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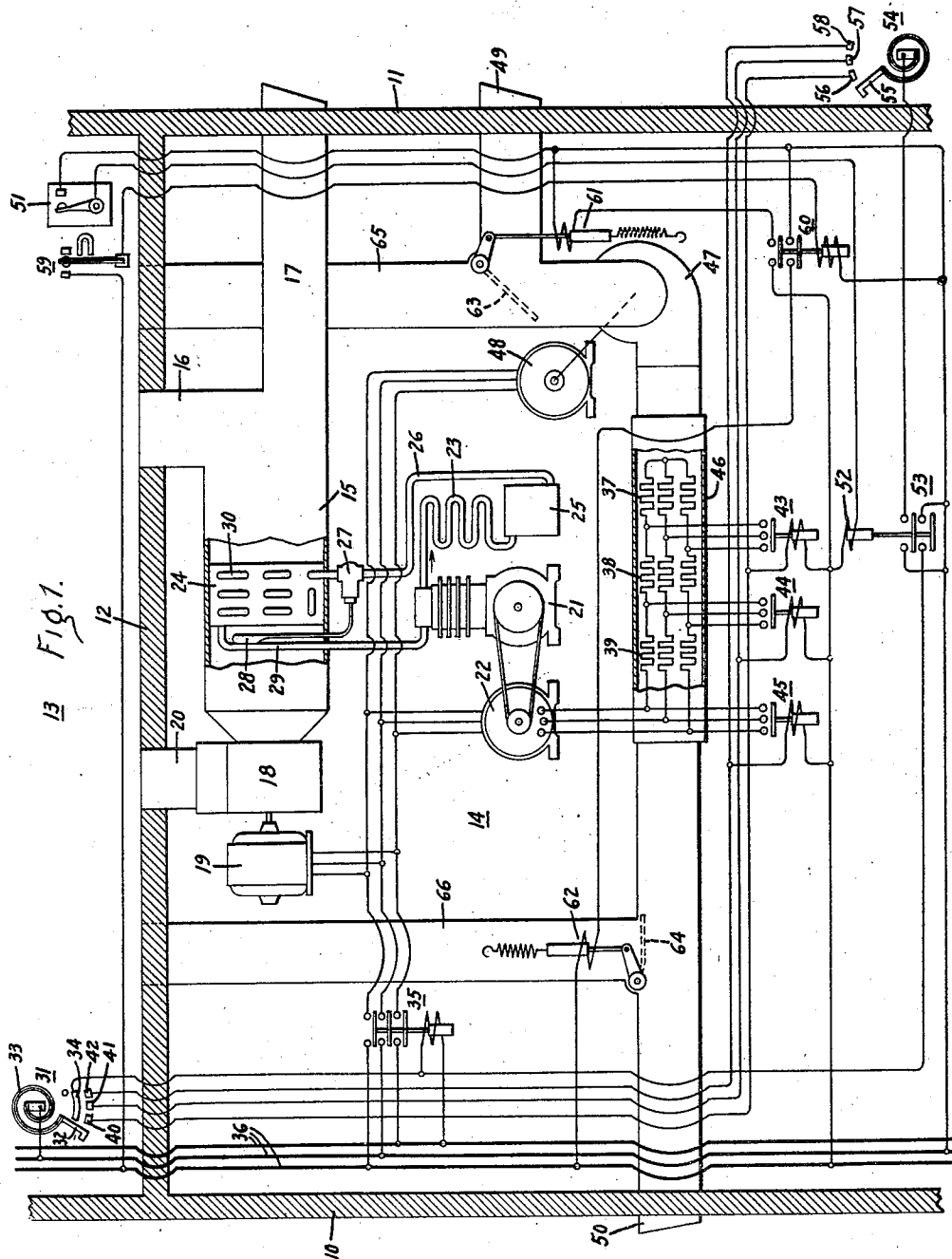
A. R. STEVENSON, JR

2,289,082

AIR CONDITIONING SYSTEM

Filed May 27, 1941

2 Sheets-Sheet 1



Inventor:
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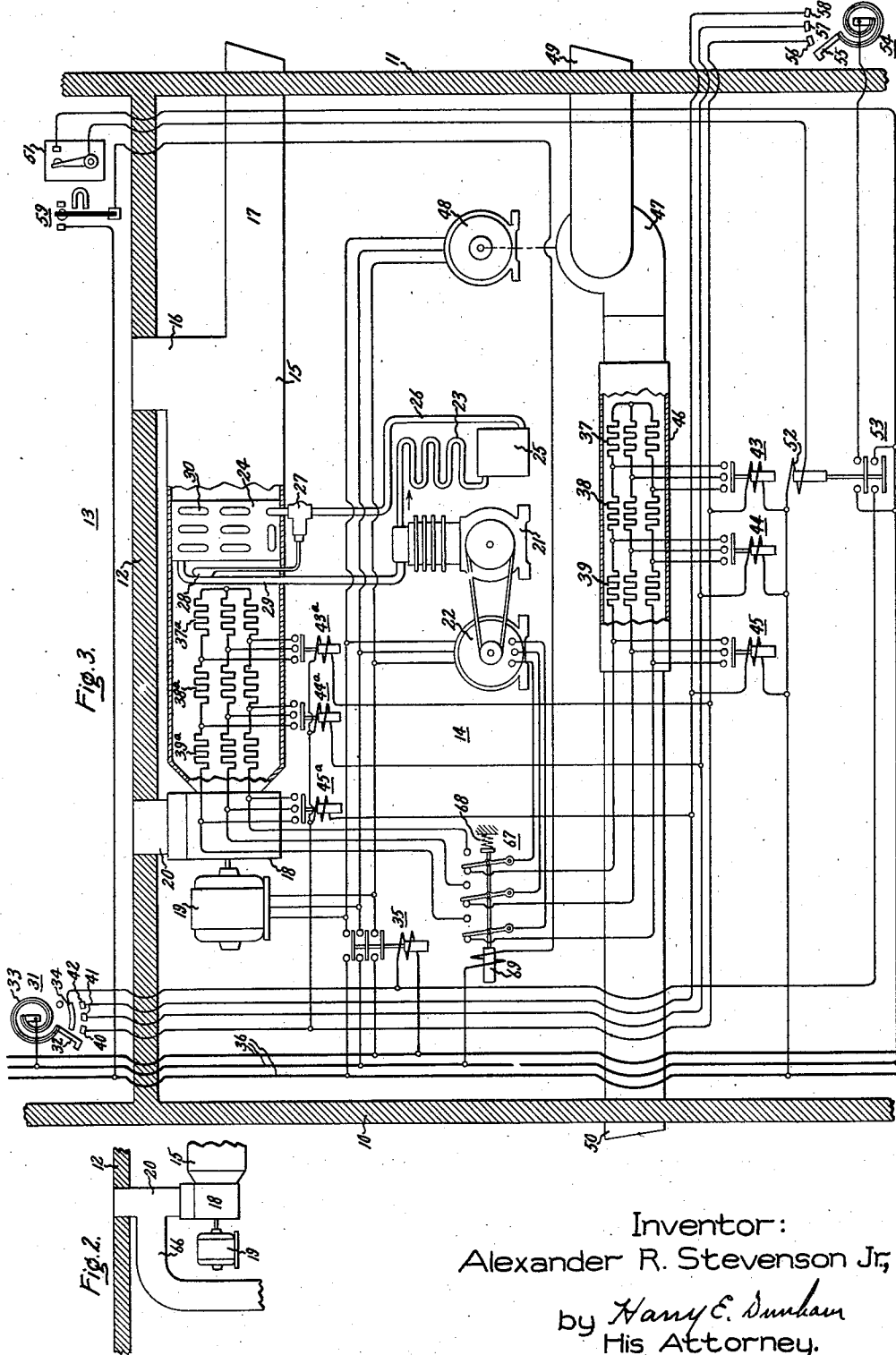
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UNITED STATES PATENT OFFICE

2,289,082

AIR CONDITIONING SYSTEM

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Application May 27, 1941, Serial No. 395,411

16 Claims. (Cl. 257—3)

My invention relates to air conditioning apparatus and particularly to electric motor driven refrigerating apparatus for cooling and dehumidifying the air within an enclosure.

Air conditioning systems which dehumidify air by cooling frequently are required to operate under atmospheric conditions such that the cooling necessary to reduce the relative humidity of the air to a desired value reduces the dry bulb temperature to a value too low for comfort. Under these conditions it is necessary to provide for reheating of the dehumidified air before it is discharged into the room or enclosure being conditioned. The conditions requiring reheating are met most frequently during mild weather, that is during the cooling season when the dry bulb temperature of the outdoor air is of the order of 85° F. or lower. Within this range of temperature, little sensible heat need be removed from the air, the amount depending primarily upon the heat load within the enclosure itself; and the full capacity of the refrigerating machine is, therefore, not required. Refrigerating machines for operation under these conditions are sometimes provided with compressors driven by variable speed electric motors or other prime movers so that the speed may be reduced as the required capacity becomes lower. A reduction of the effective compressor capacity is desirable in order to prevent frequent starting and stopping of the driving motor which would be necessary if the compressor operated at full capacity whenever there was a demand for cooling.

It is an object of my invention to provide an air conditioning system including an electric motor driven compression type refrigerating machine and an improved arrangement for providing reheating of dehumidified air.

Another object of my invention is to provide an air conditioning system including a compression type refrigerating machine driven by an electric motor and an improved arrangement for making available heat for reheating dehumidified air under conditions of operation normally requiring reheating.

Further objects and advantages of my invention will become apparent as the following description proceeds, and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of my invention reference may be had to the accompanying drawings, in which Fig. 1 shows diagrammatically an air conditioning system embodying my invention;

Fig. 2 shows a modified arrangement of a portion of the duct system of Fig. 1; and Fig. 3 shows diagrammatically an air conditioning system similar to Fig. 1 embodying a further modification of my invention.

The air conditioning system shown in the drawings comprises a conditioning casing or duct to which air from the room to be conditioned and fresh air may be admitted and circulated over a cooling coil and thence delivered to the room. The cooling coil is supplied with refrigerant or cooling fluid by a suitable refrigerating machine of the compression type driven by an electric motor. The motor is of the variable speed type utilizing a resistor or resistors in one of its circuits for effecting a reduction of speed. The speed of the motor and hence the capacity of the refrigerating machine may be controlled in accordance with the temperature in the enclosure so that the speed of the machine may be reduced as the sensible heat load is reduced. Under atmospheric conditions required dehumidification of the air supplied to the enclosure, the heat dissipated in the resistors of the motor speed control is made available for reheating of the dehumidified air. The control and the degree of reheating is effected in accordance with changes in conditions of the outdoor air. The heat for reheating the air in the enclosure has been illustrated as supplied to air circulated through a separate duct although any suitable arrangement for applying heat to the dehumidified air in accordance with good air conditioning practice may be employed. In the illustrated arrangement the reheating duct is separate from the main conditioning or cooling duct and may be employed for delivering heated air to the room or for discharging the heat generated in the resistors to the outdoors in the event reheating is not required. When there is a reduction in the speed of the compressor motor, heat is available in the speed control resistors and may be employed for reheating. Furthermore, the speed of the motor is controlled in accordance with the outdoor conditions, and, during normal operation of the system, heat is always available for reheating under those conditions of operation which require reheating.

The term "condition" of air as employed in this specification and in the appended claims designates a condition of the air which may be indicated on a psychrometric chart; among these conditions are wet bulb temperature, dry bulb temperature, relative humidity and moisture content.

Referring now to the drawings, I have shown a portion of a building comprising outside walls 10 and 11 and a partition wall 12 defining a room 13 which is to be conditioned and a machinery or service room 14. Within the service room 14 is arranged a duct or casing 15 connected to receive room air through an inlet 16 and fresh air through an inlet 17 passing through the wall 11 to the outdoors. Air is circulated through the casing 15 by operation of a fan 18 driven by a motor 19 and is delivered to the room through an outlet duct 20. In order to cool and dehumidify the air in the room, I provide a refrigerating machine including a compressor 21 driven by a three-phase alternating current motor 22 and arranged to supply compressed refrigerant to a condenser 23 and to withdraw vaporized refrigerant from an evaporator 24 arranged in the duct 15. During the operation of the compressor 21, the compressed refrigerant is delivered to the condenser 23 where it is cooled and liquefied and flows to a liquid receiver 25. Liquid refrigerant from the receiver 25 flows through a liquid line 26 and thence to the evaporator 24 under control of a thermostatic expansion valve 27 having its thermal bulb or control element 28 secured in heat exchange relation with a suction line 29 connecting the evaporator 24 with the intake of the compressor 21. The evaporator 24 is preferably of the finned tube or other extended surface type comprising a conduit 30 extending back and forth across the duct 15, the end turns of the conduit 30 being shown in the drawings.

The operation of the refrigerating machine is controlled by energizing the motor 22 in accordance with the temperature of the air in the room 13 as determined by a thermostat 31. Thermostat 31 comprises a movable contact 32 actuated by a coiled bimetallic element 33. Whenever the contact 32 moves to the right and engages a stationary contact 34, a solenoid switch 35 is energized to connect the motor 22 across a three-phase supply line 36, the solenoid of the switch 35 being connected across one phase of the supply line when the contacts 32 and 34 are engaged. The switch 35 also connects the motor 19 across the supply line 36 to operate the fan 18.

The motor 22 is a wound-rotor induction motor and is provided with a plurality of sets of resistors 37, 38 and 39 which may be connected in series with the windings of the rotor to vary the resistance of the windings and thereby vary the speed of the motor. Each of the sets of resistors 37, 38 and 39 comprises three resistors, one for each phase of the winding. The thermostat 31 is provided with three additional stationary contacts 40, 41 and 42 and when the contact 32 engages these contacts in order, it actuates short circuiting switches 43, 44 and 45 respectively. These switches short out the sets of resistors 37, 38 and 39 respectively, the closing of the switch 45 shorting all the resistors and providing minimum resistance of the rotor winding and maximum speed of the motor 22. The contact 32 of the thermostat 31 moves farther to the right as the dry bulb temperature of the air in the room increases. The speed of the compressor, therefore, depends upon the temperature of the air in the room, it being higher the greater the demand for cooling.

At reduced speeds of the motor 22, when one or more of the sets of resistors 37, 38 and 39 are in the circuit of the motor rotor, heat is generated in the resistors; and, in order to remove

this heat, I provide a duct 46 surrounding the resistors and a fan 47 driven by a motor 48 for circulating air through the duct and over the resistors. The motor 48 is connected to the supply line 36 by operation of the switch 35 and operates concurrently with the motors 19 and 22. Air to be circulated over the resistors may be taken in from outdoors through an inlet duct 49 and after being heated by the resistors may be discharged outside the building through a discharge outlet 50.

During some portions of the cooling season, particularly during mild weather when the dry bulb temperature is relatively low, the thermostat 31 may be satisfied by the reduction of the dry bulb temperature in the room but the relative humidity of the air may still be above the desired value so that it is desirable to continue the operation of the refrigerating machine to remove moisture from the air in the room. In order to accomplish this I provide a humidostat 51 which upon closing its contacts connects a coil 52 of a solenoid switch 53 across one phase of the supply lines 36, thereby actuating the switch 53 and connecting the solenoid of the switch 35 across one phase of the supply lines 36 through the lower contacts of the switch 53. The upper contacts of the switch 53 prepare a circuit for an outdoor thermostat 54 having a movable contact 55 and three stationary contacts 56, 57 and 58 connected respectively to the solenoids of the switches 43, 44 and 45 on the same side as the contacts 40, 41 and 42, respectively, of the thermostat 31. The movable contact 55 of the thermostat 54 engages the stationary contacts 56, 57 and 58 in order as the temperature rises, and the speed of the motor 22 is thereby determined in the same manner as by operation of the thermostat 31. The humidostat 51 is therefore arranged to control the operation of the refrigerating machine to dehumidify air passing through the casing 15, the speed of the compressor 21 being determined in accordance with the dry bulb temperature of the outdoor air. The lower the temperature of the outdoor air, the lower is the speed of the compressor.

Should the operation of the refrigerating machine upon a call for dehumidification, as determined by the humidostat 51, reduce the dry bulb temperature of the air in the room 13 below a predetermined minimum desirable limit, a snap-acting thermostat 59 will close its contacts and operate a relay 60 to connect two solenoids 61 and 62 across one of the phases of the supply lines 36. The solenoids 61 and 62 are arranged to actuate two dampers 63 and 64, respectively, so that the damper 63 closes the inlet duct 49 and the damper 64 closes the discharge duct 50. When the dampers 63 and 64 are in their actuated positions, the fan 47 circulates air from the room through an inlet 65 and thence over the resistor and back to the room through a duct 66. This air is thus heated by any of the resistors 37, 38 and 39 which are connected in the motor circuit, and the heated air is returned to the room where it reheats the air cooled by the evaporator 24.

By reducing the speed of the motor compressor unit when the outdoor temperature is relatively low, the period of operation of the compressor is increased and short cycling is prevented. At the same time the heat which is made available by the reduction of the speed of the motor may be utilized for reheating the air in the enclosure. This feature further insures a longer period of

operation of the refrigerating machine and thus helps to reduce objectionable short cycling.

During the operation of the air conditioning system just described, the refrigerating machine normally would be controlled in accordance with room temperature by operation of the thermostat 31 and as long as the thermostat 31 is not satisfied the refrigerating machine will be maintained in operation by the thermostat. When the thermostat is satisfied and the relative humidity of the air in the enclosure remains above the desired maximum value, the humidostat 51 will close its contacts to continue the operation of the refrigerating machine, the speed of the operation under this condition depending upon the position of the outdoor thermostat 54. Should the continued operation of the compressor reduce the dry bulb temperature of the room below a desired minimum, the thermostat 59 will actuate the dampers 62 and 63 to utilize the heat generated in the resistors 37, 38 and 39 by reheating the air in the room. The requirements for reheating normally occur during mild weather conditions and the speed of the motor during such conditions and under operation of the humidostat is determined by the outdoor thermostat 54.

While I have shown the air heated by the resistors 37, 38 and 39 utilized for reheating by admitting the heated air directly to the room, it is obvious that any other arrangement for applying the reheat in accordance with good air conditioning practice may be employed. In some installations it might be advisable to join the ducts 20 and 66 so that the heated and cooled air streams would be mixed before admission to the room, this arrangement being shown in Fig. 2. In other cases it might be desirable to locate the resistors 37, 38 and 39 in the main air conditioner, for example, in the casing 15 between the evaporator 24 and the fan 18. Furthermore, it might be desirable to provide two groups of the resistors 37, 38 and 39, one in the heat dissipating duct 46 for discharging the heat outdoors and the other in the casing 15 for heating the air after it passes over the evaporator. These latter two arrangements are shown in Fig. 3 in which the same numerals have been employed to indicate parts of the system which correspond to those in Fig. 1.

The air conditioning system shown in Fig. 3 differs from that shown in Fig. 1 in that a second set of motor speed control resistors 37a, 38a and 39a is provided and is arranged in the duct 15 between the evaporator 24 and the fan 18 so that air cooled by the evaporator may be reheated by passing over the second set of resistors. The ducts 65 and 66 are not employed in Fig. 3, and instead of controlling the dampers 62 and 63 at low temperature, the room thermostat 59 operates a change-over switch 67 whereby either the group of resistors 37, 38 and 39 or the group of resistors 37a, 38a and 39a may be connected in the rotor circuit of the motor. The switch 67 is biased to the left by compression spring 68 and normally connects the resistors 37, 38 and 39 to the rotor windings of the motor. However, when the thermostat 59 operates on low temperature it energizes a coil 69 and moves the switch 67 to the left, thereby connecting the resistors 37a, 38a and 39a to the rotor windings. In order to select which one of the resistors in the duct 15 is to be connected to the motor to provide a desired speed, short-circuiting switches 43a, 44a and 45a corresponding to the switches 43, 44 and 45 are

provided. These switches are energized simultaneously with the switches 43, 44 and 45, either by operation of the indoor thermostat 31 or the outdoor thermostat 54. It will, therefore, be apparent that the speed of the motor selected by either of the thermostats will be the same regardless of which of the groups of resistors is selected by the switch 67, and the switch 67 performs the same function as dampers 62 and 63 in Fig. 1 and thus makes possible the reheating of the air circulated in the duct 15 by heat generated in the speed controlling resistors. Since the thermostat 59 operates only after the thermostat 31 has been satisfied, it is readily apparent that the resistors 37a, 38a and 39a are connected in the rotor circuit only in accordance with the operation of the outdoor thermostat 54. The resistors 37, 38 and 39 normally are controlled only in response to the indoor thermostat 31. However, it will be obvious that the outdoor thermostat 54 may, under certain conditions, take control after there has been a demand by the humidostat 51 for reduction of humidity and before the temperature in the room 13 has been reduced sufficiently to cause operation of the thermostat 59.

From the foregoing it is readily apparent that I have provided a simple and effective arrangement for making possible the reheating of dehumidified air under conditions which normally require reheating, and that this arrangement provides an economical and efficient system permitting the compressor to operate for a longer period at reduced capacity and minimizing short cycling of the refrigerating machine.

While I have shown a particular embodiment of my invention in connection with a system for controlling the dry and wet bulb temperatures of the air within a room, other applications will readily be apparent to those skilled in the art. I do not, therefore, desire my invention to be limited to the particular construction shown and described and I intend in the appended claims to cover all modifications within the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Apparatus for conditioning the air within an enclosure including a refrigerating machine comprising a compressor and a condenser and an evaporator for cooling the air in the enclosure, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, and means dependent upon a predetermined condition of the air in the enclosure for actuating said control apparatus to operate said motor at a reduced speed and for supplying to the air in the enclosure heat generated in said resistor.

2. Apparatus for conditioning the air within an enclosure including a refrigerating machine comprising a compressor and a condenser and an evaporator, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, means arranged to utilize said evaporator for cooling and dehumidifying air to be discharged into said enclosure, means dependent upon a high relative humidity of the air in the enclosure for actuating said control apparatus to operate said motor at

a reduced speed, and means dependent upon a predetermined low temperature of the air in the enclosure for supplying to the air in the enclosure heat generated by said resistor.

3. Apparatus for conditioning the air within an enclosure including a refrigerating machine comprising a compressor and a condenser and an evaporator, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, selectively operable means for actuating said control apparatus to determine the operating speed of said motor, means dependent upon a predetermined condition of the air in the enclosure for utilizing said evaporator to cool and dehumidify air to be discharged into said enclosure, and means dependent upon a predetermined low temperature of the air in the enclosure for supplying to the enclosure heat generated in said resistor.

4. Apparatus for conditioning the air within an enclosure including a refrigerating machine comprising a compressor and a condenser and an evaporator, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, means dependent upon a predetermined condition of the air in the enclosure for utilizing said evaporator to cool and dehumidify air to be discharged into said enclosure, means dependent upon the load requirements of said machine for actuating said control apparatus selectively to determine the operating speed of said motor, and means dependent upon a predetermined low temperature of the air in the enclosure for supplying to the enclosure heat generated in said resistor.

5. Apparatus for conditioning the air within an enclosure including a refrigerating machine comprising a compressor and a condenser and an evaporator, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, means dependent upon the relative humidity of the air in the enclosure for utilizing said evaporator to cool and dehumidify air to be discharged into said enclosure, means including a thermostat responsive to the temperature of the outdoor air for actuating said control apparatus selectively to determine the operating speed of said motor, said last mentioned means being arranged to decrease the speed of said motor upon a lowering of the temperature of the outdoor air below a predetermined value, and means dependent upon a predetermined low temperature of the air in the enclosure for supplying to the enclosure heat generated in said resistor.

6. Apparatus for conditioning the air within an enclosure including a refrigerating machine comprising a compressor and a condenser and an evaporator for cooling the air in the enclosure, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, means for circulating air over said resistor to remove heat generated thereby, and means operable in a first position to utilize air circulated over said resistor for heating the air in the enclosure and operable in a second position for discharging to the atmosphere

outside the enclosure the air circulated over said resistor.

7. Apparatus including a duct for conditioning the air within an enclosure, means for circulating air through said duct and into the enclosure, means including a refrigerating machine having a compressor for cooling air circulated through said duct, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, means including a duct for circulating air over said resistor and operable in a first position to discharge the air externally of the enclosure and in a second position to discharge the air into the enclosure, and means dependent upon a predetermined condition of the air within said enclosure for actuating said control apparatus to operate said motor at a reduced speed and to actuate said last mentioned means to its second position to utilize heat generated in said resistor for reheating air cooled by said refrigerating machine.

8. Apparatus including a duct for conditioning the air within an enclosure, means for circulating air through said duct, and into the enclosure, means including a refrigerating machine having a compressor for cooling air circulated through said duct, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, means including a duct for circulating air over said resistor, means selectively operable to a first position for directing air circulated over said resistor into the enclosure and operable to a second position for directing air circulated over said resistor to the atmosphere outside the enclosure, means dependent upon the relative humidity of the air in the enclosure for effecting operation of said refrigerating machine, and means dependent upon a predetermined low temperature of the air in the enclosure for actuating said selectively operable means to its first position to circulate air over said resistor and into said enclosure.

9. Apparatus including a duct for conditioning the air within an enclosure, means for circulating air through said duct and into the enclosure, means including a refrigerating machine having a compressor for cooling air circulated through said duct, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, means including a duct for circulating air over said resistor, selectively operable means movable to a first position for directing air circulated over said resistor into the enclosure to heat the air in the enclosure and movable to a second position for directing air circulated over said resistor to the atmosphere outside the enclosure, means responsive to the temperature of the air in the enclosure for effecting operation of said refrigerating machine, means dependent upon the relative humidity of the air in the enclosure for effecting operation of said refrigerating machine, means dependent upon a predetermined minimum permissible temperature of the air in the enclosure for maintaining said selectively operable means in its first position, and means dependent upon a condition of the outdoor air for actuating said control apparatus to determine the speed of said motor when operation of said refrigerating ma-

chine is effected by said relative humidity dependent means.

10. Apparatus including a duct for conditioning the air within an enclosure, means for circulating air through said duct and into the enclosure, means including a refrigerating machine having a compressor for cooling air circulated through said duct, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, means including a duct for circulating air over said resistor, means selectively operable to a first position for directing air circulated over said resistor into the enclosure and operable to a second position for directing air circulated over said resistor to the atmosphere outside the enclosure, means responsive to the temperature of the air in the enclosure for effecting operation of said refrigerating machine and for actuating said control apparatus to determine the speed of said motor, humidity responsive means dependent upon the relative humidity of the air in the enclosure for effecting operation of said refrigerating machine when said temperature responsive means is satisfied, means dependent upon the temperature of the outdoor air for actuating said control apparatus to determine the speed of said motor when operation of said refrigerating machine is effected by said humidity dependent means, and means dependent upon a predetermined low temperature of the air in the enclosure for actuating said selectively operable means to its first position to circulate air over said resistor and into said enclosure.

11. Apparatus including a duct for conditioning the air within an enclosure, means for circulating air through said duct and into the enclosure, means including a refrigerating machine having a compressor for cooling air circulated through said duct, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, means including a duct for circulating air over said resistor, means selectively operable to a first position for directing air circulated over said resistor into the enclosure and operable to a second position for directing air circulated over said resistor to the atmosphere outside the enclosure, and means dependent upon a predetermined condition of the air in the enclosure for effecting operation of said refrigerating machine and for actuating said selectively operable means to its first position to circulate air over said resistor and into said enclosure.

12. An air conditioning system including a cooling unit for cooling the air within an enclosure, a refrigerating machine including a compressor for supplying refrigerant to said cooling unit, a prime mover for driving said compressor, control means arranged to vary the speed of said prime mover for operating said compressor at reduced speeds, heat being generated in said control means during operation of said prime mover at reduced speeds, and means dependent upon a condition of the air in the enclosure for supplying heat generated in said control means to the air in said enclosure.

13. An air conditioning system including a cooling unit for cooling the air within an enclosure, a refrigerating machine including a com-

pressor for supplying refrigerant to said cooling unit, an electric motor for driving said compressor, means including a resistor in a circuit of said motor for operating said motor at a reduced speed whereby heat is generated in said resistor, means dependent upon a reduced load requirement of said machine for actuating said last mentioned means to reduce the speed of said motor, and means dependent upon a condition of the air in the enclosure for supplying heat generated in said resistor to the air in the enclosure.

14. An air conditioning system including a cooling unit for cooling the air within an enclosure, a refrigerating machine including a compressor for supplying refrigerant to said cooling unit, an electric motor for driving said compressor, control means including a resistor for operating said motor at a reduced speed whereby heat is generated in said resistor, means dependent upon the relative humidity of the air in the enclosure for energizing said motor to operate said refrigerating machine, means dependent upon the temperature of the atmosphere outside said enclosure for actuating said control means to determine the speed of operation of said motor, and means for discharging into said enclosure heat generated in said resistor at reduced speeds of said motor.

15. Apparatus including a duct for conditioning the air within an enclosure, means for circulating air through said duct and into the enclosure, means including a refrigerating machine having a compressor for cooling air circulated through said duct, an electric motor for driving said compressor, control apparatus for said motor including a resistor for providing a plurality of motor speeds whereby heat is generated in said resistor at a reduced speed of said motor, said resistor being arranged within said duct whereby air circulated through said duct passes over said resistor before being discharged from said duct, and means dependent upon a predetermined condition of the air within said enclosure for actuating said control apparatus to operate said motor at a reduced speed whereby air cooled within said duct is reheated by heat generated within said resistor.

16. Apparatus including a duct for conditioning the air within an enclosure, means for circulating air through said duct and into the enclosure, means including a refrigerating machine having a compressor for cooling air circulated through said duct, an electric motor for driving said compressor, control apparatus for said motor for providing a plurality of motor speeds, said control apparatus including two resistors, one located outside said duct and the other located within said duct, means responsive to the temperature of the air in the enclosure for effecting operation of said refrigerating machine and for actuating said control apparatus to utilize said one of said resistors for providing a reduced speed of said motor, means dependent upon the relative humidity of the air in the enclosure for effecting operation of said refrigerating machine when said temperature responsive means is satisfied, and means dependent upon a predetermined low temperature of the air in the enclosure for actuating said control means to utilize said other of said resistors for operating said motor at a reduced speed and for reheating air circulated through said duct.

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