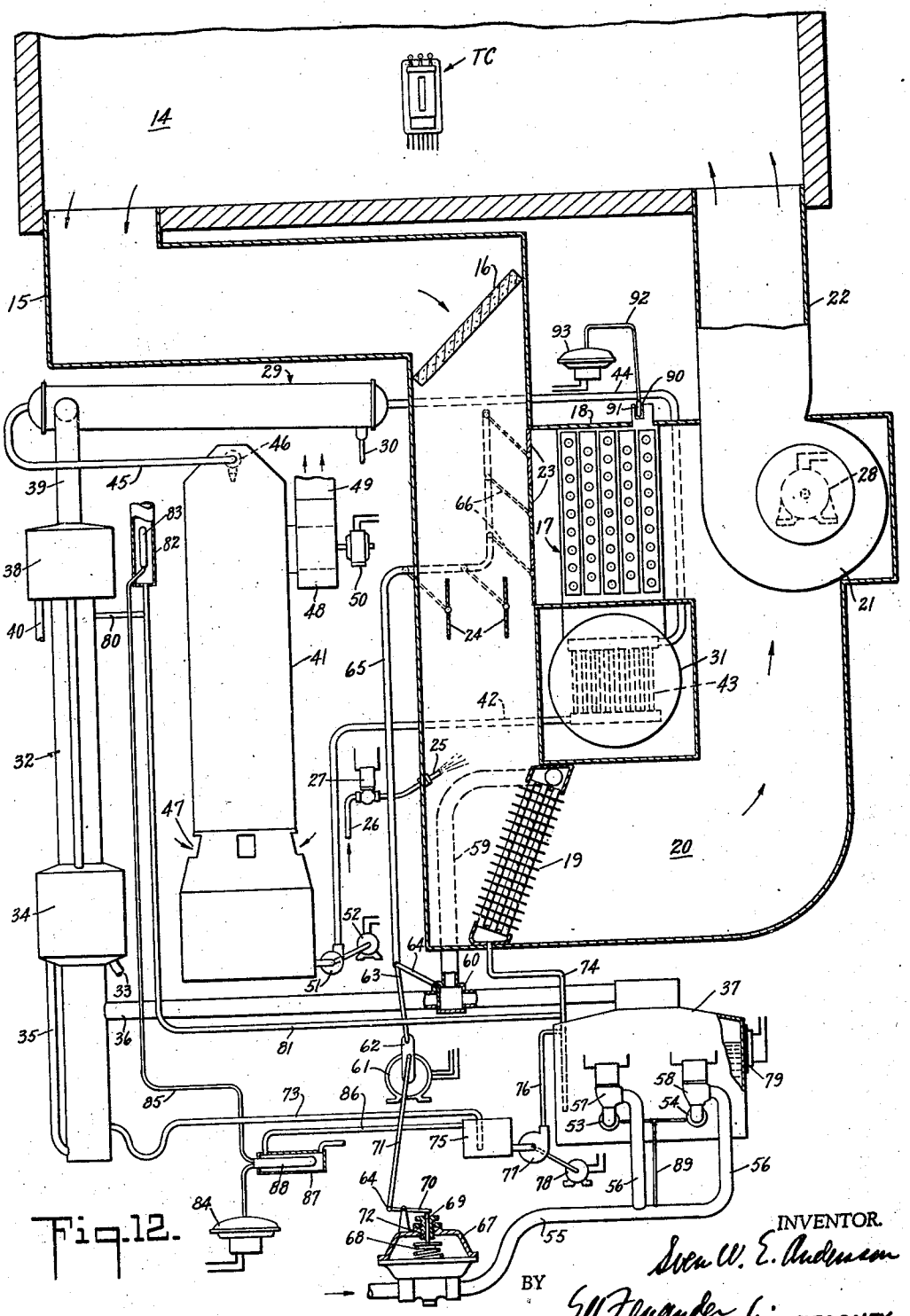


Fig. 12.

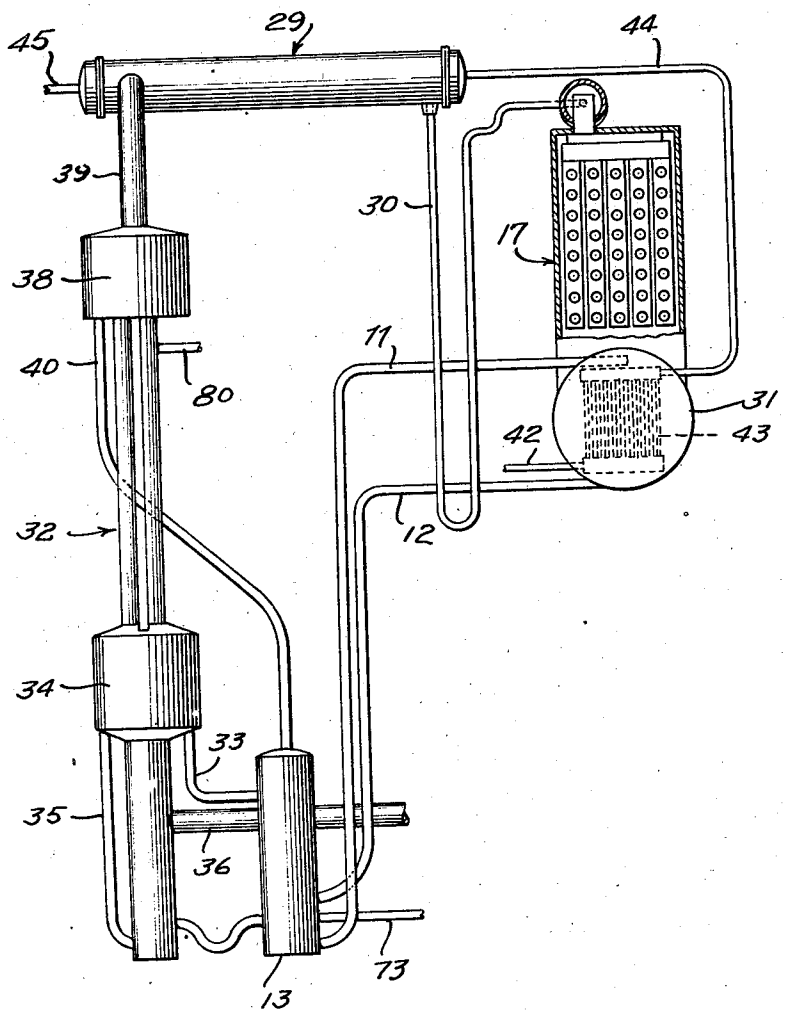
INVENTOR.
Sven W. E. Andersson
BY
W. Flanders
ATTORNEY

Aug. 7, 1945. S. W. E. ANDERSSON 2,381,427

AIR CONDITIONING

Filed Aug. 14, 1941 6 Sheets-Sheet 6

Fig. 13.



INVENTOR
Sven W. E. Andersson
BY E. A. Fernandez
his ATTORNEY

Patented Aug. 7, 1945 2,381,427

UNITED STATES PATENT OFFICE

2,381,427

AIR CONDITIONING

Sven W. E. Andersson, Evansville, Ind., assignor to Servel, Inc., New York, N. Y., a corporation of Delaware

Application August 14, 1941, Serial No. 406,777

31 Claims. (Cl. 257—3)

This invention relates to air conditioning and is especially concerned with control of air conditioning systems. More particularly, the invention relates to control of air conditioning systems arranged to heat and humidify air during periods of cold weather, to coal and dehumidify air during periods of warm weather, and to provide ventilation alone when desired. In the illustrated embodiment which discloses one manner of practicing the invention, the control is shown in connection with a combined heating, cooling and ventilating system in which cooling of air is effected by refrigeration apparatus of the kind operated by heat.

The control provided is of the proportioning type in which heating or cooling of air is regulated by steps or stages by controlling in steps or stages the supply of heat to the air conditioning system both during the heating and cooling periods. In the embodiment disclosed this is accomplished by controlling in steps or stages the supply of fuel to burner structure arranged to heat a boiler in which steam is produced, and utilizing the steam as a medium either to cause heating of air by a heater or to effect heating of a generator or heat receiving part of refrigeration apparatus to cause cooling of air by a cooling element.

The control comprises a thermostat device which is located so that it will be affected by the ambient temperature in an enclosure in which the air is to be conditioned. The thermostat device serves as a part of an electrical system to which is connected the electrical apparatus associated with the air conditioning system. The electrical apparatus includes electromagnetically operated valves for controlling the fuel supply, electric motors for operating auxiliary equipment associated with the air conditioning system, relays for completing and opening the circuits in which the electric motors are connected, and safety switches which become effective to protect the air conditioning system when faulty operation occurs. In regulating the heat supply by steps or stages in the manner referred to above, the component and subsidiary parts of the control are so correlated and interrelated that many parts can be utilized when the air conditioning system is either operating to heat or cool air or simply provide ventilation.

The thermostat device includes three control switches each operable to initiate a succession of events depending upon whether heating or cooling of air or simply ventilating will provide the best comfort conditions. The electrical circuits embodied in the control are so interrelated that even when the control switches are improperly manipulated, as when the switches are operated in an attempt to effect heating and cooling of air at the same time, the air conditioning system will not respond to such improper handling of the control switches and will remain ineffective to cause either heating or cooling of air without endangering or impairing the normal function of any part of the control. Provision is also made so that continuous or constant ventilation can be obtained during the periods when the air conditioning system is rendered operable to heat or cool air and ordinarily shuts down when the desired air temperature is reached.

It is desired to point out at the outset, before proceeding with a more detailed description of the invention, that the thermostat device is not only dependable in operation but is extremely sensitive and responds rapidly to change of air temperature. The factors of dependability, sensitivity and responsiveness have been obtained in the thermostat device provided by constructing and arranging the parts so that no one part will be subjected to strains or excessive force, and by employing an expansible fluid thermostat in which all parts are continuously heated except a thin walled thermal sensitive element which is the coldest part and arranged to be readily influenced by air temperature.

The novel features which are believed to be characteristic of the invention are set forth with particularity in the claims. The invention, both as to organization and method, together with the objects and advantages thereof, will be better understood by reference to the following description taken in connection with the accompanying drawings forming a part of this specification, and of which:

Fig. 1 is a perspective view of a thermostat control embodying the invention which serves as a single point for controlling heating, cooling and ventilating of an enclosure by a heating, cooling and ventilating system;

Fig. 2 is a vertical sectional view of the control illustrated in Fig. 1;

Fig. 3 is a horizontal sectional view, taken at line 3—3 of Fig. 2, to illustrate more clearly the swinging gate embodied in the control;

Fig. 4 is a front view of the control, taken at line 4—4 of Fig. 2, with the front cover plate in Fig. 1 removed and partly in section, to illustrate parts of the control more clearly;

Fig. 5 is a vertical sectional view, taken at line

5—5 of Fig. 2, to illustrate more clearly the swinging gate and associated parts of the control;

Fig. 6 is a side view, taken at line 6—6 of Fig. 5, with the control partly broken away and in section, to illustrate parts thereof more clearly;

Fig. 7 is a fragmentary sectional view, taken at lines 7—7 of Figs. 6 and 8, to illustrate the switch structure embodied in the control;

Fig. 8 is a fragmentary sectional view, taken at line 8—8 of Fig. 7, to illustrate the switch structure more clearly;

Fig. 9 is a fragmentary rear view of the control, taken at line 9—9 of Fig. 2, showing the circuit connecting panel to illustrate more clearly the association of the control and several electrical circuits controlled thereby;

Fig. 10 is a view diagrammatically illustrating the association of the manual switches at the top of the thermostat control, the thermostatically operated switches mounted within the control casing, and the circuit connecting panel;

Fig. 11 is a view diagrammatically illustrating the several electrical circuits controlled by the thermostat control and the connection of these circuits to the circuit connecting panel;

Fig. 12 is a view diagrammatically illustrating a combined heating, cooling and ventilating system, the auxiliary equipment for the system, and control devices and safety features with which are associated the several electrical circuits controlled by the thermostat control, as shown in Fig. 11; and

Fig. 13 is a view diagrammatically illustrating the refrigeration apparatus of which parts are shown in Fig. 12.

Description of Air Conditioning System, Auxiliary Equipment and Safety Devices

Referring to Fig. 12, a combined heating and cooling system is arranged in a duct system through which air is drawn from an enclosure 14 and thereafter returned to the enclosure after being treated. The duct system includes a duct 15 through which air is withdrawn from the enclosure 14 and in which may be disposed a filter 16 for removing foreign matter from the air. A cooling element 17 is disposed in a duct 18 and a heater 19 is located in the lower part of a U-shaped duct 20, the opposing vertical arms of which are connected at their upper ends to duct 18. Air is drawn through ducts 18 and 20 by a blower 21 from which air is discharged through a duct 22 to the enclosure 14.

Suitable dampers 23 are provided to control flow of air past cooling element 17, and similar dampers 24 are disposed in the lefthand arm of duct 20 to control flow of air past heater 19. When cooling element 17 is operative to effect cooling of air and dampers 23 are opened and dampers 24 are closed, cooling effect is transmitted to air flowing through duct 18 from the enclosure 14 and duct 15. When heater 19 is operative to effect heating of air and dampers 24 are opened and dampers 23 are closed, heating effect is transmitted to air flowing through duct 20 from the enclosure 14 and duct 15.

During the heating periods, water may be sprayed into the air stream through a nozzle 25 located in the lefthand arm of duct 20. The water is delivered to nozzle 25 through a conduit 26 from a suitable source of supply, an electrically operated solenoid valve 27 being connected in the conduit to control flow of water therethrough. In this manner proper humidification of air can be effected during the periods when air is being heated by heater 19.

The treated air, which is either heated or cooled, as explained above, is discharged by blower 21 through conduit 22 to the enclosure 14. When ventilating alone is desired, the blower 21 can be operated with both the cooling element 17 and heater 19 inoperative, so that air will be drawn from the enclosure 14 past filter 16 and then returned to the enclosure through duct 22. The blower 21 is connected to a suitable electric motor 28 which is indicated in dotted lines in Fig. 12.

The cooling element 17 forms part of refrigeration apparatus of a two-pressure absorption type and like that desscribed in application Serial No. 239,762 of A. R. Thomas and P. P. Anderson, Jr., filed November 10, 1938, now Patent No. 2,282,503 granted May 12, 1942. In a system of this type liquid refrigerant, such as, for example, water, is introduced into the upper part of cooling element 17 from a condenser 29 through a path of flow including a conduit 30, as shown most clearly in Figs. 12 and 13. The liquid refrigerant evaporates in cooling element 17 with consequent absorption of heat to produce a refrigerating or cooling effect to cool air drawn through duct 18, as explained above. The refrigerant vapor formed in cooling element 17 flows therefrom to an absorber 31 in which the vapor is absorbed into a liquid absorbent, such as, for example, lithium chloride solution. The absorption liquid enriched in refrigerant is conducted from absorber 31 to a generator 32 in a path of flow including a conduit 12, a first passage of heat exchanger 13, a conduit 33, vessel 34 and conduit 35. Within generator 32 are disposed a plurality of riser tubes enveloped by a chamber formed by the outer shell to which steam is supplied through a conduit 36 from a boiler 37. The heating of the riser tubes by the steam causes refrigerant vapor to be expelled from the absorbent, the expelled vapor being effective to raise liquid absorbent by gas or vapor-lift action. The expelled vapor passes through the upper ends of riser tubes into a vapor separator 38 and thence flows through a conduit 39 to condenser 29 in which the vapor is liquefied. The liquid refrigerant formed in condenser 29 flows through conduit 30 to the upper part of cooling element 17, as explained above, to complete the refrigerating cycle. The raised absorption liquid from which refrigerant vapor has been expelled is conducted from the upper part of generator 32 to absorber 31 to absorb refrigerant vapor, this liquid being conducted to the absorber in a path of flow including a conduit 40, a second passage of heat exchanger 13 and conduit 11.

The disclosure in the aforementioned Thomas and Anderson application may be considered as being incorporated in this application, and, if desired, reference may be made thereto for a detailed description of the refrigeration apparatus.

The condenser 29 and absorber 31 constitute heat rejecting parts of the refrigeration apparatus and are cooled by a suitable cooling medium such as, for example, water, which is continuously circulated in a closed circuit through a spray-type cooling tower 41. The cooled water is conducted through a conduit 42 through banks of tubes 43 within absorber 31 whereby heat, resulting from absorption of refrigerant vapor by liquid absorbent, is given up to the cooling water. The water is conducted from absorber 31 through a conduit 44 to condenser 29 in which heat of condensation, resulting from condensation of refrigerant vapor, is given up to the cooling water.

The water flows from condenser 29 through a conduit 45 to spray nozzles disposed in the upper part of the cooling tower 41, one of which is indicated at 46 in Fig. 12. The water passing downward in tower 41 flows in intimate contact with an upwardly flowing stream of air which is drawn through an inlet 47 by a fan 48, and exhausted or discharged from the upper part of the cooling tower at an outlet 49. The fan 48 is arranged to be driven by an electric motor indicated at 50. The water, which is cooled by partial evaporation into the upwardly flowing air stream in tower 41, collects in a sump at the bottom of the tower and is conducted therefrom through conduit 42 to absorber 31 by a pump 51 operated by an electric motor 52.

The steam boiler 37 is arranged to be heated by two burners 53 and 54 with the flames produced thereby adapted to pass into flues which are in communication with heating tubes disposed within the boiler. A combustible gas is delivered to the burners through conduits 55 and 56 from a suitable source of supply, the flow of gas to the burners 53 and 54 being controlled by electrically-operated solenoid valves 57 and 58, respectively. Suitable tubing 89 is connected to conduit 55 and arranged to terminate in the vicinity of burners 53 and 54 to provide pilot flames for igniting the gas discharged from the burners when the solenoid operated valves 57 and 58 are opened after a period when no gas flows to the burners.

In addition to supplying steam from the boiler 37 to generator 32 of the refrigeration apparatus, steam is also supplied to heater 19 through a part of conduit 36 and a conduit 59. A steam valve 60 is provided at the junction of conduits 36 and 59 to control the flow of steam either to the generator 32 or to heater 19. The steam valve 60 is provided with a valve member which is movable between two positions by a two-position electrically operated control motor 61. The two-position motor 61 may be of any well known type which, when caused to move from either one of its two positions to the other position, becomes deenergized when the other position is reached. As diagrammatically illustrated in Fig. 12, a crank 62 provided on control motor 61 is operatively connected by a link 63 to an angularly movable lever 64 which is capable of actuating steam valve 60. In the illustrated position of lever 64, it may be assumed that the flow of steam to generator 32 is shut off and that all of the steam can flow through conduit 59 to heater 19. When the two-position control motor 61 is caused to operate to move crank 62 from the position shown to its other position, as will be described presently, the steam valve 60 is actuated to permit all of the steam from boiler 37 to pass through conduit 36 to generator 32 and to shut off flow of steam to heater 19.

At the same time that the two-position control motor 61 operates steam valve 60, the dampers 23 and 24 are also actuated to direct air either past cooling element 17 or heater 19. This is accomplished by suitable mechanism which operatively connects crank 62 and the dampers 23 and 24. As diagrammatically illustrated in Fig. 12, this mechanism includes a bar 65 and a plurality of links 66 connecting the latter and the shafts upon which the dampers are journalled. In the assumed position of steam valve 60, with all of the steam being supplied to heater 19 and the latter being operative to effect heating of air, dampers 23 are closed and dampers 24 are open. When the control motor 61 is caused to operate to render cooling element 17 effective to cool air, simultaneously with such operation of the control motor the dampers 24 are closed and dampers 23 are opened.

In a combined heating and cooling system of the type described there is usually the requirement of a higher heat input to the boiler 37 during a heating period than during a cooling period. In either period it is essential that the pressure of the gas supplied to burners 53 and 54 be maintained substantially constant. To this end a gas pressure regulator 67 is provided in gas conduit 55, and provision is made for utilizing the same regulator for both the heating and cooling periods. As diagrammatically illustrated in Fig. 12, this is accomplished by providing a spring 68 which acts against the regulator diaphragm, the tension of which can be varied by a pin 69 capable of being moved downward by a lever 70 pivoted to a raised part of the regulator.

The lever 70 is also operated through a link 71 by the two-position control motor 61. During the heating periods the lever 70 is in the lower position shown and acts on pin 69. Under these conditions gas is supplied to burners 53 and 54 at a constant pressure dependent upon the extent to which spring 68 is compressed by pin 69. When the two-position control motor 61 is caused to move to the position it assumes during a cooling period, the right hand end of lever 70 is raised and does not act on pin 69. Under these conditions gas is delivered at a lower constant pressure than during the heating period, whereby heat is supplied at a lower rate to the boiler 37 by the burners 53 and 54.

The condensate formed in heater 19 flows by gravity directly into the boiler 37 through a conduit 74 which extends below the boiler liquid level. The condensate formed in the steam chamber of generator 32 flows by gravity through conduit 73 to a condensate collection vessel 75. From vessel 75 the condensate is returned through conduit 76 and the lower part of conduit 74 to the boiler 37 by a pump 77 operated by an electric motor 78. Although not illustrated, the boiler 37 is connected to a suitable source of water supply through which additional make-up water may be added from time to time, responsive to a liquid level control device of any well-known type, to keep the water at a desired level in the boiler 37.

When the water level becomes too low in boiler 37 a safety device or low water cut-out relay 79 becomes effective to shut off flow of gas to burners 53 and 54, as will be described presently. As best shown in Fig. 11, the low water cut-out relay 79 is of an electric type in which an electric circuit is completed through the body of water in the boiler 37. Since a portion of the body of water in the boiler is utilized to complete an electric circuit, it will be apparent that when the water falls below a predetermined level the electric circuit will be opened.

The steam boiler 37 operates substantially at atmospheric pressure, there being a steam vent 80 at the upper part of the steam chamber in generator 32 and a steam vent 81 for the heater 19. The vent 81 is connected to conduit 74 above the liquid column formed in this circuit by the returning condensate. Since the condensate formed in heater 19 trickles down along the inside walls of the upper part of conduit 74 and does not completely block off or seal the radiator from the vent 81, it will be clear that steam can flow from the heater 19 through the vent 81. The vents 80 and 81 are joined to provide a com-

mon steam vent from which steam can pass from either heater 19 or generator 32 to the atmosphere.

In the common vent 82 is disposed a thermal bulb 83 which forms part of an expansible fluid thermostat for controlling an electric switch indicated at 84. The expansible fluid thermostat, which includes a capillary tube 85 connecting bulb 83 and switch 84, contains a suitable volatile fluid the pressure of which increases and decreases with corresponding changes of temperature. When no steam passes through vent 82, switch 84 is normally closed, and when steam does pass through the vent and effects heating of bulb 83, the expansible fluid thermostat becomes operative to cause opening of switch 84. As will be described presently, opening of switch 84 opens an electric circuit which causes electrically operated solenoid valves 57 and 58 to shut off flow of gas to the burners 53 and 54 and also render inoperative the auxiliary equipment associated with the air conditioning system and described above.

The single steam vent control just described takes the place of many controls that otherwise would be necessary to insure safe operation of the refrigeration system and also of the heating system. In the event that the temperature of generator 32 rises because of blocking of the absorption liquid in the riser tubes therein, steam will flow through vent 80 into the common vent 82 and then pass into the atmosphere. Flow of steam through vent 82 from generator 32 may also occur because of rise in temperature of the generator resulting from cessation of cooling water supply to the absorber 43 and condenser 29. During the heating periods when heating is being effected by the heater 19, there may be loss of air circulation in duct 20 due to the operating failure of the blower 21. Under these conditions loss of load on the heater 19 will cause flow of steam through vent 81 into the common vent 82 to effect heating of bulb 83, so that switch 84 will be opened to cut off the gas supply to the burners 53 and 54 and shut down the air conditioning system, as explained above.

The switch 84 is also caused to open and shut off supply of gas to burners 53 and 54 in the event there is failure of pump 77 to return condensate from vessel 75 through conduit 76 to the boiler 37. Thus, when the pump 77 fails to return to the boiler the condensate collecting in vessel 75 during a cooling period, the liquid level rises to a predetermined level and then overflows through a conduit 86 into a well 87 from which it flows to waste.

In the well 87 is disposed a thermal bulb 88 which is connected in capillary tube 85 and forms with thermal bulb 83 a part of the same expansible fluid thermostat associated with switch 84. Warm condensate normally does not enter well 87 through overflow conduit 86, so that thermal bulb 88 will be ineffective to cause opening of switch 84. In the event that thermal bulb 88 becomes heated due to warm condensate overflowing into well 87 because of failure of pump 77, the volatile fluid in the expansible fluid thermostat becomes sufficiently heated to cause opening of switch 84, so that valves 57 and 58 will close to shut off flow of gas to burners 53 and 54.

The cooling element or evaporator 17 is formed with a raised part or dome having a well 90 in which is disposed a thermal bulb 91. The thermal bulb 91 forms a part of an expansible fluid thermostat and is connected by a capillary tube 92 to an electrical switch indicated at 93. The expansible fluid thermostat contains a suitable volatile fluid the pressure of which decreases with fall of temperature. When the cooling element 17 falls below a predetermined low temperature the pressure of the volatile fluid decreases sufficiently to cause normally closed switch 93 to open. This may occur, for example, when the blower 21 becomes inoperative during a cooling period and air ceases flowing over the surfaces of cooling element 17. When switch 93 opens the refrigeration apparatus and auxiliary equipment associated therewith are shut down, as will be described presently.

Description of Thermostat Control TC

In the above described air conditioning system in which heating, cooling, and ventilating are effected, it will now be understood that all of the auxiliary equipment, including the control and safety devices, are electrically operated or actuated. Referring now more particularly to Figs. 1, 2 and 4, the control for the air conditioning system comprises a thermostat control or device TC provided with a heating switch H, a ventilating switch V and a cooling switch R. Within the thermostat control TC are disposed switches S_1 and S_2 which are caused to operate with rise and fall of temperature. As shown in Fig. 12, the thermostat control TC is located in the enclosure 14 so that it is capable of effecting control responsive to a temperature condition affected by the air in the enclosure.

The switches H, V, R, S_1 and S_2 are connected in several electrical circuits located within the thermostat control TC, as diagrammatically illustrated in Fig. 10, which have terminal connections at a panel P located at the rear of the control TC. To this same panel P are electrically connected the devices constituting the auxiliary equipment and control and safety mechanisms associated with the air conditioning system, as diagrammatically illustrated in Fig. 11. When one of the switches H, V, or R is manually operated at the top of the control TC, certain of the electrical circuits in control TC are completed, depending upon the positions of switches S_1 and S_2, so that the devices connected to the terminals on panel P with which these completed circuits are associated will be energized to render the air conditioning system operative to effect either heating, cooling, or simply ventilating.

Referring now more particularly to Figs. 1 to 9 inclusive, the thermostat control TC comprises a casing 100 mounted on back plate 101 which is adapted to be fastened on a wall in any suitable manner. To the top part of plate 101 is secured an angle member 102, as shown in Figs. 2 and 5, having the horizontal part thereof serving as a support for the heating switch H, ventilating switch V, and cooling switch R. Each of the switches H, V, and R is enclosed in a casing 103 and provided with a snap acting operating lever or member 104 which extends through the top of the casing 100. The switches H and R are of the double-pole, double-throw type, and the switch V is of the single pole, double-throw type, as diagrammatically illustrated in Fig. 10, with these switches being connected to panel P in a manner to be described presently.

As best shown in Figs. 2, 5 and 6, a U-shaped main bracket 105 is located within the casing 100 having the horizontal arms thereof secured at their rear ends by screws 106 to the back plate 101. A vertical plate 107, which will be referred to as a swinging or hinged door, is journaled at 108

to the top and bottom horizontal arms of main bracket 105. Tongues 109 are secured at one edge by screws 110 to the hinged door 107, as shown in Fig. 5. At a region near the hinge side of the hinged door 107, the latter is formed with threaded openings to receive set screws 111 which are positioned to bear against the free ends of tongues 109, that is, the ends opposite to the ends secured at 110 to the hinged door 107.

Referring more particularly to Figs. 5 and 6, the hinged door 107 is biased toward the front of the casing 100 by coil springs 112 each having one end secured to the front vertical part of main bracket 105 and the other end secured to the edge of the hinged door 107 to which the tongues 109 are secured. In the path of movement of the hinged door 107 are disposed the pins or plungers 113 of switches S_1 and S_2 which are mounted by screws 114 to the vertical part of main bracket 105, as best shown in Figs. 2, 4, and 6. As diagrammatically illustrated in Fig. 10, the switches S_1 and S_2 are spring biased to a first position to complete one electric circuit and are movable to another position to complete another electric circuit when pins 113 are moved toward the front vertical part of main bracket 105.

The switches S_1 and S_2 are completely enclosed and of the well-known micro-switch type, as illustrated in Figs. 7 and 8. The switches S_1 and S_2 include a movable element 115 which is fastened at 116 to one switch terminal. The element 115 is provided with outer arms 117 which are arranged to spring-bias the element 115 to the position shown in Fig. 8, so that the element 115 contacts an L-shaped stationary element 118 which is fastened at 119 to a second switch terminal. The pin 113 forms part of a disc 120 which bears against element 115 whereby, with movement of pin 113 toward the left in Fig. 3, element 115 is caused to move and contact another L-shaped element 121 which is inverted from the L-shaped element 118 and fastened to a third switch terminal 122.

As best shown in Figs. 2 and 3, movement of the pins 113 toward the left is effected by movement of the hinged door 107 toward the front vertical part of main bracket 105. When the hinged door 107 moves toward the rear of thermostat control TC, the pins 113 also move toward the right since the elements 115 of switches S_1 and S_2 are spring-biased to move to the rear position shown in Fig. 8 and also diagrammatically illustrated in Fig. 10. As just pointed out, the fastenings at 116, 119 and 122 of switches S_1 and S_2 constitute terminals which are recessed to receive the securing screws 114. As shown most clearly in Fig. 4 the screws 114 also serve to fasten conductors 217, 218, 250, 251, 261 and 262 in place to connect the switches S_1 and S_2 in the several electric circuits with which they are associated, as will be pointed out presently. In order that the securing screws 114 are effectively insulated from one another, the openings through which they pass in the vertical part of main bracket 105 are considerably larger than the screws. As best shown in Figs. 2 and 4, the screws 114 and switches S_1 and S_2 are properly located in position by a plate 123 which is fastened by screws 124 to the front vertical part of main bracket 105. The positioning plate 123 is formed of insulating material and provided with openings which are approximately the size of screws 114, whereby the latter are positioned to hold switches S_1 and S_2 in their desired relationship with other parts of the thermostat control TC.

An expansible fluid thermostat, which operates responsive to a temperature condition of the air in enclosure 14, is employed to cause hinged door 107 to move rearwardly against the action of coil springs 112. The expansible fluid thermostat includes a thermal bulb 125 which is located in the bottom part 126 of thermostat control TC. The bottom part 126 is formed of suitable material having poor thermal conductivity, such as Bakelite, for example, and is provided with a recess 127 in the extreme lower part and openings 128 in the front and side walls thereof. The thermal bulb 125 is located in the recess 127 and extends from the front part of the block 126 toward the rear part thereof opposite the side openings 128, so that air circulating in the enclosure readily contacts and flows over the exterior surfaces of the thermal bulb 125. The rear part of the bulb 125 is held in position by a lock plate 129, also formed of a material having poor thermal conductivity, which is fastened by screws 130 to the bottom of the block 126.

The thermal bulb 125 is connected by a capillary tube 130 to a pair of expansible and contractible elements 131 and 132, as best shown in Fig. 2. Referring more particularly to Figs. 2 and 5, the capillary tube 130 passes through an opening in the rear of block 126 and also through a slot in the bottom horizontal arm of main bracket 105. The upper end of capillary tube 130 is spirally wound about a hollow hub member 133 having a passage to which the extreme upper end of the capillary tube is secured. As shown most clearly in Figs. 2 and 6, the hub member 133 is secured by screws 134 to the hinged door 107. By clamping the capillary tube 130 at 98 to the lower part of main bracket 105, as shown in Fig. 2, movements of the thermal bulb 125 and the bottom part of capillary tube 130 will not be transmitted to the top spiral part of the capillary tube.

The elements 131 and 132 are in the form of expansible bellows or hollow diaphragms with one face of rear bellows 131 secured to hub member 133 and the other face thereof secured to a second hollow hub member 135. One face of the front bellows 132 is secured to the hub member 135 and the other face thereof is in the form of a solid disc or diaphragm. The expansible bellows 131 and 132 and the passages in hub members 133 and 135 form a completely enclosed space which is in communication with the upper end of capillary tube 130. The expansible bellows 131 and 132, capillary tube 130 and thermal bulb 125 constitute an expansible fluid thermostat which is filled with a suitable volatile fluid having an increasingly higher pressure with rise of temperature which causes swelling of the bellows and a decreasingly lower pressure with fall of temperature to allow contraction of the bellows.

To the peripheral edge portion of bellows 132 is fixed one end of a leaf spring 136, the other end of which is provided with a depression arranged to contact and engage the center region of the bellows. The depression in leaf spring 136 receives a pointed end of a pin 137, the other pointed end of which fits into a recess in a set screw 138. The ends of pin 137 are formed with more or less smooth rounded points rather than sharp points. The set screw 138 threadedly engages an adjustment nut 139 which in turn threadedly engages a bushing 140 secured in an

opening in the front vertical part of main bracket 105.

A circular dial plate 141 provided with a dial marked with temperature indicia is fixed to the front part of adjustment nut 139. The peripheral edge portion of dial plate 141 is serrated at 142 and arranged to be accessible at an opening or notch 143 in casing 100 to facilitate turning the dial. The temperature indicia are located on the dial plate 141 so as to pass in the region of a window 144 in casing 100. By turning the serrated peripheral edge portion 142 of dial 141, therefore, the dial can be turned so that the desired temperature reading will be opposite the notch in window 144. In order to insure that dial plate 141 will remain at the position to which it is adjusted, a coil spring 145 is interposed between the rear face of the dial and the front vertical part of main bracket 105. The tension of spring 105 is such that dial plate 141 can readily be turned and at the same time sufficient friction is provided to hold the dial in any position to which it is moved.

Within and at the rear of casing 100 is provided a heating element 146 which is connected to terminals T_1 and T_2 on panel P, as shown in Fig. 10. The heating element 146 is provided to improve the responsiveness of the expansible fluid thermostat, as will be described hereinafter.

The parts of the thermostat control TC are interrelated in such a manner that dependable and accurate control of air temperature is effected. While considerable power is produced by the swelling of bellows 131 and 132, the hinged door 107 is arranged in such a manner that the microswitches S_1 and S_2 are not directly acted upon by the bellows. In control TC the greatest swelling causes the hinged door 107 to move from and not toward the switches S_1 and S_2, whereas in controls employing expansible bellows it is usually the practice for the swelling of such bellows to cause force to be imposed upon the switch mechanism. The highest force is imparted to the switches S_1 and S_2 when the hinged door 107 moves toward the front vertical part of main bracket 105 and the tongues 109 engage and cause movement of the switch pins or plungers 113. This movement of the hinged door 107 is effected by the pulling action of coil springs 112 resulting from contraction of the bellows 131 and 132. Hence, the coil springs 112, which determine the highest force exerted on the switch mechanism, are made relatively weak and just strong enough to pull the plungers or pins 113 a distance sufficient to actuate the switches S_1 and S_2, as will be explained presently.

The provision of the hinged door 107 is particularly advantageous in that the tongues 109 can be mounted thereon at one end and the set screws 111 employed to adjust the position of the free ends of the tongues to determine the particular moment when the tongues contact and engage the pins 113. This insures accurate setting of the instant when it is desired to actuate the switches S_1 and S_2 after a definite amount of movement of the hinged door 107, and is a decided improvement over an arrangement where set screws alone are employed, because set screws tend to wobble and move in the threads in which they are engaged.

In order to reduce to a minimum the friction produced at the operative connection of bellows 132 and set screw 138 the tapered-ended needle or pin 137 is employed. The needle 137 is offset with respect to the pivotal connection 108 of the hinged door 107, and even with sidewise movement of the bellows resulting from the slight angular movement of hinged door 107, the needle 137 can freely deviate to a cocked position from a straight-line position. The fact that the needle 137 can move freely, together with the provision of making the ends thereof tapered, insures that the same sensitivity is obtained at all times irrespective of the position of the needle with respect to the bellows 132. If the ends of needle 137 are too sharply pointed, objectionable wear results. For this reason the tapered ends are slightly rounded and lapped in to insure permanent calibration.

The leaf spring 136 is provided to prevent the needle 137 from dropping out of place in the event that the bellows 131 and 132 contract considerably, as when the thermostat control TC is shipped during cold weather. The leaf spring 136 is relatively weak with the end thereof adjacent the center of bellows 132 normally bearing against the latter. With considerable contraction of bellows 131 and 132, the leaf spring 136 exerts sufficient force against one end of needle 137 to hold the latter in position. In such case there is slight movement of spring 136 with respect to bellows 132, and when the bellows 131 and 132 again expand sufficiently to assume a position in the normal temperature range encountered during operation of the air conditioning system, the depressed portion of spring 136 is again pressed against the forward diaphragm of the bellows 132.

The main bracket 105 is made exceptionally rigid and strong because all of the working parts of the thermostat control TC are mounted on this bracket. In fastening the main bracket 105 to the back plate 101 only two fastening screws 106 are employed, as best shown in Fig. 2. Further, the contact surfaces between main bracket 105 and backplate 101 are small by forming lips 97 at the rear ends of the top and bottom horizontal arms, as shown in Fig. 6, which are considerably narrower than the width of bracket 105. With this arrangement bending or warping of bracket 105 is avoided as much as possible in the event backplate 101 is bent or strained when mounted in position, so that the likelihood of parts getting out of adjustment is minimized.

Electrical System Connecting Thermostat Control TC and Electrical Apparatus Associated with Air Conditioning System

The terminal panel P is fixed to the rear side of back plate 101, as shown in Figs. 2 and 9. The manually operable switches H, V and R at the top of thermostat control TC, and switches S_1 and S_2, which are operable in accordance with rise and fall of air temperature in the enclosure 14, are connected in several electric circuits to different terminals on the panel P. In order to simplify as much as possible the illustrations of the structural features in Figs. 1 to 8 inclusive, the electrical connections of the several switches to the terminals on panel P have been omitted in these figures. The connections to panel P of the several switches described above are, however, diagrammatically illustrated in Fig. 10 to facilitate an understanding of the control circuits. The circuits shown in Fig. 10 and their association with the circuits illustrated in Fig. 11 will now be explained in describing the operation of the air conditioning system.

When it is desired to operate the air conditioning system described above, main switch 200

in Fig. 11 is closed, so that the primary winding 201 of transformer 202 will be connected to a suitable alternating current source of electrical energy. The circuit completed for energizing the transformer 202 includes conductors 203 and 204 which are connected to the source of electrical supply and in which is provided the switch 200, and conductors 205 and 206 which are connected to opposite terminals of the primary winding 201. The transformer 202 is a step-down transformer with one terminal of the low voltage secondary winding 207 connected by conductor 208 to terminal T_2 on panel P, and the other terminal thereof connected by conductors 209 and 210 to terminal T_1 on the panel. Hence, when main switch 200 is closed, terminals T_1 and T_2 on panel P are energized and any circuit completed across these terminals will also be energized.

Heating

Let us assume now that main switch 200 is closed and that it is desired to operate the air conditioning system in Fig. 12 to heat air in the enclosure 14. Let us further assume that the dial mounted on plate 141 is turned so that the number opposite the notch in window 144 corresponds to the temperature, such as, 70° F., for example, at which it is desired to maintain the air in enclosure 14.

The lever 104 of the heating switch H at the extreme left-hand side of thermostat control TC in Fig. 1 is then snapped to its forward position to cause operation of the air conditioning system to render the latter operable to effect heating. Referring more particularly to Fig. 10, movement of lever 104 of the heating switch H causes the movable elements 211 thereof to move from the "off" position to the "on" position. When the temperature of the air is sufficiently high, that is, at 70° F. (the assumed temperature at which it is desired to maintain the air in the enclosure 14), switches S_1 and S_2 are in the positions shown in Fig. 10 and none of the circuits of the devices shown in Fig. 11 is completed, so that no heating of air is effected by the air conditioning system.

When the air temperature starts to fall below the desired temperature of 70° F., the pressure of the volatile fluid in the expansible fluid thermostat decreases so that the bellows 131 and 132 contract. With contraction of bellows 131 and 132 the coil springs 112 are effective to pull the hinged door 107 toward the front vertical part of main bracket 105. As shown in Fig. 10, the forward movement of the hinged door 107 causes movement of the pins 113 of switches S_1 and S_2. The switches S_1 and S_2 are so located and arranged that the movable element 115 of the bottom switch S_2 is actuated first with movement of the hinged door 107 toward the front vertical part of bracket 105, and, with continued movement of the hinged door in the same direction, the movable element 115 of the top switch S_1 is thereafter actuated.

When the movable element 115 of the bottom switch S_2 is actuated, this element moves with a snap action from the position shown in solid lines to that shown in dotted lines in Fig. 10. When this occurs a number of circuits are completed across the terminals T_1 and T_2 on panel P to render the air conditioning system operable to heat air in the enclosure 14.

The above described movement of element 115 of switch S_2 to the dotted line position in Fig. 10 completes a first circuit from T_1 through conductor 212, left-hand element 213 of switch R, conductor 214, connecting link 215 on panel P, conductor 216, left-hand element 211 of switch H (which is assumed to be in the "on" position), conductor 217, element 115 of switch S_2, conductor 218, right-hand element 211 of switch H, conductor 219, element 220 of switch V and conductor 221 to the terminal V on panel P.

Referring now to Fig. 11 the completed first circuit further includes a conductor 222 which is connected to terminal V, coil of blower motor relay 223, conductors 224 and 225, normally closed switches 84 and 93 and conductor 226 to terminal T_2 on panel P.

Since terminals T_1 and T_2 are energized when main switch 200 is closed, as pointed out above, and the circuit just described is completed across these terminals, it will be evident that the coil of blower motor relay 223 is energized to close this relay. Energization and closing of relay 223 completes a circuit for the blower motor 28 across conductors 203 and 204. This circuit from the source of electrical supply includes conductors 203 and 227, the movable element of relay 223 and conductor 226 which is connected to one terminal of blower motor 28. The opposite terminal of blower motor 28 is connected by conductors 229 and 204 back to the source of electrical supply.

In the circuit described above, which is completed from the terminal T_1 on panel P to the terminal V, the circuit was followed from the element 115 of the bottom switch S_2 in Fig. 10 through conductor 218 to the right-hand element 211 of switch H. From the terminal T_1 a second circuit is completed which includes a portion of the first circuit up to and including the conductor 218. From conductor 218 the second circuit also includes conductor 320 which is connected to terminal S_2 on panel P. Referring now to Fig. 11, the second circuit further includes conductor 231 which is connected to terminal S_2, solenoid-operated gas valve 58, conductor 232, the movable element of low-water cutout relay 79, conductor 225, normally closed switches 84 and 93, and conductor 226 to terminal T_2 on panel P.

The second circuit just described includes the low-water cutout relay 79 which, as pointed out above in describing the air conditioning system and devices associated therewith, is of the type in which an electric circuit is completed through a portion of the body of water in the boiler 37. When the water in the boiler 37 is at or above a predetermined level, the circuit for relay 79 is completed across the terminals T_1 and T_2 on panel P. This circuit from terminal T_1 includes conductors 210 and 233 to one terminal of the relay 79, the opposite terminal thereof being connected through conductor 225, normally closed switches 84 and 93 and conductor 226 to the terminal T_2. With the coil of relay 79 being energized, the movable element of this relay will be actuated to its closed position immediately upon closing of the main switch 200. With relay 79 closed, it will be apparent that the second circuit described will be completed across the terminals T_1 and T_2 on panel P to actuate and open the electrically-operated solenoid valve 58.

With movement of the element 115 of bottom switch S_2 to the dotted line position shown in Fig. 10, a third circuit is completed which also includes a portion of the first described circuit up to and including conductor 218. From conductor 218 the third circuit includes the right-hand element 211 of switch H, conductor 234, the

right-hand element 213 of switch R and conductor 235 which is connected to terminal H on panel P. Referring now to Fig. 11, the third circuit further includes a conductor 236 which is connected to terminal H, the two-position electric motor 61, conductor 225, normally closed switches 84 and 93 and conductor 226 which is connected to terminal T_2. In addition to completing a circuit for the two-position electric motor 61, the third circuit also completes a circuit for the electrically-operated solenoid valve 27 which is connected to conductors 236 and 225 in parallel with the two-position electric motor 61.

When the element 115 of bottom switch S_2 moves to its dotted-line position in Fig. 10, therefore, the three above-described circuits, which are completed through terminals V, S_2, and H on panel P, cause energization of solenoid-operated water valve 27, blower motor 28, solenoid-operated gas valve 58 and two-position electric motor 61. As shown in Fig. 12, the opening of gas valve 58 allows gas to be supplied through conduits 55 and 56 to the burner 54. The gas discharged from the burner 54 is ignited by the pilot flame formed at the end of tubing 89, so that boiler 37 is heated.

At the same time that heat is being supplied to the boiler 37 to produce steam, the two-position electric motor 61 becomes operative to actuate the steam valve 60 so that all of the steam produced in the boiler will flow through conduit 59 to the heater 19. Simultaneously with the actuation of steam valve 60 the right-hand end of lever 70, which is operatively connected to the two-position electric motor 61, moves downward to the position shown in Fig. 12 to increase the tension of spring 68 of the gas pressure regulator 67. By increasing the tension of spring 68 gas is supplied to burner 54 at a higher constant pressure than during the periods when the air conditioning system is operating to effect cooling of air, as explained above. The above-described actuation of steam valve 60 by the two-position electric motor 61 also causes closing of dampers 23 and opening of dampers 24.

The energization of blower motor 28 renders the blower 21 operative to cause circulation of air past the heater 19, the air being withdrawn from the enclosure 14 through ducts 16 and 20 and the heated air being returned through duct 22 to the enclosure. The opening of solenoid-operated water valve 27 permits water to be supplied to nozzle 25 so that humidification of air can be effected. The condensate formed in heater 19 returns through conduit 74 to the boiler 37 by gravity.

In the event that steam flows from heater 19 through vent 81 to the common vent 82, due to operating failure of the blower 21, for example, the thermal bulb 83 becomes heated and the expansible fluid thermostat of which this bulb forms a part causes switch 84 to open. As shown in Fig. 11, opening of switch 84 opens all of the circuits connected to the terminal T_2 on panel P, so that the circuits for all of the devices are broken including the circuits in which are connected the gas valve 58, blower motor relay 223, low-water cutout 79, the water valve 27, and two-position motor 61. When the operating failure is corrected and the thermal bulb 83 is no longer heated by steam in the common vent 82, the normal operation of the system described above is resumed to effect heating of air in the enclosure 14. The switch 84 may be of the manual re-set type so that manual closing of the switch will be necessary before the system again becomes operative to effect heating of air.

In the event that the water in boiler 37 falls below the predetermined level determined by the location of the low-water cutout relay 79, this relay will open to break the circuit in which the solenoid-operated gas valve 58 is connected, as shown in Fig. 11. However, when gas valve 58 is closed due to deenergization of the low-water cutout relay 79, the other circuits remain completed so that the entire system is not completely shut down.

When the air temperature continues to fall below the desired temperature of 70° F., even when the single burner 54 is operating as a result of the movement of element 115 of the bottom switch S_2 to the dotted line position shown in Fig. 10, the continued movement of the hinged door 107 toward the front vertical part of main bracket 105 imparts sufficient movement to the top pin 113 in Fig. 10 to move the element 115 of switch S_1 with a snap action from the position shown in solid lines to that shown in dotted lines. When this occurs the circuits already completed as a result of the prior movement of element 115 of the bottom switch S_2 remain intact to cause heating of air in the enclosure. In addition, a circuit is completed from the terminal T_1 which includes a portion of the first-described circuit up to and including the conductor 217. From conductor 217 the additional circuit includes a conductor 250, element 115 of top switch S_1, and conductors 251 and 252 which are connected to terminal S_1 on panel P. Referring now to Fig. 11, the additional circuit further includes a conductor 253, solenoid-operated gas valve 57 and conductor 254 which is connected to the terminal T_2 in the same manner as solenoid-operated gas valve 58.

Hence, when there is such fall of temperature that the expansible bellows 131 and 132 contract sufficiently to allow the hinged door 107 to cause the element 115 of the top switch S_1 to move to its dotted-line position after similarly actuating the bottom switch S_2, all of the devices energized as a result of the actuation of the bottom switch S_2 remain energized and a single new circuit is completed to open solenoid-operated gas valve 57. With opening of gas valve 57 gas is also supplied to the burner 53 to increase the rate at which heat is supplied to the boiler 37, so that an increased amount of heating will be effected by the heater 19.

Conversely, when the air temperature in enclosure 14 rises, the bellows 131 and 132 expand and swell due to increase in pressure of the volatile fluid within the expansible fluid thermostat with which the bellows are associated. The swelling and expanding of bellows 131 and 132 produces a force which is exerted against the hinged door 107 to cause the latter to move rearwardly against the action of coil springs 112. When the hinged door 107 has moved rearwardly sufficiently, the element 115 of the top switch S_1 moves back to the solid line position in Fig. 10. This movement of element 115 toward the right is inherent in switch S_1 because, as explained above, the elements 115 of the switches S_1 and S_2 are spring-biased to move rearward when the hinged door 107 is in such a position that it will not restrain or limit rearward movement of the pins 113.

With movement of the element 115 of top switch S_1 toward the right in Fig. 10, the circuit from terminals T_1 to S_1 on panel P is broken

wherefore the circuit for the solenoid-operated gas valve 57 is opened to cause the latter to close. The closing of gas valve 57 shuts off flow of gas to burner 53 to reduce the heat supply to the boiler 37 and hence decrease the amount of steam produced and delivered to heater 19.

When the air temperature in the enclosure 14 rises to the desired temperature at which the dial mounted on plate 141 is set, sufficient expansion and swelling of bellows 131 and 132 results to cause the hinged door 107 to move rearwardly such a distance that the element 115 of the bottom switch S_2 snaps rearwardly to the solid line position in Fig. 10. With movement of element 115 of the bottom switch S_2 to the right in Fig. 10, all of the circuits previously completed from terminals T_1 to V, H, and S_2 on panel P are broken, so that all of the devices connected to these terminals are deenergized to shut down the system. When the temperature of air in the enclosure 14 again falls below the desired temperature of, say, 70° F., switch S_2 is again actuated to cause the air conditioning system to operate to effect heating of air flowing past heater 19.

Ventilating

Let us assume that main control switch 200 in Fig. 11 is closed so that a circuit formed across the terminals T_1 and T_2 on panel P will be completed to cause energization of any device connected therein. Let us further assume that simply ventilating of enclosure 14 is desired, without heating or cooling of air delivered thereto through duct 22. In such case the middle or center lever 104 at the top of thermostat control TC in Fig. 1 is snapped to its forward position for operating ventilating switch V.

Referring more particularly to Fig. 10, movement of lever 104 of switch V causes the movable element 220 thereof to move from the "off" position to the "on" position to complete a circuit across the terminals T_1 and T_2 for the blower motor relay 223 in Fig. 11. This circuit includes conductor 212 which is connected to the terminal T_1, conductor 257, element 220 of switch V, and conductor 221 which is connected to the terminal V on panel P. Referring now to Fig. 11, the circuit being described includes the conductor 222 which is also connected to terminal V, coil of blower motor relay 223, conductors 224 and 225, normally closed switches 84 and 93 and conductor 226 to terminal T_2 on panel P. With energization of the blower motor relay 223, the movable element thereof closes to complete the circuit for the blower motor 28 across conductors 203 and 204, as previously explained above under the heading "Heating." By completing the circuit for blower motor 28, the blower 21 is operated to withdraw air from the enclosure 14 through duct 15 and return air through duct 22 back to the enclosure 14, thereby effecting ventilation of the enclosure 14. This feature is desirable during periods when neither heating nor cooling of air are necessary and yet the amount of comfort that occupants desire is improved considerably when air circulation and air cleaning are effected.

Cooling

Let us assume now that main switch 200 in Fig. 11 is closed and that it is desired to operate the air conditioning system in Fig. 12 to effect cooling of air in the enclosure 14. The lever 104 of the cooling switch R at the extreme right-hand side of thermostat control TC in Fig. 1 is snapped to its forward position to cause operation of the air conditioning system so as to effect air cooling.

Referring more particularly to Fig. 10, movement of lever 104 of switch R causes the movable elements 213 thereof to move from the "off" position to the "on" position. When the temperature of the air is sufficiently low, that is, the temperature at which it is desired to maintain the air in the enclosure 14, switches S_1 and S_2 are in the dotted line positions shown in Fig. 10 and none of the circuits of the devices shown in Fig. 11 is completed, so that no cooling of air is effected by the air conditioning system.

When the air temperature starts to rise above, say 70° F., for example, the pressure of the volatile fluid in the expansible fluid thermostat increases to cause the bellows 131 and 132 to swell and expand. With swelling of bellows 131 and 132, the hinged door 107 is forced rearwardly from the front vertical part of main bracket 105 against the action of coil springs 112. As shown in Fig. 10, the rearward movement of the hinged door permits movement of the pins 113 of switches S_1 and S_2 toward the right. With movement of the hinged door 107 toward the right in Fig. 10, the movable element 115 of the top switch S_1 first moves with a snap action to its solid line position, and, with continued movement of the hinged door in the same direction, the movable element 115 of the bottom switch S_2 thereafter moves with a snap action to its solid line position.

When the movable element 115 of top switch S_1 moves with a snap action from the position shown in dotted lines to that shown in solid lines, a number of circuits are completed across the terminals T_1 and T_2 on panel P to render the air conditioning system operable to cool air in the enclosure 14. The above-described movement of element 115 of top switch S_1 to the solid line position in Fig. 10 completes a first circuit from T_1 through conductors 212 and 260, left-hand element 211 of switch H, conductor 216, connecting link 215 on panel P, conductor 214, left-hand element 213 of switch R (which is now assumed to be in the "on" position), conductors 261 and 262, element 115 of top switch S_1, conductor 251, right-hand element 211 of switch H, conductor 219, element 220 of switch V and conductor 221 to the terminal V on panel P. Referring now to Fig. 11, the first circuit also includes conductor 222 which is connected to terminal V, coil of blower motor relay 223, conductors 224 and 225, normally closed switches 84 and 93 and conductor 226 to terminal T_2 on panel P. With completion of the circuit just described across the terminals T_1 and T_2, the coil of blower motor relay 223 is energized to close the movable element associated therewith to complete a circuit for the blower motor 28 across conductors 203 and 204. This circuit has previously been described above under the headings "Heating" and "Ventilating" and will not be repeated here.

In the first circuit described above, which is completed from the terminal T_1 to the terminal V, the circuit was followed from the element 115 of the top switch S_1 in Fig. 10 through conductor 251 to the right-hand element 211 of switch H. From the terminal T_1 a second circuit is completed which includes a portion of the first circuit up to and including the conductor 251. From conductor 251 the second circuit also includes conductor 252 which is connected to terminal S_1 on panel P. Referring now to Fig. 11, the sec-

ond circuit further includes conductor 253 which is connected to terminal S_1, solenoid-operated gas valve 57, conductors 254 and 232, the movable element of low water cut-out relay 79, conductor 225, normally closed switches 84, 93, and conductor 226 to terminal T_2 on panel P. As already pointed out above under the heading "Heating," the low water cutout relay 79 is immediately energized when main switch 200 is closed as long as the water in the boiler 37 is at a predetermined level. In the second circuit just described, the energization of solenoid-operated gas valve 57 is effected to cause this valve to open.

With movement of the element 115 of top switch S_1 to the solid line position shown in Fig. 10, a third circuit is completed which also includes a portion of the first described circuit up to and including conductor 251 and right-hand element 211 of switch H. From the element 211 of switch H the third circuit includes conductor 234, the right-hand element 213 of switch R, and conductor 263 which is connected to terminal C on panel P. Referring now to Fig. 11, the third circuit further includes a conductor 264 which is connected to terminal C, the two-position electric motor 61, conductor 225, normally closed switches 84 and 93 and conductor 226 which is connected to terminal T_2. The circuit completed for the motor 61 through terminal C causes the motor to turn to a position opposite to the position taken when a circuit is completed for this motor through terminal H and conductor 236.

In addition to completing a circuit for the two-position electric motor 61 the third circuit also completes a circuit for the spray tower relay 265 which is connected by conductors 266 and 267 to conductors 264 and 225 in parallel with the two-position electric motor 61.

With completion of the above described third circuit resulting in energization of the coil of relay 265, the movable elements thereof close to complete circuits for the spray tower motors 50 and 52 and the condensate pump motor 78. The circuits for the spray tower motors 50 and 52 from the source of electrical supply include conductors 203, 240 and 268, the movable elements of relay 265 and conductors 269 and 270 to the terminals of the spray tower motors 50 and 52. From the opposite terminals of motors 50 and 52 the circuits include conductors 229 and 204 which are connected to the source of electrical supply. In addition, the energization of relay 265 completes a circuit from the source of supply through conductors 203 and 240, one of the movable elements of the relay 265 and conductor 243 to one terminal of the condensate pump motor 78. The circuit from the opposite terminal of motor 78 includes conductors 244, 229 and 204 which are connected to the source of electrical supply.

When the element 115 of top switch S_1 moves to its solid line position in Fig. 10, therefore, the three above-described circuits, which are completed through terminals V, S_1 and C on panel P, cause energization of blower motor 28, solenoid-operated gas valve 57, two-position electric motor 61, spray tower motors 50 and 52, and condensate pump motor 78. As shown in Fig. 12, the opening of gas valve 57 allows gas to be supplied through conduits 55 and 56 to the burner 53. The gas discharged from the burner 53 is ignited by the pilot flame formed at the end of tubing 89 so that boiler 37 is heated.

At the same time that heat is being supplied to the boiler 37 to produce steam, the two-position electric motor becomes operative to actuate the steam valve 60 so that all of the steam produced in the boiler will flow through conduit 36 to generator 32 of the refrigeration apparatus. By supplying steam to generator 32, the refrigeration apparatus operates in the manner described above so that cooling element 17 becomes effective to produce a refrigerating or cooling effect. Simultaneously with the actuation of steam valve 60 the lever 70, which is operatively connected to the two-position motor 61, moves from the position shown clear of pin 69 in Fig. 12. With the right hand end of lever 70 in its raised position gas is supplied to burner 53 at a constant pressure dependent upon the tension of spring 68. Under these conditions gas is delivered at a lower constant pressure than during the periods when the air conditioning system is operating to effect heating of air, as explained above. The above-described actuation of steam valve 60 by the motor 61 also causes closing of dampers 24 and opening of dampers 23.

The energization of blower motor 28 causes operation of blower 21 so that air is withdrawn from the enclosure 14 past cooling element 17 in duct 18, the cooled air being returned through duct 22 to the enclosure. The energization of spray tower motor 50 causes operation of the blower 48 for drawing air upwardly through the cooling water tower 41. At the same time the motor 52 becomes effective to operate pump 51 for circulating cooling water through the absorber 23 and condenser 49 of the refrigeration apparatus. The condensate formed in generator 32 flows through conduit 73 to the vessel 75 and is returned therefrom to the boiler 37 by pump 77 which is actuated by the condensate pump motor 78.

In the event that steam flows from generator 32 through vent 80 to the common vent 82 for any of the reasons previously given, the thermal bulb 83 becomes heated to cause switch 84 to open all of the circuits connected to the terminal T_2 on panel P, in the same manner that all of the circuits are broken during a heating period, as explained above. Likewise, if there is operating failure of the condensate pump 77 or the water in boiler 41 falls below the normal predetermined level determined by the location of the low water cut out relay 79, the switch 84 will open if the former occurs and the circuit for the solenoid-operated gas valve 57 will be broken if the latter occurs. In the event that cooling element 17 falls below a predetermined low temperature, the thermal bulb 91 becomes sufficiently cool to cause switch 93 to open all of the circuits connected to the terminal T_2 on panel P, so that all of the electrical circuits are broken to shut down the air conditioning system.

When the air temperature continues to rise above the desired temperature, even when the single burner 53 is operating as a result of the movement of element 115 of the top switch S_1 to the solid line position shown in Fig. 10, the continued movement of the hinged door 107 rearwardly from the front vertical part of main bracket 105 permits the bottom pin 113 to move to the right to allow the element 115 of the bottom switch S_2 to move with a snap action from the position shown in dotted lines to that shown in solid lines. When this occurs the circuits already completed as a result of the prior movement of element 115 of the top switch S_1 remain intact to effect cooling of air in the enclosure. In addition, a circuit is completed from the ter-

minal T_1 which includes a portion of the first described circuit up to and including the conductor 261. From conductor 261 the additional circuit includes element 115 of the bottom switch S_2 and conductors 218 and 230 which are connected to terminal S_2 on panel P. Referring now to Fig. 11, the additional circuit further includes conductor 231 which is connected to the terminal S_2, and solenoid-operated gas valve 58 which is connected to the terminal T_2 in the same manner as solenoid-operated gas valve 57.

Hence, when there is such rise of temperature that the expansible bellows 131 and 132 swell sufficiently to cause the hinged door 107 to permit the element 115 of the bottom switch S_2 to move to its solid line position after previously permitting the element 115 of the top switch S_1 to move toward the right, all of the devices energized as a result of the actuation of the top switch S_1 remain energized and a single new circuit is completed to open solenoid-operated gas valve 58. With opening of gas valve 58 gas is also supplied to burner 54 to increase the rate at which heat is supplied to the boiler 37 so that an increased amount of cooling will be effected by the cooling element 17.

Conversely, when the air temperature in enclosure 14 falls, the bellows 131 and 132 contract due to decrease in pressure of the volatile fluid within the expansible fluid thermostat with which the bellows are associated. With contraction of bellows 131 and 132 the coil springs 112 are effective to pull the hinged door 107 toward the front vertical part of main bracket 105. When the hinged door 107 has moved forward sufficiently the pin 113 of the bottom switch S_2 causes the element 115 associated therewith to move with a snap action to the dotted line position in Fig. 10.

With movement of the element 115 of bottom switch S_2 toward the left in Fig. 10, the circuit from terminals T_1 to S_2 on panel P is broken, so that the circuit for the solenoid-operated gas valve 58 is opened to cause the latter to close. The closing of gas valve 58 shuts off flow of gas to burner 54 to reduce the heat supply to the boiler 37 and hence decrease the amount of steam produced and delivered to generator 32. With a reduction in the quantity of steam supplied to generator 32 the cooling effect produced by cooling element 17 is likewise reduced.

When the air temperature in the enclosure 14 falls to the desired temperature at which the dial mounted on plate 141 is set, sufficient contraction of bellows 131 and 132 results to cause the hinged door 107 to move forward such a distance that the element 115 of the top switch S_1 moves with a snap action to the dotted line position in Fig. 10. When the element 115 of the top switch S_1 moves to the left in Fig. 10 all of the circuits previously completed from terminals T_1 to V, S_1 and C on panel P are broken, so that all of the devices connected to these terminals are deeneregized to cause the system to shut down. When the temperature of air in the enclosure 14 again rises above the desired temperature, switch S_1 is again actuated to cause the air conditioning system to effect cooling of air flowing past cooling element 17.

Operation of electrical system when several control switches are "on" at the same time

When both the heating and ventilating switches H and V are moved to the "on" positions the air conditioning system becomes operable to heat air in the enclosure 14. The circuits completed from terminals T_1 to S_2 and H on panel P in such case are the same as the second and third circuits described above under the heading "Heating." The circuit from terminals T_1 to V differs from the circuit previously described under the heading "Heating" and includes conductor 212 which is connected to terminal T_1, conductor 257, element 220 of switch V and conductor 221 which is connected to terminal V. With the circuits completed from terminals T_1 to V, S_2 and H, the devices connected to these terminals and also T_2 will be energized to cause heating of air in the manner described above under the heading "Heating."

When both the cooling and ventilating switches R and V are moved to the "on" positions the system becomes operative to effect cooling of air in the enclosure 14. The circuits from terminals T_1 to S_1 and C on panel P in such case are the same as the second and third circuits described above under the heading "Cooling." The circuit from terminals T_1 to V differs from circuit previously described under the heading "Heating," and is the same as that just described when both switches H and V are moved to the "on" positions at the same time. With the circuits completed from terminal T_1 to V, S_1 and C, the devices connected to these terminals and T_2 will be energized to effect cooling of air in the manner described under the heading "Cooling."

When both the heating and cooling switches H and R are moved to the "on" positions no circuits are completed from T_1 to other terminals on the panel P. This is quite evident because the conductor 212, which is connected to terminal T_1, cannot complete any circuit through the left-hand element 213 of switch R; and the conductor 260, which is connected through conductor 212 to the terminal T_1, cannot complete any circuit through the left-hand element 211 of switch H. Also, the conductor 257, which is connected through conductor 212 to the terminal T_1, cannot complete any circuit across the element 220 of the switch V. Since none of the circuits is completed from terminal T_1 to another terminal on the panel P when both switches H and R are moved to the "on" positions, none of the devices will be energized so that the system will be ineffective either to heat or cool the air in the enclosure 14.

When all the switches H, V and R are moved to the "on" positions no circuits are completed from T_1 across the movable elements 211 and 213 of switches H and R, respectively, in the manner just described when both of these switches are moved to the "on" positions. However, when switch V is moved to its "on" position at the same time as the switches H and R, a circuit is completed from terminal T_1 to V on panel P in the same manner described above when switches H and V are moved at the same time to their "on" positions. Hence, when all three switches on thermostat control TC are moved to the "on" positions, ventilating of enclosure 14 will be effected.

In view of the foregoing, it will be evident that when switches H and V are in the "on" positions at the same time, ventilating of the enclosure 14 is constantly effected even when the air temperature rises sufficiently to render the system ineffective for heating air. Likewise, when switches R and V are in the "on" positions at the same time, ventilation is effected even when the air temperature is sufficiently low to cause the re-

frigeration apparatus to shut down. In most cases it is desirable to keep the ventilating switch V in the "off" position when heating is being effected, so that there will be intermittent operation of the blower **21**; and to keep the switch V in the "on" position when cooling is being effected, so that there will be continuous operation of blower **21** to promote the best comfort conditions.

Electrical system modified for heating only

When it is desired to employ thermostat control TC for heating only, with all of the circuit connections available at a future time when the refrigeration apparatus and devices associated therewith are added to the air conditioning system, the control TC may be modified so that the heating switch H will be effective to control heating irrespective of the position of the cooling switch R. Such modification may include the removal of connecting link **215** on panel P and the substitution therefor of connecting links **273** and **274**, as indicated in dotted lines in Fig. 10. By providing link **273** a circuit is provided from terminals T_1 to V during heating which is generally similar to that described above under the heading "Heating" and differs therefrom only in that a shunt or by-pass is provided around the left-hand element **213** of cooling switch R. Hence, irrespective of the position of switch R the circuit from T_1 to V includes link **273** and conductor **216** to the left-hand element **211** of switch H. From this point the circuits to terminals H, S_2 and V are similar to the circuits described above under the heading "Heating," except for the following possible modification of the circuit to the terminal H which involves the connecting link **274**.

The connecting link **274** is provided so that a circuit will always be completed from terminals T_1 to H when switch H is moved to its "on" position, irrespective of position of the right-hand element **213** of switch R. When the switch R is in the position shown in Fig. 10, the circuit to terminal H is completed through conductor **234**, the right-hand element **213** of switch R and conductor **235** which is connected to terminal H. When the switch R is moved to its "on" position, the circuit from conductor **234** is then completed through the right-hand element **213** of switch R and conductor **263** which is connected to terminal C. In order that the circuit will still be completed to terminal H even when the switch R is in the "on" position, the connecting link **274** is provided from terminal C to H. Hence, irrespective of the position of switch R in Fig. 10, when the switch H is in its "on" position and there is a demand for heat, a circuit will aways be completed to terminal H so that the devices connected thereto and also to terminal T_2 will be energized to render the system operative to heat air in the enclosure **14**.

SENSITIVITY OF THERMOSTAT CONTROL TC

Under the heading "Description of Thermostat control TC" appearing above, the structural features of the control have already been described. The interrelation of the subsidiary and component parts of the control TC is such that dependable and sensitive control or air temperature is effected. In a control which has been built and like that illustrated in Figs. 1 to 9 inclusive and described above, each of switches S_1 and S_2 is caused to operate with a temperature change in a range between 0.3 to 0.6° F.; that is, with such temperature change, a snap-action of each switch is effected. In such control the bellows **131** and **132** are formed of beryllium-copper approximately .016 inch thick with the diaphragms being heat treated to maximum hardness after the peripheral edges thereof have been secured by silver solder. The bellows **131** and **132** formed of beryllium-copper together expand approximately .0016 inch per degree Fahrenheit to effect a snap-action movement of each micro-switch S_1 and S_2 employed in the control, a movement of only .00015 to .00035 inch being required with a change in pressure of 1¼ to 2 ounces on the plungers or pins **113**.

The expansible fluid thermostat of which the bellows being described form a part preferably has a so-called limited charge of isobutane, that is, the charge of volatile fluid is sufficient to produce saturated vapor with a temperature as high as 95° F., which is safely above the upper limit of the thermostat adjustment of control TC. In such case the bellows **131** and **132** contain superheated vapor above 95° F., so that the pressure at extremely high temperatures frequently encountered during shipping and storage only increases slowly according to the ideal gas law. By employing an expansible fluid thermostat having only a limited charge, the pressure increase that occurs with rise of temperature above the normal working temperature range is limited, so that the diaphragms of the bellows can be formed from relatively thin material from which more useful movement can be obtained. It is desirable to employ a volatile fluid having a high vapor pressure, such as isobutane, for example, in order to reduce the effect of barometric changes. Hence the expansible fluid thermostat including the bellows **131** and **132** should be sufficiently strong to withstand the pressures of volatile fluids having a high vapor pressure.

The thickness of the diaphragms forming the bellows **131** and **132** and the size thereof should always be selected so that straining above the elastic limit is avoided under all the conditions encountered.

As explained above under the heading "Cooling" the top switch S_1 is moved first from the dotted line to the solid line position in Fig. 10 with rise of air temperature, and thereafter the bottom switch S_2 is similarly moved with further rise of air temperature. The adjustments embodied in control TC are made so that, when the temperature increases during a cooling period from the desired temperature and the hinged door **107** is pushed rearwardly due to expansion of the bellows **131** and **132**, the top switch S_1 is operated first. In the control TC referred to above, this is accomplished by first positioning the top tongue **109** by the set screw **11** associated therewith so that the top switch S_1 is operated when the hinged door is moved from a position parallel to the front vertical part of main bracket **105** a distance in a range varying from .00015 to .00035 inch. This operation of switch S_1 in the control being described requires a temperature rise of between 0.3 to 0.6° F. A slight movement of the hinged door **107** is preferably allowed before the bottom switch S_2 is actuated, such movement in one instance corresponding approximately to a temperature change of about 0.2° F. The bottom switch S_2 in the control referred to above is then operated with a further temperature rise between 0.3 to 0.6° F.

In the two-step or two-stage control just described, therefore, the operation of both burners **53** and **54** is effected with a temperature differential of approximately or slightly greater than 1 F. The two steps or stages of operation can, o

course, be adjusted to come closer together and even overlap, if desired. By moving the bottom screw 111 inward at the rear of hinged door 107 to cause the free end of the bottom tongue 109 to move toward the front vertical part of main bracket 105, the temperature change that occurs between the operation of the top and bottom switches is increased.

The factors that determine the extent of temperature change that should occur between operating the system with the first step or one burner and with both steps or two burners include the size of the space in which air is to be treated or conditioned, the heat capacity of the building or dwelling, and the time lag that occurs when the control equipment and associated devices are set into operation and also rendered inoperative. In view of the foregoing, it will now be understood that the thermostat control TC is extremely sensitive by virtue of the structure and interrelation of the component parts thereof and the fact that a negligible amount of friction is produced during operation of the control.

RESPONSIVENESS OF THERMOSTAT CONTROL TC

In addition to being extremely dependable and sensitive in operation the thermostat control TC embodies an expansible fluid thermostat which is so constructed and arranged that the control is exceptionally rapid in responding to change of air temperature. For this reason the thermostat control TC is provided with an expansible fluid thermostat which comprises not only the expansible and contractible bellows 131 and 132, which is the usual practice in bellows type thermostatic controls heretofore provided, but also the capillary tube 130 and thermal bulb 125. In addition, the heater 146 is provided to cause heating of air within the casing 100, so that the bellows 131 and 132 and larger part of capillary tube 130 will be disposed in an environment which is at a slightly higher temperature than the bulb 125 located in the recess 127 formed in the bottom part of the control.

In any expansible fluid system the pressure therein always corresponds to the temperature of the coldest part, because the temperature attained by the coldest part determines the amount of volatile fluid in liquid phase and in gas or vapor phase. When the temperature of the coldest part rises a greater amount of volatile fluid is in gas phase to cause the pressure in the system to increase; and conversely, when the temperature of the coldest part falls, some condensation occurs with a smaller amount of volatile fluid in gas phase to cause the pressure in the system to reduce.

In order to insure that the thermal bulb 125 will always be at a lower temperature than other parts of the thermostat system, and hence serve as the only sensitive part of the system, the other parts thereof comprising the capillary tube 130 and bellows 131 and 132 are always kept somewhat above the ambient temperature by the heating element 146. With the thermal bulb 125 serving as the only sensitive part of the expansible fluid thermostat, the bulb is preferably formed of very thin material to reduce its heat capacity to a minimum with the material possessing good heat conductivity to effect rapid heat transfer.

One of the factors to be considered in obtaining a control which responds rapidly is the internal volume of the entire expansible fluid thermostat of which the sensitive bulb forms a part. For a given transfer of heat to the sensitive bulb a definite quantity of volatile liquid vaporizes, and the smaller the internal volume of the expansible fluid thermostat the greater will be the pressure increase resulting from vaporization of such definite quantity of volatile liquid. Hence it is exceedingly important to employ an expansible fluid thermostat having as small an internal volume as practicable and at the same time of such proportion that adequate mechanical energy will be produced to cause operation of the thermostat control TC.

The thin-walled thermal bulb 125 at the bottom of the control TC is well exposed to the air so that the thermostat as a whole responds rapidly to changes in air temperature. It is desirable to form the bulb 125 as small as practicably possible and with relatively thin walls, so that there is very little heat absorption by the metal with rise of air temperature and very little heat dissipation by the metal with fall of temperature. This is quite different from expansible fluid thermostats of the type heretofore provided which employ expansible and contractible bellows alone and are relatively sluggish in operation because of the relatively large amount of heat required to be taken up and given off by the diaphragm metal forming the bellows.

With the so-called limit charge of isobutane, for example, the sensitive bulb 125 only contains volatile liquid in the order of a few hundredths of a cubic inch at the lowest regulating temperature of 55° F. With rise of air temperature heat from the air is transmitted through the thin-walled sensitive bulb 125 to cause some vaporization of the liquid. Since a greater amount of volatile fluid is now in gas phase within the thermostat system, the internal pressure increases to cause mechanical movement of the control parts, the bellows 131 and 132 acting with considerable power to effect movement of the hinged door 107. Conversely, with fall of air temperature heat is immediately given up by the volatile fluid through the thin-walled bulb 125 to cause some condensation of vapor. Since less volatile fluid is now in vapor phase the internal pressure within the thermostat system is reduced to cause or permit movement of the control parts.

It should be understood that the heater 146 is continuously and constantly heating the interior of casing 100 of the thermostat control TC. The heater 146 is immediately energized across terminals T_1 and T_2 on panel P when the main control switch 200 is closed, as best shown in Fig. 11. The heater 146 insures that the temperature within casing 100 will always be slightly higher than the temperature of air flowing over and in contact with the exterior surfaces of thermal bulb 125, so that the latter will always be the coldest part of the thermostat system. It should be understood that the heater 146 increases and improves the responsiveness of the thermostat system as a whole and is utilized both during heating and cooling periods, and hence differs from the usual type of artificial heater heretofore provided in controls of this character in that the latter are employed intermittently and not continuously and are utilized only during the heating periods to offset poor responsiveness by improving the sensitivity of the control solely to terminate the heating period in accordance with a false room temperature.

In the control referred to above in which bellows 131 and 132 formed of beryllium-copper are employed, the capillary tube 130 is formed of soft annealed copper and the sensitive bulb 125 is

formed of brass having a wall thickness of .0035 inch and an outside diameter of $\frac{7}{32}$ inch. The size of heater 146 is approximately 0.5 watt which has been found to keep the average temperature within the casing 100 approximately 5° F. above the room temperature. This temperature differential appears to be sufficient for all ordinary conditions, whereby the interior of the control TC is well above the ambient temperature even with rapid rise of the latter temperature.

With the heater being used continuously to heat the interior of casing 100 during operation of the air conditioning system, the control mechanism can be completely enclosed so that the component and individual parts thereof will be protected from dust and other foreign matter in the air. Hence, louvers or slotted openings to allow flow of air into the interior of the control casing are not required, so that the sensitivity of the control TC will not be impaired by accumulation of dust and the like. In order to protect the sensitive bulb 125 from the heated space within the casing 100 the bottom 126 is formed of a suitable material, such as Bakelite, for example, having poor heat conductivity. The bottom 126 is formed with the enlarged recess 127 to receive the sensitive bulb 125 and the openings 128 are formed at the front and sidewalls thereof whereby the bulb is adequately exposed to circulating room air.

While the bottom 126 is formed of insulating material so that the sensitive bulb 125 is as close as possible to room air temperature, the bulb may actually be one or two degrees above the room air temperature due to slight heat leakage to the bulb. Compensation can readily be made for such a condition by properly setting the dial 141 on the adjustment nut 139.

The thermometer on the front face of the control TC, which is shown in Fig. 1, is also compensated to indicate the correct room air temperature even though there is heat leakage from within the casing 100.

Instead of providing a separate sensitive bulb 125 the lower end portion of capillary tube 130 may be arranged to serve as the sensitive part of the expansible fluid thermostat. If desired, heat dissipating fins may be provided along the capillary tube 130 to reduce the amount of heat transmitted through the tube to the sensitive bulb 125. In order to reduce heat leakage to the bulb through the capillary tube the latter may be formed of material such as, for example, stainless steel, having poorer heat conductivity than copper. In view of the foregoing, it will now be understood that the thermostat control TC embodies an expansible fluid thermostat which is so constructed and arranged that the control responds rapidly to change of air temperature.

Conclusion

In the above described control circuit it will now be understood that after the main control switch 200 is closed, the thermostat device TC constitutes a single control point at which either cooling, heating, or simply ventilating may be effected to obtain the best comfort conditions. The thermostat device TC cannot be injured or harmed by moving a plurality of the switches H, V and R to the "on" positions at the same time, as explained above. By completely enclosing the thermostat device TC the accumulation of dust on the control parts therein is avoided. This is made possible by the arrangement of the parts of the expansible fluid thermostat in which the thin-walled sensitive element thereof is located outside and in a recess at the bottom part of the casing 100.

The control device TC is so constructed and arranged that many of the parts are utilized both during the heating and cooling periods. This not only provides a compact control but inherently embodies many safety features in connection with the multiple operation of switches H, V and R. For example, switches S_1 and S_2 which are of the micro-switch type, as explained above, are connected in the electrical system in such a manner that they are utilized for controlling the heat supply both during the heating and cooling periods. Thus duplicate sets of switches are not required for the control for the heating and cooling periods.

In view of the fact that steam is supplied both to the heater 19 and generator 32 at atmospheric pressure and these parts are connected to a common vent 82, the single steam vent control provided takes the place of many controls that otherwise would be necessary to insure safe operation of the refrigeration system and heating system. In the event steam flows from heater 19 or generator 32 through the common vent 82 to effect heating of thermal bulb 83, or condensate overflows from vessel 75 into well 87 to effect heating of thermal bulb 88, the expansible fluid thermostat of which the thermal bulbs 83 and 88 form a part becomes effective to operate switch 84. Since switch 84 is connected through conductor 226 to terminal T_2, as shown in Fig. 11, and all of the circuits necessary to cause operation of the air conditioning system are completed through this last-mentioned terminal, it will be evident that the opening of switch 84 opens all of the electric circuits to shut down the system either when heater 19 is effecting heating or cooling element 17 is effecting cooling.

In addition to the single steam vent control, the low-water cutout 79 is provided for boiler 37 to protect the latter when the water falls below a predetermined level therein. When the low-water cutout relay 79 is opened the circuits for the gas valves 57 and 58 are broken, as best shown in Fig. 11, whereby these valves are closed to shut off the supply of fuel to the burners 53 and 54. However, the circuits for the other electrical devices are not broken when the low-water cutout relay becomes effective to shut down burners 53 and 54. When the water in the boiler 37 again reaches the predetermined level the low-water cutout relay 79 becomes energized, whereby the circuits for the gas valves 57 and 58 again can be completed to supply fuel to the burners 53 and 54 providing the circuits for the solenoid-operated gas valves are completed through the switches S_1 and S_2 in thermostat device TC.

Although a single embodiment of the invention has been shown and described, it will be apparent to those skilled in the art that various modifications and changes may be made without departing from the spirit and scope of the invention. It is therefore contemplated to cover all modifications and changes which come within the spirit of the invention, as pointed out in the following claims.

What is claimed is:

1. An air conditioning system comprising a heater arranged to effect heating of air, a refrigeration unit including an evaporator arranged to effect cooling of air, apparatus to effect operation of said heater and said refrigeration unit, and a

control for said apparatus responsive to a condition affected by air adapted to be conditioned by said system, said control including parts operable in one sequence to control said apparatus when heating of air by said heater is desired and in another sequence to control said apparatus when cooling of air by said evaporator is desired.

2. An air conditioning system comprising a heater arranged to effect heating of air, a refrigeration unit including an evaporator arranged to effect cooling of air, apparatus to effect operation of said heater and said refrigeration unit, a control for said apparatus responsive to a condition affected by air adapted to be conditioned by said system and including parts operable in one sequence to control said apparatus when heating of air by said heater is desired and in another sequence to control said apparatus when cooling of air by said evaporator is desired, and structure associated with said control for selectively determining said one or other sequence of operation of said parts.

3. An air conditioning system comprising a heater arranged to effect heating of air, refrigeration apparatus operated by heat and including an evaporator arranged to effect cooling of air, heating means for said heater and said refrigeration apparatus, a control including a plurality of elements operable in one sequence to control the heat supplied by said heating means to said refrigeration apparatus when it is desired to effect cooling of air and operable in another sequence to control the heat supplied by said heating means to said heater when it is desired to effect heating of air, said elements being operable responsive to a condition affected by air adapted to be conditioned by said system, and structure for selectively determining said one or other sequence of operation of said elements.

4. An air conditioning system comprising a heater arranged to effect heating of air, refrigeration apparatus operated by heat and including a cooling element arranged to effect cooling of air, heating means for said heater and said refrigeration apparatus, and a control responsive to a temperature condition affected by air adapted to be conditioned by said system, said control comprising electrical circuits including a plurality of switches operable in one sequence to control in steps or stages the heat supplied by said heating means to said refrigeration apparatus when it is desired to effect cooling of air and operable in another sequence to control in steps or stages the heat supplied by said heating means to said heater when it is desired to effect heating of air.

5. An air conditioning system comprising a heater arranged to effect heating of air, refrigeration apparatus operated by heat and including a cooling element arranged to effect cooling of air, heating means for said heater and said refrigeration apparatus, a control comprising electrical circuits including a plurality of switches operable in one sequence to control in steps or stages the heat supplied by said heating means to said refrigeration apparatus when it is desired to effect cooling of air and operable in another sequence to control in steps or stages the heat supplied by said heating means to said heater when it is desired to effect heating of air, said switches being operable responsive to a temperature condition affected by air adapted to be conditioned by said system, and additional switch mechanism associated with said electrical circuits for selectively determining said one or other sequence of operation of said first-mentioned switches.

6. An air conditioning system for an enclosure comprising a heater arranged to effect heating of air, refrigeration apparatus operated by heat and including a cooling element arranged to effect cooling of air, heating means for said heater and said refrigeration apparatus, and a control comprising electrical circuits including switch mechanism operable in one manner to control the heating of said refrigeration apparatus by said heating means when cooling of air is desired and operable in another manner to control the heating of said heater by said heating means when heating of air is desired, said switch mechanism being operable responsive to a temperature condition affected by air adapted to be conditioned by said system, and additional switch mechanism associated with said electrical circuits operable to determine said one or other particular manner in which said first-mentioned switch mechanism is caused to operate to control said heating means.

7. An air conditioning system comprising a heater arranged to effect heating of air in a space, a refrigeration unit including an evaporator arranged to effect cooling of air in the space, apparatus for operating said heating and said refrigeration unit, a control for said apparatus comprising a casing adapted to be located in the space and including a plurality of parts therein operable in one sequence to control the operation of said heater by the apparatus and operable in another sequence to control the operation of said refrigeration unit by the apparatus, said control being responsive to a temperature condition affected by air in the space, and structure carried by said casing and associated with said control for selectively determining said one or other sequence of operation of said parts.

8. An air conditioning system comprising a heater arranged to effect heating of air in a space, refrigeration apparatus operated by heat and including a cooling element arranged to effect cooling of air in the space, heating means for said heater and said refrigeration apparatus, a control comprising electrical circuits including a plurality of switches operable in one sequence to control in steps or stages the heat supplied by heating means to said refrigeration apparatus when it is desired to effect cooling of air and operable in another sequence to control in steps or stages the heat supplied by said heating means to said heater when it is desired to effect heating of air in the space, said switches being operable responsive to a temperature condition affected by air in the space, said control including a casing adapted to be located in the space and within which said switches are disposed, and additional switch mechanism carried by said casing and associated with said electrical circuits for selectively determining said one or other sequence of operation of said switches.

9. An air conditioning system comprising a heater arranged to effect heating of air in a space, a refrigeration unit including an evaporator arranged to effect cooling of air in the space, a control comprising a casing adapted to be located in the space and including a plurality of parts therein operable in one sequence to control said heater when heating of air is desired and operable in another sequence to control said refrigeration unit when cooling of air by said evaporator is desired, structure carried by said casing and associated with said control for selectively determining the sequence of operation of said parts, and means including an expansible

fluid thermostat having one portion within said casing operatively associated with said parts and another portion outside said casing arranged to be influenced by the air in the space.

10. An air conditioning system comprising a heater arranged to effect heating of air in a space, a refrigeration unit including an evaporator arranged to effect cooling of air in the space, apparatus for operating said heater and said refrigeration unit, a control for said apparatus comprising a casing adapted to be located in the space and including a plurality of parts therein operable in one sequence to control operation of said heater by the apparatus and operable in another sequence to control operation of said refrigeration unit by the apparatus, structure carried by said casing and associated with said control for selectively determining said one or other sequence of operation of said parts, an expansible fluid thermostat including an expansible and contractible element operatively associated with said parts within said casing and a thermal sensitive element in fluid communication with said expansible element, said thermal sensitive element being located outside said casing so that air circulating in the space flows in contact therewith, and means for heating the interior of said casing so that said thermal sensitive element is the coldest part of said expansible fluid thermostat.

11. An air conditioning system comprising a heater arranged to effect heating of air in a space, refrigeration apparatus operated by heat and including a cooling element arranged to effect cooling of air in the space, heating means for said heater and said refrigeration apparatus, a control comprising electrical circuits including a plurality of switches operable in one sequence to control in steps or stages the heat supplied by said heating means to said refrigeration apparatus when it is desired to effect cooling of air and operable in another sequence to control in steps or stages the heat supplied by said heating means to said heater when it is desired to effect heating of air, said control including a casing adapted to be located in the space and within which said switches are disposed, an expansible fluid thermostat for said control including an expansible and contractible element within said casing operatively associated with said switches, a thermal sensitive element in fluid communication with said expansible element and disposed outside said casing so that air in the space flows in contact therewith, means for heating the interior of said casing so that said thermal sensitive element is the coldest part of said expansible fluid thermostat, and additional switch mechanism carried by said casing and associated with said electrical circuits for selectively determining said one or other sequence of operation of said switches.

12. An air conditioning system comprising a heater arranged to effect heating of air, refrigeration apparatus operated by heat and including a cooling element arranged to effect cooling of air, heating means for said heater and said refrigeration apparatus, a control operable responsive to a temperature condition affected by the air adapted to be conditioned by said system, said control comprising electrical circuits including switch mechanism manually operable to cause operation of said heating means at a time when heating of air by said heater is desired or at a time when cooling of air by said cooling element is desired, and means including said switch mechanism associated with said electrical circuits so that, even though said switch mechanism may be manually operated in an effort to cause both heating of air by said heater and cooling of air by said cooling element at the same time, such operation of said switching mechanism causes both said heater and said cooling element to remain ineffective to cause heating and cooling, respectively, of air.

13. An air conditioning system comprising a blower; a heater; a refrigeration unit including an evaporator; a control for said blower, heater and refrigeration unit to control heating and cooling of air; such control being responsive to a condition affected by air adapted to be heated or cooled by said system; and mechanism associated with said control to cause operation of said blower without heating and cooling of air so as to effect ventilation alone, to cause constant operation of said blower during periods when heating and cooling of air are intermittently effected by said heater and evaporator, respectively, and to cause intermittent operation of said blower during periods of heating and cooling; such intermittent operation of said blower being effected when said control becomes effective to cause heating of air by said heater and cooling of air by said evaporator.

14. An air conditioning system comprising a blower; a heater; a refrigeration unit including an evaporator; a control for said blower, heater and refrigeration unit to control heating and cooling of air; such control being responsive to a condition affected by air adapted to be heated or cooled by said system; mechanism including a plurality of manually operable switches associated with said control to cause operation of said blower without heating and cooling of air to effect ventilation alone, to cause constant operation of said blower during periods when heating and cooling of air are intermittently effected by said heater and evaporator, respectively, and to cause intermittent operation of said blower during periods of heating and cooling; such intermittent operation of said blower being effected when said control becomes effective to cause heating of air by said heater and cooling of air by said evaporator; and said mechanism being associated with said control in such a manner that manual operation of said switches to cause heating of air by said heater and cooling of air by said evaporator cannot be effected at the same time.

15. An air conditioning system comprising a heater, refrigeration apparatus operated by heat and including a cooling element, structure including a blower arranged to cause circulation of air when ventilation is desired, to cause heating of air by the heater when heating is desired and to cause cooling of air by the cooling element when cooling is desired, heating means for said heater and said refrigeration apparatus, a control operable responsive to a temperature condition affected by the air being conditioned by said system, said control comprising a single thermal responsive unit and electrical circuits including switch mechanism operable to control said heating means and said blower at a time when heating of air by said heater is desired or at a time when cooling of air by said cooling element is desired, and also operable to control operation of said blower to produce ventilation without heating and cooling of air by said heater and said cooling element, respectively.

16. An air conditioning system comprising a heater arranged to effect heating of air in a space;

refrigeration apparatus operated by heat and including an evaporator arranged to effect cooling of air in the space; heating means for said heater and said refrigeration apparatus; structure including a blower arranged to cause circulation of air when ventilation is desired, to cause heating of air in the space by said heater when heating is desired, and to cause cooling of air in the space by said evaporator when cooling is desired; a control comprising a casing adapted to be located in the space and responsive to a temperature condition affected by air therein; said control comprising a single thermal responsive unit and electrical circuits including switch mechanism carried by said casing arranged to render said heating means and said blower operable at a time when heating of air by said heater is desired or at a time when cooling of air by said evaporator is desired, and said switch mechanism also being arranged to render said blower operable to produce ventilation without heating and cooling of air by said heater and said evaporator.

17. An air conditioning system including a heater arranged to effect heating of air, a refrigeration unit having a cooling element arranged to effect cooling of air, apparatus to effect operation of said heater and said refrigeration unit, a control member for said apparatus, and structure responsive to temperature of air adapted to be conditioned by said system for operating said control member, said structure including an angularly movable part arranged to be operatively associated with said control member and an expansible fluid thermostat having an element supported on said angularly movable part so as to be bodily movable therewith.

18. In mechanism of the character described, a control member movable between first and second positions and biased to move toward said first position, an angularly movable part, an element supported on said part and operative responsive to temperature to cause movement of said part, said part with movement thereof being arranged to operate said control member, said angularly movable part being unconnected to the control member to permit movement of the part on an increase in temperature to prevent the control member from being subjected to excessive force, structure including said part being movable to cause said control member to move from said first position toward said second position with fall of temperature at which time the pressure produced by said element decreases, and to cause said control member to move from said second position to said first position with rise of temperature at which time the pressure produced by said element increases.

19. In mechanism of the character described, a control member movable between first and second positions and biased to move toward said first position, an angularly movable part, an expansible thermostat element supported on said part, so as to be bodily movable therewith, said angularly movable part being unconnected to the control member to permit movement of the part on an increase in temperature to prevent the control member from being subjected to excessive force said expansible thermostat being positioned to effect movement of said part in a direction to cause said control member to move from said first position toward said second position with fall of temperature at which time the pressure produced by said expansible thermostat decreases, and to effect movement of said part in an opposite direction to cause said control member to move from said second position toward said first position with rise in temperature at which time the pressure produced by said expansible thermostat increases.

20. In mechanism of the character described, a control member movable between first and second positions and biased to move toward said first position, an angularly movable part, a strip having one region thereof secured to said part, a set screw on said part arranged to press against a second region of said strip removed from said one region, a resilient element arranged to cause said part to move in one direction, said control member being unconnected to said part and said strip and having a portion in the path of movement of said other region of said strip so that, with movement of said angularly movable part and said strip secured thereto in said one direction, movement is imparted to said control member to cause the latter to move from said first position toward said second position, and structure including an element responsive to temperature operative to effect movement of said angularly movable part in a direction opposite to said one direction against the action of said resilient element to cause said control member due to said bias to move from said second position toward said first position.

21. In mechanism of the character described, a control member movable between first and second positions and biased to move toward said first position, an angularly movable part, resilient means arranged to cause said part to move in one direction, said part with movement thereof in said one direction being arranged to cause said control member to move from said first position toward said second position, an element responsive to temperature mounted on and supported by said angularly movable part so as to be bodily movable therewith, and structure for imparting movement to said temperature responsive element to adjust the position of the latter, said temperature responsive element being operative to effect movement of said angularly movable part in a direction opposite to said one direction against the action of said resilient element to cause said control member due to said bias to move toward said first position, said angularly movable part being unconnected to the control member to permit movement of the part on an increase in temperature to prevent the control member from being subjected to excessive force,

22. In mechanism of the character described, a control member movable between first and second positions and biased to move toward said first position, an angularly movable part, an expansible and contractible thermostat element carried by said part, a movable support, a pin held in position between said support and said thermostat element solely by frictional engagement at each end thereof, resilient means to cause said angularly movable part to move in one direction toward said movable support, said part with movement thereof in said one direction being arranged to cause said control member to move from said first position toward said second position, said expansible thermostat element being arranged to effect movement of said angularly movable part in a direction opposite to said one direction against the action of said resilient means to cause said control member to move toward said first position, and structure cooperating with said pin whereby said pin will remain in position even when said expansible thermostat element and said movable support

are spaced apart a distance greater than the length of said pin.

23. In mechanism of the character described, a control member, structure comprising a plurality of parts including a pin and a thermal element for operating said control member, said pin at opposite ends thereof being tapered to form more or less rounded points, said pin being frictionally held at said rounded points between two of said parts of which one is angularly movable, and resilient means for keeping said pin in position even when said two parts are spaced apart a distance greater than the length of said pin.

24. An air conditioning system comprising refrigeration apparatus operated by heat and including a cooling element arranged to effect cooling of air, heating means to supply heat to said refrigeration apparatus, an electrical control operable responsive to a temperature condition affected by the air adapted to be cooled for normally controlling said heating means, and a safety device associated with said electrical control for modifying the normal control of said heating means when said cooling element reaches a predetermined low temperature to reduce the heat supplied to said refrigeration apparatus.

25. An air conditioning system comprising refrigeration apparatus operated by heat and including a heat receiving part provided with a chamber and a cooling element arranged to effect cooling of air, a conduit connected to supply steam to said chamber from a source of supply, a condensate line to conduct from said chamber condensate formed therein, a pump connected to cause flow of condensate in said line, a control operable responsive to a temperature condition affected by the air adapted to be cooled by said cooling element for normally controlling the flow of steam through said conduit, and a safety device associated with said control for modifying said normal control when said pump becomes ineffective to cause flow of condensate in said line to reduce the flow of steam through said conduit.

26. An air conditioning system comprising refrigeration apparatus operated by heat and including a heat receiving part provided with a chamber and a cooling element arranged to effect cooling of air, a conduit connected to supply steam to said chamber from a source of supply, a vent to atmosphere for said chamber, a condensate line to conduct from said chamber condensate formed therein, a pump connected to cause flow of condensate in said line, a control operable responsive to a temperature condition affected by the air adapted to be cooled by said cooling element for normally controlling flow of steam through said conduit, and structure associated with said control for modifying said normal control to reduce the flow of steam through said conduit either when steam flows from said chamber through said vent into the atmosphere or when said pump becomes ineffective to cause flow of condensate in said line.

27. An air conditioning system including a refrigeration unit having a cooling element arranged to effect cooling of air, apparatus to effect operation of said refrigeration unit, a control member for said apparatus, and structure responsive to temperature of air adapted to be cooled by said refrigeration unit for operating said control member, said structure including an angularly movable part arranged to be operatively associated with said control member, and an expansible fluid thermostat having its expansible element mounted and supported on said angularly movable part so as to be bodily movable therewith.

28. In mechanism of the character described, a control member movable between first and second positions and only biased to move in one direction toward said first position, an angularly movable part, a resilient element arranged to cause said part to move in a second direction opposite to said one direction, said part being arranged upon movement in said second direction to cause said control member to move from said first position toward said second position against said bias, and structure including an element supported on said part and operative responsive to temperature to effect movement of said part in said one direction against the action of said resilient element, said angularly movable part being unconnected to the control member to permit movement of the part on an increase in temperature to prevent the control member from being subjected to excessive force so that the latter can also freely move in said one direction from said second position toward said first position due to said bias.

29. In a mechanism of the character described, a control member, and structure responsive to temperature for operating said control member, said structure comprising an angularly movable part arranged upon movement thereof in one direction to move toward said control member, and an expansible fluid thermostat having an expansible element supported on said angularly movable part, said angularly movable part being movable in a direction opposite to said one direction with expansion of said expansible element, and said angularly movable part being unconnected to the control member to permit movement of the part on an increase in temperature to prevent the control member from being subjected to excessive force.

30. In mechanism of the character described, a control member, structure comprising a plurality of parts including a pin and a thermal element for operating said control member, said pin being held in position between two of said parts solely by frictional engagement at each end thereof, and resilient means cooperating with one of said parts so that said pin will remain in position even when said two parts are spaced apart a distance greater than the length of said pin.

31. The combination with a room to be cooled of an air conditioning system including refrigeration apparatus having a cooling element arranged to effect cooling of air in said room but located outside of said room, a control operable responsive to a temperature condition of air in said room for normally controlling said refrigeration apparatus, and a device outside of said room for modifying the normal control of the refrigeration apparatus when said cooling element reaches a predetermined low temperature to reduce the cooling effect produced by said cooling element.

SVEN W. E. ANDERSSON.