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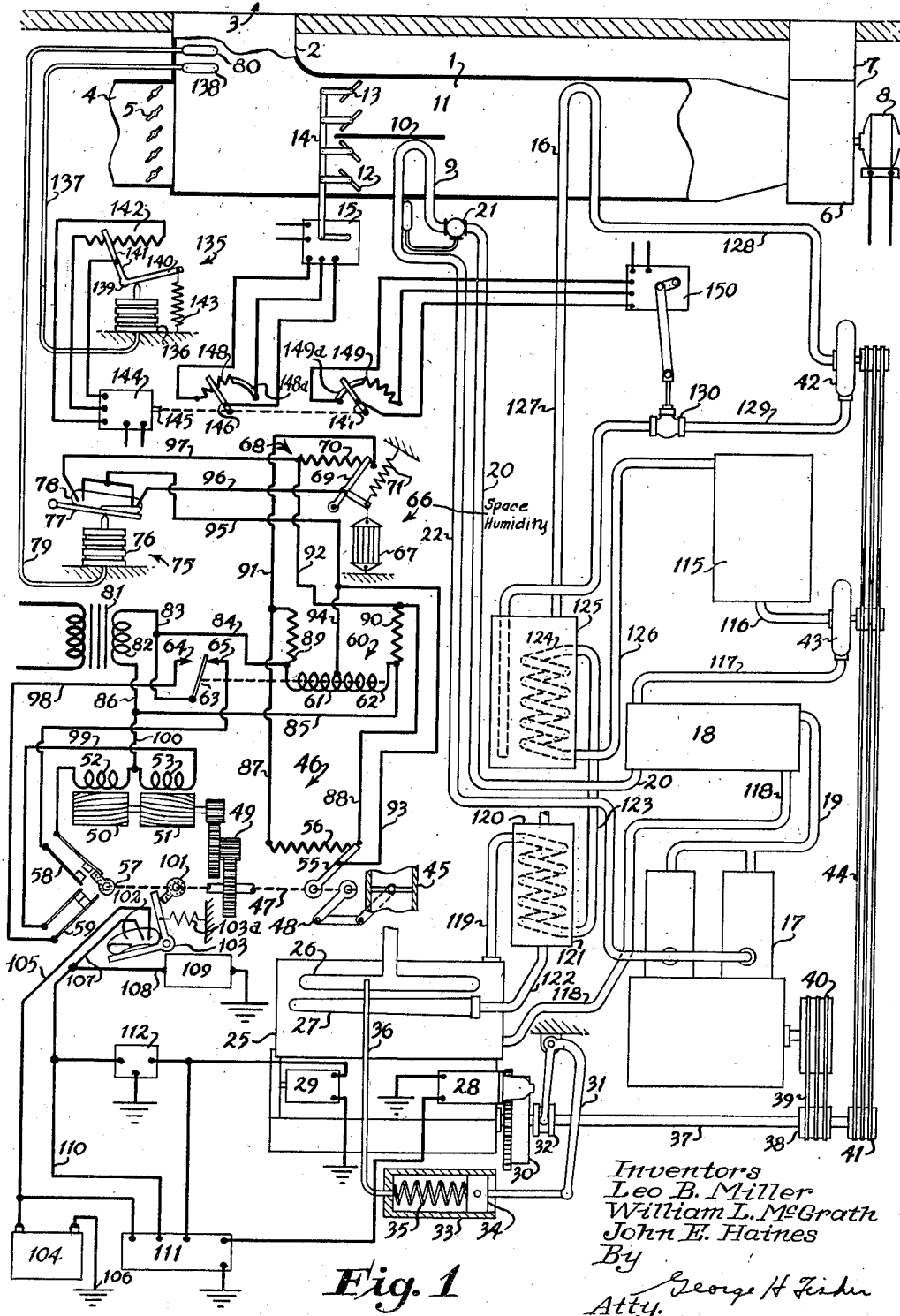
L. B. MILLER ET AL

2,274,153

AIR CONDITIONING SYSTEM

Filed July 16, 1937

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Fig. 2a

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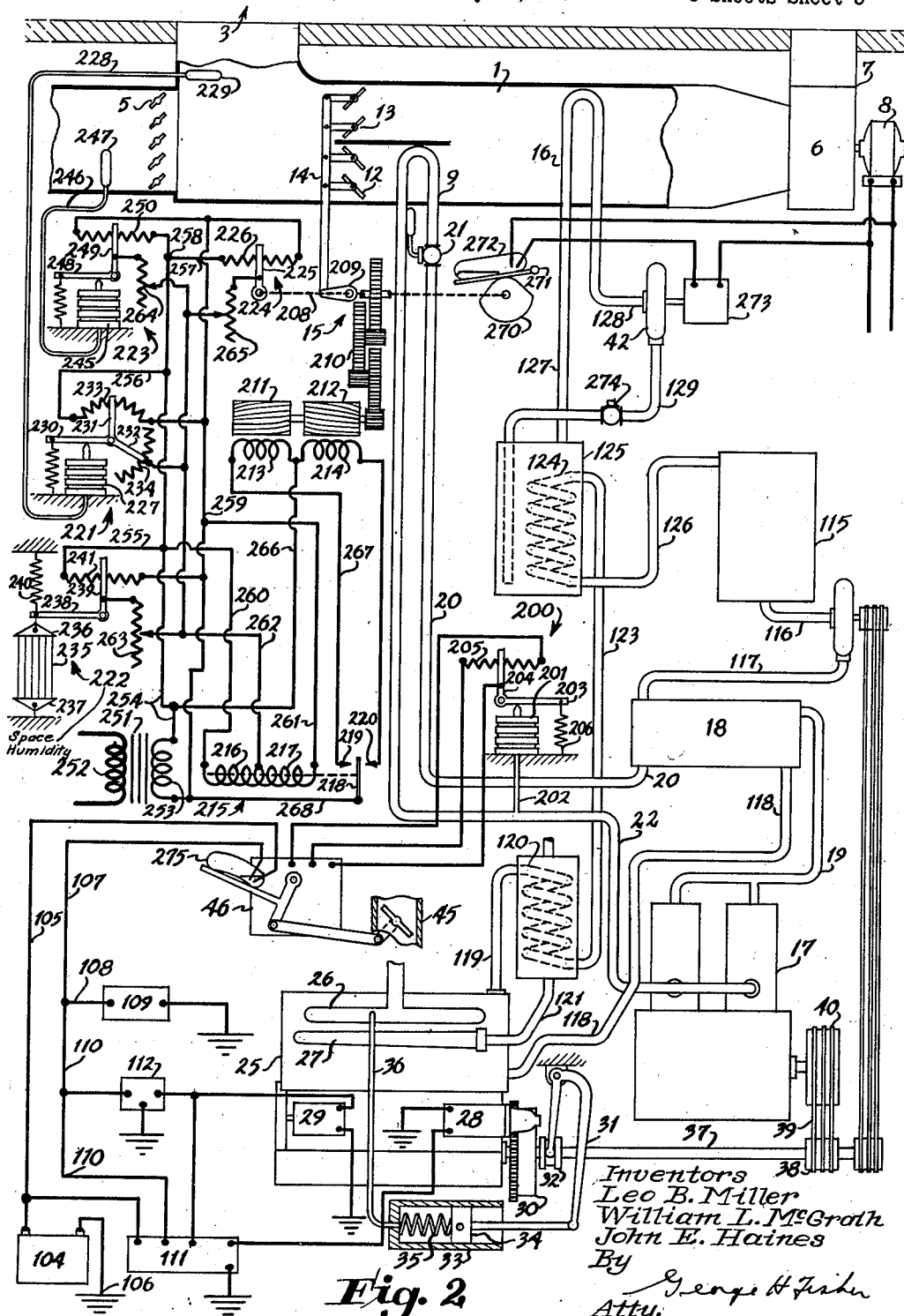


Fig. 2

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UNITED STATES PATENT OFFICE

2,274,153

AIR CONDITIONING SYSTEM

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23 Claims. (Cl. 62—6)

This invention relates to air conditioning systems and is more particularly concerned with air conditioning systems for summer cooling of the type utilizing a compression refrigeration system wherein the compressor is driven by means of an internal combustion engine.

One object of our invention is to provide an air conditioning system adapted to economically maintain proper temperature conditions within a space, such system being driven by an internal combustion engine and being provided with a reheater for reheating the air after being cooled and dehumidified, such reheater being supplied with waste heat from the engine.

More specifically, it is an object of our invention to provide a system of the type mentioned, with an automatic control system for varying the output of the engine and the operation of the reheater in accordance with changes in temperature and humidity conditions in a manner to maintain proper psychrometric conditions within the conditioned space.

A further object of our invention is the provision of a novel reheater arrangement for an air conditioning system having an internal combustion engine driven compressor, the heating medium for the reheater being heated by being passed in heat exchange relationship with a heat exchange fluid which is circulated to absorb heat from the engine cylinders and the exhaust gases. A still further object is to provide an arrangement for storing the waste heat ejected by the engine as by storing a body of heated fluid which is heated with such waste heat, this stored heat being available for satisfying various demands for heat such as for supplying domestic hot water and for reheat. More specifically, it is an object of our invention to automatically utilize the stored heating fluid for reheat as by passing said fluid through the reheater when reheat is required.

Another object of our invention is to provide a control arrangement for an internal combustion driven air conditioning system which acts automatically to control the relative humidity within the conditioned space by varying the output of the internal combustion engine in accordance with changes in relative humidity, such system also acting automatically to start and stop the engine.

Another object of our invention is the provision of an air conditioning system having a cooling and dehumidifying device of the type having a damper controlled by-pass therearound and a reheater, the by-pass and reheater being

sequentially controlled in such manner that the reheater is not placed into operation until the by-pass damper is wide open, thereby avoiding addition of heat to the air being conditioned at all times except when such addition of heat is necessary in order to secure the required amount of dehumidification.

Another object is the provision of an air conditioning system having a refrigeration system for cooling and dehumidifying and having also a reheating means, such system being provided with a control arrangement for automatically controlling the operation of the refrigeration system and the reheater, such control arrangement acting to control the operation of the refrigeration system in accordance with the suction or low side pressure and to control the operation of the reheater in accordance with temperature and/or humidity conditions of the space being conditioned in a manner to maintain such conditions within predetermined ranges of values.

Other objects will become apparent from the following description and the appended claims.

For a full disclosure of our invention, reference is made to the following detailed description and to the accompanying drawings, in which—

Figure 1 illustrates diagrammatically an air conditioning system embodying one form of our invention.

Figure 1a shows the same system as Figure 1 but omits the wiring diagram.

Figure 2 illustrates diagrammatically another form which our invention may take, and

Figure 2a is a simplified showing of Figure 2, omitting the wiring diagram.

Referring now to Figure 1, reference character 1 indicates an air conditioning chamber having a return air inlet duct 2 which leads from a space to be conditioned 3. Conditioning chamber 1 is also provided with a fresh air inlet duct 4, this duct being provided with suitable dampers 5 for controlling the admittance of fresh air. To the discharge end of conditioning chamber 1 is connected a fan 6, the discharge of this fan being connected to a discharge duct 7 which leads to the conditioned space 3. The fan 6 is provided with suitable driving means such as an electric motor 8. Located within the conditioning chamber 1 is a cooling coil 9, a baffle 10 being provided for forming a by-pass passage 11 around said cooling coil. For controlling the flow of air through the cooling coil 9 and the by-pass passage 11, face dampers 12 and by-pass dampers 13 are provided, these dampers being

actuated by a rod 14 which is connected to the actuating arm of proportioning motor 15, the arrangement being such that when the face dampers are moved towards closed position the by-pass dampers are simultaneously moved towards open position and vice versa. The face dampers 12, it will be understood, are never entirely closed by motor 15 and permit air to flow across coil 9 at all times. Also located in the conditioning chamber 1 is a reheater 16.

For supplying liquid refrigerant to the cooling coil 9 and for withdrawing evaporated refrigerant therefrom, a compression type of condensing unit is provided which comprises a compressor 17 and a condenser 18. The discharge of the compressor 17 is connected by means of conduit 19 to the refrigerant inlet of condenser 18. To the refrigerant outlet of the condenser is connected a conduit 20 which may lead through a suitable receiver (not shown), to the inlet of an expansion valve 21. This expansion valve may be of any desired type and is herein illustrated as being of the thermostatic type comprising a temperature control bulb connected to the outlet of the cooling coil 9. Said cooling coil outlet is connected by a conduit 22 to the suction side of the compressor 17. Compression refrigeration systems of this type are well known in the art and hence a detailed description of the operation of such a system is unnecessary here. However, it may be stated that operation of the compressor 17 causes chilling of the cooling coil 9, and that the amount of cooling done by cooling coil 9 varies with the compressor speed.

For driving the compressor 17 an internal combustion engine 25 is provided, this engine having the usual inlet manifold 26, exhaust manifold 27, starting motor 28, generator 29, and a fly-wheel 30 which has located therein a suitable clutching mechanism. In starting an engine of this type it is desirable to disconnect it from its load and for this purpose an automatic clutching mechanism is provided which comprises a bell crank lever 31 for actuating the clutch release collar 32, the bell crank lever being connected to a pneumatic motor 33. The pneumatic motor 33 comprises a piston 34 located in a suitable cylinder, this piston being urged outwardly by a spring 35, this causing disengagement of the clutching mechanism. The interior of the cylinder is connected by a conduit 36 to the intake manifold 26. By this arrangement, when the engine 25 is started the resulting vacuum in the intake manifold will cause movement of the piston 34 against the action of the spring 35 to engage the clutching mechanism, thus causing the engine 25 to rotate the drive shaft 37. The drive shaft 37 carries a pulley 38 which drives the belts 39 which in turn rotate the pulley 40 mounted on the compressor shaft, and in this manner the compressor 17 is driven by the internal combustion engine 25. Also mounted upon the shaft 37 is a second pulley 41, this pulley being provided for driving the pumps 42 and 43 through the medium of belts 44.

For controlling the speed of the engine 25 a throttle valve 45 is provided which controls the flow of a combustible mixture of fuel and air into the engine cylinders. It will be understood that a suitable fuel mixing device (not shown) is employed for mixing the fuel and air prior to passage to the throttle valve 45. The throttle valve 45 is controlled by means of a proportioning motor generally indicated at 46, this motor

comprising an operating shaft 47 upon which is mounted an actuating lever 48 which is connected to the throttle valve by suitable linkage. The operating shaft 47 is rotated through a gear train 49 by means of a pair of induction motors comprising armatures 50 and 51 and cooperating field coils 52 and 53. It will be understood that energization of the field coil 52 will cause rotation of the shaft 47 in one direction and energization of the field coil 53 will cause rotation of said shaft in the opposite direction, the shaft 47 remaining stationary when both field coils are deenergized. No novelty is claimed for the proportioning motor illustrated herein, this type of proportioning motor being shown in the patent to D. G. Taylor No. 2,028,110, and being controlled by a relay of the electrically balancing type. Mounted on the shaft 47 is an arm 55 which cooperates with a resistance 56 to form a balancing potentiometer. Also mounted on the shaft 47 is an insulated actuating member 57 for actuating the limit switches 58 and 59, these limit switches being provided for deenergizing the field coils 52 and 53 when the shaft 47 is rotated to one limit or the other of its travel.

For controlling the energization of the field coils 52 and 53, a balancing type of relay is provided, this relay being generally indicated as 60 and comprises a pair of connected relay coils 61 and 62 for controlling through a suitable armature, a switch arm 63 which cooperates with a pair of contacts 64 and 65. When the relay coils 61 and 62 are equally energized, the armature will assume a midposition in which the switch arm 63 is disengaged from both contact 64 and contact 65. If, however, the relay coil 62 is energized more highly than relay coil 61 the switch arm 63 will be brought into engagement with the contact 65. Conversely, if relay coil 61 is energized more highly than relay coil 62 the switch arm 63 will be caused to engage the contact 64.

In accordance with our invention the speed of the engine is controlled in accordance with the relative humidity of the space being conditioned, and for this purpose the humidity controller 66 is provided for controlling the relative energizations of the relay coils 61 and 62. The humidity controller 66 comprises a humidity responsive device 67 for controlling a potentiometer 68, this potentiometer comprising a slider 69 cooperating with a resistance coil 70. The humidity responsive device comprises upper and lower clamping members for securing a plurality of hairs or other moisture responsive strands, the lower clamping member being connected to a suitable fixed support and the upper clamping member being connected so as to actuate the slider 69. A spring 71 is provided for urging movement of the slider 69 against the action of the humidity responsive device. Upon an increase in humidity the strands of the moisture responsive device 67 will increase in length, this permitting rotation of the slider 69 in a counter-clockwise direction under the action of spring 71. A decrease in humidity, however, will cause the moisture responsive strands to decrease in length, this causing rotation of slider 69 in a clockwise direction against the action of spring 71.

For supplementing the control of the balancing relay 60 by the humidity controller 66, a temperature controller 75 is provided, this temperature controller comprising a bellows 76 which is secured to a fixed support at its lower end and which is arranged to operate a pivoted mercury

switch carrier 77 which carries a mercury switch 78. The bellows 76 is connected by a capillary tube 79 to a control bulb 80 which is located in the return air duct 2. The bellows 76, tube 79 and bulb 80 contain a suitable volatile fluid wherefore varying pressures are caused to occur within the bellows 76 for varying temperatures to which the control bulb 80 is subjected. Upon an increase in temperature the pressure of the volatile fill will increase, this causing expansion of the bellows 76 thus rotating the mercury switch carrier in a counter-clockwise direction. Conversely, upon a falling temperature the bellows 76 will contract, causing rotation of the switch carrier 77 and mercury switch 78 in the opposite direction. This instrument may be so designed and adjusted that when the temperature of the return air is below 82° F., the bellows 76 will be contracted sufficiently to cause the switch 78 to be tilted so that its right-hand contacts are closed. When, however, the temperature of the return air exceeds 82° F., the bellows 76 will expand to cause breaking of the right-hand contacts of mercury switch 78 and making of the left-hand contacts thereof.

Reference character 81 indicates a step-down transformer connected to any suitable source of power, the secondary 82 of said transformer being connected across the serially connected relay coils 61 and 62 by means of wires 83, 84, 85 and 86. Also connected across the serially connected relay coils 61 and 62 are the resistance 56 of the balancing potentiometer and the control resistance 70 of the humidity controller, the resistance 56 being connected to said relay coils by means of wires 87 and 88 and the protective resistances 89 and 90. The control resistance 70 is connected to said relay coils by wires 91 and 92 through the protective resistances 89 and 90. The slider 55 of the balancing potentiometer is connected to the junction of the relay coils 61 and 62 by means of wires 93 and 94. The junction of relay coils 61 and 62 is also connected to the common terminals of the mercury switch 78 by means of wires 94 and 95. The right-hand terminal of mercury switch 78 is connected by a wire 96 to the slider 69 of the humidity controller. It should thus be seen that when the mercury switch 78 is tilted to the position shown, the slider 69 of the humidity controller is connected to the junction of relay coils 61 and 62. The left-hand contact of the mercury switch 78 is connected by means of wire 97 to the left-hand end of the control resistance 70.

From the foregoing wiring connections, it will be apparent that the slider 69 of the humidity controller 66 will place the portion of the control resistance 70 which lies to the left of said slider in parallel with the relay coil 62, and will place the portion of resistance 70 lying to the right of the slider in parallel with the relay coil 61. Thus as the slider 69 moves across the control resistance to the left due to an increase in relative humidity, the portion of the resistance 70 which is in parallel with the relay coil 62 will be decreased and the portion of said resistance which is in parallel with the relay coil 61 will be increased. This will result in an increase in current flow through the relay coil 61 and a decrease in current flow through the relay coil 62 which causes engagement of switch arm 63 with contact 64. Engagement of switch arm 63 with contact 64 will energize the field coil 53 by a circuit as follows: Transformer secondary 82, wire 83, switch arm 63, contact 64, wire 98, limit switch

59, wire 99, field coil 53, wire 100 and wire 86 to the other side of secondary 82. This will result in rotation of the shaft 47 in a direction to cause opening of the throttle valve 45 and to cause counter-clockwise rotation of the slider 55 of the balancing potentiometer. This movement of the slider 55 will have the effect of decreasing the portion of balancing resistance 56 which is in parallel with the relay coil 61 and increasing the portion of said resistance which is in parallel with the relay coil 62. This action therefore tends to balance out the initial unbalancing effect on the relay 60 caused by the humidity controller 66. When the movement of slider 55 is such that its balancing action balances out the initial unbalancing action of the humidity controller, the relay coils 61 and 62 will become equally energized thereby causing the switch arm 63 to disengage contact 64, thus, stopping the motor in this new position. It should thus be seen that the angular travel of the shaft 47 will be proportional to the travel of the slider 69 of the humidity controller across the control resistance 70. It should be apparent that upon decrease in relative humidity the slider 69 will travel in the opposite direction across the control resistance 70, this unbalancing the relay 60 in the opposite direction, thus causing the switch arm 63 to engage the contact 65 for energizing the field coil 52 which will result in the shaft 47 being rotated in a direction to close the throttle valve 45. It should also be apparent that this rotation of the shaft 47 will cause the balancing potentiometer to stop the motor in a position corresponding to the position of the slider 69 on the control resistance 70.

From the foregoing description, it should be apparent that as long as the return air temperature is below 82° F. the proportioning motor will adjust the throttle valve 45 in accordance with variations in relative humidity within the conditioned space, the throttle valve being opened to cause an increase in speed of the engine as the humidity increases, and being closed to decrease the speed of the engine as the humidity decreases. With the parts in the position shown, it will be noted that the slider 69 of the humidity controller is engaging the extreme right-hand end of the control resistance 70 thus indicating that the humidity of the air within the conditioned space is very low. For this condition it will be noted the proportioning motor has assumed a position in which the throttle valve 45 is completely closed, the limit switch 58 at this time being opened to deenergize the motor field 52. If should at any time the temperature of the air within the conditioned space exceed 82° F., the temperature controller 75 will cause the mercury switch 78 to be tilted in a counter-clockwise direction to break the right-hand contacts and to make the left-hand contacts. The breaking of the right-hand contacts will disconnect the slider 69 from the junction of the relay coils 61 and 62 and thus the position of the slider 69 on the resistance 70 will no longer have any effect upon the energization of said relay coils. The making of the left-hand contacts of mercury switch 78 will cause the relay coil 62 to be substantially short-circuited by the following circuit: left-hand end of relay coil 62, wire 94, wire 95, mercury switch 78, wire 97, wire 92, and protective resistance 90 to the right-hand end of relay coil 62. This will cause the relay coil 61 to be considerably more highly energized than relay coil 62 thus causing switch arm 63 to engage the con-

tact 64 which in turn will result in rotation of the shaft 47 in a direction to open the throttle valve 45. Due to the substantial short-circuiting of the relay coil 62, the balancing potentiometer will be incapable of rebalancing the relay 60 and therefore the throttle valve 45 will be moved to wide open position for causing the engine to operate at maximum speed for reducing the excessive temperature.

From the foregoing description, it should be apparent that so long as the space temperature is below a predetermined value, the compressor speed and hence the coil temperature will be controlled in accordance with the relative humidity conditions within the conditioned space. Thus as the relative humidity increases, the compressor speed will be increased, this resulting in a lowering of coil temperature. This lowering in the cooling coil temperature will result in an increase of the dehumidifying action of said coil. Similarly, upon falling relative humidity the compressor speed will be reduced, this causing the cooling coil temperature to increase thereby decreasing the dehumidifying action of said cooling coil. By controlling the compressor speed in accordance with the relative humidity within the conditioned space, this condition is maintained within predetermined limits. If at any time the temperature within the conditioned space becomes excessive, it will be apparent that the temperature controller 75 will cause operation of the compressor at maximum output for reducing such excessive temperature condition.

Our invention also contemplates the provision of automatic stopping and starting mechanism for the internal combustion engine 25. This mechanism will now be described. Actuated by the proportioning motor shaft 47 is a switching member 101 which is arranged to actuate the auxiliary switch formed of mercury switch 102 which is mounted upon carrier 103. The switching member 101 is so adjusted upon the shaft 47 that when the throttle valve is closed to such a point as to indicate the minimum desired operation of the engine 25, said switching member will cause tilting of mercury switch 102 to open position. When, however, the throttle valve 45 is opened sufficiently to cause efficient and satisfactory operation of the engine 25, the switching member 101 will permit tilting of switch 102 to closed position under the action of tension spring 103a.

Reference character 104 indicates a storage battery, one terminal of which is connected by means of wire 105 to the mercury switch 102, and the other terminal of which is connected by wire 106 to a suitable ground connection. The other terminal of mercury switch 102 is connected by wires 107 and 108 to one terminal of an ignition coil 109 for the engine 25, the other terminal of said ignition coil being grounded. By the arrangement just described, the ignition coil 109 will be energized whenever the throttle valve 45 is opened sufficiently to permit closing of the mercury switch 102. The mercury switch 102 is also connected by wire 110 to the starting motor relay 111. Thus simultaneously with the energizing of the ignition coil 109 the starting motor relay will be caused to energize the starting motor 28 for cranking the engine. This starting motor relay is arranged to automatically cause deenergization of the starting motor 28 when the engine starts, and is also arranged to prevent energization of said starting motor so long as the engine is in operation. For the constructional details of the

starting motor relay 111 and the principles of operation thereof, reference is made to Patent No. 1,773,913 issued on August 26, 1930, to L. K. Loehr et al. Reference character 112 indicates an automatic cut-out for the generator 29 which disconnects said generator from the storage battery whenever the engine is out of operation.

From the foregoing it should be seen that when the throttle valve is automatically opened to such an extent as to permit satisfactory operation of the engine, the engine will be automatically started by the closing of mercury switch 102. It should also be apparent that when the throttle valve 45 is closed to such an extent that the engine no longer operates satisfactorily and efficiently, the switching member 101 will cause opening of mercury switch 102 which will deenergize the ignition coil 109 for the engine, thus placing said engine out of operation.

Our invention contemplates not only controlling the compressor speed in accordance with relative humidity, but also contemplates control of the temperature of the conditioned space by controlling the amount of air passed over the cooling coil 9, and also by reheating the air when necessary. Our invention further contemplates the recovering of the waste heat given off by the internal combustion engine and the condenser, and the utilizing of this waste heat for reheating when necessary, and also for other uses such as providing a supply of domestic water. This heat recovery system will now be described. Reference character 115 indicates a suitable form of cooler which may take the form of an evaporative cooler or a spray pond. Connected to the cooler 115 is a conduit 116 for withdrawing cold water from said cooler, this conduit being connected to the intake of circulating pump 43, the discharge of said pump being connected by a conduit 117 to the cooling water inlet of the condenser 18. The cooling water outlet of the condenser 18 is connected by a conduit 118 to the inlet of the cooling water jacket of the engine 25, the outlet of said jacket being connected by a conduit 119 to the coil 120 located within the exhaust gas heat exchanger 121. This heat exchanger is connected by pipe 122 to the exhaust manifold 27 and hence the exhaust gases for the engine pass in contact with the coil 120 located within the heat exchanger. The outlet of the cooling coil 121 is connected by a conduit 123 to the inlet of coil 124 which is located within a storage tank 125. The outlet of the heat exchange coil 124 is connected by a conduit 126 to the inlet of the cooler 115.

From the foregoing it should be seen that cold water is first passed through the condenser for cooling the condenser to effect liquification of the gaseous refrigerant, this cooling water thereby becoming heated by the heat withdrawn from the refrigerant. This heated water then passes into the water jacket of the engine which is considerably warmer than the condenser and is thereby further raised in temperature. Finally this water passes through the exhaust gas heat exchanger wherein it comes into heat exchange relationship with the extremely hot exhaust gases, and is thereby raised to a high degree of temperature, this highly heated water then flowing through the heat exchange coil 124 thereby giving up the heat which it has received to the hot water or other fluid located in the storage tank 125.

The water or other fluid in the storage tank 125 may obviously be used for any desired purpose, such as providing a supply of domestic hot water. This heated fluid is also adaptable for

providing a supply of heat to the reheater 16 and for this purpose the reheater 16 is connected to the outlet of the storage tank 125 by means of conduit 127. The outlet of the reheater 16 is connected by a conduit 128 to the intake of the circulating pump 42, the discharge of this pump being connected by conduit 129 to the inlet of the storage tank 125, a throttling valve 130 being interposed in said conduit.

In accordance with one form of our invention, we provide a temperature controlled system for maintaining the temperature within the conditioned space within predetermined limits, this being accomplished by controlling the flow of air over the cooling coil, and also by providing reheat. In accordance with our invention, upon falling temperature we first gradually reduce the air flow across the cooling coil 9 and increase the air flow through the by-pass, and if the temperature still continues to fall after the by-pass is wide open the reheater is placed into operation. The control mechanism for achieving this result will now be described.

Reference character 135 indicates generally a temperature controller, this temperature controller comprising a bellows 136 which is fixedly secured at its lower end and which is connected by means of a capillary tube 137 to a control bulb 138 located in the return air duct 2. The bellows 136 is arranged to cooperate with a bell crank lever 139 having an actuating arm 140 and a control arm 141, said control arm 141 being arranged to contact a control resistance 142 to form a control potentiometer. A spring 143 is connected to the actuating arm 140 and urges this arm downwardly against the bellows 136. The bellows 136, tube 137, and bulb 138 are filled with a suitable volatile fluid wherefore the pressures within bellows 136 will vary with the temperature to which the control bulb 138 is subjected. When the return air temperature increases, the pressure of the volatile fluid will increase, this causing expansion of the bellows 136 and movement of the control arm 141 to the left across resistance 142 against the action of spring 143. Upon falling return air temperature, the pressure of the volatile fill decreases, this permitting the spring 143 to cause travel of control arm 141 across the control resistance 142 in the opposite direction.

The return air controller 135 is connected to the proportioning motor 144, this motor being of the type shown and described in the Taylor Patent 2,028,110. As should now be apparent, the shaft 145 of the proportioning motor 144 will assume angular positions corresponding to the position of the control arm 141 on the control resistance 142. In other words, for each value of return air temperature the operating shaft 145 will assume a corresponding angular position. Mounted upon the operating shaft 145 are sliders 146 and 147 which cooperate with control resistances 148 and 149 respectively. The control resistance 148 and slider 146 comprise a control potentiometer for controlling the proportioning motor 15 which operates the face and by-pass dampers 12 and 13. The resistance 149 and the slider 147 comprise a control potentiometer for controlling the proportioning motor 150 which operates the reheat control valve 130. It will be noted that the control resistances 148 and 149 are arranged so as to occupy but a portion of the range of rotation of their respective sliders, the resistance 148 being arranged to the left of the center of movement of the sliders

146 and 147, and the resistance 149 being arranged to the right of such center of rotation. By this arrangement, it will be seen that as the shaft 145 rotates from its extreme counter-clockwise limit of rotation, the slider 146 will travel across the resistance 148 while the slider 147 engages contact segment 149a which is attached to the extreme left-hand end of resistance 149. Upon continued clockwise rotation of the shaft 145, the slider 146 will ride off the resistance 148 onto contact segment 148a, and the slider 147 will ride from the contact segment 149a onto the control resistance 149.

The proportioning motor 15 is connected to the resistance 148 and the slider 146 in such manner that upon clockwise rotation of the slider 146, the by-pass damper 13 is opened and the face damper 12 is closed. The proportioning motor 150 which controls the valve 130 is connected to the resistance 149 and the slider 147 in such manner that as the slider 147 is rotated in a clockwise direction the valve 130 is gradually opened. With the operating shaft 145 in the position shown, the slider 146 is engaging the midportion of the resistance 148 and consequently the proportioning motor 15 has assumed a position in which the face and by-pass dampers are in midposition. Also the slider 147 is contacting the contact segment 149a and therefore the proportioning motor 150 has assumed the position in which the reheat valve 130 is closed. If now should the return air temperature decrease, the temperature controller 135 will cause the proportioning motor 144 to rotate the shaft 145 in a clockwise direction, this causing movement of the slider 146 across the resistance 148 to the right, thereby causing the proportioning motor 15 to open further the by-pass damper 13 and to close further the face damper 12. At this time, the valve 130 will remain closed due to the slider 147 not having yet engaged the end of control resistance 149. Upon a further fall in temperature, the by-pass dampers 13 will be further opened and the face dampers 12 will be further closed, and when the fall in temperature is such that the slider 146 engages the extreme right-hand end of the resistance 148, the by-pass dampers 13 will be completely opened. Upon continued fall in temperature the slider 146 will begin sliding across the resistance 149, this causing the proportioning motor 150 to open gradually the valve 130. By this arrangement it should be apparent that so long as the space temperature is above a predetermined value the reheater valve 130 will remain closed and the control of the temperature will be effected solely by adjusting the face and by-pass dampers. When, however, the by-pass dampers are moved to completely open position and the temperature continues to fall, the reheater control valve 130 will begin opening, thereby providing a supply of heated fluid to the reheater, the quantity of heated fluid supplied being progressively increased as the temperature continues to fall.

From the foregoing description it should be apparent that our invention provides automatic control of the internal combustion engine in accordance with the relative humidity of the space to be conditioned, this system acting automatically to start the engine whenever the relative humidity rises to such a value that the cooling load would be sufficient to require the engine to operate at a satisfactory operating speed. It should further be apparent that as the relative

humidity increases, the speed of the engine will be increased, this causing the temperature of the cooling coil to be decreased thereby increasing the dehumidifying effect of the coil to prevent further increase in such relative humidity. Upon a decrease in relative humidity, the speed of the engine will be decreased, thus decreasing the temperature of the cooling coil and thereby decreasing the dehumidifying action. The compressor speed is therefore controlled in a manner to maintain proper relative humidity conditions within the space so long as the temperature within the space is not excessive.

Simultaneously with the control of the cooling coil temperature by the relative humidity conditions, the flow of air over the cooling coil is controlled in order to maintain the temperature conditions within the space at the desired value. Thus as the temperature within the space increases, the air flow across the cooling coil is increased to increase the cooling action of said cooling coil. It will be apparent that this increase in air flow will result in increasing the temperature of the cooling coil, thereby decreasing the dehumidifying effect of such coil. This will result in the relative humidity within the space eventually increasing and the humidity controller 66 in response will cause the speed of the engine to be increased to carry this increase in cooling load due to the temperature increase within the space. It should also be apparent that upon a decrease in temperature within the space the temperature controller 135 will act to cause closing of the face dampers 12 and opening of the by-pass dampers 13, this decreasing the flow of air across the cooling coil 9 thereby decreasing the cooling effect of said coil upon the air, thus tending to prevent further fall in space temperature.

In the event that the cooling load is light but the relative humidity within the space is excessive, the cooling coil may be lowered in temperature for dehumidification purposes, to such an extent that the space is overcooled even though the by-pass dampers 13 are wide open. If such a condition should occur, the temperature controller 135 will cause opening of the reheat control valve 130 thus providing a supply of heat for heating the air after it has been cooled for dehumidifying purposes. By the sequential control of the face and by-pass dampers and of the reheater, reheat is first provided by by-passing air around the cooling coil and when such arrangement is incapable of preventing the temperature from falling, the reheater is placed into operation. This sequential control thus provides reheat without actually adding heat to the air being conditioned so long as possible, and adds heat to the air being conditioned only when the operation of the system for dehumidification results in cooling of the air to such an extent that reheat is required. Then and only then is reheat supplied.

From the foregoing description, it should also be apparent that whenever the temperature within the conditioned space becomes excessive, the control of the speed of the internal combustion engine is taken away from the humidity controller and the engine is operated even though the humidity may be relatively low. The system which we have disclosed, therefore, provides a very flexible and simple arrangement for maintaining proper conditions within the conditioned space regardless of the type of conditioning load.

Figure 2

Referring now to Fig. 2, we have shown in this figure a modified form of control system. The internal combustion engine controls, the refrigeration system and the conditioning chamber are substantially the same as in Fig. 1 and are indicated by the same reference characters. In this embodiment, however, the compressor speed is not varied in accordance with changes in relative humidity as in Fig. 1, but is varied in a manner to maintain the air leaving the cooling coil at a constant dew-point temperature. For this purpose the compressor is controlled in accordance with the suction pressure of the refrigeration system by means of the suction pressure controller 200, this controller being arranged to control the proportioning motor 46 which in turn adjusts the throttle valve 45. Also, in Fig. 2, instead of controlling the dampers 12 and 13 in accordance with return air temperature alone, the control of said dampers is effected in accordance with the effective temperature within the conditioned space, the value of effective temperature being raised or lowered in accordance with variations in outside temperature.

Due to the use of dew-point control, it is desirable to pass air over the cooling coil at all times. For this purpose, the face dampers 12 may be arranged so that they do not completely close, thereby insuring that at least a predetermined amount of air will flow across said coil at all times.

Referring now to the suction pressure controller 200, this controller comprises a bellows 201, the interior of which is connected to the suction line 22 of the refrigeration system by means of a conduit 202. The bellows 201 is arranged to actuate a bell-crank lever comprising an actuating arm 203 and a control arm 204, said control arm cooperating with a control resistance 205 to form a control potentiometer for controlling the proportioning motor 46. The actuating arm 203 is connected to a spring 206 which urges said arm downwardly against the bellows 201. Upon an increase in suction pressure the bellows 201 will expand, this causing counter-clockwise rotation of actuating arm 203 and movement of control arm 204 to the left across control resistance 205, this causing the proportioning motor 46 to rotate its operating arm in a direction to open further the throttle valve 45. Upon a decrease in suction pressure the bellows 201 will be contracted by the action of spring 203, this causing travel of the control arm 204 to the right across resistance 205, which in turn results in movement of the proportioning motor 46 in a direction to move the throttle valve towards closed position. The suction pressure controller 200 therefore acts to increase the speed of the engine upon an increase in suction pressure and to decrease the speed of the engine upon a decrease in suction pressure in a manner to maintain the suction pressure within predetermined limits.

The proportioning motor 15 which actuates the face and by-pass dampers 12 and 13 comprises an operating shaft 208 upon which is mounted a lever 209 which in turn is connected to the operating member 14 for the dampers. The operating shaft 208 is rotated through a gear train 210 by means of a pair of induction motors comprising armatures 211 and 212 and corresponding field coils 213 and 214. It will be understood that the motor formed of armature 211 and field coil 213 acts to drive the operating shaft 208 in one di-

rection and that the motor formed of armature 212 and field coil 214 acts to drive said operating shaft in the opposite direction.

The energization of field coils 213 and 214 is controlled by means of the balancing relay 215, this relay comprising connected relay coils 216 and 217. The relay coils 216 and 217 control through a suitable armature a switch arm 218 which cooperates with a pair of contacts 219 and 220. It will be understood that when relay coil 217 is energized more highly than relay coil 216, the switch arm 218 will engage the contact 220. Conversely, when the relay coil 216 is energized more highly than relay coil 217 the switch arm 218 will be caused to engage the contact 219.

For controlling the energization of the relay coils 216 and 217 are a return air temperature controller 221, a space relative humidity controller 222, an outside temperature compensator 223, and the balancing potentiometer 224, this balancing potentiometer comprising a slider 225 mounted upon the operating shaft 208 of the proportioning motor, and a balancing resistance 226.

Referring to the return air temperature controller 221, this controller comprises a bellows 227 connected by a capillary tube 228 to a control bulb 229 located in the return air duct. It will be understood that if desired this controller may be located within the conditioned space instead of in the return air duct. The bellows, bulb, and tube are filled with a suitable volatile fluid wherefore the pressures within the bellows vary in accordance with the return air temperature. The bellows 227 is fixed at its lower end and is arranged to actuate a lever 230 which in turn actuates a control arm 231 and a corrector arm 232, the control arm 231 engaging a control resistance 233 and the corrector arm 232 engaging a corrector resistance 234. It will be understood that as the space temperature decreases, the bellows will contract under the action of the spring shown, this causing counter-clockwise rotation of the control arms 231 and 232 across their respective resistances, and that upon an increase in temperature, the bellows 227 will expand thus causing movement of said control arms in the opposite direction.

The humidity controller 222 comprises a humidity responsive device including a plurality of strands 235 of hair or other moisture responsive material, these strands being connected at their upper ends to a clamping member 236 and at their lower ends to a clamping member 237, this clamping member being secured to a suitable stationary element. The upper clamping member 236, however, is connected to the actuating arm 238 of a bell crank lever including a control arm 239. A tension spring 240 is also connected to the actuating arm 238 and serves to maintain the strands 235 taut. Upon a decrease in relative humidity, the strands 235 will decrease in length, this causing downward movement of the actuating arm 238 against the action of the spring 240 thus rotating the control arm 239 to the left across its control resistance 241. Upon an increase in humidity, however, the strands 235 will increase in length and the actuating arm and control arm will be rotated in the opposite direction under the action of the spring 240.

The outside temperature compensator 223 comprises a bellows 245 which is connected by a tube 246 to a control bulb 247 which may be located in the fresh air duct. This bulb, tube and bellows are filled with a suitable volatile fluid wherefore the pressure within the bellows 245

varies in accordance with outside temperature. Bellows 245 cooperates with a bell crank lever having an actuating arm 248 and a control arm 249, said control arm cooperating with the control resistance 250 to form a control potentiometer. It will be apparent that upon an increase in outside temperature, the bellows 245 will expand against the action of the spring shown, thus causing movement of the control arm 249 to the right across the control resistance 250. Conversely, upon a decrease in temperature the bellows 245 will contract and the control arm 249 will be moved in the opposite direction under the action of the spring.

Reference character 251 indicates a step-down transformer having a high voltage primary 252 and a low voltage secondary 253. The upper end of secondary 253 is connected to a wire 254, this wire in turn being connected to the left end of resistance 241 by wire 255, to the left end of resistance 233 by wire 256, to the left end of the balancing resistance 226 by the wire 257, and to the right-hand end of resistance 250 by wire 258. To the lower end of the transformer secondary 253 is connected a wire 259, this wire being connected to the other ends of the four resistances just mentioned. The left-hand end of the relay coil 216 is connected to the wire 254 by means of wire 260 and is therefore connected to the upper end of the transformer secondary 253. The right-hand end of the relay coil 217 is connected by wire 261 to the wire 259 and is therefore connected to the lower end of the transformer secondary. From the foregoing wiring arrangement, it should be apparent that the three control resistances 233, 241 and 250, the balancing resistance 226, and the relay coils 216 and 217 in series, are connected in parallel across the terminals of the secondary 253. A flow of current will therefore take place through each of the resistances and through the relay coils. To the junction of relay coils 216 and 217 is connected a wire 262, this wire being connected to the control arms 231, 239, 249, and to the balancing arm 226 as shown, rheostats 263, 264 and 265 being interposed between this wire 262 and the control arms 239, 249, and the balancing arm 225 respectively. By this arrangement it will be apparent that each of the control arms and the balancing arm divides its respective resistance into a first portion which is in parallel with the relay coil 216 and a second portion which is in parallel with the relay coil 217. Movement of any one of the control arms or the balancing arm across its respective resistance will therefore vary the resistance in parallel with each of the relay coils, and thereby vary the relative energizations of said relay coils.

With the controllers in the position shown, each control arm is engaging the midportion of its corresponding resistance and the proportioning motor 15 has therefore assumed an intermediate position in which the balancing arm 225 engages the center of the balancing resistance 226, this resulting in the relay coils 216 and 217 being equally energized, thereby causing the switch arm 218 to be disengaged from the contacts 219 and 220. For this position of the motor the dampers 12 and 13 are each in half-open position. If now should the space temperature increase, the control arm 231 of the controller 221 will be shifted to the right, this decreasing the portion of the control resistance 233 which is in parallel with the relay coil 217 and increasing the portion of said resistance which is in parallel

with the relay coil 216. This will result in a decrease in current flow through the relay coil 217 and an increase in the current flow through relay coil 216, this causing the switch arm 218 to engage the contact 219 and energize the motor field 213 by a circuit as follows: transformer secondary 253, wire 254, wire 266, motor field 213, wire 267, contact 219, switch arm 218, and wire 268 to the other side of secondary 253. This energization of the motor field 213 will cause the operating shaft of the motor to be rotated in a direction to open the face dampers 12 and to close the by-pass dampers 13. At the same time the balancing arm 225 will be shifted to the left across the balancing resistance 226. This will decrease the portion of said balancing resistance which is in parallel with the relay coil 216 and increase the portion of said resistance which is in parallel with the relay coil 217, this causing an increase in current flow in the relay coil 217 and a decrease in current flow in relay coil 216, thereby tending to balance out the initial unbalancing effect of the controller 221. When the shaft 208 has been rotated sufficiently to cause the balancing potentiometer to balance out the initial unbalancing action of the controller 221, the current flow in the relay coils 216 and 217 will become equalized, this resulting in the switch arm 218 disengaging the contact 219 thereby stopping the motor in this new position. It will be apparent that the greater the initial unbalancing action is, the further the shaft 208 must rotate for causing the balancing potentiometer to balance out such unbalancing action. The rotation of the shaft 208 will therefore be in proportion to the movement of the control arm 231 on its control resistance. The movements of the face and by-pass dampers will therefore be in proportion to the space temperature change. Upon a fall in temperature it will be apparent that the controller 221 will cause the relay coil 217 to be more highly energized than the relay coil 216, this causing the switch arm 218 to engage the contact 220, this energizing the motor field 214 to rotate the shaft 208 in a direction to close the face dampers 12 and to open the by-pass dampers 13. As in the case of increasing temperature, the movement of the dampers 12 and 13 upon falling temperature will be in proportion to the change in temperature.

The control arrangement just described will act to maintain the space temperature within the range of the controller 221 assuming of course that the capacity of the refrigeration system is sufficient for all conditions. Thus, if the cooling load should increase, the space temperature will increase and in response to such an increase in temperature the controller 221 will cause the face dampers to be opened further and the by-pass dampers to be moved towards closed position. This will result in an increase in air flow across the cooling coil, thereby increasing the cooling effect of the refrigeration system to offset the increase in refrigeration load.

It will be noted that the rheostat 265 is interposed between the balancing potentiometer and the junction of the relay coils 216 and 217. The purpose of this rheostat is to desensitize the balancing potentiometer, thereby increasing the sensitivity of the controller 221. In other words, the rheostat 265 acts to limit the flow of current through the balancing arm 225 of the balancing potentiometer and thus decreases the effect of said balancing potentiometer upon the relative energizations of relay coils 216 and 217.

By thus desensitizing the balancing potentiometer relative to the control potentiometer of the controller 221, a relatively small movement of the control arm 231 on its control resistance 233 may be made to create an unbalancing action on the relay 215 such that a relatively large movement of the balancing potentiometer is required for rebalancing. Thus by properly adjusting the rheostat 265, the proportioning motor 15 may be made to shift the dampers from one extreme position to the other for a movement of the control arm 231 through but part of its operating range. In other words, the rheostat 265 acts to make the operating range of the controller 221 less than its total range.

If the humidity within the space should increase, the control arm 239 will be shifted to the right across the control resistance 241, this having the effect of decreasing the portion of said resistance which is in parallel with the relay coil 217 and increasing the portion of said resistance which is in parallel with the relay coil 216, thus causing a decrease in current flow in coil 217 and an increase in current flow in coil 216, this causing the switch arm 218 to engage the contact 219, thereby energizing the motor field 213 to cause rotation of the operating shaft 208 in the direction to open the face dampers 12 and to close the by-pass dampers 13. The resulting movement of the balancing potentiometer will tend to balance out the initial unbalancing effect created by the controller 222, and when the rotation of the shaft 208 is such that the balancing potentiometer completely balances out said unbalancing effect, the switch arm 218 will disengage contact 219, thereby stopping the motor and dampers in this new position. Upon a decrease in humidity it will be apparent that the opposite action will take place. In other words, the operating shaft of the motor will be rotated in the opposite direction an amount corresponding to the decrease in humidity. The humidity controller 222 will therefore act to cause the proportioning motor 15 to position the dampers for increasing the air flow across the cooling coil 9 upon an increase in humidity and to cause opposite movement upon a decrease in humidity.

Assuming now that the space temperature remains constant but the relative humidity increases, the controller 222 in the manner just described will cause movement of the face damper 12 towards open position and the by-pass damper 13 towards closed position. This will result in an increase in cooling effect of the cooling coil 9 which ultimately will result in the space temperature beginning to fall. As the space temperature falls, the controller 221 will cause the proportioning motor 15 gradually to close the face dampers 12 and to open the by-pass dampers 13, thereby decreasing the cooling effect of the system, and when the space temperature falls sufficiently that the decrease in cooling effect caused thereby is sufficient to prevent further fall in temperature, the space temperature will be held constant at this new value. Hence upon an increase in humidity, the controller 221 will be caused to maintain a lower value of space temperature. In a similar manner, it will be apparent that upon a decrease in humidity, the controller 222 will be caused to maintain an increased value of temperature. The humidity controller 222 therefore acts as a compensator or adjustor for the return air temperature controller 221; said humidity con-

troller acting to change the control point of said temperature controller upon variation in humidity. It will be observed that the rheostat 263 is connected between the control arm 239 of said humidity controller and the junction of the relay coils 216 and 217. The purpose of this rheostat is to vary the effect of the humidity controller upon the control point of the temperature controller. By properly adjusting this rheostat, the humidity controller may be made to vary the control point of the temperature controller upon a change in relative humidity an amount which just compensates for the change in effective or comfort temperature caused by such change in relative humidity. The temperature controller 221 and the humidity controller 222 therefore cooperate to maintain a constant effective temperature within the space, the dry bulb temperature being raised or lowered upon changes in relative humidity to accomplish this result.

Assuming now that the space temperature and relative humidity remain constant, if the outside temperature should increase, the control arm 249 of the controller 223 will be shifted to the right across the control resistance 250, this acting to decrease the portion of said resistance which is in parallel with the relay coil 216, and to increase the portion of said resistance which is in parallel with the relay coil 217, this causing an increase in current flow in relay coil 217 and a decrease in current flow in relay coil 216, which results in the switch arm 218 engaging the contact 220 for rotation of the operating shaft 208 in a direction to close the face dampers 12 and to open the by-pass dampers 13. Simultaneously the balancing arm 225 of the balancing potentiometer will be shifted to the right across the resistance 226, this decreasing the portion of said resistance which is in parallel with relay coil 217 and increasing the portion of said resistance which is in parallel with relay coil 216, thereby tending to balance out the initial unbalancing action of the controller 223. When the movement of the dampers and the balancing arm 225 is sufficient to cause rebalancing of the relay, the switch arm 218 will disengage contact 220 and the proportioning motor will stop in this new position. It should thus be apparent that upon an increase in outside temperature, the controller 223 will act to cause the air flow across the cooling coil 9 to be decreased and the air flow by-passed therearound to be increased. Upon a decrease in outside temperature the opposite action will take place, that is, the dampers will be moved so that the air flow across the cooling coil 9 is increased.

Assuming now that the outside temperature rises, the dampers 12 and 13 will be positioned in the manner just described to cause a decrease in flow of air across the cooling coil thereby decreasing the cooling effect of said coil. This decrease in cooling effect will eventually result in rising of temperature within the conditioned space, this rise in temperature acting upon the controller 221 in a manner to cause opening of the face dampers 12 and closing of the by-pass dampers 13 to increase gradually the cooling effect. When the rise in space temperature is such that the resulting increase in cooling effect caused by the controller 221 is sufficient to prevent further rise in temperature, the space temperature will be held constant at this new value. The outdoor temperature responsive controller therefore acts upon rising outdoor temperature to cause the return air temperature controller to

maintain a higher value of temperature within the conditioned space. It will be apparent that upon falling outdoor temperature, the opposite action will take place, namely, the controller 221 will be caused to maintain a lower value of temperature within the conditioned space. The purpose of this controller is to provide an adjustment of indoor temperature with outdoor temperature in accordance with standard air conditioning practice. By adjusting the rheostat 264 the effect of the controller 223 on the control point of the indoor controller 221 may be varied as desired.

In this embodiment of the invention, the use of a reheater in many cases will be unnecessary for the by-pass arrangement will usually provide sufficient reheat for the air discharged from the cooling coil. In certain installations, however, the continuous operation of the cooling coil for maintaining a constant dew-point of the discharged air may at times cause overcooling of the conditioned space, and a reheater may therefore be desirable. If desired, the reheater if employed may be sequentially controlled with the face and by-pass dampers as in Fig. 1. In Fig. 2, however, instead of illustrating modulating control of the reheater as in Fig. 1, we have shown in this figure a two-position type of control. This reheat controller comprises a cam 270 mounted upon the operating shaft 208 of the proportioning motor 15, this cam cooperating with a pivoted switch carrier 271 carrying a mercury switch 272. The cam 270 is arranged upon the proportioning motor shaft 208 in such manner that the switch is tilted to closed position only when the operating shaft is moved to its extreme limit of rotation, in which the face dampers 12 are moved to their minimum positions and the by-pass dampers 13 are opened. For other positions of the face and by-pass dampers, the cam 270 will cause tilting of the mercury switch 272 to open position. The pump 42 in this instance, instead of being driven by the internal combustion engine is driven by an electric motor 273, the operation of this motor being controlled by the mercury switch 272. From this arrangement, it will be apparent that as the space temperature falls, the face dampers 12 will be closed gradually and the by-pass dampers 13 will be opened gradually. Upon continued fall in temperature, the face dampers 12 will eventually assume a maximum closed position and the by-pass dampers will assume a wide open position, at which time the cam 270 will be rotated just sufficiently to cause making of mercury switch 272 which results in operation of the pump motor 273, causing a circulation of heated water from the storage tank 125 through the reheater 16 and back to the tank. When the pump is out of operation, circulation of water from the tank 125 through the reheater 16 is prevented by means such as a loaded check valve 274.

During the operation of the system just described, it will be apparent that the return air temperature controller 221, the humidity controller 222, and the outside temperature controller 223 will act to position the face and by-pass dampers in such manner that an effective temperature, as determined by the prevailing value of outside temperature, is maintained. Thus upon an increase in the effective temperature, the face dampers 12 will be moved towards open position and the by-pass dampers 13 will be moved towards closed position in a manner to increase the cooling effect of the system suf-

ficiently to prevent further increase in effective temperature. The resulting increase in air flow over the cooling coil 9 will increase the amount of refrigerant evaporated within said cooling coil, and hence will cause the suction pressure to increase. This increase in suction pressure will effect the suction pressure controller 200 in a manner to cause the proportioning motor 46 to open the throttle valve 45 farther. This will increase the flow of fuel to the internal combustion engine 25, thereby increasing its speed which in turn results in increased output of the compressor 17. In this manner the compressor output will be increased upon an increase in effective temperature within the space. Upon falling effective temperature, it will be apparent that the opposite action will take place, namely, that the face and by-pass dampers will be positioned to restrict the flow of air across the cooling coil 9. This will result in less refrigerant being evaporated within said cooling coil, which in turn will cause lowering of the suction pressure. In response to this decrease in suction pressure, the pressure controller 200 will cause operation of the proportioning motor 46 in a direction to move the throttle valve 45 towards closed position. This will result in decreasing the fuel supply to the engine, thereby decreasing the operation of the compressor in a manner to prevent further decrease in suction pressure. Upon falling temperature, therefore, the system will act to decrease the flow of air over the cooling coil 9 and this will result in the suction pressure controller causing slowing down of the engine speed. The control system which we have disclosed will therefore act to vary the engine speed in accordance with the cooling load.

Upon continued fall in cooling load the space temperature will decrease further, this eventually resulting in partially closing of the face dampers 12 and opening of the by-pass dampers 13, thereby reducing the air flow across the cooling coil 9 to a minimum. At this time the mercury switch 272 will be tilted to closed position by the cam 270 which causes operation of the pump 42 for supplying heated fluid to the reheater 16, thereby preventing any further fall in temperature.

It will be noted that in this embodiment the proportioning motor 46 which positions the throttle valve 45 actuates also a mercury switch 275, this mercury switch corresponding to the mercury switch 102 of Figure 1. Thus whenever the throttle valve 45 is closed to such an extent as to indicate that the engine is operating at too low a speed for satisfactory operation, the mercury switch 275 will be tilted to open position, this causing stopping of the engine. It will also be apparent that as the suction pressure rises and causes the proportioning motor 46 to open the throttle valve 45 to such an extent as to demand operation of the engine at a satisfactory speed, the mercury switch 275 will be tilted to closed position, this energizing the ignition circuit for the engine and also energizing the starting apparatus therefor, thereby placing the engine in operation. By this arrangement, therefore, the speed of the engine will be varied in accordance with the refrigeration load, and when the refrigeration load falls to such an extent as to require operation of the engine at too low a speed the engine will be placed out of operation.

While we have shown and described only two forms which our invention may take, it is obvious that many other changes which are within the

scope of our invention will be apparent to those skilled in the art. We therefore desire to be limited only by the scope of the appended claims and the prior art.

We claim as our invention:

1. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for conditioning thereof, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, an internal combustion engine for driving said compressor, control means for varying the speed of said internal combustion engine, motor means for adjusting said control means to vary said compressor output, humidity responsive means for controlling said motor means in a manner to cause the engine speed to be increased progressively with increasing humidity, and means responsive to temperature for also controlling said motor means, said temperature responsive means being arranged to cause increase in speed of said engine when the temperature exceeds a predetermined value.

2. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for conditioning thereof, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, an internal combustion engine for driving said compressor, control means for varying the output of said internal combustion engine, a controller for stopping and starting said internal combustion engine, motor means for adjusting said control means and for positioning said controller, said controller being positioned by said motor means to stop said internal combustion engine when the said control means is adjusted to cause an engine output below a predetermined minimum and to cause starting of said engine when said control means is adjusted to cause an engine output above said predetermined minimum, and humidity responsive means for controlling said motor means, said humidity responsive means and said motor means being arranged to cause the output of said engine to be progressively increased with increasing values of humidity.

3. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for conditioning thereof, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, an internal combustion engine for driving said compressor, control means for varying the output of said internal combustion engine, motor means for adjusting said control means to vary said output, humidity responsive means for controlling said motor means in a manner to cause the engine output to be increased progressively with increasing humidity, and means for starting said engine when said engine output controlling means is adjusted to demand an engine output above a predetermined minimum value.

4. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for conditioning thereof, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, an internal combustion engine for driving said compressor, control means for varying the output of said internal combustion engine, motor means for adjusting said control means to vary said

output, humidity responsive means for controlling said motor means in a manner to cause the engine output to be increased progressively with increasing humidity, and means for stopping said engine when said engine output controlling means is adjusted to demand an engine output below a predetermined minimum value.

5. In an air conditioning system, in combination, a cooling device through which air passing to a space is adapted to be passed for conditioning thereof, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, an internal combustion engine for driving said compressor, control means for varying the output of said internal combustion engine, motor means for adjusting said control means to vary said output, a humidity controller influenced by the space relative humidity, and means for rendering said humidity controller effective to control said motor means and hence said engine control means, said last recited means comprising means controlled by said humidity controller for varying the flow of air through said cooling device, and means actuated in response to resulting changes in condition of said cooling device connected to said motor means in a manner tending to maintain said condition at a predetermined value.

6. In an air conditioning system, in combination, a cooling device through which air passing to a space is adapted to be passed for conditioning thereof, flow control means for controlling the flow of air through said cooling device, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, an internal combustion engine for driving said compressor, control means for varying the speed of said internal combustion engine, motor means for adjusting said control means to vary said speed, space humidity responsive means for controlling said motor means in a manner to cause the engine speed to be increased progressively with increasing humidity, and space temperature responsive means for controlling said flow control means in a manner to decrease the flow of air through said cooling device upon decrease in temperature, while increasing said air flow upon increase in temperature.

7. In an air conditioning system, in combination, a cooling device through which air passing to a space is adapted to be passed for conditioning thereof, flow control means for controlling the flow of air through said cooling device, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, an internal combustion engine for driving said compressor, control means for varying the output of said internal combustion engine, motor means for adjusting said control means to vary said output, space humidity responsive means for controlling said motor means in a manner to cause the engine output to be increased progressively with increasing humidity, space temperature responsive means for also controlling said motor means, in a manner to increase the engine output independently of said humidity responsive means when space temperature rises to a predetermined high value, and space temperature responsive means for controlling said flow control means in a manner to decrease the flow of air through said cooling device upon decrease in temperature, while increasing said air flow upon increase in temperature.

8. In an air conditioning system, in combination, a cooling device through which air passing to a space is adapted to be passed for conditioning thereof, flow control means for controlling the flow of air through said cooling device, a first motor means for actuating said flow control means, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, an internal combustion engine for driving said compressor, control means for varying the speed of said internal combustion engine, a second motor means for adjusting said control means to thereby vary the speed of said engine, space temperature responsive means for controlling one of said motor means, and space humidity responsive means for controlling the other of said motor means.

9. In an air conditioning system, in combination, a cooling device through which air passing to a space is adapted to be passed for conditioning thereof, flow control means for controlling the flow of air through said cooling device, motor means for actuating said flow control means, means including space temperature and relative humidity responsive means and outside temperature responsive means for conjointly controlling said flow control means, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, control means for varying the output of said internal combustion engine, motor means for adjusting said control means to vary said output, and means responsive to the condition of said cooling device for controlling said last mentioned motor means in a manner tending to maintain said condition constant.

10. In an air conditioning system, in combination, a cooling device through which air passing to a space is adapted to be passed for conditioning thereof, flow control means for controlling the flow of air through said cooling device, motor means for actuating said flow control means, thermostatic means influenced by outside temperature for controlling said motor means to thereby vary the action of said flow control means in accordance with variations in outside temperature, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, control means for varying the output of said internal combustion engine, motor means for adjusting said control means to vary said output, and means responsive to the condition of said cooling device for controlling said last mentioned means in a manner tending to maintain said condition constant.

11. In an air conditioning system, in combination, a cooling device through which air passing to a space is adapted to be passed for conditioning thereof, flow control means for controlling the flow of air through said cooling device, motor means for actuating said flow control means, means including space temperature responsive means for controlling said motor means to thereby vary the action of said flow control means in accordance with variations in space temperature, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, control means for varying the output of said internal combustion engine, motor means for adjusting said control means to vary said output, and means responsive to the condition of said cooling device for con-

trolling said last mentioned motor means in a manner tending to maintain said condition constant.

12. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, automatic starting mechanism for said engine, said automatic starting mechanism having a control switch, a motor for actuating said speed controller and said control switch and means including a device responsive to the relative humidity in said space for determining the position assumed by said motor.

13. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, automatic starting mechanism for said engine, said automatic starting mechanism having a control switch, a motor for actuating said speed controller and said control switch, a controller for said motor, said controller being connected to said motor, and means responding to the relative humidity in said space for actuating said controller.

14. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, automatic starting mechanism for said engine, said automatic starting mechanism having a control switch, a motor for actuating said speed controller and said control switch, and means for changing the position assumed by said motor in response to changes in relative humidity, said last named means comprising a damper positioned by a humidity responsive device for controlling the load applied to said cooling device and a device responsive to the load applied to said cooling device for controlling said motor.

15. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for a conditioning action, a by-pass for flow of air around said cooling device, damper means for controlling the proportions of air passed through said cooling device and through said by-pass, damper motor means for positioning said damper means, thermostatic means responsive to the temperature in said space for controlling said damper motor means, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, automatic starting mechanism for said engine, said automatic starting mechanism having a control switch, a motor for actuating said speed controller and said control switch in a manner to start said engine and increase the speed of said engine as said motor

moves from one position to another, and a controller for controlling the position assumed by said motor.

16. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for a conditioning action, a by-pass for flow of air around said cooling device, damper means for controlling the proportions of air passed through said cooling device and through said by-pass, damper motor means for positioning said damper means, thermostatic means responsive to the temperature in said space for controlling said damper motor means, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, automatic starting mechanism for said engine, said automatic starting mechanism having a control switch, a motor for actuating said speed controller and said control switch in a manner to start said engine and increase the speed of said engine as said motor moves from one position to another, and means responding to relative humidity and connected to said motor for controlling the position assumed by said motor.

17. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for a conditioning action, a by-pass for flow of air around said cooling device, damper means for controlling the proportions of air passed through said cooling device and through said by-pass, damper motor means for positioning said damper means, thermostatic means responsive to the temperature in said space for controlling said damper motor means, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, automatic starting mechanism for said engine, said automatic starting mechanism having a control switch, a motor for actuating said speed controller and said control switch in a manner to start said engine and increase the speed of said engine as said motor moves from one position to another, and means responding to a condition which is a measure of the load applied to said cooling device by said damper means for controlling the position assumed by said motor.

18. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, automatic starting mechanism for said engine, said automatic starting mechanism having a control switch, a motor for actuating said speed controller, means responsive to the relative humidity in the space for controlling said motor to thereby vary the speed of said engine in accordance with the humidity in said space, and means for closing said control switch irrespective of the value of relative humidity when space temperature rises to a predetermined value for thereby placing said engine into operation.

19. In an air conditioning system, in combination,

bination, a cooling device through which air in a space is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, automatic starting mechanism for said engine, said automatic starting mechanism having a control switch, a motor for actuating said speed controller, means responsive to the relative humidity in the space for controlling said motor to thereby vary the speed of said engine in accordance with space relative humidity, and means for closing said control switch irrespective of the value of relative humidity in said space when the temperature rises to a predetermined value for thereby placing the engine into operation.

20. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, a motor for actuating said speed controller, said motor having control line means, a thermostat connected into said control line means for controlling said motor, and a humidity controller also connected into said control line means for causing the motor to increase the engine speed upon increase in humidity.

21. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, a motor for actuating said speed controller, said motor having control line means, a thermostat connected into said control line means for controlling said motor, a humidity responsive means also connected into said con-

trol line means for causing the motor to increase the engine speed upon increase in humidity and for starting said engine when the humidity rises above a predetermined value.

22. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, a motor for actuating said speed controller, said motor having control line means, a thermostat connected into said control line means for controlling said motor, a humidity controller also connected into said control line means for causing the motor to increase the engine speed upon increase in humidity and for stopping said engine when the relative humidity in said space falls to a predetermined value.

23. In an air conditioning system, in combination, a cooling device through which air in a space is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a mechanical refrigeration system including a compressor, a variable speed internal combustion engine for driving said compressor at varying speeds, a speed controller for said engine, automatic starting mechanism for said engine, said automatic starting mechanism having a control switch, electrical means for actuating said starting switch and said speed controller, control means for controlling said electrical means in a manner to start the engine and vary its speed, and other control means for controlling said electrical means to cause closing of said control switch irrespective of the operation of said first control means for thereby placing said engine into operation, one of said control means responding to the temperature of said space and the other of said control means responding to the relative humidity of the air in said space.

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