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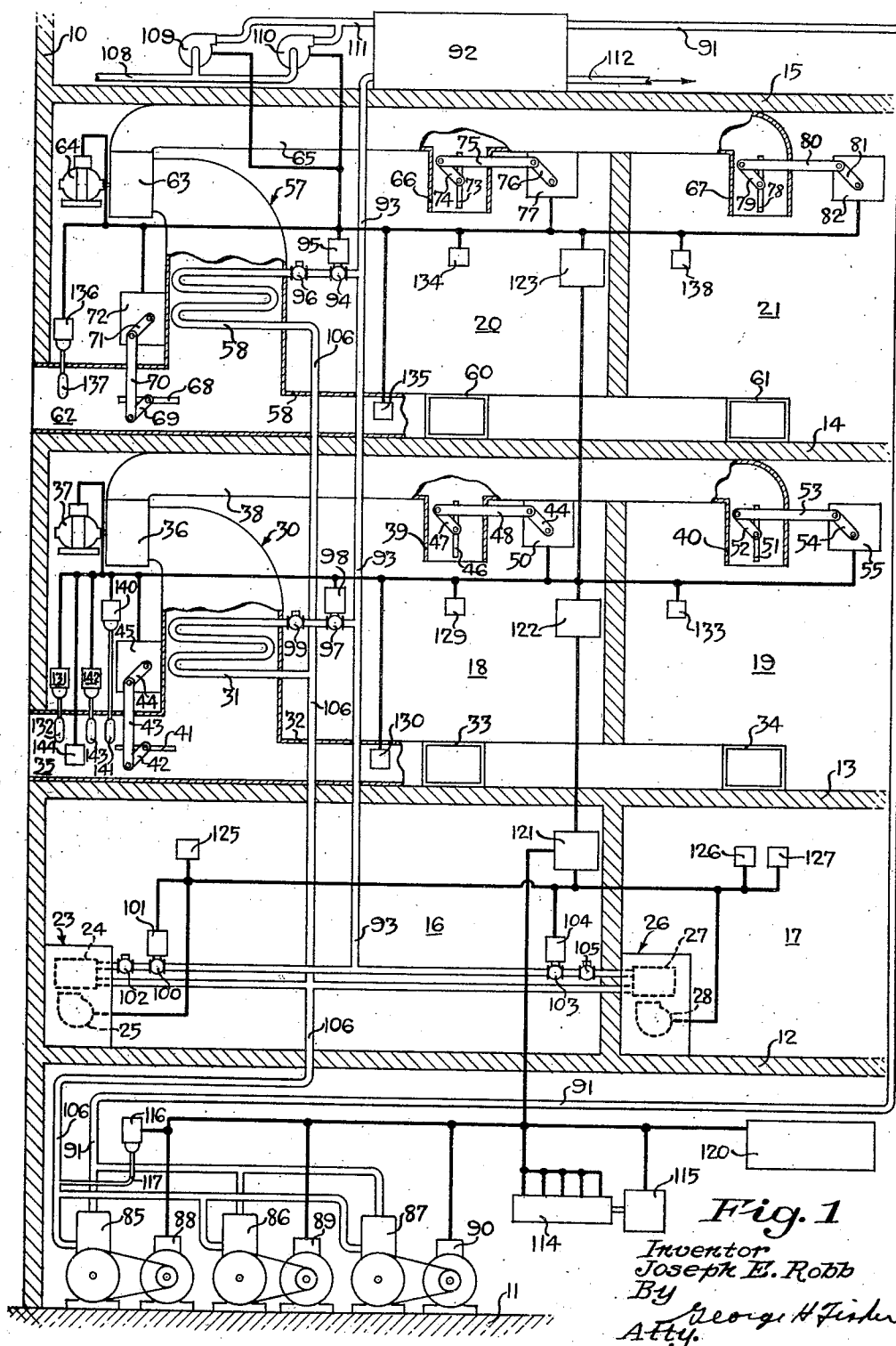
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2,273,992

AIR CONDITIONING SYSTEM

Filed March 5, 1937

6 Sheets-Sheet 1



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AIR CONDITIONING SYSTEM

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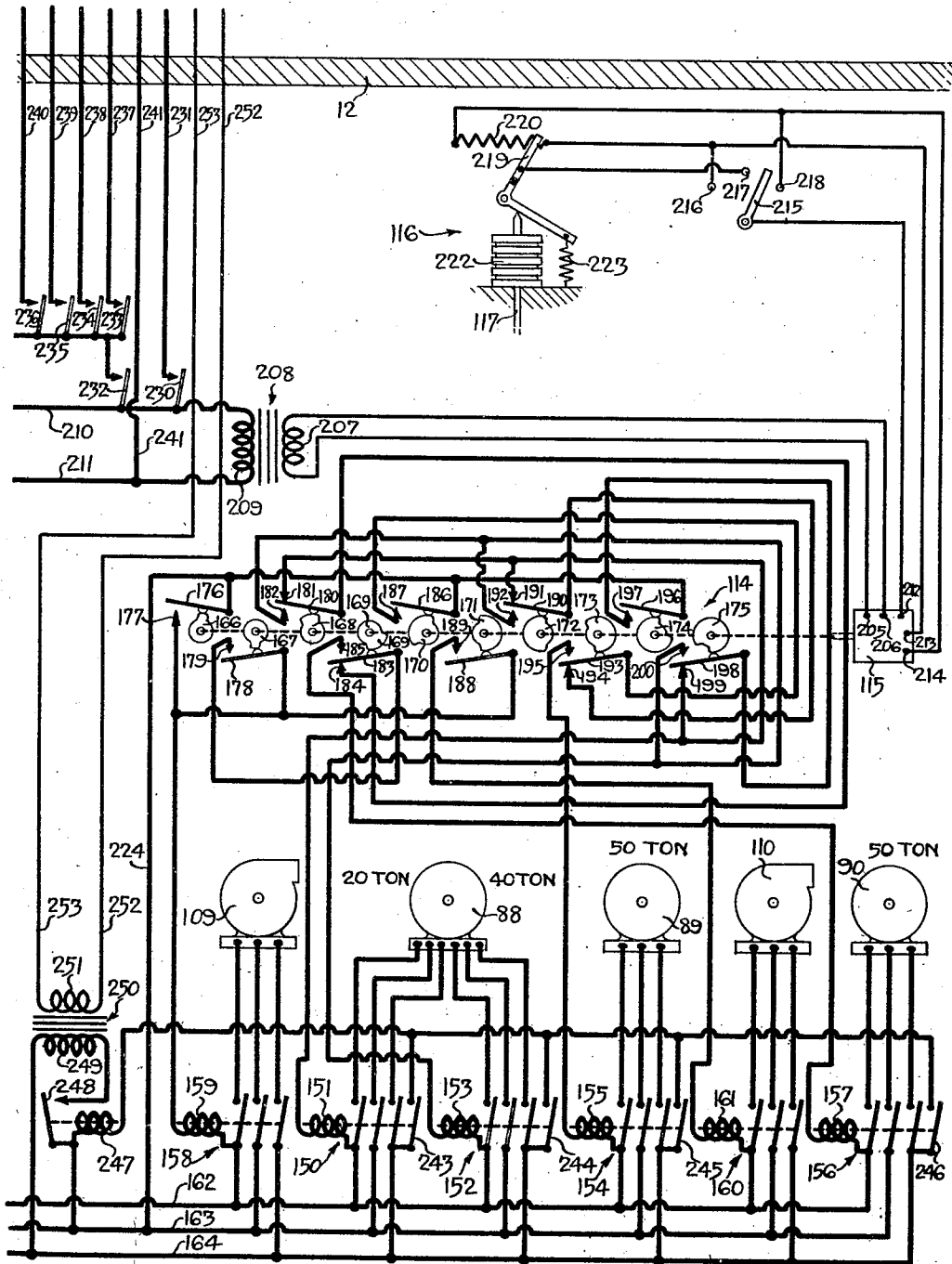


Fig. 2

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6 Sheets-Sheet 3

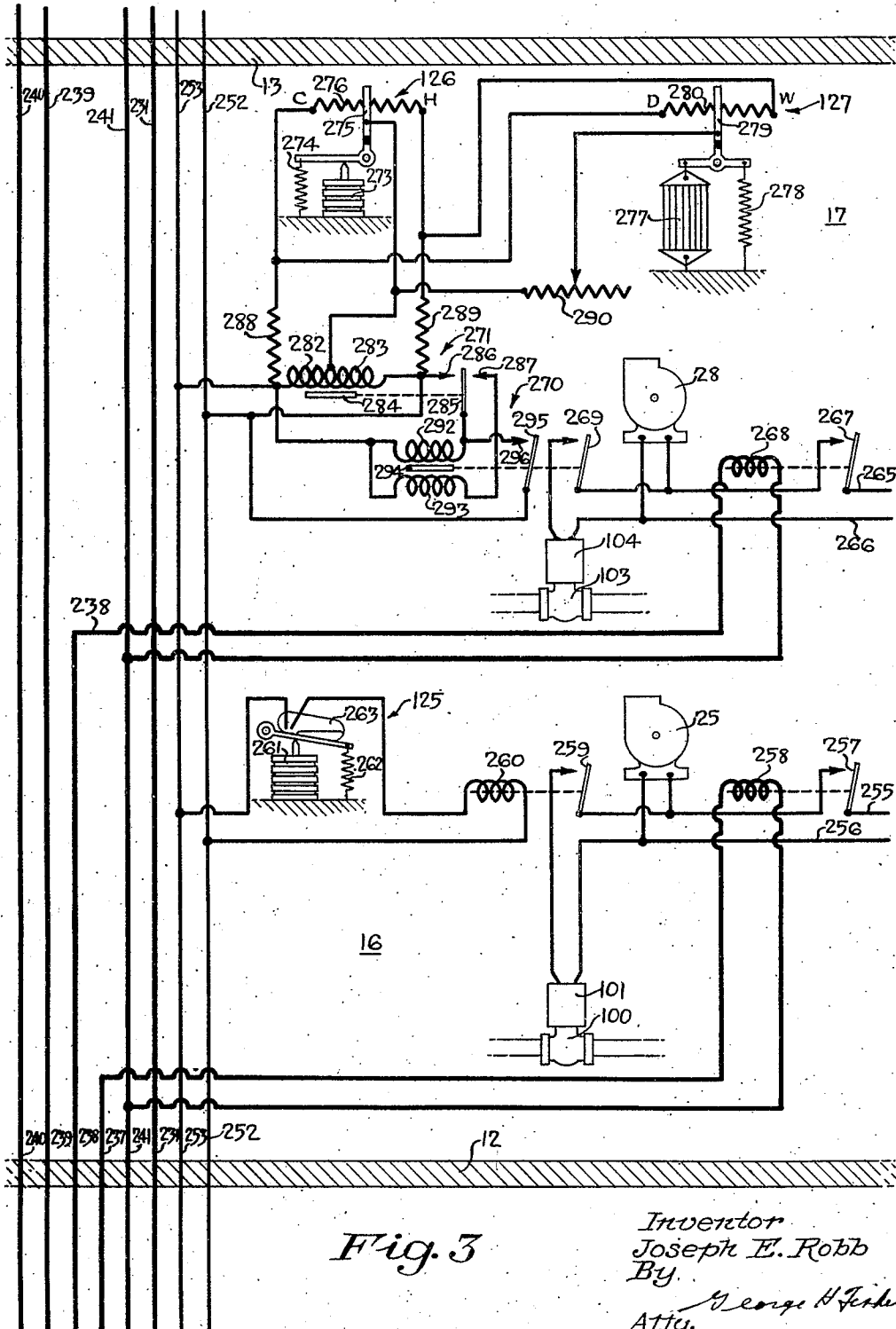


Fig. 3

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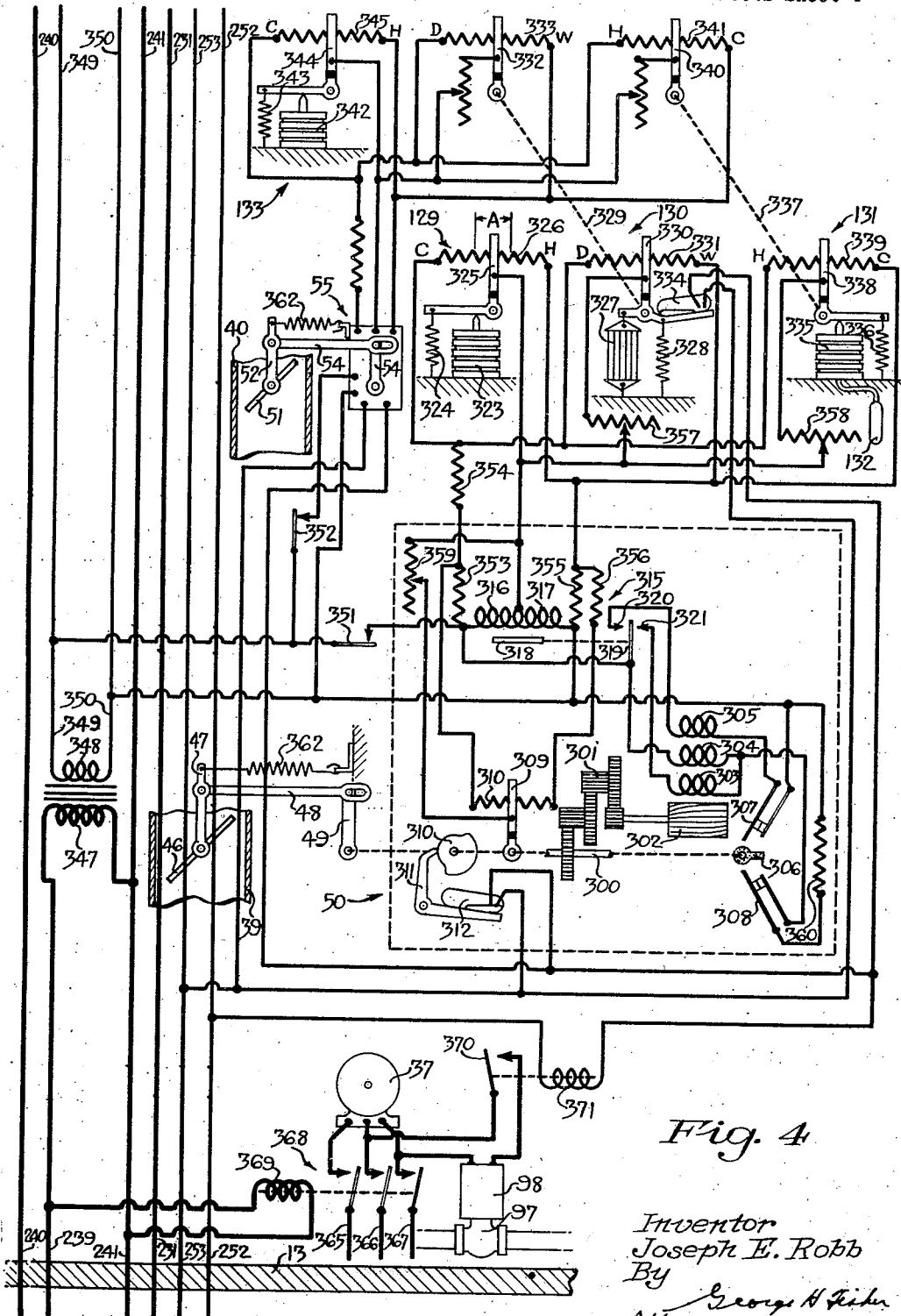
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AIR CONDITIONING SYSTEM

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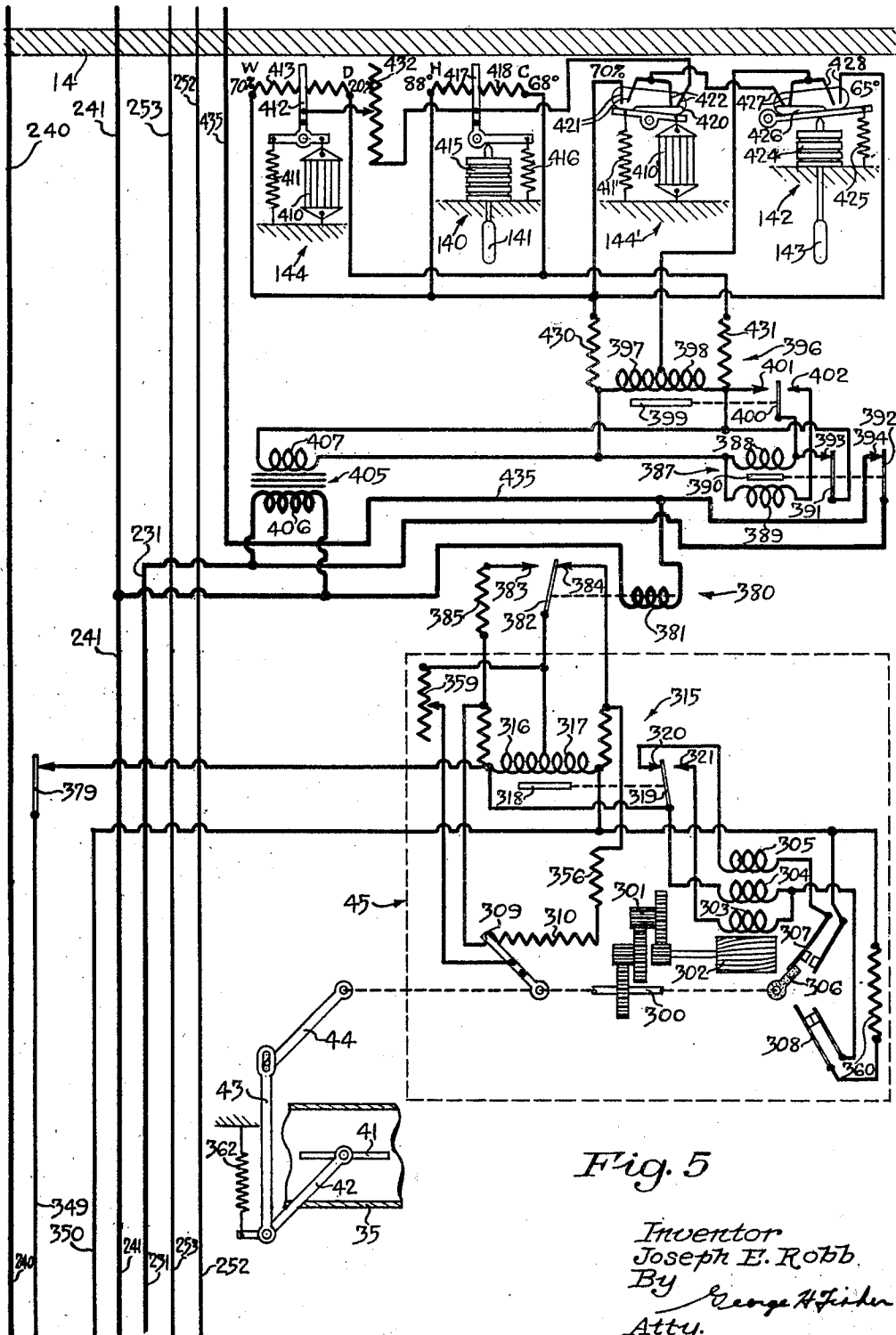
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AIR CONDITIONING SYSTEM

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AIR CONDITIONING SYSTEM

Filed March 5, 1937

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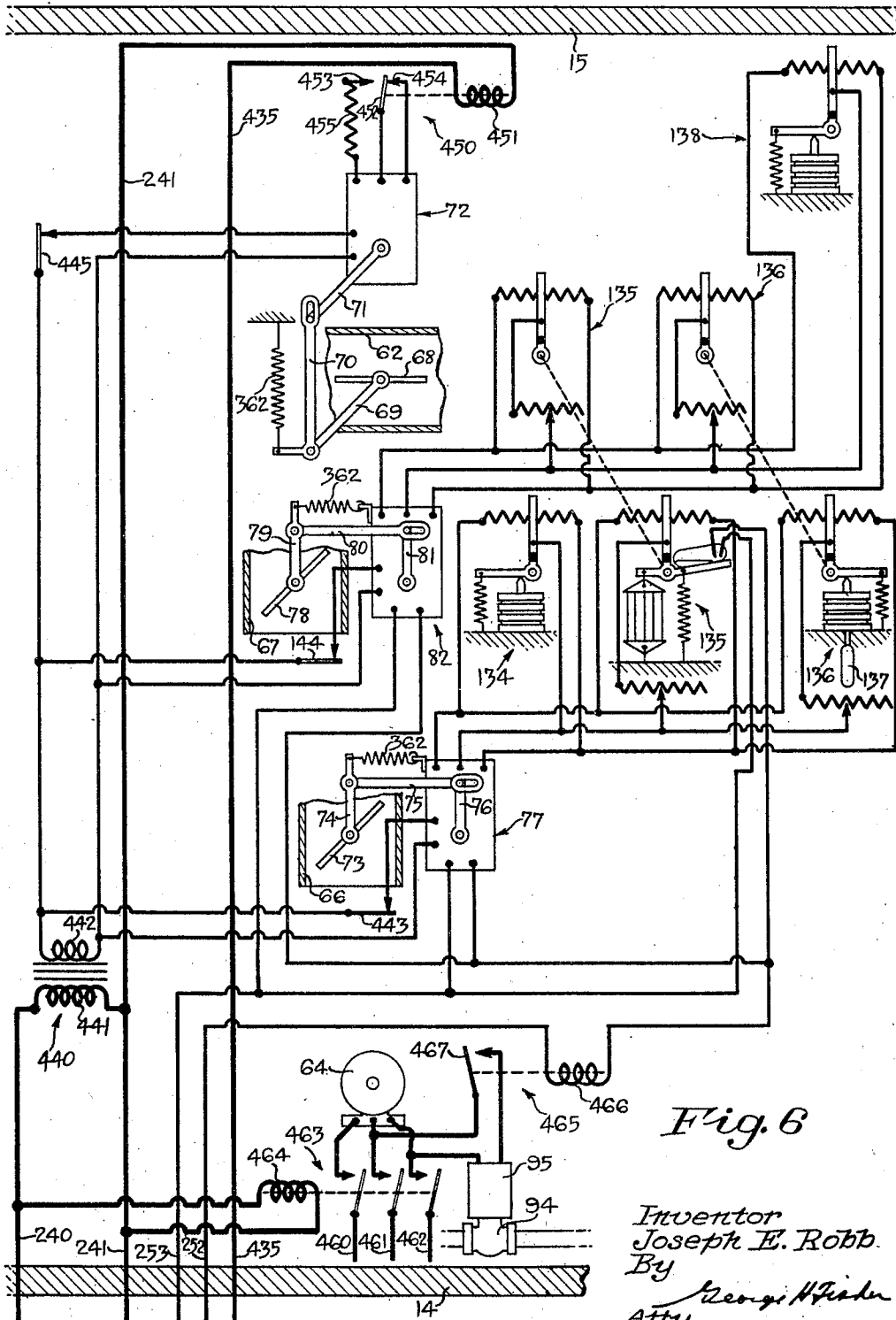


Fig. 6

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UNITED STATES PATENT OFFICE

2,273,992

AIR CONDITIONING SYSTEM

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Application March 5, 1937, Serial No. 129,201

18 Claims. (Cl. 62-6)

This invention relates to air conditioning systems.

It is an object of this invention to provide an air conditioning system for a building having novel control arrangements.

More specifically, it is an object of this invention to provide a cooling system for a building having a novel interlocking control arrangement whereby satisfactory and safe operation of the cooling system is assured.

Another object is to provide a novel control arrangement for a plurality of fresh air dampers so that all of the fresh air dampers will be controlled by a single set of controls. Installation and upkeep costs are thereby materially reduced.

A further object is to provide novel control arrangements for a building air conditioning system to maintain desired temperatures within the various zones of the building.

The combining of these novel control arrangements into a single complete air conditioning system that is accurate in its temperature regulation and flexible in operation also form objects of this invention.

Other objects and advantages will become apparent to those skilled in the art upon reference to the accompanying specification, claims and drawings.

For a more thorough understanding of this invention, reference is made to the accompanying drawings in which,

Figure 1 diagrammatically discloses a building having the air conditioning system of this invention applied thereto;

Figure 2 is a diagrammatic view showing the manner in which the refrigerating apparatus is operated;

Figure 3 is a view showing how the air conditioning apparatus for the first floor is operated;

Figure 4 is a diagrammatic view showing how the cooling coil of the second floor is controlled and how the volume dampers controlling the supply of conditioned air to the second floor are operated;

Figure 5 discloses the manner of controlling the fresh air damper for the second floor; and

Figure 6 discloses the manner of controlling the cooling coil for the third floor, of controlling the volume dampers of the third floor and of controlling the fresh air damper of the third floor by the control mechanism for the fresh air damper of the second floor.

When Figures 2 to 6 are placed end upon end they disclose the complete control system of this invention.

Referring now to Figure 1 there is diagrammatically shown for purposes of illustration a building 10 having a basement 11, a first floor

12, a second floor 13, a third floor 14 and a roof 15. The first floor may have any number of rooms, two of which are shown at 16 and 17 and the second and third floors are shown to have rooms 18, 19, 20 and 21.

Room 16 of the first floor is cooled by a cooling unit generally designated at 23 having a cooling coil in the form of an evaporator 24 and a fan 25 for circulating air over the cooling coil 24. The room 17 of the first floor is cooled by a cooling unit generally designated at 26 having a cooling coil 27 in the form of an evaporator and a fan 28 for passing air over the cooling coil 27.

The rooms 18 and 19 on the second floor are cooled by an air conditioning unit generally designated at 30. This air conditioning unit includes a cooling coil 31 in the form of an evaporator and air to be conditioned is withdrawn from the spaces or rooms 18 and 19 through a return duct 32. Suitable grills 33 and 34 are provided in the return duct 32 for this purpose. Outside or fresh air is also supplied to the air conditioning unit 30 through an outside or fresh air duct 35. Return air and outside air are drawn through the air conditioning unit 30 over the cooling coil 31 by means of a fan 36 driven by a fan motor 37 and the cooled air is delivered to the spaces 18 and 19 through a supply duct 38. Air from the supply duct 38 is discharged into the room 18 through an inlet 39 and air is also discharged into the room 19 through an inlet 40.

The supply of outside air to the air conditioning unit 30 is controlled by a fresh air damper 41. The fresh air damper 41 is operated through a crank arm 42, a link 43, and a crank arm 44 by a proportioning motor 45. The supply of air to the space 18 is controlled by a volume damper 46 which is operated through a crank arm 47, a link 48 and a crank arm 49 by a proportioning motor 50. In a like manner the supply of air to the space 19 is controlled by a volume damper 51 operated through a crank arm 52, a link 53 and a crank arm 54 by a proportioning motor 55.

The air conditioning apparatus for the third floor is in all respects the same as that for the second floor and includes an air conditioning unit 57 having a cooling coil 58 in the form of an evaporator. Return air is supplied to the air conditioning unit 57 through a return air duct 59 having grills 60 and 61. Outside air is supplied to the air conditioning unit 57 by a fresh air duct 62. A fan 63 circulates the air through the air conditioning unit 57 and this fan is operated by a fan motor 64. The fan 63 discharges air into a supply duct 65 which opens into the spaces 20 and 21 through inlets 66 and 67.

The supply of outside air to the air conditioning unit 57 is controlled by a fresh air damper 68 operated through a crank arm 69, a link 70

and a crank arm 71 by a proportioning motor 72. The volume damper 73 which controls the volume of conditioned air delivered to the space 20 is operated through a crank arm 74, a link 75 and a crank arm 76 by a proportioning motor 77. In a like manner the volume damper 78 which controls the supply of conditioned air to the space 21 is operated through a crank arm 79, a link 80 and a crank arm 81 by a proportioning motor 82.

Refrigerant is circulated through the various cooling coils by means of a plurality of compressors, three of which are shown at 85, 86 and 87. The compressors 85, 86 and 87 are operated by electric motors 88, 89 and 90 respectively. For purposes of illustration it is assumed that the compressor 85 is a two-speed compressor and that when it is operating at low speed it accomplishes 20 tons of refrigeration and when operating at high speed it accomplishes 40 tons of refrigeration. The compressors 86 and 87 are single speed compressors and each delivers 50 tons of refrigeration. The compressors 85, 86 and 87 are connected in parallel and discharge refrigerant into a pipe 91 which leads to condenser 92 located on the roof 17. Liquid refrigerant is led downwardly from the condenser 92 on the roof through a pipe 93. Refrigerant is delivered to the cooling coil 58 of the air conditioning unit 57 on the third floor through a cut-off valve 94 operated by a solenoid motor 95 and expansion valve 96. In a like manner refrigerant is supplied to the cooling coil 31 of the air conditioning unit 30 of the second floor through a cut off valve 97 controlled by a solenoid motor 98 and an expansion valve 99. Refrigerant is supplied to the cooling coil 24 of the cooling unit 23 in the space 16 through a cut-off valve 100 operated by a solenoid motor 101 and an expansion valve 102. Also, refrigerant is supplied to the cooling coil 27 of the cooling unit 26 through a cut-off valve 103 operated by a solenoid motor 104 and an expansion valve 105. Expanded refrigerant is drawn from the various cooling coils and returned to the compressors 85, 86 and 87 by a suction line 106.

Condensing water is supplied by a pipe 108, pumps 109 and 110 and a pipe 111 to the condenser 92. Condensing water is discharged from the condenser 92 through a discharge pipe 112. The pump 109 operates during light refrigerant loads to supply condensing water to the condenser 92 but when the refrigeration load is relatively heavy, pumps 109 and 110, which are in parallel, both supply condensing water to the condenser 92.

The compressor motors 88, 89 and 90 and the condensing water pumps 109 and 110 are controlled by a step controller 114. The step controller 114 is in turn operated by a proportioning motor 115 which is controlled by a potentiometer type suction pressure controller 116. The suction pressure controller 116 is connected by a pipe 117 to the suction line 106 leading to the compressors. As the suction pressure increases the various compressors and the condensing water pumps are brought into operation in a predetermined sequence in accordance with the refrigeration load. The manner in which this is accomplished is specifically shown in Figure 2.

Located in the basement is a panel board 120 and also on the first, second and third floors are panel boards 121, 122 and 123 respectively. These panel boards have suitable equipment for operating the air conditioning system manually or for

adjusting the automatic control system which controls the operation of the air conditioning system.

The solenoid motor 101 which operates the valve 100 to control the supply of refrigerant to the cooling unit 23 is controlled by a space thermostat 125. This thermostat may be of the on and off type. Space thermostat 125 maintains the dry bulb temperature of the space 16 at a substantially constant value. The solenoid motor 104 which operates the cut-off valve 103 for the cooling unit 26 is controlled by a thermostatic controller 126 and a humidity responsive controller 127. The thermostatic controller 126 and the humidity responsive controller 127 are of the proportioning type and control the solenoid motor 104 in such a manner as to maintain a substantially constant effective temperature in the space 17. While the effective temperature is maintained substantially constant in the space 17 the relative humidity in the space 17 is allowed to fluctuate.

The volume damper 46 for the room 18 on the second floor is controlled by a thermostatic controller 129 located in the room 18, a humidity responsive controller 130 located in the return air duct 32 and a temperature responsive controller 131 having bulb 132 located in the fresh air duct 35. The volume damper 46 is therefore operated in accordance with room temperature, room relative humidity and outdoor temperature to provide a compensated effective temperature control for the space 18. For a given outdoor temperature a substantially constant effective temperature is maintained within the space 18 although the relative humidity in the space 18 is allowed to fluctuate. As the outdoor temperature increases the effective temperature of the space 18 is allowed to increase but at a lesser rate. The volume damper 46 is modulated between a minimum open position and a wide open position to accomplish these results. By not completely closing the volume damper 46, circulation of air through the space 18 is at all times provided for ventilation purposes. The volume damper 51 for the space 19 of the second floor is controlled by a thermostatic controller 133 located in the space 19, the humidity responsive controller 130 and the outdoor temperature responsive controller 131. Therefore the volume damper 51 is operated in substantially the same manner as the volume damper 46 for the space 18 so that a compensated effective temperature control is provided for the space 19. The details of construction and mode of operation are more fully disclosed in Figure 4.

The volume damper 73 for the space 20 on the third floor is controlled by a thermostatic controller 134 located in the space 20, a humidity responsive controller 135 located in the return air duct and an outdoor temperature responsive controller 136 having a bulb 137 located in the fresh air duct 62. In a like manner the volume damper 78 for the space 21 is controlled by a thermostatic controller 138 located in the space 21, the humidity responsive controller 135 and the outdoor temperature responsive controller 136. A compensated effective temperature control is therefore provided for the spaces 20 and 21 a detailed showing of which is set forth in Figure 6.

The fresh air damper 41 for the second floor which is operated by the proportioning motor 45 is controlled by a temperature controller 140 of the potentiometer type having a bulb 141 located in the fresh air duct 35, a temperature re-

sponsive controller 142 of the on and off type having a bulb 143 located in the fresh air duct 35 and a humidity responsive controller 144 of both the potentiometer type and the on and off type located in the fresh air duct 35. The two temperature responsive controllers 140 and 142 and the humidity responsive controller 144 all respond to outdoor atmospheric conditions and combine their actions to control the fresh air damper 41. Specifically, the control contemplated is to maintain the fresh air damper 41 wide open when the wet bulb temperature of the outdoor air is below a given value, say 62° provided the outdoor relative humidity is less than 70 percent and the outdoor dry bulb temperature is greater than 65°. However, if the outdoor wet bulb temperature increases above 63° or the outdoor relative humidity increases above 70 percent, or the outdoor dry bulb temperature decreases below 65°, the fresh air damper 41 will be moved to a minimum open position allowing only a minimum amount of outside air to be delivered to the air conditioning unit 30 for minimum ventilation requirements. The minimum open position of the damper 41 may be adjusted to satisfy varying ventilation requirements and also means are provided for completely closing the fresh air damper 41 in case the fan 36 is not operating. The damper may also be completely closed manually at will. This mode of operation is more specifically set forth in Figure 5.

By means of suitable wiring connections illustrated in Figures 5 and 6 the same set of controls that control the fresh air damper 41 also control the fresh air damper 68 for the third floor and by reason of this installation costs are materially reduced. The control of a plurality of fresh air dampers by a single set of controls is a salient feature of this invention.

Whenever any of the volume dampers 46 or 51 are moved from the minimum open position toward the wide open position upon a call for cooling, the refrigerant cut-off valve 97 for that zone is opened so that cooling will be afforded. In a like manner, whenever either of the volume dampers 73 and 78 for the third floor are moved from the minimum open position, the cut-off valve 94 is opened to supply refrigerant to the cooling coil 58 for that zone. If no cooling is required for the second floor the volume dampers 46 and 51 move to a minimum open position and the cut-off valve 97 is closed and also if no cooling is required for the third floor the cut-off valve 94 is closed in the same manner. This feature provides an economical mode of operation. If there be no demand for cooling on the second floor and the relative humidity should increase to a predetermined value the cut-off valve 97 will be opened by the humidity responsive controller 130 for dehumidifying purposes. In other words, a high limit humidity control is provided for the second floor. In exactly the same manner a humidity high limit control is provided for the third floor. As stated above, when the demand for cooling is satisfied the volume dampers 46, 51, 73 and 78 do not entirely close but move to a minimum open position. Under these conditions the air circulates slowly over the cooling coils and the temperature thereof is reduced below the dew-point and therefore dehumidified. In this manner the relative humidity of the air in the spaces 18, 19, 20 and 21

may be reduced even though there is no demand for sensible cooling.

Provision is also made for preventing opening of any of the cut-off valves which control the supply of refrigerant to the various cooling coils in case none of the compressors are in operation. The purpose of this is to prevent stored refrigerant in the roof condensers 92 under pressure to escape and cool the cooling coils and to prevent equalizing of the pressures on the high and low side of the refrigerating system. This would tend to fill the compressors in the suction side with refrigerant during periods when the compressors are idle. In other words, a safety interlock is provided to prevent disrupting of the refrigerating system in case the compressors are not operating. The specific manner in which this is accomplished is illustrated in Figure 2 when taken in connection with the remaining Figures 3 to 6. Also the refrigerant cut-off valve of any zone cannot be opened in case the fan of that zone is not operating.

For a more detailed description of how the compressors and the condensing water pumps are operated reference is made to Figure 2. The compressor motors are shown at 88, 89 and 90 and the condensing water pumps are shown at 109 and 110. The two-speed compressor motor 88 is controlled by a magnetic starter 150 having an operating coil 151 and a magnetic starter 152 having an operating coil 153. When the coil 151 is energized the compressor motor 88 is operated at slow speed to provide 20 tons of refrigeration and when the coil 153 is energized the compressor motor 88 is operated at fast speed to provide 40 tons of refrigeration. The 50 ton compressor motor 89 is controlled by a magnetic starter 154 having an operating coil 155 and the other 50 ton compressor motor 90 is controlled by a magnetic starter 156 having an operating coil 157. The condensing water pump 109 is controlled by a magnetic starter 158 having an operating coil 159 and the condensing water pump 110 is controlled by a magnetic starter having an operating coil 161. Three phase power is supplied to the compressor motors and the condensing water pumps by means of line wires 162, 163 and 164. It is therefore apparent that when any magnetic starter pulls in its associated pump or compressor motor is placed in operation.

The operating coils of the magnetic starters are controlled by the step controller 114 which in turn is operated by a proportioning motor 115. The proportioning motor 115 may be of the type shown in Patent No. 1,989,972 granted to Lewis L. Cunningham on Feb. 5, 1935, or of the type shown in Patent No. 2,028,110 granted to D. G. Taylor on Jan. 14, 1936. The proportioning motor 115 operates a shaft upon which are mounted cams 166 to 175 inclusive. Each of these cams operate switches comprising switch arms and contacts in a particular sequence.

With the parts in the position shown in Figure 2 the proportioning motor 115 and consequently the cams operated thereby are in an extreme position. Movement of the proportioning motor 115 away from this extreme position rotates the cams in a clockwise direction to close and open the various switches in a predetermined sequence. First, the switch arm 176 is moved into engagement with a contact 177 and the switch arm 178 is moved into engagement with a contact 179; second, switch arm 180 is moved out of engagement with contact 181 and into engagement with contact 182; third, switch arm 183 moves out

of engagement with contact 184 and into engagement with contact 185; fourth, switch arm 186 moves into engagement with contact 187; fifth, switch arm 188 moves into engagement with contact 189 and switch arm 190 moves out of engagement with contact 191 and into engagement with contact 192; sixth, switch arm 193 moves out of engagement with contact 194 and into engagement with contact 195; seventh, switch arm 196 moves into engagement with contact 197; eighth, switch arm 198 moves out of engagement with contact 199 and into engagement with contact 200. When the switch arm 190 is ultimately moved into engagement with contact 200 the proportioning motor 115 is in the other extreme position. When the proportioning motor 115 is moved from this extreme position to the first extreme position the cams 175 are rotated in a counter-clockwise direction and the same switching action is accomplished except in reverse order.

The proportioning motor 115 is provided with power terminals 205 and 206 which are connected across a secondary 207 of a step-down transformer 208 having a primary 209 connected across line wires 219 and 211 leading from some source of power (not shown). The step-down transformer 208 therefore provides power for the proportioning motor 115. The proportioning motor 115 is also provided with control terminals 212, 213 and 214. The control terminal 212 is connected to a switch arm 215 which is adapted to engage contacts 216, 217 or 218. The suction pressure controller 116 may comprise a slider 219 adapted to slide across a resistance element 220. The slider 219 and the resistance element 220 form a control potentiometer for the proportioning motor 115. The slider 219 is operated by a bellows 222 against the tension of a spring 223. The bellows 222 is connected by pipe 117 to the suction line 190 of the refrigeration apparatus. By adjusting the tension in the spring 223 the pressure setting of the suction pressure controller 116 may be adjusted. The right end of the resistance element 220 and the contact 215 are connected to the control terminal 213 of the proportioning motor. In a like manner the left end of the resistance element 220 and the contact 218 are connected to the control terminal 214 of the proportioning motor 115. The contact 217 is connected to the slider 219 of the suction pressure controller 116.

When the switch arm 215 engages the contact 217 the controller 116 positions the proportioning motor 115 in a manner well known in the art. With the slider 219 in the position shown in the drawing the proportioning motor 115 is in the extreme position shown in the drawing and all of the compressors and the condenser water pumps are shut down. As the slider 219 moves from the right to the left in response to an increase in suction pressure the proportioning motor 115 is moved out of the extreme position to perform the above outlined switching action by the step controller 114. When the switch arm 215 is moved out of engagement with the contact 217 automatic control of the proportioning motor 115 by the suction pressure controller 116 is prevented. Movement of the switch arm 215 into engagement with contact 216 operates the proportioning motor 115 to an extreme position to move the switches of the step controller to the position shown in the drawing to render all of the compressor motors and the condenser pumps inoperative. Movement of the

switch arm 215 into engagement with the contact 218 operates the proportioning motor 115 to the other extreme position whereupon the maximum refrigeration tonnage is obtained. Therefore, the switch arm 215 is capable of placing the refrigerating mechanism under automatic control, of stopping operation of the refrigerating apparatus and of operating the refrigerating apparatus at maximum capacity.

Assume now that the switch arm 215 is engaging the contact 217 whereby the proportioning motor 115 is controlled by the suction pressure controller 116, the suction pressure is low indicating that the compressors need not operate. The parts are therefore in the position shown in Figure 2. Upon an increase in suction pressure, the switch arm 176 engages the contact 177 and the switch arm 178 engages the contact 179. A circuit is therefore completed from the line wire 163 through wire 224, switch arm 176, contact 177, operating coil 159 of the magnetic starter 158 back to the other line wire 162. This places the pump 199 in operation. A circuit is also completed from line wire 153 through wire 224, switch arm 176, contact 177, switch arm 178, contact 179, switch arm 183, contact 184, switch arm 189, contact 181, operating coil 151 of magnetic starter 150 back to the other line wire 162. This places the compressor motor 88 in operation at low speed to supply 26 tons of refrigeration.

Upon a further increase in suction pressure the switch arm 189 is moved out of engagement with the contact 181 to break the circuit through the operating coil 151 of the magnetic starter 150 and is moved into engagement with the contact 182 to complete a circuit from line wire 163 through wire 224, switch arm 176, contact 177, switch arm 178, contact 179, switch arm 182, contact 184, switch arm 189, contact 182 and operating coil 153 of the magnetic starter 152 back to the other line wire 162. Completion of this circuit causes operation of the compressor motor 88 at high speed to provide 40 tons of refrigeration.

Upon a further increase in suction pressure switch arm 183 moves out of engagement with contact 184 to break the circuit for the magnetic starter 152 whereupon the compressor motor 88 is rendered inoperative and is moved into engagement with the contact 185 to complete a circuit from the line wire 163 through wire 224, switch arm 176, contact 177, switch arm 178, contact 179, switch arm 183, contact 185 and operating coil 157 of the magnetic starter 156 back to the other line wire 162. Completion of this circuit pulls in the magnetic starter 156 and places the compressor motor 80 in operation whereupon 50 tons of refrigeration are obtained.

Upon a further increase in suction pressure switch arm 186 is moved into engagement with contact 187 to complete a circuit from the line wire 153 through wire 224, switch arm 186, contact 187, switch arm 193, contact 194, switch arm 199, contact 191 and operating coil 151 of the magnetic starter 150 back to the other line wire 162. This circuit pulls in the magnetic starter 150 to operate the compressor motor 82 at slow speed to provide an additional 20 tons of refrigeration and since both compressors 88 and 80 are at this time operating, 70 tons of refrigeration is provided.

Upon a further increase in suction pressure switch arm 196 is moved into engagement with contact 197 and switch arm 199 is moved out of

engagement with contact 191 and into engagement with contact 192. Movement of the switch arm 190 out of engagement with the contact 191 breaks the circuit through the magnetic starter 150 to stop slow speed operation of the compressor motor 88. Movement of the switch arm 190 into engagement with the contact 192 completes a circuit from the line wire 163 through wire 224, switch arm 186, contact 187, switch arm 193, contact 194, switch arm 190, contact 192 and operating coil 153 for the magnetic starter 152 back to the other line wire 162. Completion of this circuit pulls in the magnetic starter 152 and causes high speed operation of the compressor motor 88 to provide an additional 40 tons of refrigeration which added to the 50 tons provided by the compressor motor 90 provides 90 tons of refrigeration. At this time a circuit is also completed from the line wire 163 through wire 224, switch arm 176, contact 177, switch arm 188, contact 189 and operating coil 161 of the magnetic starter 160 back to the line wire 162. Completion of this circuit pulls in the magnetic starter 160 to place the second pump 110 in operation. Therefore, at this time 90 tons of refrigeration are being provided and both condenser pumps are operating.

Upon a further increase in suction pressure switch arm 193 is moved out of engagement with the contact 194 to break the circuit through the magnetic starter 152 which stops operation of the compressor motor 88 and is moved into engagement with contact 195 to complete a circuit from line wire 163 through wire 224, switch arm 186, contact 187, switch arm 193, contact 195 and operating coil 155 of the magnetic starter 154 back to the other line wire 162. Completion of this circuit pulls in the magnetic starter 154 to place the compressor motor 89 in operation. Both compressor motors 89 and 90 are now operating and 100 tons of refrigeration are being provided.

Upon a further increase in suction pressure the switch arm 196 is moved into engagement with the contact 197 to complete a circuit from the line wire 163 through wire 224, switch arm 196, contact 197, switch arm 198, contact 199 and operating coil 151 of the magnetic starter 150, back to the other line wire 162 to cause slow speed operation of the compressor motor 88 to provide an additional 20 tons of refrigeration and since at this time both the compressor motors 89 and 90 are also operating, 120 tons of refrigeration are being provided.

Upon a further rise in suction pressure the switch arm 198 is moved out of engagement with the contact 199 and into engagement with the contact 200. Movement of the switch arm 188 out of engagement with the contact 199 breaks the circuit through the magnetic starter 150 to stop slow speed of the compressor motor 88. Movement of the switch arm 198 into engagement with the contact 200 completes a circuit from the line wire 163 through wire 224, switch arm 196, contact 197, switch arm 198, contact 200 and operating coil 153 of the magnetic starter 152 back to the other line wire 162. Completion of this circuit pulls in the magnetic starter 152 to operate the compressor motor 88 at high speed to provide an additional 40 tons of refrigeration. Since both compressor motors 89 and 90 are also operating at this time, 140 tons of refrigeration are provided.

By reason of the above arrangement upon an increase in refrigeration load the refrigeration

tonnage produced by the refrigerating apparatus is increased in small and graduated steps in the following manner: 20, 40, 50, 70, 90, 100, 120 and 140 tons. This is all accomplished by the use of only three compressors, one of the compressors having two-speed operation. Also when the refrigerating apparatus operates to give 90 tons of refrigeration, both condenser pumps 109 and 110 are operated. In this manner the amount of refrigeration produced by the refrigerating apparatus is modulated in accordance with the refrigerating load so that the correct amount of cooling is at all times maintained in the various cooling coils located on the floors above. Upon a decrease in refrigeration load the suction pressure decreases and the refrigeration tonnage is decreased in the same steps.

A switch 230 connects a wire 231 with the line wire 210. A switch 232 connects the line wire 210 with switches 233, 234, 235 and 236. The switches 233 to 236 are connected in parallel. The switches 233 to 236 control the supply of electrical energy to wires 237, 238, 239 and 240 respectively. A wire 241 is connected to the other line wire 211. The wires 231, 237, 238, 239, 240 and 241 extend upwardly to the various floors of the building and supply power to the various control instruments and motors on the upper floors. The switches may be located on the control panel 120. The purpose of the switches 230, 232, 233, 234, 235 and 236 will be pointed out more fully hereafter.

Magnetic starters 150, 152, 154 and 156 for the compressor motors 88, 89 and 90 also operate switches 243, 244, 245 and 246 respectively. These switches are connected to the line wire 164 and also are connected in parallel to one end of a relay coil 247, the other end of the relay coil 247 being connected to the line wire 163. The relay coil 247 operates a switch 248 so that when the relay coil 247 is energized the switch 248 is closed to supply power from the line wires 163 and 164 to a primary 249 of a step-down transformer 250 having a secondary 251. Since the switches 243, 244, 245 and 246 are connected in parallel and are operated by the magnetic starters, when any compressor motor is placed in operation the relay coil 247 is energized, the switch 248 is closed and power is supplied to the step-down transformer 250. If none of the compressor motors are operating the switch 248 opens and the supply of power to the step-down transformer 250 is interrupted. The secondary 251 of the step-down transformer 250 is connected to wires 252 and 253 which extend upwardly to the various floors of the building. The purpose of this arrangement will be pointed out more fully hereafter.

The particular manner in which the control of the cooling units 23 and 26 of the first floor is accomplished is shown in Figure 3. The cut-off valve for controlling the supply of refrigerant to the cooling coil 24 for the space 16 is shown at 100 and the fan for circulating air over this cooling coil is shown at 25. Power is supplied to the fan 25 and the solenoid motor 101 for the cut-off valve 100 by means of line wires 255 and 256 leading from some source of power (not shown). A switch 257 is closed upon energization of a relay coil 258 to cause operation of fan 25, the circuit being completed from the line wire 255 through switch 257, fan 25 back to the other line wire 256. The relay coil 258 is connected across wires 237 and 241 extending upwardly from the basement and when both switches 232 and 233 in

the basement are closed the relay coil 258 is energized and the fan 25 is placed in operation.

The circuit to the solenoid motor 101 is controlled by a switch 259 which is closed when a relay coil 260 is energized under the control of the room thermostat generally designated at 125. The room thermostat 125 may include a bellows 261 containing a volatile fluid responsive to changes in temperature of the space 16. The bellows 261 expands against the tension of a spring 262 to operate a mercury switch 263 to a circuit closing position upon an increase in temperature above a predetermined value. The temperature setting of the thermostat 125 may be adjusted by adjusting the tension in the spring 262. When the temperature of the space 16 increases to a predetermined value a circuit is completed from wire 253 through the mercury switch 263 and relay coil 260 back to the wire 262. Completion of this circuit energizes the relay coil 260 to close the switch 259 whereupon the cut-off valve 100 is opened to supply refrigerant to the cooling coil 24 of the space 16. Since the power supply for the solenoid motor 101 is taken from the fan circuit the cut-off valve cannot be opened unless the fan 25 is operating and since the power supply for the relay coil 260 is transmitted through the wires 252 and 253 from the transformer 250 in the basement the switch 259 for controlling the solenoid motor 101 cannot be closed unless at least one of the compressor motors is in operation. From this it is seen that upon a call for cooling by the space thermostat 125 the refrigerant cut-off valve 100 is opened providing at least one of the compressor motors is in operation and providing the fan 25 is in operation.

Referring now to the upper portion of Figure 3 the method of controlling the temperature of the space 17 on the first floor is shown. The cut-off valve is shown at 103, the fan is shown at 28, the space thermostatic controller at 126 and the space humidity responsive controller at 127. Power is supplied to the fan 28 by line wires 265 and 266. The fan is placed in operation when a switch 267 is closed upon energization of a relay coil 268. The relay coil 268 is connected across wires 238 and 241 leading from the basement. Therefore, when switches 232 and 234 in the basement are closed the relay coil 268 is energized to close the switch 267 which causes operation of the fan 28. The solenoid motor 104 which operates the cut-off valve 103 is controlled by a switch 269 so that when the switch 269 is closed and the fan 28 is in operation the cut-off valve 103 is opened to supply refrigerant to the cooling coil 27 for the space 17. The switch 269 is controlled by a relay generally designated at 270 and this relay is in turn controlled by a relay generally designated at 271. The relay 271 is controlled by the combined action of the space thermostatic controller 126 and the humidity responsive controller 127.

The space thermostatic controller 126 may comprise a bellows 273 containing a volatile fluid and operating against a spring 274 for moving a slider 275 with respect to a resistance element 276. The slider 275 and the resistance element 276 provide a control potentiometer which is adjusted in accordance with variations in space temperature. Upon an increase in space temperature the slider 275 is moved to the right in the direction indicated by the character H and upon a decrease in temperature the slider is moved to the left in the direction indicated by the character C. The humidity responsive con-

troller 127 may comprise a humidity responsive element 277 operating against a tension spring 278 for moving a slider 279 with respect to a resistance element 280. The slider 279 and the resistance element 280 form a compensating potentiometer operating in accordance with variations in space relative humidity. Upon an increase in relative humidity the humidity responsive element 277 operates to move the slider 279 to the right in the direction indicated by the character W and upon a decrease in relative humidity the slider 279 is moved to the left in the direction indicated by the character D.

The relay 271 may comprise relay coils 282 and 283 for operating an armature 284. The armature is connected to a switch arm 285 which is adapted to engage contacts 286 and 287. When the relay coil 282 is energized more than the relay coil 283 the switch arm 285 engages contact 286 and when the relay coil 283 is energized more than the relay coil 282, the switch arm 285 engages the contact 287. The inner ends of the relay coils 282 and 283 are joined together and the outer ends thereof are connected across the wires 252 and 253 which lead from the step-down transformer 250 in the basement. The relay coils therefore are connected in series with respect to each other and across the source of power. The left end of the relay coil 282 is connected through a protective resistance 288 to the left ends of the control potentiometer resistance 276 and the compensating potentiometer resistance 280. In a like manner the right end of the relay coil 283 is connected through a protective resistance 289 to the right ends of the control potentiometer resistance 276 and the compensating potentiometer resistance 280. The junction of the relay coils 282 and 283 is connected to the slider 275 of the control potentiometer and to the slider 279 of the compensating potentiometer. A variable resistance 290 is connected in series with the slider 279 of the compensating potentiometer to desensitize the controlling action of the compensating potentiometer. By reason of these wiring connections it is seen that the control potentiometer and the compensating potentiometer are connected in parallel with each other and in parallel with the series connected relay coils 282 and 283.

The relay generally designated at 270 comprises a relay coil 292 and a relay coil 293 for operating an armature 294. The armature 294 operates the switch 269 and also operates a switch arm 295 with respect to a contact 296. When neither relay coil 292 or 293 is energized the switches 295 and 269 are opened by means of springs, gravity or other means (not shown). When the relay coil 292 is energized the switches 295 and 269 are closed. The relay coil 293 is adapted to counteract the action of the relay coil 292 so that when both relay coils 292 and 293 are energized the switches 295 and 269 are opened by means of springs, gravity or other means (not shown). In other words, the relay pulls in when the relay coil 292 is energized and drops out when both coils 292 and 293 are energized or when neither relay coil 292 or 293 is energized.

With the parts in the position shown in the drawing the slider 275 of the room thermostatic controller and the slider 279 of the humidity responsive controller are in a mid-position and therefore the relay coils 282 and 283 are equally energized. The switch arm 285 is in a mid-position with respect to the contacts 286 and 287

and the relay 270 is out. Upon an increase in space temperature or upon an increase in space relative humidity the slider 275 or the slider 279 is moved to the right to cause partial short circuiting of the relay coil 283 to decrease the energization thereof and to increase the energization of the relay coil 282. This causes movement of the switch arm 285 into engagement with the contact 286 to complete a circuit from wire 252 through contact 286, switch arm 285 and relay coil 292 back to the other wire 253. Completion of this circuit energizes the relay coil 292 to close switch 269 and move switch arm 295 into engagement with contact 296. Closure of the switch 269 causes opening of the cut-off valve 103 providing the fan 28 is operating to supply refrigerant to the cooling coil 27. Movement of the switch arm 295 into engagement with the contact 296 completes a maintaining circuit for the relay coil 292 which may be traced from the wire 252 through switch arm 295, contact 296 and relay coil 292 back to the other wire 253. Therefore the relay coil 292 is maintained energized even though the switch arm 285 be moved out of engagement with the contact 286.

As a result of opening of the cut-off valve in this manner either the space temperature decreases or the space relative humidity decreases to move the slider 275 or the slider 279 to the left. When the slider 275 or the slider 279 has moved sufficiently far to the left to partially short circuit the relay coil 282, the relay coil 283 becomes more highly energized than the relay coil 282 whereupon the switch arm 285 moves into engagement with the contact 287. This completes a circuit from the wire 252 through switch arm 295, contact 296, switch arm 285, contact 287 and relay coil 293 back to the other wire 253. This causes energization of the relay coil 293 to drop out the relay whereupon the switch arm 295 moves out of engagement with contact 296 and switch 269 opens. The supply of refrigerant to the cooling coil 27 is thus interrupted. Since the relays 271 and 270 are controlled in this manner by both room dry bulb temperature and room relative humidity the solenoid motor 104 is therefore operated in accordance with the effective temperature of the space 17 to maintain the effective temperature substantially constant. Since the controlling action of the humidity responsive controller 127 is desensitized by the variable resistance 270 the cut-off valve 103 is controlled primarily in response to variations in dry bulb temperature which is compensated by variations in space relative humidity. By properly adjusting the variable resistance 270 the effective temperature of the space 217 may be maintained substantially constant although the relative humidity of the space 17 is allowed to fluctuate.

Since the supply of electrical energy to the relays 270 and 271 is received from the step-down transformer 250 in the basement it is impossible to pull in the relay 270 in case none of the compressors are operating. It follows then that the cut-off valve 103 is opened and closed in accordance with the effective temperature of the space 17 but it is impossible to open the cut-off valve 103 if the fan 28 is not operating or if none of the compressors are operating.

Figure 4 shows the manner in which the volume dampers 46 and 51, the fan motor 37 and the cut-off valve 97 for the second floor are operated. The proportioning motor 50 which operates the volume damper 46 and the propor-

tioning motor 55 which operates the volume damper 51 may be of the type disclosed in Patent No. 2,032,658 granted to W. H. Gille on March 3, 1936. The proportioning motors 50 and 55 are therefore spring returned or power failure type motors. The proportioning motor 50 may comprise a shaft 300 for operating the crank arm 49. The shaft 300 is driven through a reduction gear train 301 by a motor rotor 302. The motor rotor 302 is operated by three field windings 303, 304 and 305. The field winding 304 is a holding winding to maintain the motor in any of its adjusted positions. The field winding 305 is an energizing winding and when the windings 304 and 305 are energized the damper 46 is moved towards an open position against the action of a spring 362. The field winding 303 is a bucking winding and when both windings 303 and 304 are energized they neutralize the effect of each other and the spring 362 operates the damper 46 toward a closed position. The shaft 300 operates an abutment member 306 which is adapted to open limit switches 307 and 308 when the motor is moved to either extreme position. The shaft 300 also operates a slider 309 with respect to a resistance element 310, the slider and the resistance element forming a balancing potentiometer. The shaft 300 also operates a cam 310 which works against a bell crank lever 311 carrying a mercury switch 312. The arrangement is such that when damper 46 is in a minimum open position, the switch 312 is opened and when the damper 46 is moved toward a wide open position from the minimum open position, the switch 312 is closed.

The proportioning motor includes a relay generally designated at 315. The relay comprises relay coils 316 and 317 for operating an armature 318. The armature 318 in turn operates a switch arm 319 with respect to contacts 320 and 321. When the relay coil 316 is energized more than the relay coil 317 the switch arm 319 is moved into engagement with the contact 320. When the relay coil 317 is energized more than the relay coil 316, switch arm 319 is moved into engagement with the contact 321. When the relay coils 316 and 317 are equally energized the switch arm 319 is maintained spaced midway between the contacts 320 and 321 as shown in Figure 4.

The proportioning motor 50 is controlled by the room thermostatic controller 129, the relative humidity responsive controller 130 and the outdoor thermostatic controller 131. The room thermostatic controller 129 may comprise a bellows 323 containing a volatile fluid for acting against a spring 324 to move a slider 325 with respect to a resistance element 326. The slider 325 and the resistance element 326 form a control potentiometer. Upon an increase in space temperature the bellows expands to move the slider 325 towards the right in the direction indicated by the character H. Upon a decrease in space temperature the slider 325 moves toward the left in the direction indicated by the character C.

The relative humidity responsive controller 130 may comprise a humidity responsive element 327 operating against a spring 328 to rotate a shaft 329. The shaft 329 operates a slider 330 with respect to a resistance element 331 and also a slider 332 with respect to a resistance element 333. The slider 330 and the resistance element 331 and the slider 332 and the resistance element 333 form compensating potentiometers.

Upon an increase in relative humidity the sliders 330 and 332 are moved to the right in the direction indicated by the character W, and upon a decrease in relative humidity the sliders 330 and 332 are moved to the left in the direction indicated by the character D. The humidity responsive controller 130 also includes a mercury switch 324 and this switch is operated to a closed position when the relative humidity increases to a predetermined high value.

The outdoor thermostatic controller 131 may comprise a bellows 335 connected to the bulb 132 containing a volatile fluid and located in the fresh air duct 35. The bellows 335 operates against a spring 336 for operating a shaft 337. The shaft 337 operates a slider 339 with respect to a resistance element 339 and a slider 340 with respect to a resistance element 341. The slider 339 and the resistance element 339 and the slider 340 and the resistance element 341 form compensating potentiometers. Upon an increase in outdoor temperature the sliders 338 and 340 are moved to the left in the direction indicated by the character H and upon a decrease in outdoor temperature the sliders 338 and 340 are moved to the right in the direction indicated by the character C.

The room thermostatic controller 133 may comprise a bellows 342 containing a volatile fluid for operating against a spring 343 to move a slider 344 with respect to a resistance element 345. Upon an increase in space temperature effecting the space thermostatic controller 133 the slider 344 is moved to the right in the direction indicated by the character H and upon a decrease in space temperature the slider 344 is moved to the left in the direction indicated by the character C.

Power is supplied to the proportioning motors 50 and 55 from a step-down transformer, the primary 347 of which is connected across wires 237 and 241. The secondary 348 of the step-down transformer is connected to wires 349 and 350. The wire 349 is connected to the left end of the relay coil 316 of the motor 50 through a switch 351 and the wire 350 is connected to the right end of the relay coil 317. In a like manner power is supplied to the proportioning motor 55 through a switch 352. From this it is seen that if the switches 332 and 325 in the basement are closed and the switches 351 and 352 are closed power is supplied to the proportioning motors 50 and 55. Opening of the switches 332 or 325 in the basement deenergizes the step-down transformer and therefore interrupts the supply of power to the proportioning motors 50 and 55. Opening of the switch 351 interrupts the supply of power to the proportioning motor 50 and likewise opening of the switch 352 interrupts the supply of power to the proportioning motor 55.

The left end of the relay coil 316 is connected through a protective resistance 353 and a limiting resistance 354 to the left ends of the resistance elements 326, 331 and 339. The right end of the relay coil 317 is connected through a protective resistance 355 to the right ends of the potentiometer resistance elements 326, 331 and 339. The left end of the relay coil 316 is also connected through the protective resistance 353 to the left end of the balancing potentiometer resistance element 310 and the right end of the relay coil 317 is connected through the protective resistance 355 and a resistance 356 to the right end of the balancing potentiometer resistance element. The junction of the relay coils 316 and

317 is connected to the slider 309 of the balancing potentiometer, the slider 325 of the space thermostatic controller, the slider 300 of the humidity responsive controller and the slider 338 of the outdoor thermostatic controller. A resistance 357 is connected in series with the slider 330, a resistance 358 is connected in series with the slider 339 and a resistance 359 is connected in series with the slider 309. From the above it is seen that the control potentiometer, the two compensating potentiometers and the balancing potentiometer are all connected in parallel with the series connected relay coils 316 and 317 and across the wires 349 and 350.

With the parts in the position shown in Figure 4 the holding winding 304 of the proportioning motor is energized by reason of a circuit extending from the wire 349 through switch 351, winding 304, limit switch 303 and resistance 360 back to the other wire 350. Therefore the proportioning motor 50 and the damper 46 are maintained in their adjusted positions against the action of the spring 362. Omitting for the time being the controlling action of the humidity responsive controller 130 and the outdoor thermostatic controller 131, an increase in the temperature of the space 10 causes movement of the slider 325 to the right. This decreases the energization of the relay coil 317 and increases the energization of the relay coil 316 to move the switch arm 319 into engagement with contact 320. This completes a circuit from the wire 349 through switch 351, switch arm 319, contact 320, winding 305 and limit switch 307 back to the other wire 350. Both windings 304 and 305 are energized and the motor operates to move the damper 46 toward an open position against the action of the spring 362. Operation of the motor 50 to move the damper 46 towards an open position causes left hand movement of the slider 309 of the balancing potentiometer. This left hand movement of the slider 309 decreases the energization of the relay coil 316 and increases the energization of the relay coil 317 and when the slider 309 is moved sufficiently far to the left to rebalance the energization of the relay coils 316 and 317 the slider 319 is moved out of engagement with the contact 320 to break the circuit through the winding 305. Winding 304 still remains energized and therefore the damper 46 is maintained in its newly adjusted position. In this manner damper 46 is modulated towards an open position in accordance with the amount of increase in space temperature.

Upon a decrease in space temperature slider 325 is moved toward the left to decrease the energization of the relay coil 316 and increase the energization of the relay coil 317 with consequent movement of the switch arm 319 into engagement with the contact 321. This completes a circuit from the wire 349 through switch 351, switch arm 319, contact 321, bucking winding 303, limit switch 308 and resistance 360 back to the other wire 350. Energization of the field winding 303 in this manner neutralizes the holding action of the holding winding 304 and the spring 362 moves the damper 46 towards a closed position. Movement of the damper 46 towards a closed position causes right-hand movement of the slider 309 to decrease the energization of the relay coil 317 and increase the energization of the relay coil 316. When the slider 309 has moved sufficiently far to the right to rebalance the energizations of the relay coils 316 and 317 the switch arm 319 is moved out of engagement with the contact 321

whereupon the bucking winding 303 is deenergized. Motor 50 and the damper 46 will be maintained in the newly adjusted position since the holding winding 304 remains energized. In this manner the damper 46 is modulated towards a closed position in accordance with the amount of decrease in space temperature.

The variable resistance 359 in series with the slider 309 of the balance potentiometer is utilized for desensitizing the rebalancing action of the balancing potentiometer whereupon movement of the slider 325 of the control potentiometer through the range A will cause complete opening and closing movement of the damper 46. The compensating potentiometer of the humidity responsive controller 130 is connected in parallel with the control potentiometer of the room thermostatic controller 129 and tends to operate the proportioning motor 50 in substantially the same manner as the control potentiometer operates the proportioning motor. Resistance 357 in series with the slider 330 is utilized to desensitize the controlling effect of the humidity responsive device 130 and therefore the humidity responsive device 130 acts to shift the control range A of the control potentiometer of the room thermostat 129. Upon an increase in relative humidity the control range A is moved to the left so that lower temperatures will be maintained within the space 18. Upon a decrease in relative humidity the control range A is moved to the right so that increased temperatures are maintained in the space 18. In this manner a substantially constant effective temperature is maintained in the space 18 although the relative humidity of the space 18 is allowed to fluctuate.

The compensating potentiometer of the outdoor thermostatic controller 131 is connected in parallel with the control potentiometer of the room thermostat 129 and by reason of the variable resistance 358 in series with the slider 338 the compensating potentiometer of the outdoor thermostat 131 operates to further shift the control range A of the control potentiometer. Upon an increase in outdoor temperature the control range A is shifted to the right so that higher temperatures are maintained in the space 18. Upon a decrease in outdoor temperature, the control range A is shifted to the left so that lower temperatures are maintained in the space. In this manner the effective temperature of the space 18 is allowed to increase as the outdoor temperature increases and the effective temperature is decreased as the outdoor temperature decreases.

The proportioning motor 55 which operates the damper 51 is controlled in exactly the same manner as the proportioning motor 50 which operates the damper 46 to maintain a substantially constant effective temperature in the space 19 which is adjusted in accordance with variations in outdoor temperature. Therefore a further description of the operation of the volume damper 51 is not considered necessary. However, it is noted at this point that a single relative humidity responsive controller 130 located in the return air duct and a single outdoor thermostatic controller 131 having the bulb 132 located in the fresh air duct compensate both room thermostats 129 and 133 to maintain the desired temperatures within the spaces 18 and 19.

The resistance 354 in series with the left ends of the potentiometers controlling the operation of the proportioning motor 50 is utilized to prevent complete closing of the damper 46. In other

words the damper 46 cannot be completely closed even though there is no demand for cooling. Therefore, a minimum flow of air through the spaces 18 and 19 for ventilation purposes is provided. The minimum open position of the damper 46 may be adjusted by adjusting the resistance value of the resistance 354. If, however, the switches 351 and 352 are opened or if the switches 232 and 235 in the basement are opened the supply of power to the proportioning motors 50 and 55 is interrupted and the springs 362 will move the dampers 46 and 51 to a complete closed position. In this manner a complete shut-down is provided.

Power is supplied to the fan motor 37 of the air conditioning unit 30 by line wires 365, 366 and 367. The supply of power to the fan motor 37 is controlled by a magnetic starter 368 having an operating coil 369. The operating coil 369 is connected across wires 239 and 241 so that if switches 232 and 235 in the basement are closed the operating winding 369 is energized and the fan motor 37 is operated. Opening of either of the switches 232 or 235 in the basement de-energizes the operating winding 369 to drop out the magnetic starter 368 whereupon operation of the fan motor 37 is stopped. Solenoid motor 98 which operates the refrigerant cut-off valve 97 for the air conditioning unit 30 receives its supply of power from the fan circuit and therefore if the fan 37 is not operating the refrigerant cut-off valve 97 cannot be opened.

Located in series with the solenoid motor 98 is a switch 370 operated by a relay coil 371. When the relay coil 371 is energized the switch 370 is closed and the refrigerant cut-off valve 97 is opened providing the fan motor 37 is operating. The relay coil 371 is controlled by the switch 312 operated by the proportioning motor 50, by a similar switch operated by the proportioning motor 55 and by the switch 334 operated by the humidity responsive device 130. These three switches are arranged in parallel so that when any one of them is closed the refrigerant cut-off valve 97 is opened. When either of the dampers 46 and 51 are moved from their minimum open position towards the open position the switches operated by the proportioning motors 50 and 55 are closed to energize the relay coil 371 to open the refrigerant cut-off valve 97. If the relative humidity in the return air duct 32 increases to a predetermined high value the refrigerant cut-off valve 97 is opened regardless of the position of the dampers 46 and 51. The supply of power to the relay coil 371 is obtained from wires 252 and 253 leading upwardly from the step-down transformer 250 in the basement. Therefore if the step-down transformer 250 is not energized it is impossible to close the switch 370. As pointed out above the energization of the step-down transformer 250 is controlled by the compressor starters. Therefore if none of the compressors are operating it is impossible to open the refrigerant cut-off valve 97.

Figure 5 discloses the manner of operating the fresh air damper 41 for controlling the supply of fresh air to the spaces 18 and 19. The damper 41 is operated by the proportioning motor 45 which may be the spring returned or power failure type shown and described in Patent No. 2,032,658 granted to W. H. Gille on March 3, 1936. Since the construction of this proportioning motor is exactly the same as the proportioning motor 50 illustrated in Figure 4 like reference characters have been utilized to indicate the parts

thereof. Power is supplied to the proportioning motor 45 by wires 349 and 350 leading from the secondary 348 of the transformer illustrated in Figure 4. Therefore, when switches 232 and 235 in the basement are closed and the switch 379 illustrated in Figure 5 is closed, power is supplied to the proportioning motor 45. Opening of any of these switches interrupts the supply of power to the proportioning motor 45 and the spring 362 moves the damper 41 to a complete closed position in the manner pointed out in connection with the proportioning motor 50 of Figure 4.

The proportioning motor 45 is operated by a relay generally designated at 380. The relay 380 comprises a relay coil 381 for operating a switch arm 382 with respect to contacts 383 and 384. The arrangement is such that when the relay coil 381 is energized the switch arm 382 moves into engagement with contact 384 to substantially short circuit the relay coil 317 to decrease the energization of the relay coil 316. Since the relay coil 317 is substantially completely short circuited the damper 41 is moved to a wide open position. When the relay coil 381 is deenergized the switch arm 382 engages contact 383 and since a resistance 385 is in series with the contact 383 the relay coil 316 is only partially short circuited to decrease the energization thereof and increase the energization of the relay coil 317. As a result the damper 41 is moved toward a closed position by the spring 362, the amount of closing movement of the damper being dependent upon the resistance value of the resistance 385 in series with the contact 383. This insures at all times a minimum supply of fresh air to satisfy ventilating requirements. By adjusting the resistance value of the resistance 385 the minimum position of the damper 41 may be adjusted. From this it is seen that when the relay 380 is pulled in the damper 41 assumes a wide open position, when the relay 380 drops out the damper assumes a minimum open position depending upon the value of the resistance 385. When the supply of power to the proportioning motor 45 is interrupted, as by opening switch 379 or switches 232 or 235 in the basement, the damper 41 is completely closed.

The relay 380 is controlled by a relay 387 which may comprise an energizing coil 388 and a bucking coil 389 for controlling the operation of an armature 390. When the relay coil 388 is energized the armature 390 operates to move switch arms 391 and 392 into engagement with contacts 393 and 394. When the relay coil 388 is deenergized or when the relay coil 389 and the relay coil 388 are energized the switch arms 391 and 392 are moved out of engagement with their respective contacts 393 and 394 by means of springs, gravity or other means (not shown).

The relay 387 is in turn controlled by a relay generally designated at 396. This relay 396 may comprise relay coils 397 and 398 for operating an armature 399. The armature 399 in turn operates a switch arm 400 with respect to contacts 401 and 402. When the relay coil 397 is energized more than the relay coil 398 the switch arm 400 is moved into engagement with the contact 401 and when the relay coil 398 is energized more than the relay coil 397 the switch arm 400 is moved into engagement with the contact 402.

Power is supplied to the relays 387 and 396 by means of a step-down transformer 405 having a primary 406 connected across wires 231 and 241. When the switch 230 in the basement is closed

the transformer 405 becomes energized and is capable of supplying power to the two relays 387 and 396. The relay coils 397 and 398 are connected in series with respect to each other and across the secondary 407 of the step-down transformer 405. The relay 396 is controlled by the humidity responsive controller 144 located in the fresh air duct 35, the proportioning type thermostat 140 having a bulb 141 located in the fresh air duct 35 and the on and off type thermostat 142 having a bulb 143 located in the fresh air duct 35. As pointed out above the humidity responsive controller 144 includes a proportioning type controller and an on and off type controller but for purposes of illustration in Figure 5 the humidity responsive controller is shown to comprise two controllers, a proportioning type controller 144 and an on and off type controller 144'. The proportioning type humidity responsive controller 144 comprises a humidity responsive element 410 for acting against a spring 411 to operate a slider 412 with respect to a potentiometer resistance element 413. Upon an increase in the relative humidity of the outdoor air the slider 412 moves to the left in the direction indicated by the character W and upon a decrease in relative humidity the slider 412 moves to the right in the direction indicated by the character D. For purposes of illustration it is assumed that the slider 412 engages the W end of the resistance element 413 when the relative humidity is 70 percent and engages the D end when the relative humidity decreases to 20 percent.

The proportioning type temperature responsive controller comprises a bellows 415 suitably connected to the bulb 141 located in the fresh air duct 35. The bellows 415 operates against a spring 416 to move a slider 417 with respect to a resistance element 418. Upon an increase in outdoor dry bulb temperature the slider 417 moves to the left in the direction indicated by the character H and upon a decrease in outdoor temperature the slider 417 moves to the right in the direction indicated by the character C. For purposes of illustration it is assumed that the slider 417 reaches its extreme left hand position when the dry bulb temperature is 88° and reaches the extreme right hand position when the dry bulb temperature is 68°.

The on and off type humidity responsive controller 144' comprises a humidity responsive element 410' operating against a spring 411' to position a mercury switch 420. The mercury switch is provided with left electrodes 421 and right electrodes 422 the inner electrodes being common. The mercury in the mercury switch normally bridges the right electrodes 422 but when the relative humidity rises to 70 percent the mercury bridges the left electrodes 421.

The on and off type temperature responsive controller comprises a bellows 424 suitably connected to the bulb 143 located in the fresh air duct 35. The bellows 424 operates against a spring 425 to position a mercury switch 426. The mercury switch 426 is provided with left electrodes 427 and right electrodes 428 the inner electrodes being common. The mercury in the mercury switch 426 normally bridges the left electrodes 427 but when the outdoor temperature decreases to 65° the mercury bridges the right electrodes 428.

The left end of the relay coil 397 is connected through a protective resistance 430 to the left ends of the resistance elements 413 and 418, the outer one of the left electrodes 421 of the mer-

cury switch 420 and the outer one of the right electrodes 428 of the mercury switch 426. The right end of the relay coil 398 is connected through a protective resistance 431 to the right ends of the resistance elements 413 and 418. The slider 412 of the proportioning type humidity responsive controller 144 is connected through a variable resistance 432 to the slider 417 of the temperature responsive controller 140. The slider 417 is in turn connected to the outer one of the right electrodes 422 of the mercury switch 420. The inner electrode 422 and the inner electrode 421 are connected together and to the outer electrode 427 of the mercury switch 426. The inner electrodes 427 and 428 are connected to the junction of the relay coils 397 and 398. With the parts in the position shown in Figure 5 it is seen that the sliders 412 and 417 are connected to the junction of the relay coils 397 and 398 and therefore the potentiometers of the humidity responsive controller 144 and the temperature responsive controller 140 are connected in parallel with the series connected relay coils 397 and 398 and across the secondary 407.

The relay 396 is therefore controlled by the combined action of outdoor relative humidity and outdoor dry bulb temperature. Upon a decrease in outdoor temperature or upon a decrease in outdoor relative humidity the sliders 417 and 412 are moved to the right to partially short circuit the relay coil 398 to decrease the energization thereof and increase the energization of the relay coil 397. This causes movement of the switch arm 400 into engagement with the contact 401 to complete a circuit from the left end of the secondary 407 through contact 401, switch arm 400 and relay coil 398 back to the right end of the secondary 407. As a result the relay coil 398 is energized to move the switch arms 391 and 392 into engagement with contacts 393 and 394. Movement of the switch arm 391 into engagement with the contact 393 completes a maintaining circuit for the relay coil 398 which may be traced from the left end of the secondary 407 through switch arm 391, contact 393 and relay coil 398 back to the right end of the secondary 407. In this manner the relay coil 398 is maintained energized even though the switch arm 400 should move out of engagement with contact 401. Movement of the switch arm 392 into engagement with the contact 394 completes a circuit from the wire 231 through switch arm 392, contact 394 and relay coil 381 back to wire 241. The relay coil 381 is therefore energized and the switch arm 392 is moved into engagement with the contact 384 to open wide the fresh air damper 41.

Upon an increase in outdoor relative humidity or an increase in outdoor dry bulb temperature the sliders 412 and 417 move to the left to partially short circuit the relay coil 397 to decrease the energization thereof and increase the energization of the relay coil 398. The switch arm 400 is thereupon moved into engagement with the contact 402 to complete a circuit from the left end of the secondary 407 through switch arm 391, contact 393, switch arm 400, contact 402 and bucking coil 389 back to the right end of the secondary 407. Both coils 388 and 389 are energized and the switch arms 391 and 392 move out of engagement with their respective contacts 393 and 394. As a result the relay 380 drops out and the fresh air damper 41 moves to a minimum position depending upon the resistance value of the resistance 385.

By assuming the outdoor relative humidity limits as 70 percent and 20 percent and the outdoor dry bulb limits as 88° and 68° and by properly adjusting the resistance 432, the two instruments provide a wet bulb temperature control. This will become apparent upon references to a psychometric chart. The arrangement is such that as long as the outdoor wet bulb temperature is below 63° the fresh air damper 41 will be wide open but when the outdoor wet bulb temperature increases above 63° the fresh air damper 41 will be moved to a minimum position. The wet bulb temperature maintained in the building is usually around 63° and therefore if the outdoor wet bulb temperature is less than 63° it is more efficient to utilize outdoor air for conditioning purposes than recirculated air. However, if the outdoor wet bulb temperature should be greater than 63° it will be more efficient to use recirculated air for conditioning purposes. Therefore the control of the fresh air damper in this manner gives the most efficient operation of the air conditioning system.

The on and off type humidity responsive controller 144' is utilized to operate the fresh air damper 41 to a minimum position when the outdoor relative humidity increases to 70 percent even though the outdoor wet bulb temperature should be below 63°. In other words, the humidity responsive controller 144' provides a humidity high limit control. When the outdoor relative humidity rises to 70 percent the circuit between the junction of the relay coils 397 and 398 and the sliders 417 and 412 is broken whereby the controllers 144 and 140 are rendered inoperative to control the proportioning motor 45. The junction of the coils 397 and 398 is then connected through the left contacts 421 of the mercury switch 420 and through the protective resistance 430 to the left end of the relay coil 397 to substantially completely short circuit the relay coil 397 to move the switch arm 400 into engagement with contact 402. The relays 387 and 380 thereupon drop out and the damper 41 is moved to a minimum position. The on and off type temperature controller 142 is utilized for moving the fresh air damper 41 to minimum position when the outdoor dry bulb temperature decreases to 65° even though the outdoor wet bulb temperature is below 63°. When the outdoor dry bulb temperature decreases to 65° the circuit to the sliders 417 and 412 is broken to render the controllers 140 and 144 inoperative to control the proportioning motor 45. Also when the mercury bridges the two right electrodes 428 the relay coil 397 is substantially completely short circuited to move the switch arm 400 into engagement with the contact 402 whereupon the relays 387 and 380 drop out to move the fresh air damper 41 to a minimum position.

By reason of the above arrangement it is seen that the fresh air damper is maintained in a wide open position when the wet bulb temperature of the outdoor air is above 63°, when the dry bulb temperature is above 65° and when the relative humidity is less than 70 percent. If the wet bulb temperature increases above 63°, if the dry bulb temperature decreases below 65° or if the relative humidity increases above 70 percent the fresh air damper 41 is moved to a minimum position. By opening the switch 230 in the basement the supply of power to the relays 387 and 396 is broken and the damper 41 is moved to a minimum position. By opening the switch 379 which controls the supply of power to the proportioning

motor 45 the motor 45 becomes deenergized and the fresh air damper 41 is completely closed.

Figure 6 discloses the manner in which the volume dampers 73 and 78 and the fresh air damper 68 for the third floor are operated. In addition Figure 6 shows the manner in which the fan motor 64 and the refrigerant cut-off valve 94 for the third floor are operated. The volume dampers 73 and 78 are operated by spring return power failure motors 77 and 72 respectively and the fresh air damper 68 is operated by a spring return power failure type motor 72. These three motors may be of the type illustrated in Figures 4 and 5. The proportioning motor 77 for the volume damper 73 is operated by a room thermostatic controller 134, a humidity compensator 135 and an outdoor temperature compensator 136 to provide a compensated effective temperature control for the space 20 in exactly the same manner as that type of control is provided for the space 18. Similarly the proportioning motor 82 for operating the volume damper 78 is controlled by a room thermostatic controller 138, humidity compensator 135 and an outdoor temperature compensator 136 to give compensated effective temperature control of the space 21 in exactly the same manner as that type of control is obtained for the space 19. Therefore a further description of the temperature control for the spaces 20 and 21 is not considered necessary.

The proportioning motor 72 which operates the fresh air damper 68 is controlled by a relay 450 having a relay coil 451 for operating a switch arm 452 with respect to contacts 453 and 454, the arrangement being similar to that shown in Figure 5. When the relay coil 451 is energized the fresh air damper 68 is moved to a wide open position and when the relay coil 451 is deenergized the fresh air damper 68 is moved to a minimum position as determined by the resistance value of the resistance 455. The relay 450 is controlled by the relay 387 of Figure 5. A wire 435 connects the relay coil 451 of Figure 6 in parallel with the relay coil 381 of Figure 5 so that when the relay 387 is pulled in both relays 380 and 450 are pulled in and therefore both fresh air dampers 41 and 68 are moved to a wide open position. When the relay 387 of Figure 5 drops out both relays 380 and 450 drop out and both fresh air dampers 41 and 68 are moved to a minimum position. By reason of this arrangement a single set of controls is utilized for operating a plurality of fresh air dampers. Duplication of controls is eliminated and installation costs may be materially reduced.

Power is supplied to the three proportioning motors 77, 82 and 72 by a step-down transformer 440 having the primary 441 connected across wires 240 and 241. If both switches 232 and 236 in the basement are closed power is supplied to this step-down transformer 440. The three proportioning motors 77, 82 and 72 are connected in parallel across the secondary 442 of the step-down transformer 440 and in circuit with each proportioning motor 77, 82 and 72 is a switch 443, 444 and 445 respectively whereby the power supplied to each proportioning motor may be individually interrupted so that any one of the dampers may be moved to a complete closed position. By opening the switch 232 or the switch 236 in the basement the supply of power to all of the proportioning motors 77, 82 and 72 is interrupted and all of the dampers on the third floor will be moved to a closed position.

Power is supplied to the fan motor 64 by line

wires 460, 461 and 462 and the supply of power to the fan motor 64 is controlled by a magnetic starter 463 having an operating coil 464. The operating coil 464 is connected across wires 240 and 241 so that when switches 232 and 236 in the basement are closed the operating coil 464 is energized to cause operation of the fan motor 64. The solenoid motor 95 which operates the refrigerant cut-off valve 94 derives its power from the fan circuit so that the cut-off valve may only be opened when the fan motor 64 is operating. The solenoid motor 95 is controlled by a relay 465 having a relay coil 466 for operating a switch 467. When the relay coil 466 is energized the switch 467 is caused to open the cut-off valve 94 provided the fan motor 64 is operating. The relay coil 466 is operated by switches in the proportioning motors 77 and 82 which control the volume dampers and by a switch operated by the humidity responsive controller 135. These switches are all arranged in parallel so that any one of them may cause opening of the cut-off valve. This arrangement is exactly the same as the arrangement for the second floor and therefore a further description is not considered necessary. Power is supplied to the relay coil 466 by wires 252 and 253 leading upwardly from the step-down transformer 250 located in the basement. Therefore the relay 465 may be pulled in only when at least one of the compressors is operating.

From the above it is seen that I have provided an air conditioning system for a building incorporating novel control arrangements. The combining of these novel control arrangements into a single complete air conditioning system provides an air conditioning system that is accurate in its temperature regulation and extremely flexible in its operation.

Although for purposes of illustration I have shown one form of this invention, other forms thereof may become apparent to those skilled in the art upon reference to this specification and therefore this invention is to be limited only by the scope of the appended claims and prior art.

I claim as my invention:

1. In an air conditioning system, the combination of a cooling means, fan means for circulating air in contact with the cooling means and into a space to be cooled, damper means for controlling the volume of air so circulated, means responsive to variations in space temperature for controlling the damper means, valve means for controlling the supply of cooling fluid to the cooling means, means for opening the valve means as the damper means is moved toward an open position, and means for preventing opening of the valve means in case the fan means is not operating.

2. In an air conditioning system, the combination of a cooling means, fan means for circulating air in contact with the cooling means and into a space to be cooled, damper means for controlling the volume of air so circulated, means responsive to variations in space temperature for controlling the damper means, valve means for controlling the supply of cooling fluid to the cooling means, means for opening the valve means as the damper means is moved toward an open position, means responsive to space relative humidity for opening the valve means independently of the operation of the damper means, and means for preventing opening of the

valve means in case the fan means is not operating.

3. In an air conditioning system, the combination of a cooling means, fan means for circulating air in contact with the cooling means and into a space to be cooled, damper means for controlling the volume of air so circulated, means responsive to variations in space temperature for controlling the damper means, a cooling apparatus for supplying cooling fluid to the cooling means, valve means controlling the supply of cooling fluid to the cooling means, means for opening the valve means as the damper means is moved toward an open position, and means for preventing opening of the valve means in case the fan means or the cooling apparatus is not operating.

4. In an air conditioning system, the combination of a cooling means, fan means for circulating air in contact with the cooling means and into a space to be cooled, damper means for controlling the volume of air so circulated, means responsive to variations in space temperature for controlling the damper means, a cooling apparatus for supplying cooling fluid to the cooling means, valve means controlling the supply of cooling fluid to the cooling means, means for opening the valve means as the damper means is moved toward an open position, means responsive to space relative humidity for opening the valve means independently of the operation of the damper means, and means for preventing opening of the valve means in case the fan means or the cooling apparatus is not operating.

5. In an air conditioning system for a building having a plurality of zones, the combination of an air conditioning unit for each zone, a duct for each air conditioning unit for admitting outdoor air to that air conditioning unit, a damper in each duct for controlling the admission of outdoor air to the air conditioning units, and control means associated with one of the air conditioning units for controlling all of the dampers.

6. In an air conditioning system for a building having a plurality of zones, the combination of an air conditioning unit for each zone, a duct for each air conditioning unit for admitting outdoor air to that air conditioning unit, a damper in each duct for controlling the admission of outdoor air to the air conditioning units, automatically operated control means associated with one of the zones for opening all of the dampers when the admission of outdoor air is indicated, and means for closing any of the dampers at will independently of the automatically operated control means.

7. In an air conditioning system for a building having a plurality of zones, the combination of an air conditioning unit for each zone, a duct for each air conditioning unit for admitting outdoor air to that air conditioning unit, a damper in each duct for controlling the admission of outdoor air to the air conditioning units, control means associated with one of the air conditioning units for controlling all of the dampers, a cooling means in each air conditioning unit, a cooling apparatus for supplying cooling fluid to all of the cooling means, a valve for each cooling means for controlling the supply of cooling fluid to the cooling means, thermostatic control means in each zone for controlling the valve of that zone to maintain desired temperature conditions in each zone, and means for preventing

opening of any of the valves in case the cooling apparatus is not operating.

8. In an air conditioning system for a building having a plurality of zones, the combination of an air conditioning unit for each zone, a duct for each air conditioning unit for admitting outdoor air to that air conditioning unit, a damper in each duct for controlling the admission of outdoor air to the air conditioning units, control means associated with one of the air conditioning units for controlling all of the dampers, a cooling coil in each air conditioning unit, a plurality of compressors for supplying cooling fluid to all of the cooling coils and for withdrawing expanded refrigerant therefrom, means responsive to suction pressure for placing in operation the compressors in a predetermined sequence as the suction pressure increases, a valve for each cooling coil for controlling the supply of refrigerant to the cooling coils, thermostatic means in each zone for controlling the valve of that zone to maintain desired temperature conditions in each zone, and means for preventing opening of any of the valves in case none of the compressors are operating.

9. In an air conditioning system, the combination of a cooling means, fan means for circulating air in contact with the cooling means and for delivering cooled air to a space to be conditioned, damper means for controlling the volume of air delivered to the space, control means responsive to dry bulb temperature and relative humidity of the space for modulating the damper means between a minimum open position and a wide open position to maintain desired effective temperatures in the space but allowing the relative humidity to fluctuate, valve means controlling the supply of cooling fluid to the cooling means, means controlled by the damper means to close the valve means when the damper means is moved to a minimum open position and to open the valve means when the damper means moves away from the minimum open position toward the wide open position, and means operative when the space relative humidity increases to a predetermined value for opening the valve means even though the damper means is in a minimum open position.

10. In an air conditioning system, the combination of cooling means, fan means for circulating air in contact with the cooling means and into a space to be cooled, volume damper means for controlling the volume of air so circulated, means responsive to variations in space temperature for controlling the volume damper means, mechanism for supplying cooling fluid to the cooling means, means operated upon movement of the volume damper means toward an open position for controlling the mechanism to supply cooling fluid to the cooling means, and means operative upon stopping of the fan means for controlling the mechanism to stop the supply of cooling fluid to the cooling means irrespective of the operation of the volume damper means.

11. In an air conditioning system, the combination of cooling means, fan means for circulating air in contact with the cooling means and into a space to be cooled, volume damper means for controlling the volume of air so circulated, means responsive to variations in space temperature for controlling the volume damper means, mechanism for supplying cooling fluid to the cooling means, means operated upon movement of the volume damper means toward an open position for controlling the mechanism to supply

cooling fluid to the cooling means, means responsive to space relative humidity for controlling the mechanism independently of the operation of the volume damper means to supply cooling fluid to the cooling means when the space relative humidity increases to a predetermined value, and means operative upon stopping of the fan means for controlling the mechanism to stop the supply of cooling fluid to the cooling means irrespective of the operation of the volume damper means and the controlling action of the relative humidity responsive means.

12. In a refrigerating system having an evaporator for cooling a medium, a condenser and a compressor, the combination of, control means responsive to suction pressure for starting and stopping operation of the compressor for maintaining the suction pressure within desired limits, valve means for controlling the flow of refrigerant through the evaporator, thermostatic means responsive to the temperature of the medium being cooled by the evaporator for controlling the valve means to maintain the temperature of the medium within desired limits, and means operative upon stopping of the compressor by said control means for closing the valve means regardless of the controlling action of the thermostatic means.

13. In a refrigerating system having a condenser, a compressor and a plurality of evaporators for cooling a medium, the combination of, control means responsive to suction pressure for starting and stopping operation of the compressor for maintaining the suction pressure within desired limits, valve means associated with each evaporator for controlling the flow of refrigerant through its associated evaporator, thermostatic means associated with each evaporator and responsive to the temperature of the medium being cooled thereby for controlling the valve means of that evaporator to maintain the temperature of the medium within desired limits, and means operative upon stopping of the compressor by said control means for closing all of the valve means regardless of the controlling action of the thermostatic means.

14. In an air conditioning system, the combination of, cooling means in the form of an evaporator, fan means for passing air in contact with the cooling means and into a space to be cooled, a compressor for supplying refrigerant to the cooling means and withdrawing refrigerant therefrom, control means responsive to suction pressure for starting and stopping operation of the compressor for maintaining the suction pressure within desired limits, valve means for controlling the flow of refrigerant through the cooling means, thermostatic means responsive to space temperature for controlling the valve means to maintain the space temperature within desired limits, and means operative upon stopping of the compressor by said control means and upon stopping of the fan means for closing the valve means regardless of the controlling action of the thermostatic means.

15. In a refrigerating system having a condenser, a plurality of evaporators for cooling a medium and a plurality of compressors for supplying refrigerant to the evaporators and for withdrawing refrigerant therefrom, the combination of, control means responsive to suction pressure for starting and stopping operation of the compressors in a predetermined sequence as

the suction pressure varies to maintain the suction pressure within desired limits, valve means for each evaporator for controlling the flow of refrigerant therethrough, thermostatic means responsive to the temperature of the medium being cooled for controlling the valve means to maintain the temperature of the medium within desired limits, and means operative upon stopping of all of the compressors by said control means for closing all of the valve means regardless of the controlling action of the thermostatic means.

16. In a mechanical refrigerating system, the combination of, evaporator means, a plurality of compressors of different capacities for supplying refrigerant to the evaporator means and for withdrawing refrigerant therefrom, control means responsive to variations in a demand for increased compressor capacity, and switching means operated by said control means upon a progressive increase in said demand for selectively starting and stopping the various compressors singly or in combinations to increase the total compressor capacity in a number of steps exceeding the number of compressors.

17. In an air cooling apparatus for a plurality of enclosures, the combination of a plurality of evaporators for respectively cooling the air for the enclosures, means responsive to the temperature of the air in the enclosures for controlling the operation of their respective evaporators, a plurality of refrigerant compressors connected in parallel for supplying liquid refrigerant for the evaporators, means responsive to a condition the value of which normally varies upon variation in the total capacity of the evaporators that are controlled to operate, means controlled by said responsive means for effecting operation of a portion of the compressors when said condition is at a first predetermined value, means controlled by said responsive means for effecting operation of a second portion of the compressors of greater capacity than the first portion when said condition is at a second predetermined value, and means controlled by said responsive means and operative when said condition is at a third predetermined value for effecting operation of all of the compressors.

18. In an air conditioning apparatus for a plurality of enclosures, the combination of a plurality of evaporators for respectively cooling the air for the enclosures, a plurality of compressors of various capacities for supplying liquid refrigerant to the evaporators, means responsive to a condition of the air in the enclosures for controlling the flow of refrigerant to the respective evaporators, an electrical control circuit, means normally influenced by the operation of the various refrigerant flow controlling means for varying a characteristic of said electrical circuit, a device connected in the electrical circuit, responding to said characteristic of the circuit and movable to various positions corresponding to various values of said characteristic, means effective in one position of the device for initiating operation of a low capacity compressor, means effective in a second position of the device for terminating operation of the low capacity compressor and for initiating operation of a high capacity compressor and means effective in a third position of the device for effecting operation of both of the compressors.

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