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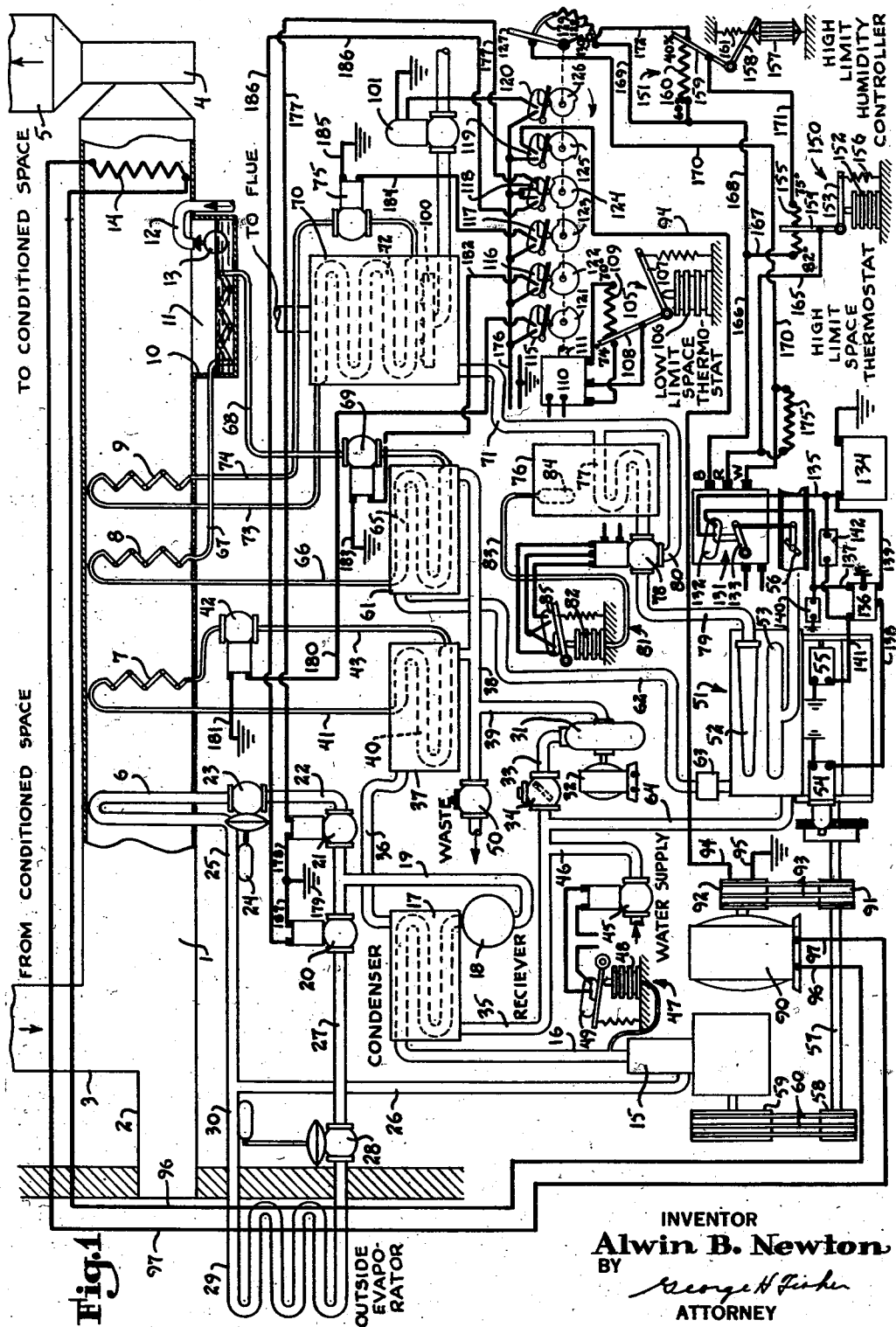
A. B. NEWTON

2,266,238

AIR CONDITIONING SYSTEM

Filed Feb. 7, 1938

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

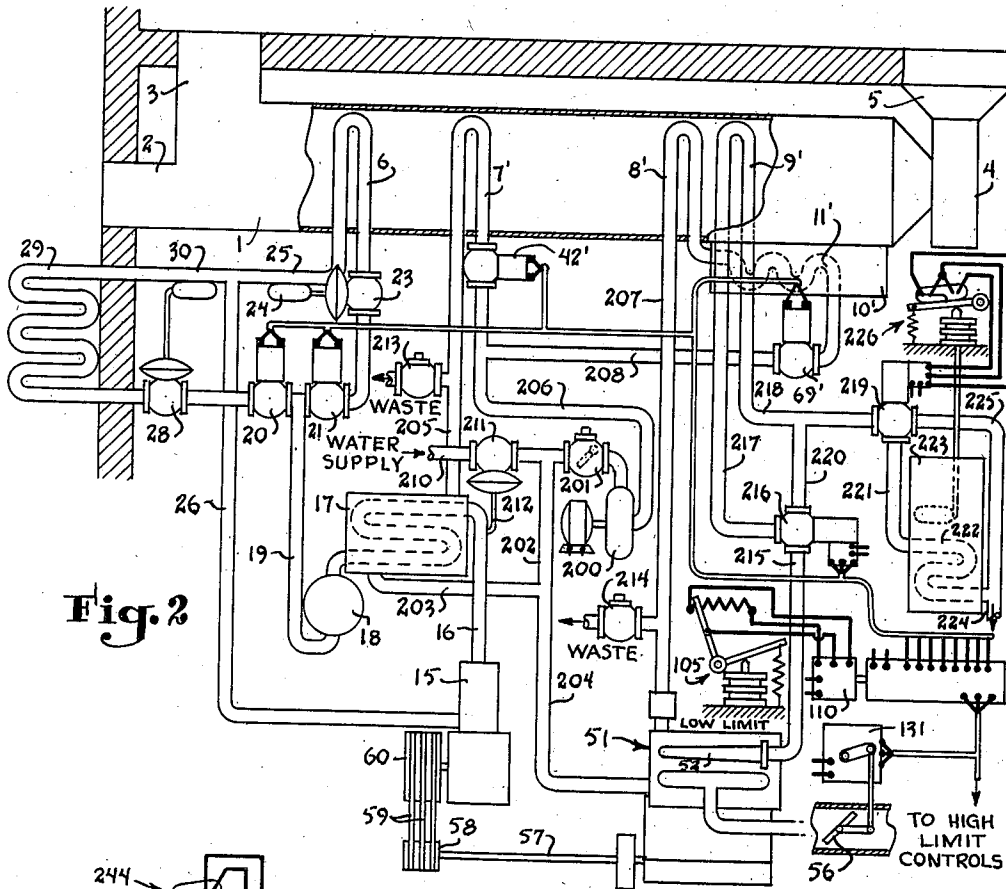


Fig. 2

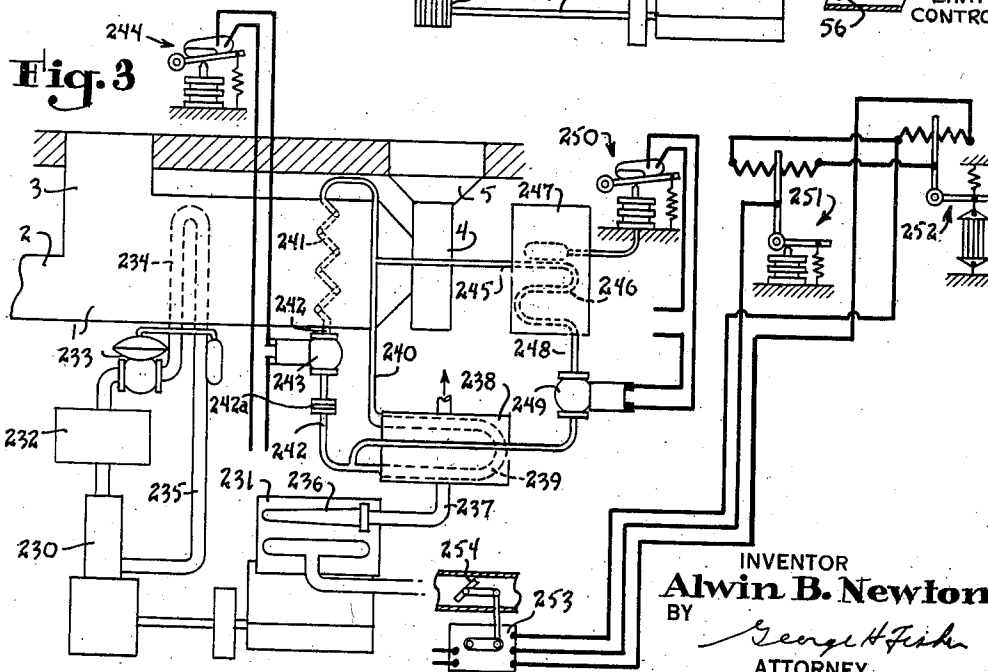


Fig. 3

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2,266,238

AIR CONDITIONING SYSTEM

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23 Claims. (Cl. 257—3)

This invention relates in general to air conditioning systems and is more particularly concerned with air conditioning systems of the type which are adapted to cool a space during the summer and to heat a space during the winter.

The primary object of my invention lies in the provision of a novel year-around air conditioning system which is adapted to automatically maintain the proper temperature and humidity within a conditioned space at all times. More specifically, it is an object of this invention to provide a refrigeration system which is especially adapted for air conditioning purposes, such system acting to cool the space when cooling is required and to heat the space when heating is required, the heat utilized for heating the space being pumped from a source of heat at a low temperature level to a higher temperature for heating the space.

A further object of this invention is the provision of a system of this type with a heat engine type of prime mover such as an internal combustion engine, and the provision of means for automatically cooling the engine and condenser when the system is operating on the summer cycle, and for transferring heat from the engine and condenser to the space when heat is necessary for maintaining proper conditions within the space.

Another object is in the provision of a system of this type with an easily controlled and efficient arrangement for transferring heat from the exhaust gases of the internal combustion engine to the space and/or for transferring waste heat from the engine to a supply of domestic water for heating the same.

In systems of this general type wherein heat is pumped from outside into the space by means of a reversed refrigeration system, the capacity of the system tends to decrease as the outdoor temperature falls. Heretofore, this has limited the application of installations of this character to locations in mild climates. It is a further object of my invention to provide a system of this type which may be utilized in severe climates as well as in mild climates, thereby enabling the advantages and economy of reversed cycle systems to be had in severe climates where economy in heating is an important factor. In accordance with my invention, this result is achieved by the use of an additional heating device which is driven by the internal combustion engine which drives the refrigeration compressor, and which remains out of operation as long as the reversed cycle system remains effective, but which replaces the reversed cycle system for supplying

heat and for loading the engine when the reversed cycle system becomes ineffective.

Another factor which has limited the commercial development of reversed cycle systems is the initial cost of systems of this character. Due to systems of this type requiring considerably more apparatus than other types of systems such as steam, hot water, or hot air systems, reversed cycle systems have not been commercially feasible. It is an object of my invention to provide an arrangement for considerably lowering the initial costs of systems of the reversed cycle type. This object is achieved by the provision of an auxiliary heating device for supplying additional heat to the system, and a control mechanism for placing this auxiliary heater in operation during peak load conditions. By this arrangement, the installation may be made considerably smaller than would be necessary for carrying peak loads which occur during only a very small part of the heating season.

A further object of this invention is the provision of a simple and effective automatic control system for systems of the type mentioned, which provides for maintaining proper temperature and humidity conditions within the conditioned space.

Other objects of my invention lie in various sub-combinations forming part of the complete system, and will become apparent from the following description and the appended claims.

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

Figure 1 shows diagrammatically one form which my invention may take;

Figure 2 illustrates diagrammatically a modification of the system shown in Figure 1; and in which

Figure 3 shows a modified form of exhaust gas heat utilizing means which may be employed independently or with the systems shown in Figures 1 and 2.

Referring to Figure 1, reference character 1 indicates a conditioning chamber having a fresh air inlet 2 and a return air inlet 3 which conducts air from a space being conditioned to the chamber 1. The discharge end of the conditioning chamber 1 is connected to the inlet of a fan 4, which in turn is connected to a discharge duct 5 for conveying conditioned air to the space being conditioned. Within the chamber 1 is located a direct expansion cooling coil 6, a condenser heating coil 7, a jacket water heating coil 8, and an exhaust heating coil 9. Also located within

the conditioning chamber 1 is a humidifier 10 which may take the form of a water pan having a heating coil 11 located therein. The humidifier 10 may be provided with a water supply pipe 12 and a float valve 13 for maintaining a predetermined water level within the water pan. Also located within the conditioning chamber 1 is an electric strip heater 14.

The direct expansion cooling coil 6 forms a part of a refrigeration system including a compressor 15. The discharge line 16 of the compressor leads to a condenser 17 for condensing the compressed refrigerant discharged by the compressor. The condensed refrigerant passes from the condenser 17 into a receiver 18 and from this receiver passes through a liquid line 19 which leads to a pair of solenoid or electrically controlled valves 20 and 21. The outlet of valve 21 is connected by means of a pipe 22 to an expansion valve 23 which is located at the inlet of the evaporator coil 6. This expansion valve may be of any desired type having a bulb 24 connected to the evaporator outlet pipe 25. The pipe 25 is in turn connected to a pipe 26 which leads to the compressor inlet. The valves 20 and 21 are arranged to be alternately opened or closed by means of a control device which will be described hereinafter. Hence when the valve 21 is opened, the valve 20 will be closed. Under these conditions, it will be apparent that liquid refrigerant will flow from the receiver 18 through the expansion valve 23 into the cooling coil 6, thereby causing chilling of this coil and evaporation of refrigerant within the coil, the evaporated refrigerant passing back to the compressor.

When the valve 20 is opened and the valve 21 is closed, however, liquid refrigerant will flow through valve 20 and pipe 27 to an expansion valve 28 which is located at the inlet of an outside evaporator coil 29 and will flow from this coil through a pipe 30 to the compressor inlet pipe 26 and hence back to the compressor. This action will cause heat energy to be absorbed by evaporation of the refrigerant within the evaporator 29, this heat then being supplied to the condenser 17 from which it will be transmitted to the heating coil 7 in a manner which will be described hereinafter. The outside evaporator, it will be understood, may be subjected to outside atmosphere, may be placed underground, or may take the form of a heat exchanger through which well water or other heating medium is passed. From the description thus far it will be apparent that the compressor 15, condenser 17, and evaporators 6 and 29 constitute a reversible cycle refrigeration system which is adapted to cool the air whenever the valve 21 is opened and which is adapted to heat the air whenever the valve 20 is opened.

During the heating cycle of the system, it is necessary to transfer heat from the condenser 17 to the heating coil 7 which is located within the conditioning chamber. For this purpose a circulating pump 31 is provided. This pump may be driven by an electric motor 32 or if desired may be driven by the same prime mover which drives the compressor 15. The pump 31 is connected to a discharge pipe 33 leading to a check valve 34, which in turn is connected by a conduit 35 leading to the condenser 17. The cooling medium outlet of the condenser 17 is connected by a pipe 36 to a heat exchanger 37, the cooling medium passing through this heat exchanger into a conduit 38 which is connected

by a pipe 39 to the inlet of the pump 31. By this arrangement, it will be apparent that cooling medium is circulated by the pump 31 through the condenser and the heat exchanger 37 for thereby transferring heat from the condenser to the heat exchanger 37.

The heat exchanger 37 is provided with a heating coil 40. One end of this heating coil is connected by a pipe 41 to the inlet of the coil 7 which is located within the chamber 1. The outlet of the coil 7 is connected to an electrical control valve 42, the outlet of this valve being connected by a pipe 43 to the inlet of the coil 40. Coils 40 and 7 are therefore connected together for forming a closed circulatory system. This system may be charged with a volatile fluid such as alcohol or ether. When the valve 42 is opened, this volatile fluid will be evaporated within the coil 40, thereby cooling the heat exchange medium being discharged from the condenser. The evaporated fluid will then pass through the pipe 41 to the heating coil 7 wherein it will condense, thereby giving up the heat absorbed from the condenser to the air passing over coil 7. The condensed fluid will then pass through the valve 42 and pipe 43 back to the coil 40 for re-evaporation. When the valve 42 is closed, however, condensed volatile fluid will be trapped above the valve 42 thereby filling or partially filling coil 7 with condensate and also preventing any condensate from entering the coil 40. This will in turn partially or completely place the heat exchanger 7 out of operation, depending upon the length of time that valve 42 is closed. By this arrangement, the valve 42 handles only a small quantity of condensed fluid and hence this valve may be relatively small.

During the cooling cycle of this system, the valve 42 will be normally closed and hence no heat will be transferred from the condenser to the heating coil 7. At this time, the condenser will be cooled by the passage of water from an outside source, such as a cooling tower, through the condenser. This arrangement will now be described. Reference character 45 indicates an electrical control valve, the inlet of which may be connected to a suitable source of cooling medium, such for instance as a cooling tower or a water main. The outlet of this valve is connected by a pipe 46 to the pipe 35 which leads to the condenser 17. While the valve 45 may be controlled in various manners in accordance with my invention, I prefer to control this valve by means of a pressure controller 47 which is responsive to the pressure of the compressed refrigerant. This pressure controller may consist of a bellows 48 which is connected by a tube to the high pressure refrigerant line 16. This bellows may actuate a pivoted mercury switch carrier which carries a mercury switch 49 which is connected in series with the valve 45. This controller may be so designed and adjusted as to maintain the mercury switch 49 open so long as the pressure of the compressed refrigerant is below the value prevailing when the heating coil 7 is in operation while causing closing of the mercury switch 49 and consequent opening of the water valve 45 whenever the refrigerant pressure exceeds this value. When the system is operating on the heating cycle, heat will be transferred from the condenser to the heating coil 7 in such quantities as to prevent the pressure of the compressed refrigerant from rising above the setting of the pressure controller 49 and consequently the valve 45 will be closed for prevent-

ing the supply of outside cooling water to the condenser. However, when the system is operating on the cooling cycle, closure of the valve 42 will prevent heat from being transferred from the condenser to the heating coil 7. This will result in the temperature of the condenser cooling medium rising, which will be followed by a rise in pressure of the condensed refrigerant. This pressure will continue to rise until it reaches the setting of the pressure controller 47 and causes this controller to close the mercury switch 49 for opening the water supply valve 45. Cooled water from an outside source will then flow through the pipes 46 and 35 into the condenser for condensing the refrigerant. This condenser cooling water will then pass through the pipe 36 into the heat exchanger 37 and from the heat exchanger 37 to the pipe 38, and will flow from pipe 38 through a relief valve 50. The cooling medium discharged through the relief valve 50 will then be either returned to the cooling tower, if such is used, or will be wasted. It will be understood that the relief valve 50 will be loaded sufficiently to prevent opening thereof unless the valve 45 is opened. Consequently, whenever the valve 45 is closed, the relief valve 50 will close for maintaining the condenser cooling circuit closed at such time.

Referring to the compressor 15, this compressor may be driven by means of an internal combustion engine 51. This engine may be provided with the usual exhaust manifold 52, intake manifold 53, starting motor 54, and generator 55. This engine may also be provided with a throttle valve or other type of speed or out-put controller 56. The engine 51 may drive the compressor 15 by means of any suitable power transmission means, such means being illustrated herein as comprising a drive shaft 57, pulleys 58 and 59, and cooperating belts 60.

In accordance with my invention, provision is made for utilizing the waste heat of the engine for supplementing the effect of the reverse cycle refrigeration system in heating the space during the heating cycle of the system, and for providing reheat when necessary during the cooling cycle. In order to transfer heat from the cylinder walls of the engine to the air being conditioned, a jacket water heat exchanger 61 is provided. This jacket water heat exchanger 61 is connected to the outlet of the engine water jacket by means of a pipe 62 which may have interposed therein a thermostat 63 for preventing overcooling of the engine. The outlet of the exchanger 61 is connected to the pipe 38 which leads to the circulating pump 31, and the discharge of the circulating pump 31 is connected to the engine water jacket by means of a pipe 64. By this arrangement, hot water is circulated from the engine water jacket through the heat exchanger 61 and is returned to the engine water jacket by means of the circulating pump 31. The circulating pump 31, therefore, acts to cause both a circulation of cooling water through the condenser 17 and the heat exchanger 40, and a circulation of cooling water between the engine water jacket and the heat exchanger 61.

The heat exchanger 61 is provided with a coil 65. The outlet of this coil 65 is connected by a conduit 66 to the inlet of the jacket water heating coil 8 which is located within the conditioning chamber 1. The outlet of coil 8 is connected by a conduit 67 to the heating coil 11 located within the humidifier pan and the outlet of this coil is connected by means of a conduit 68 to the

inlet of the coil 65, an electric control valve 69 being interposed in this conduit. The arrangement just described forms a closed heat transfer system, and this system may be charged with a volatile fluid. When the valve 69 is opened, liquid volatile fluid will be allowed to enter the coil 65. This will evaporate within the coil 65 thereby cooling the water being discharged from the engine into the heat exchanger 61. The evaporated fluid then passes to the heating coil 8 wherein it condenses and gives up its heat to the air flowing across coil 8. The condensed or partially condensed volatile fluid will then pass from the coil 8 through pipe 67 into heating coil 11 in the humidifier pan, and will give up its remaining heat to the water in this pan. The condensed volatile fluid will then flow back to the coil 65 and the cycle will be repeated. When the valve 69 is closed, however, the volatile fluid will be trapped and consequently no evaporation will take place within the coil 65 thereby stopping the transfer of heat between the exchanger 61 and the coil 8.

In order to transfer the heat of the exhaust gases to the air passing through the conditioning chamber, a heat exchanger 70 may be provided, this exchanger 70 being connected to an exhaust pipe 71, which in turn is connected to the exhaust manifold of the engine. The exhaust gases from the engine pass over a coil 72 which is located within the heat exchanger 70. The coil 72 may be connected by a pipe 73 to the inlet of the exhaust heating coil 9 which is located within the conditioning chamber, and the outlet of the latter coil may be connected by pipe 74 to the inlet of coil 72, thereby forming a closed heat transfer system. This system may also be charged with a volatile fluid for thereby transferring heat from the coil 72 to the coil 9. Similarly, to the other closed heat transfer systems described, this heat transfer system may be provided with a control valve 75 for preventing the transfer of heat from coil 72 to the heating coil 9.

If desired, the exhaust gases may be also utilized for heating domestic water. For this purpose a domestic hot water tank 76 having a heating coil 77 may be utilized. In order to prevent overheating of the domestic water, a three-way valve 78 may be interposed between the exhaust pipe 79 and the heating coil 77, this valve also being connected to a by-pass 80 for by-passing exhaust gases around the coil 77. The valve 78 may be controlled by means of a thermostat 81 which is responsive to the temperature of the domestic hot water. The thermostat 81 may include a bellows 82 which is connected by a capillary tube 83 to a control bulb 84 located within the tank 76. This bellows cooperates with a pivoted mercury switch carrier having mounted thereon a mercury switch 85. The bellows, bulb and tube are charged with a volatile fluid, as is well known in the art, and consequently the pressure within bellows 82 will vary in accordance with the temperature of the domestic hot water. The mercury switch 85 is connected into the control circuit of the three-way valve 78, and consequently the position assumed by the valve 78 will be dependent upon the temperature of the domestic hot water. When this temperature is below a predetermined value, such as 160° F., the thermostat 81 will position the mercury switch 85 for causing the valve 78 to pass all of the exhaust gases through the heating coil 77. When the domestic water

temperature becomes excessive, however, the bellows will expand, tilting the mercury switch 85 to the position shown for thereby causing the valve 78 to by-pass the exhaust gases around the heating coil 77.

With a reversed cycle heating system as described, it will be apparent that as the outdoor temperature becomes colder, less and less heat will be picked up by the outside evaporator. This will result in less evaporated refrigerant being returned from the outside evaporator 29 to the compressor which will, in turn, result in decreasing the load on the compressor. This action will, in turn, reduce the load applied upon the engine 51 and consequently the waste heat given off by the engine will be lowered. Thus at the very time that more heat is necessary for heating the space, the system will tend to become unloaded thereby actually supplying a smaller quantity of heat than at times when the heating load is relatively light. In order to avoid this shortcoming of a reversed cycle heating system, I have provided for loading the engine 51 whenever the reverse cycle refrigeration system becomes ineffective for heating the space. This arrangement will now be described. Reference character 90 indicates an electric generator which is driven by the internal combustion engine through the medium of pulleys 91 and 92 over which run belts 93. The pulley 92 is preferably provided with a suitable electrically controlled or magnetic clutching device which is controlled by wires 94 and 95 for thereby selectively connecting the generator to the engine shaft, or for disconnecting the generator therefrom. The generator 90 may be connected by wires 96 and 97 to the strip heater 14 which is located within the conditioning chamber. It will be apparent that whenever the clutch forming a part of pulley 92 is engaged, the generator 90 will be rotated by the engine, thereby loading the engine 51 and supplying energy to the strip heater 14. Thus, the additional load upon the engine is utilized for heating the space. Due to the throwing of this electric heater load upon the engine 51, the waste heat given off by the engine will be increased and consequently more heat will be supplied to the air by the heaters 8 and 9. Hence, when the clutch is engaged the heat out-put of the system will be considerably increased thereby providing for heating the space despite the fact that the outside temperature may fall so low as to make the reversed cycle heating system ineffective.

In accordance with my invention, I also provide for supplying outside heat to the system whenever the system becomes incapable of heating the space by the action of the internal combustion engine alone. For this purpose, a gas or other suitable type burner 100 may be located within the exhaust gas heat exchanger 70. This gas burner may be controlled by means of a motorized gas valve 101, which in turn, is controlled by the control mechanism which will be hereinafter described. My invention also provides for automatically controlling the system just described in a manner to provide for maintaining proper temperature and humidity conditions within the conditioned space during the entire year. This action is obtained by the control system which will now be described.

Reference character 105 indicates generally a low limit thermostat which may be located within the space being conditioned or in the return duct 3. This thermostat may be of any desired

type and is shown herein as comprising a bellows 106 which cooperates with a bell-crank lever having an actuating arm 107 and a control arm 108. The control arm 108 is arranged for engagement with a control resistance 109 forming a control potentiometer which controls the proportioning motor 110. The proportioning motor 110 may be of the type shown and described in Patent No. 2,028,110 issued to Daniel G. Taylor on January 14, 1936. This motor is adapted to be controlled by a potentiometer type of controller and assumes intermediate positions corresponding to the position of the potentiometer slider upon the potentiometer coil. In the present instance, the thermostat 105 is connected to the proportioning motor 110 in a manner to cause clockwise rotation of its operating shaft 111 as the slider 108 moves to the right across the resistance 109. Hence, upon a decrease in space temperature, the bellows 106 of the thermostat 105 will contract, thereby causing movement of the slider 108 to the right across the resistance 109 which will be followed up by a clockwise movement of the motor shaft 111. The thermostat 105 may be so designed as to cause engagement of the slider 108 with the extreme left-hand end of resistance 109 when the space temperature rises to 74° F., and to engage the extreme right-hand end of said resistance when the space temperature falls to 70° F. Hence, by this arrangement the motor shaft 111 will assume an extreme counter-clockwise position when the space temperature is at or above 74° F., will gradually shift clockwise upon fall in temperature, and will reach its extreme clockwise limit of rotation when the space temperature falls as low as 70° F.

The various control valves 20, 21, 42, 69, 75, and 101 are preferably of the type which remain closed when deenergized and which open when energized. These valves and the magnetic clutch of generator pulley 92 are controlled by means of a series of mercury switches 115, 116, 117, 118, 119 and 120 which are actuated sequentially by means of a series of cams 121, 122, 123, 124, 125, and 126 which are mounted upon the motor shaft 111. These cams are arranged on the shaft 111 in a manner to cause sequential closing of the mercury switches in the order named as the shaft 111 rotates in a clockwise direction and to cause these switches to be tilted to open position in reverse order as the shaft 111 is rotated in the opposite direction. Also mounted upon the motor shaft 111 is a slider 127 which is arranged to cooperate with a resistance 128, a long contact segment 129 and a short contact segment 130. The resistance 128 and the slider 127 are arranged to control a proportioning motor 131 which is arranged for actuating the throttle valve 56. As will be more completely described later, the movement of the slider 127 in a clockwise direction across the resistance 128 will have the effect of causing the proportioning motor 131 to open the throttle valve 56 wider. Therefore, this arrangement will provide for increasing the engine speed upon a decrease in space temperature.

Preferably, the engine 51 is provided with an arrangement for causing automatic starting of the engine whenever the throttle valve is opened and for stopping the engine whenever the throttle valve 56 is moved to closed position by its controller. For this purpose the proportioning motor 131 may be provided with an auxiliary switch 132 which is illustrated herein as being of the mercury type which is actuated by means

of the actuating lever 133 of the proportioning motor. This switch is so mounted upon the lever 133 as to be tilted to closed position whenever the throttle valve 56 is opened slightly, and is arranged to be tilted to open position whenever the throttle valve 56 is closed beyond this point. The mercury switch 132 is arranged to control an automatic starting circuit for the engine which will now be described. Reference character 134 indicates a storage battery, one terminal of which may be grounded as shown. The other terminal of the storage battery 134 is connected to the switch 132 by means of wire 135, and the switch 132 is also connected to the control terminal of a starting relay 136 by means of wire 137. This starting relay may be of the type shown in Patent No. 1,773,913 issued to L. K. Loehr et al. on August 26, 1930. This type of starting relay is arranged to energize the starting motor whenever the control circuit for the relay is energized, and for this purpose the starting relay 136 is connected to the starting motor 54 and to the storage battery 134 by means of wires 138 and 139. The wire 137 which leads from the mercury switch 132 to the control terminal of the starting relay is also connected to the engine ignition coil 140. Hence, when the mercury switch 132 is closed by opening movement of the throttle valve 56, the ignition circuit for the engine will be completed, and also the starting relay will be energized for completing a circuit from the battery through the starting motor, thereby cranking the engine. This starting relay is also arranged to deenergize the starting motor automatically when the engine starts, as indicated by the starting motor taking less current. This relay is also arranged in a manner to prevent energization of the starting motor so long as the engine is in operation, as indicated by operation of the generator. For this purpose the starting relay is connected to the generator 55 by means of a wire 141. The generator 55 is also connected to the battery 134 through a reverse current relay 142 in the usual manner. By the arrangement just described, whenever the throttle valve 56 is opened, the ignition circuit for the engine will be completed and the starting motor will be caused to operate until the engine is started, at which time it will be automatically deenergized. The engine 51 will then continue to operate until the throttle valve 56 is closed thereby opening the mercury switch 132 and breaking the ignition circuit.

The throttle valve motor 131 is also arranged to be controlled by means of a high limit space thermostat 150 and a high limit humidity controller 151. Referring to the thermostat 150, this thermostat may be located either within the conditioned space or within the return duct 3. This controller may be of any desired type and is illustrated as comprising a bellows 152 cooperating with a bell-crank lever having an actuating arm 153 and a control arm or slider 154 which is arranged to engage a resistance 155 for forming a control potentiometer. The bellows 152 contains a suitable volatile fluid and consequently this bellows expands and contracts with changes in temperature. Upon an increase in temperature, the bellows 152 will expand thereby rotating arm 153 in a counter-clockwise direction against the action of spring 156, thus shifting the slider 154 to the left across the resistance 155. Upon a decrease in temperature, the bellows 152 will contract under the action of spring 156 thereby shifting slider 154 to the right

across resistance 155. This instrument may be so designed and adjusted that the slider 154 will engage the right-hand end of resistance 155 when the space temperature falls to 75° F. and to engage the left-hand end of resistance 155 when the space temperature rises to 82° F.

Referring to the humidity controller 151, this controller may comprise a humidity responsive device 157 formed of strands of hair, or other moisture responsive material, this device being arranged to actuate a bell-crank lever having an actuating arm 158 and a control arm or slider 159. The slider 159 in turn is adapted to engage a resistance 160 for forming a control potentiometer. Upon a decrease in relative humidity, the strands 157 will shrink thereby causing a counter-clockwise movement of the bell-crank lever against the action of a spring 161, thus shifting the slider 159 to the right across resistance 160. As the relative humidity increases, however, the strands will increase in length thereby permitting the spring 161 to shift slider 159 to the left. This instrument may be so designed and adjusted as to cause the slider 159 to engage the right-hand end of resistance 160 when the relative humidity falls below 40%, while engaging the left-hand end of said resistance when the humidity rises to 60%.

The proportioning motor 131 is preferably of the type shown and described in the Taylor patent previously mentioned. Upon reference to this patent, it will be noted that this type of proportioning motor is provided with three control terminals and which are herein marked as R, B and W. The motor is adapted to assume positions corresponding to the relative values of the resistance connected between terminals R and B and between terminals R and W. For instance, if the resistance interposed between terminals R and B is exactly equal to the resistance interposed between terminals R and W, the motor will assume mid-position. If the terminals R and B should be substantially short-circuited, however, while resistance is interposed between terminals R and W, the motor will run to an extreme position at which the motor valve is wide open. On the other hand, should the terminals R and W be short-circuited while resistance is interposed between terminals R and B, the motor will run to its other extreme position at which the throttle valve is completely closed. For intermediate relationships between the resistance which is connected between terminals R and B and R and W, it will be understood that the motor 131 will assume intermediate positions corresponding to the relationship between the resistances.

The type of proportioning motor just described is, of course, adapted to be controlled by means of one or more potentiometer type of controllers, and in accordance with my invention, the throttling valve motor 131 is controlled by the conjoint action of the high limit space thermostat 150, the high limit humidity controller 151, and the potentiometer formed by slider 127 and resistance 128 which is actuated by the low limit space thermostat 105 through the medium of the proportioning motor 110. Referring to the connections between the motor 131 and the various control potentiometers, it will be noted that terminal R of the motor is connected by wire 165 to the slider 154 of the high limit controller 150. The terminal B of the motor is connected by wires 166, 167, 168, and 169 to the left-hand ends of resistances 155 and 160 and to the con-

tact segment 130 which is joined to the lower end of resistance 128. The terminal W of the motor is connected to the upper end of resistance 128 through the contact segment 129 by means of wire 170. The right-hand end of the resistance 155 is connected to the slider 159 by means of wire 171, and the right-hand end of resistance 160 is connected to the slider 127 by wire 172.

With the sliders 127, 154 and 159 in the position shown, the space temperature is approximately 78.5° as indicated by the slider 154 engaging the center of resistance 155. For this value of temperature, the slider 127 is engaging the upper end of contact segment 129 due to the proportioning motor 110 having been rotated to its extreme counter-clockwise position. Also, the space relative humidity is below 40% as indicated by the slider 159 of the humidity controller engaging the right-hand end of resistance 160. With the sliders 127 and 159 in the positions shown, the high limit thermostat 150 will be placed in full control of the motor 131. It will be noted that the slider 154 of this controller is directly connected to terminal R of the motor and the left-hand end of resistance 155 is connected directly to terminal B of the motor by wires 166 and 167. The right-hand end of the resistance 155 at this time is connected to terminal W of the motor as follows: terminal W, wire 170, segment 129, slider 127, wire 172, slider 159, and wire 171 to the right-hand end of resistance 155. It will now be apparent that the slider 154 of the thermostat 150 is dividing the resistance 155 into one portion which is connected across terminals R and B of the motor and into another portion which is connected across terminals R and W of the motor. Due to the resistances connected across the motor being equal, the motor has assumed mid-position in which the throttle valve 56 is half open as shown.

If the space temperature should increase, the slider 154 will be shifted to the left across resistance 155 which will decrease the portion of this resistance which is connected across terminals R and B and will increase the portion of the resistance which is connected across terminals R and W. In response to this change in relationship between the resistances connected across the motor terminals, the motor will rotate its operating lever 133 in a clockwise direction an amount corresponding to the movement of the slider 154 across the resistance 155. This will shift the throttle valve 56 to a further open position and thus increase the speed of the engine. This, in turn, will cause more cooling to be done by the system for counteracting the rise in temperature. Conversely, should the space temperature fall, the slider 154 will be shifted to the right across resistance 155 thereby decreasing the resistance connected between terminals R and W and increasing the resistance connected between terminals R and B. This will cause movement of the motor 131 in the opposite direction for moving the throttle valve 56 to a further closed position, thus decreasing the engine speed to counteract the drop in temperature. From the foregoing, it should be apparent that when the space temperature is above 75° F. and the humidity is at 40% or below, the high limit space thermostat 150 will be in full control of the engine speed and will gradually vary this engine speed in a manner tending to maintain the constant space temperature. Due to the wide range of the controller 150, however, this controller will

not maintain a constant temperature but will permit the temperature within the space to rise as the cooling load increases. For light load conditions indicating relatively low outside temperature, it will be apparent that the engine need only run at slow speed and such engine speed would occur with the slider 154 adjacent the right-hand end of resistance 155 which would occur at, for instance, 76° F. In order for the engine speed to increase the space temperature must rise, and consequently as the load on the system increases, the space temperature must rise to such a value that the controller 150 causes operation of the engine 51 at a speed which prevents further rise in temperature. Consequently, as the outdoor temperature increases, the temperature maintained by the high limit space thermostat will be increased.

The control arrangement disclosed will also cause operation of the engine in the event that the relative humidity becomes excessive and this will occur even though the space temperature may be below the control point of the high limit controller 150. A condition of this type often exists during cool damp weather. At this time, the slider 154 of the controller 150 will engage the right-hand end of resistance 155. This will connect terminal R of the motor 131 to the slider 159 of the humidity controller as follows: terminal R, wire 165, slider 154, and wire 171 to slider 159. Terminal B of the motor 131, it will be noted, is connected directly to the left-hand end of resistance 160 by wires 166 and 168. Terminal W of the motor at this time is connected to the right-hand end of resistance 160 as follows: terminal W, wire 170, segment 129, slider 127, and wire 172 to resistance 160. Therefore, at this time the potentiometer of the humidity controller is operatively connected to the proportioning motor 131 for controlling the position assumed by this motor. With the slider 159 in the position shown at which the relative humidity is low, terminals R and W of the motor will be substantially short-circuited, while the entire resistance 160 will be connected between terminals R and B. This would cause the motor 131 to completely close the throttle valve 56 thereby preventing operation of the engine. If, however, the relative humidity increases, the slider 159 will travel to the left across resistance 160 which will place a portion of the resistance 160 between terminals R and W and will decrease the portion of the resistance which is connected between terminals R and B. This will cause the motor 131 to open the throttle valve an amount corresponding to the movement of the slider 159 across resistance 160. Therefore, the humidity controller 151 is capable of causing opening of the throttle valve and operation of the engine whenever the relative humidity becomes excessive. The high limit thermostat 150 and the humidity controller 151, therefore, cooperate in controlling the throttle valve position, and the position assumed by the throttle valve is determined by the conjoint action of these two controllers, the throttle valve being opened further upon an increase in either temperature or humidity and being moved towards closed position upon a decrease in values of these conditions.

During the heating cycle of the system, the relative humidity will usually be below 4%, and hence the slider 159 will engage the right-hand end of resistance 160, as shown. Also at this time, the space temperature will be below 75° F. and consequently the slider 154 of thermostat

150 will engage the right-hand end of resistance 155. This action will connect the slider 127 of the winter control potentiometer to terminal R of the motor as follows: terminal R, wire 165, slider 154, wire 171, slider 159, and wire 172 to slider 127. Terminal W of the motor it will be noted, is connected to the contact segment 129 by means of wire 170, and terminal B of the motor is connected to the contact segment 130 by wires 166, 168, and 169. This, therefore, places the potentiometer formed of slider 127 and resistance 128 in operative control of the proportioning motor 131. At this time, it will be noted that resistances 155 and 160 are connected in parallel between terminals R and B of motor 131. Thus resistance 155 is connected across terminals B and R as follows: terminal R, wire 165, slider 154, resistance 155, wire 167, and wire 166 to terminal B. The resistance 160 will be connected in parallel with resistance 155 by means of wire 171, slider 159, and wire 168. These resistances being connected across terminals R and B would have the effect of crowding the operating range of the potentiometer formed of slider 127 and resistance 128 towards one end of resistance 128. In order to avoid this result and thereby obtain closer control, the effect of resistances 155 and 160 is balanced out by means of resistance 175 which is connected between terminals R and W. This resistance 175 is made equal in value to the combined parallel resistances 155 and 160 and consequently completely balances the effect of these resistances on the proportioning motor 131.

As pointed out previously, the slider 127 is rotated in a counter-clockwise direction upon a decrease in space temperature. With the low limit controller 105 in the position shown, the space temperature is at or above 74° F., and consequently the motor shaft 111 is in its extreme counter-clockwise limit of rotation at which the slider 127 engages the upper end of segment 129. For this value of space temperature, the terminals R and W of the motor 131 will be substantially short-circuited while the resistance 128 will be connected across terminals R and B. This would cause the motor 131 to completely close the throttle valve 56 and place the engine 51 out of operation. As the space temperature begins falling, the motor shaft 111 will be rotated clockwise. However, until the space temperature falls to 72° F., the slider 127 will merely contact the contact segment 129 and no change in position of the throttle valve motor will take place. If the space temperature falls below 72° F., the slider 127 will begin contacting the resistance 128 and will place part of this resistance between terminals R and W and will decrease the portion of this resistance which is connected between terminals R and B. This will cause the motor 131 to open the throttle valve 56 an amount proportionate to the movement of slider 127 across the resistance 128. Consequently, as the space temperature falls below 72° F., the engine 51 will be placed into operation and its speed will be increased upon further decrease in temperature below this value. When the space temperature falls to 70° F., the slider 127 will engage the lower end of resistance 128 and consequently will cause the throttle valve 56 to be wide open. Upon still further decrease in temperature, the slider 127 will engage the contact segment 130. This will permit the throttle valve to continue to remain in wide open position. From the foregoing, it will be seen that the low limit space thermostat 105 will take control of

the engine speed when the space temperature begins falling below 72° F. and will modulate the engine speed in a manner tending to maintain the space temperature between limits of 72° F. and 70° F. The control arrangement just described, therefore, will cause operation of the engine whenever the space temperature rises to a value indicating that cooling is necessary or falls to such a value as to indicate that heating is necessary. Also, the engine will be placed into operation whenever the space relative humidity becomes excessive. In addition, the engine speed will be modulated in accordance with the requirements for cooling, for heating, or for dehumidification.

Operation of Figure 1

With the parts in the position shown, the system is operating on the cooling cycle, as indicated by the slider 154 of the high limit space thermostat engaging the center of resistance 155. This in the manner just described has caused the motor 131 to shift the throttle valve 56 to half open position. At this time, the mercury switch 132 is closed and consequently the engine is in operation. Due to the space temperature being above 74° F., the low limit space thermostat has caused the proportioning motor 110 to rotate the shaft 111 to an extreme counter-clockwise position, thereby causing the mercury switches 115, 116, 117, 119 and 120 all to be opened. Inasmuch as the mercury switches 115, 116, 117 and 120 are connected in circuit with the valves 42, 69, 75, and 101, respectively, and these valves are of the type which close when deenergized, all of these valves are closed. Therefore, the heating coils 7, 8 and 9 are out of operation, and due to valve 101 being closed, the auxiliary gas heating burner 100 will not be operating. The mercury switch 119 controls the magnetic clutch in the drive for generator 90. Due to this switch being open, the clutch is disengaged and consequently the generator 90 is not being driven at this time. The mercury switch 118 at this time is tilted for causing bridging of the right-hand electrodes thereof which will cause energization of valve 21 as follows: line wire 176, right-hand electrodes of mercury switch 118, wire 177, valve 21, and wire 178 to ground 179. Therefore, at this time the valve 21 will be opened thus placing the air stream or summer evaporator 6 into operation for cooling the air. Due to the valve 42 being closed, heat is not absorbed from the condenser cooling water by the heat exchanger 37 and consequently the pressure of the compressed refrigerant has risen to a value which causes the pressure controller 47 to open the water supply valve 45, thereby supplying cooling water to the condenser and to the internal combustion engine 51, thus providing for condensing the compressed refrigerant and for preventing the engine 51 from overheating. During this operation of the system on the cooling cycle, the engine speed will be increased upon increase in either temperature or relative humidity and will be decreased upon decrease in value of these conditions in a manner to maintain proper comfort conditions within the conditioned space, as previously described.

In the event that the relative humidity should be excessive while the space temperature is relatively low as occurs in cool damp weather, the relative humidity controller will cause operation of the engine 51 for dehumidifying the air, even though no cooling is required. Due to the cooling action which necessarily accompanies the de-

humidifying action of the coil 6, the space temperature will begin falling. When the space temperature begins falling below 74° F., the low limit controller 105 will cause clockwise rotation of the shaft 111. The first action of this rotation will be to close the mercury switch 115. Closure of this switch will energize the valve 42 as follows: line wire 176, mercury switch 115, wire 180, valve 42, and wire 181 to ground. Energization of valve 42 will cause opening thereof which places the heat transfer system between heat exchanger 37 and the heating coil 7 in operation. This will provide heat for reheating the air after it has been cooled due to the action of cooling coil 6. The heater 7, it should be noted, is supplied with heat absorbed from the condenser and internal combustion engine. Due to the cooling effect of heat exchanger 40 on the water circulated in the system, the cooling effect of the condenser will be increased which will cause the compressor discharge pressure to decrease, thereby causing closing of the water supply valve 45. This, therefore, provides for economy in cooling water supply for the condenser and internal combustion engine as it reduces the necessary additional cooling water to a minimum.

The described control arrangement for the reheater coil 7 will provide for "floating" control of the effective area of the reheater coil 7 in accordance with the demand for reheat. Prior to the demand for reheat, it will be understood that the reheater coil 7 will be full of condensate due to the trapping of condensate therein by the closed valve 42. Upon demand for reheat, the valve 42 will be opened in the manner described, thus allowing condensate to trickle from the coil into the boiler or heat exchanger 40. Due to this withdrawal of condensate from coil 7, vapor will take the place of the withdrawn condensate, thus causing a portion of the coil area to become heated. If the demand for reheat is light, the space temperature will rise sufficiently to cause the valve 42 to be again closed before a large portion of the coil will be made effective. The coil will then begin refilling with condensate which will eventually result in reopening of the valve 42 due to falling space temperature. It will be apparent that the heavier the demand for reheat becomes, the longer valve 42 will remain open. Consequently, as the heat demand becomes heavier, the effective coil area will be increased. The control arrangement just described will therefore act to vary the effective reheater coil area in accordance with demand for reheat.

Under normal conditions, the reheater coil 7 will be sufficient for supplying the necessary reheat. If, however, an unusual condition should occur requiring an extraordinary amount of reheat, the space temperature will fall further, thus causing shaft 111 to be rotated clockwise thereby closing the mercury switch 116 which energizes valve 69 as follows: line wire 176, mercury switch 116, wire 182, valve 69, and wire 183 to ground. At this time, the valve 42 will remain open thus placing the entire surface of coil 7 in operation. Also at this time the effective heating surface of the heating coil 8 will be varied in the same manner as described in connection with coil 7, for maintaining a constant temperature within the space.

In the event that heating coils 7 and 8 should fail to supply the necessary reheat, the shaft 111 will rotate still further for closing mercury switch 117, which will energize valve 75 as fol-

lows: line wire 176, mercury switch 117, wire 184, valve 75, and wire 185 to ground. This will place the heating coil 9 in operation, and its effective area will be varied in a manner to supply the necessary reheat as previously described. From the foregoing, it will be apparent that the heating coils are operated in sequence, and the effective area of each is controlled in a manner to provide a graduating control of reheat over a very wide range.

As the weather changes from a value requiring cooling or dehumidification to a value requiring heating, the space temperature will begin falling and also the space relative humidity will be below 40% and consequently the control arms of the sliders 154 and 159 of the controllers 150 and 151 will engage the right-hand ends of their respective resistances, which in a manner previously described places control of the throttle valve motor with the potentiometer formed of slider 127 and resistance 128. As the space temperature continues to fall, the shaft 111 will be rotated clockwise thereby sequentially closing the mercury switches 115, 116 and 117 which will open valves 42, 69, and 75 for conditioning the heating coils 7, 8, and 9 for operation, thereby providing for transferring the condenser heat, the jacket heat of the engine, and the exhaust heat of the engine to the air. Until the space temperature falls to 72° F., no heat for the space will be necessary. Until this occurs, the slider 127 will continue to ride on segment 129, and hence the engine will not be placed into operation. Also the mercury switch 118 will remain in the position shown which causes energization of the valve 21 and deenergization of valve 20 which will permit the system to operate on the cooling cycle under control of the high limit humidity controller in the event that the humidity should become excessive. However, when the space temperature falls to 72° F., the mercury switch 118 will be tilted to its other position thereby deenergizing the valve 21 for placing the air stream evaporator 6 out of operation. This will also cause energization of valve 20 as follows: line wire 176, left-hand electrodes of mercury switch 118, wire 186, valve 20, and wire 187 to ground. This will result in opening of the valve 20 for placing the outside evaporator 29 into operation. Therefore, when the space temperature falls to 72° F., the action of the refrigeration system will be reversed from cooling to heating. As the space temperature falls below 72° F., the slider 127 will traverse the resistance 128 and thus increase the engine speed. As previously described, the engine speed will be increased and decreased in a manner to maintain the space temperature between 70° F. and 72° F.

As weather conditions become severe, the amount of heat which can be picked up by the outside evaporator 29 will decrease. This will result in a smaller amount of evaporated refrigerant passing to the compressor, which would have the action of unloading the compressor. Due to this unloading of the compressor, the engine 51 will be unloaded and consequently will deliver a smaller amount of waste heat. Thus at this time when the heating load is the greatest, the reversed cycle system tends to refuse to function thereby causing the heat supply to the space to begin falling off. This action will result in the space temperature continuing to fall. When the space temperature falls to a value, for instance, of 69° F., the cam 125 on shaft 111 will

cause closure of mercury switch 119 which will energize the magnetic clutch in the generator drive as follows: line wire 176, mercury switch 119, wire 94, magnetic clutch, and wire 95 to ground. This will cause engagement of the magnetic clutch and consequently will place the generator 90 into operation. Operation of generator 90 will cause heating of the strip heater 14 for thereby increasing the amount of heat supplied to the space. Also, due to the additional load impressed upon the engine 51, the engine will supply an increased amount of waste heat to the space. Thus, whenever the outdoor temperature becomes so low as to render the reversed cycle heating system ineffective, the electric heater 14 is placed into operation, which has the effect of supplementing or replacing the action of the reversed cycle system. In the event that this should fail to maintain the space temperature, the shaft 111 of the proportioning motor 110 will rotate until the cam 126 causes closing of the mercury switch 120. This will cause opening of the valve 101 for supplying gas to the burner 100. This burner will be ignited by means of any suitable type of pilot, and consequently additional heat will be supplied to the system for thereby maintaining proper temperature conditions within the space.

The system just described, therefore, is entirely automatic in operation and serves to provide for heating, cooling, humidifying and dehumidification of the space.

Figure 2

Referring to Figure 2, this figure shows a system of the same general type as shown in Figure 1. In this system, however, the intermediate heat exchangers 37, 61 and 70 have been omitted and the cooling water for the condenser and internal combustion engine is passed directly through the air stream heaters 7' and 8', respectively. Also in this system, the exhaust gases are passed directly through the air stream heater 9'. The reversible cycle refrigeration system is exactly the same as illustrated in Figure 1 and consequently this system is not redescribed at this point.

Reference character 200 indicates generally a circulating pump which corresponds to the pump 32 of Figure 1. This pump discharges through a check valve 201 into a supply pipe 202 which is connected by pipes 203 and 204 to the cooling water inlet of the condenser 17 and to the inlet of the engine water jacket, respectively. The cooling water outlet of the condenser is connected to a pipe 205 which leads to the air stream heating coil 7', the outlet of which is connected to a valve 42'. The outlet of this valve, in turn, is connected to the inlet of the circulating pump 200 by means of a pipe 206. When the valve 42' is open, it will be apparent that circulating pump 200 will cause a circulation of cooling water from the outlet of the coil 7' through the condenser for condensing the refrigerant and back to the heating coil 7'. The outlet of the engine water jacket is connected by a pipe 207 to the inlet of the heating coil 8' and the outlet of this heating coil is, in turn, connected to the coil 11' which is located within the humidifier 10'. The outlet of the coil 11' is, in turn, connected to a valve 69' and this valve is, in turn, connected by a pipe 208 to the pipe 206. By this arrangement, when the valve 69' is open, the circulating pump 200 will cause a circulation of cooling water

through the engine and heating coils 8' and 11' back to the circulating pump.

As in the case of Figure 1, the heating coils 7' and 8' are not normally in operation during the cooling cycle of the system, and hence it is necessary to provide for circulating water from an outside source through the condenser 17 and the engine water jacket in order to provide for condensing of the refrigerant and cooling of the engine when the system is operating on the summer cycle. To this end, a water supply pipe 210 is connected to the discharge of the circulating pump on the down stream side of the check valve 201. Interposed in the water supply pipe 210 is a pressure actuated valve 211 which has a tube 212 connected to the compressor discharge line 16. This valve may be of the type which is biased to closed position and will remain closed until the pressure of the compressed refrigerant rises to a predetermined value. When the pressure rises to this value, the valve 211 will begin opening and supply water through the pipes 202 and 203 to the condenser 17 for thereby increasing the condensing action for maintaining the compressor head pressure at this value. This water will be discharged from the condenser by means of pipe 205 to which is connected a relief valve 213 which permits the water to flow to waste or back to the source of cooling water. During the heating cycle of the system, water supply valve 211 is closed, due to valve 42' being open. At this time the relief valve 213 will remain closed thereby preventing escape of the cooling water from the system.

When the valve 211 opens to admit cooling water to the condenser, it will also admit cooling water to the water jacket of the engine for cooling the engine, this water then flowing through relief valve 214 to waste or back to its source.

It will be understood that if desired an electrically actuated type of valve such as 45 of Figure 1 may be utilized in place of valve 211 of Figure 2, or conversely, a pressure actuated valve such as valve 211 may be used in place of valve 45 and pressure controller 47 of Figure 1.

It will be noted that in result, the system thus far described is identical with the corresponding portion of the system illustrated in Figure 1, that is, when the system is operating on the heating cycle, heat will be transferred from the condenser and the engine to the air stream by the coils 7' and 8', and during this time the water circulation system will remain closed unless the pressure of the compressed refrigerant becomes excessive, at which time water from an outside source will be supplied to the system for cooling the condenser and the engine.

The exhaust manifold 52 of the engine 51 in this embodiment of the invention is connected by means of a pipe 215 to the inlet of a three-way valve 216. One outlet of the three-way valve 216 is connected by a pipe 217 to the exhaust heating coil 9' and the outlet of this coil is connected by a pipe 218 to the inlet of a second three-way valve 219. The other outlet of the three-way valve 216 is connected by a pipe 220 to the pipe 218 and thus provides a by-pass for the exhaust gases around the heating coil 9'. The three-way valve 216 is controlled in exactly the same manner as the corresponding valve 75 of Figure 1. Thus at the time that valve 75 of Figure 1 would be open, the three-way valve 216 would be positioned so as to pass the exhaust gases through the heating coil 9'. At the time that valve 75 of Figure 1 would be closed, how-

ever, the three-way valve 218 would be positioned so as to by-pass the exhaust gases around the heating coil 9'.

One outlet of the three-way valve 19 is connected by a pipe 221 to a heating coil 222 which may be located within a domestic water tank 223. The outlet of this heating coil may be connected by a pipe 224 to a sewer or chimney. The other outlet of the three-way valve 219 is connected to a by-pass pipe 225 which leads directly to the exhaust pipe 224. The three-way valve 219 may be controlled in accordance with the temperature of the domestic water by means of a temperature controller 226 which may be of the same type as the controller 81 of Figure 1. This controller will position the valve 219 in a manner to cause the exhaust gases to be passed through the heating coil 222 so long as the temperature of the water is not excessive. When the domestic water temperature becomes excessive, however, the controller 226 will cause the three-way valve 219 to be positioned in a manner to by-pass the exhaust gases around the heating coil 222. While I have shown the domestic hot water heater as receiving exhaust gases which have been passed through the air stream heating coil 9', it will be understood that if desired the exhaust gases may be first passed through the domestic water heating coil before passing to the air stream heating coil 9'.

The controls for the system of Figure 2 may be identical with the controls described in detail for the system of Figure 1. Hence, no further description of this figure is necessary. In this case, however, it will be noted that the floating control of the area of the heating coils in accordance with the demand for reheat is not obtained, the heating coils either being entirely on or off.

Figure 3

In Figure 3, I have shown a modified arrangement for heating the air stream by exhaust heat from the engine and for heating domestic hot water. This arrangement may be employed for heating the air stream of a heating system or it may be employed for reheating in a cooling system, or both. For purpose of illustration, this arrangement is illustrated in conjunction with a simple summer air conditioning system.

Reference character 230 indicates a compressor which may be driven by an internal combustion engine 231. The compressor 230 is connected to a condenser 232, which in turn is connected to an expansion valve 233 at the inlet of a cooling coil 234 which is located within the conditioning chamber 1, the outlet of this cooling coil being connected to the compressor intake by means of a pipe 235.

The exhaust manifold 236 of the engine is connected by a pipe 237 to heat exchanger 238. Located within the heat exchanger 238 may be a coil 239, the upper end of which may be connected to a pipe 240 which leads to the inlet of a heating coil 241 located within the conditioning chamber 1. The outlet of this coil is connected by a conduit 242 to the inlet of the coil 239. Interposed in the conduit 242 is a valve 243 which may be of the electrically actuated type. The valve 243 may be controlled if desired by means of a low limit space temperature controller 244 which may be of any desired type and which is arranged to energize the valve 243 whenever the space temperature falls to a predetermined low value.

The pipe 240 leading from the outlet of the coil 239 is also connected to a pipe 245 which leads to a heating coil 246 which may be located within a domestic hot water tank 247. The outlet of coil 246 is connected by means of a conduit 248 to the inlet of coil 239 of heat exchanger 238. Interposed in conduit 248 is a valve 249. This valve 249 may be controlled by means of a thermostat 250 which is responsive to the temperature of the domestic water. So long as the water temperature is below a predetermined value, the controller 250 will cause the valve 249 to be energized for thereby maintaining said valve open. However, when the space temperature becomes excessive, the controller 250 will deenergize valve 249 for allowing this valve to close.

From the foregoing, it will be seen that the coils 239, 241 and 246 form a closed heat transfer system. This system is charged with a volatile heat transfer medium. When the valves 243 and 249 are open, condensed heat transfer medium will flow from the coils 241 and 246 into the coil 239 in which it will evaporate and pass back to the coils 241 and 246 for thereby heating the air and the domestic hot water. If the valve 243 is closed, however, the condensed heat transfer medium will be prevented from leaving the coil 241 and consequently this coil will fill up with condensed heat transfer medium which will prevent further heating of the air stream.

By the arrangement just described, the effective heating area of the reheat coil 241 will be varied in accordance with the demand for reheat. Upon a call for reheat, the thermostat 244 will cause an opening of the valve 243 which will allow the condensed heat transfer medium to slowly trickle from the coil 241 which will empty a portion of this coil and permit vapor from the coil 239 to flow into this portion of coil 241. The rate of flow of condensate from coil 241 may be restricted when valve 243 is open by means of an orifice plate or valve device such as at 242a, or this result may be obtained by properly sizing the condensate return pipe 242. If the demand for reheat is relatively light, this small portion of the coil will be adequate for supplying the necessary reheat and consequently the air temperature will rise again to a point at which the thermostat 244 causes closing of valve 243. The coil 241 will then continue to heat for a while but will begin filling up with condensed heat transfer medium once more which will eventually result in the thermostat 244 again opening the valve 243, allowing more condensed heat transfer medium to flow from the coil 241. If the demand for reheat becomes heavy, the space temperature will not rise as soon as it would if the demand were lighter and consequently more condensed heat transfer medium will be allowed to flow from the coil 241. This will increase the effective area of the coil 241 and will cause this coil to supply a greater amount of reheat to the space. It will thus be seen that this arrangement provides for automatically varying the effective heating surface of the reheat coil 241 in accordance with the demand for reheat. While no receiver has been shown, it will be understood that in installations where the return lines do not have sufficient volumetric capacity to store the necessary volume of liquid, a receiver may be provided in the return lines for providing the necessary storage space.

It will be apparent that the action of the domestic hot water heating coil will be similar to that of the reheat coil 241. In other words, when

the domestic water requires heating, the valve 249 will be opened thus allowing the condensed heat transfer medium to flow from the coil 246 for thereby permitting this coil to heat the domestic water. When the domestic water is heated sufficiently, however, the valve 249 will be closed which traps condensed heat transfer medium in the coil 246 for thereby causing it to fill up, which will stop its heating effect.

The engine 231 may be controlled in any desired manner and is preferably controlled by means of a temperature controller 251 and a humidity controller 252, these controllers being arranged to control a proportioning motor 253 which actuates the engine throttle valve 254. The wiring between the controllers 251 and 252 and the proportioning motor 253 is substantially the same as indicated in Figure 1, and accordingly, is not described here. By this arrangement, the engine speed will be increased upon an increase in either temperature or humidity and the engine will operate if either the temperature becomes excessive or the humidity becomes excessive. In the event that the humidity is excessive while the temperature is fairly low, the operation of the cooling coil for dehumidifying will tend to reduce the temperature of the air. The reheat control arrangement just described, however, will act to prevent this action and supply just sufficient reheat as to maintain the air temperature substantially constant.

In the foregoing description, definite values of temperature and humidity have been mentioned in order to clearly set forth the operation of the control system. These values, however, may be varied for different installations and are not to be taken as limiting.

From the foregoing detailed description, it will be apparent that I have provided a novel air conditioning system and control system therefor which acts to either cool or heat a space and which provides for automatic control of temperature and humidity. It will also be seen that my system provides for heating the space during ordinary weather by means of a refrigeration system operating upon the reverse cycle, and adds to the heat procured in this manner, the waste heat from the engine which drives the compressor thereby securing extremely economical operation. It will also be seen that my improved system provides for supplementing the action of the reversed cycle system or for replacing its action by means of an electric or other type of heating means for the engine, which acts to supply additional heat to the space and to cause the engine to supply additional waste heat. Also it will be noted that my invention provides for supplying heat from an auxiliary heater to the space whenever the internal combustion engine system is incapable of carrying the heating load. Due to this arrangement, the internal combustion engine system need not be made sufficiently large to carry the peak heating loads which occur for only a very small portion of the heating season.

While I have shown and described several embodiments of my invention, it is obvious that many other modifications of the system and sub-combinations thereof which are within the scope of my invention will occur to those skilled in the art, I therefore desire to be limited only by the scope of the appended claims as construed in the light of the prior art.

I claim as my invention:

1. In an air conditioning system for heating and cooling a space, in combination, a reversible

cycle refrigeration system adapted for selectively heating or cooling a space, said refrigeration system having a compressor, an internal combustion engine for driving the compressor, means for placing said internal combustion engine into operation upon demand for either heating or cooling, means for transferring waste heat from the engine to said space, first control means for controlling the transfer of waste heat, second control means for reversing said refrigeration system, and temperature responsive means acting upon fall in temperature to actuate said first control means for supplying waste heat to the space and acting upon a further drop in temperature to actuate said second control means to reverse the system from cooling to heating.

2. In an air conditioning system for heating and cooling a space, in combination, a refrigeration system adapted for cooling a space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, means for placing said internal combustion engine into operation upon demand for either cooling or heating, control means for rendering said refrigeration system effective or ineffective to cool said space, means for transferring jacket heat of the internal combustion engine to said space, control means for controlling the transfer of said jacket heat, means for transferring exhaust heat of said engine to said space, control means for controlling the transfer of said exhaust heat, and means for sequentially actuating said refrigeration system control means, said jacket heat transfer control means, and said exhaust heat transfer control means in a manner to first place at least one of said heat transferring means into operation and then render the refrigeration system ineffective to cool the space.

3. In an air conditioning system for heating and cooling a space, in combination, a reversible cycle refrigeration system adapted for selectively heating or cooling a space, said refrigeration system having a compressor, an internal combustion engine for driving the compressor, means for placing said internal combustion engine into operation upon demand for either heating or cooling, control means for reversing said refrigeration system, means for transferring jacket heat of the internal combustion engine to said space, control means for controlling the transfer of said jacket heat, means for transferring exhaust heat of said engine to said space, control means for controlling the transfer of said exhaust heat, and means for sequentially actuating said refrigeration system reversing means, said jacket heat transfer control means, and said exhaust heat transfer control means in a manner to first place at least one of said heat transferring means into operation and then to reverse said refrigeration system from cooling to heating.

4. In an air conditioning system for heating and cooling a space, in combination, a refrigeration system adapted for cooling a space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, means for placing said internal combustion engine into operation upon demand for either cooling or heating, control means for rendering said refrigeration system effective or ineffective to cool said space, means for transferring waste heat from said engine to said space, control means for controlling the transfer of waste heat, additional load means for said engine for

loading the engine to increase the waste heat output of said engine, control means for said additional load means, and sequential control means acting to sequentially place said waste heat transferring means into operation, to render said refrigeration system ineffective to cool the space, and to place said additional load means into operation.

5 5. In an air conditioning system for heating and cooling a space, in combination, a refrigeration system adapted for cooling a space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, means for placing said internal combustion engine into operation upon demand for either cooling or heating, control means for rendering said refrigeration system effective or ineffective to cool said space, means for transferring waste heat from said engine to said space, control means for controlling the transfer of waste heat, additional load means for said engine for loading the engine to increase the waste heat output of said engine, control means for said additional load means, auxiliary heating means for supplementing the heat supplied by the system, control means for said auxiliary heating means, and means for actuating said control means in sequence.

6. In an air conditioning system for heating a space, in combination, a reverse refrigeration system including a heat exchange device in heat exchange relationship with the space for transferring heat from a heat source of low temperature level to said space at a higher temperature for heating the space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, heat exchange means separate from said first heat exchange device for transferring waste heat from said engine to said space for supplementing the action of said reverse refrigeration system in heating said space, and means for controlling the speed of said engine in accordance with the demand for heat of said space.

7. In a system for heating a space, in combination, a refrigeration system adapted for transferring heat from a heat source at a low temperature level to said space at a higher temperature for heating said space, said refrigeration system having a compressor, driving means for said compressor, means for supplying waste heat from said driving means to said space, additional means for loading said driving means thereby to increase the amount of waste heat, said additional means acting to also supply heat to the space, and means for placing said additional loading means into operation only when the heat demand for said space exceeds a predetermined value.

8. In a system for heating a space, in combination, a refrigeration system adapted for transferring heat from a heat source at a low temperature level to said space at a higher temperature for heating said space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, means for supplying waste heat from said engine to said space, additional loading means for said internal combustion engine, said additional loading means acting to increase the waste heat output of said engine, and means for placing said additional loading means into operation when the temperature of said heat source falls so low as to cause the combined refrigeration system

heat and waste heat to be insufficient to heat said space to the desired temperature.

9. In a system for heating a space, in combination, a refrigeration system adapted for transferring heat from a heat source at a low temperature level to said space at a higher temperature for heating said space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, means for supplying waste heat from said engine to said space, means for increasing the waste heat output of said engine, and temperature responsive means for placing said last mentioned means into and out of operation.

10. In an air conditioning system, in combination, a conditioning chamber through which air is adapted to be passed for a conditioning action, a heating device in said chamber, said heating device having an inlet for vaporized heat transfer medium and an outlet for condensed heat transfer medium, a vapor generating device, means for connecting said vapor generating device to said heating device, valve means on the outlet of said heating device for trapping condensed heat transfer medium in said device to thereby reduce the portion of said heating device which is effective for heating the air, means for restricting flow of condensed heat transfer medium from said heating means when the valve means is open, and thermostatic means for controlling said valve means.

11. In an air conditioning system, in combination, a reversible cycle refrigeration system having a condenser, an inside evaporator for cooling the space, an outside evaporator for absorbing heat for delivery to said condenser, a compressor, valve means for selectively connecting said inside evaporator or said outside evaporator to said condenser and compressor, an internal combustion engine for driving said compressor, a heat transfer system for cooling said engine and condenser, a heat transfer circuit for transferring heat from said heat transfer system to a space being conditioned, control means for controlling said engine and said valve means in a manner to condition said refrigeration system for heating in winter and cooling in summer, and for placing said engine in operation upon demand for either heating or cooling, means influenced by said control means for passing outside cooling medium into said heat transfer system for cooling the engine and condenser during summer operation while maintaining said heat transfer system closed during winter operation, additional load means for loading the engine to increase the waste output thereof, and means actuated by said control means for placing said additional load means into and out of operation.

12. In an air conditioning system, in combination, a conditioning chamber through which air is adapted to be passed for a conditioning action, a refrigeration system having a cooling device in heat exchange relationship with the air flowing through said chamber for cooling and dehumidifying the same, said refrigeration system also including a compressor having driving means therefor, a heating device in said chamber for reheating the air, said heating device having an inlet for vaporized heat transfer medium and an outlet for condensed heat transfer medium, a vapor generating device receiving heat from said refrigeration system, means for connecting said vapor generating device to said heating device, valve means in the outlet of said

heating device for trapping condensed heat transfer medium in said heating device to thereby reduce the portion of said heating device which is effective for heating the air, means for restricting the flow of condensed heat transfer medium when the valve means is open, and thermostatic means for controlling said valve means.

13. In an air conditioning system, in combination, a conditioning chamber through which air is adapted to be passed for a conditioning action, a refrigeration system having a cooling and dehumidifying means in heat exchange relationship with the air flowing through said chamber for cooling and dehumidifying the same, a compressor for said refrigeration system, an internal combustion engine for driving said compressor, a reheater for reheating the air leaving said cooling and dehumidifying means, a vapor generator receiving heat from the internal combustion engine, means for conveying vapor from the generator to the reheater, a conduit for returning condensate from the reheater to the generator, valve means for controlling circulation between said generator and said reheater, means responsive to excessive humidity for placing said cooling and dehumidifying means into operation, and a thermostat responsive to demand for reheat for controlling said valve means.

14. In an air conditioning system, in combination, a conditioning chamber through which air is adapted to be passed for a conditioning action, a refrigeration system having a cooling and dehumidifying means in heat exchange relationship with the air flowing through said chamber for cooling and dehumidifying the same, a compressor for said refrigeration system, an internal combustion engine for driving said compressor, a reheater for reheating the air leaving said cooling and dehumidifying means, a vapor generator receiving heat from the internal combustion engine, means for conveying vapor from the generator to the reheater, a conduit for returning condensate from the reheater to the generator, a valve in said conduit for trapping condensate in said reheater for thereby varying the effective heating area of said reheater, a thermostatic controller, a humidity controller, one of said controllers controlling said cooling and dehumidifying means and the other of said controllers controlling said valve means.

15. In a system for heating a space, in combination, a refrigeration system adapted for transferring heat from a heat source of low temperature level to said space at a higher temperature level for heating the space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, heat exchange means for delivering waste heat from the engine to said space, additional loading means for loading said engine, and thermostatic means responsive to the demand for heat of said space for starting said engine in response to an initial demand for heat, for increasing the engine speed as the demand for heat increases, and for placing said additional loading means into operation upon further increase in heat demand.

16. In a system for heating a space, in combination, a refrigeration system adapted for transferring heat from a heat source of low temperature level to said space at a higher temperature level for heating the space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, heat exchange means for delivering waste heat

from the engine to said space, additional loading means for loading said engine, automatic starting means for said engine, a speed controller for said engine, a controller for said additional loading means, and step control means for sequentially actuating said automatic starting means, said speed controller, and said additional loading means controller in the order named, upon increase in heat demand.

17. In a system for heating a space, in combination, a refrigeration system adapted for transferring heat from a heat source of low temperature level to said space at a higher temperature level for heating the space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, heat exchange means for delivering waste heat from the engine to said space, an electric generator driven by said engine, an electric heater receiving power from said generator for additionally heating the space, a switch for controlling said electric heater, and thermostatic means responsive to the heat demand for the space for starting said engine in response to an initial demand for heat, for increasing the engine speed in response to increase in demand for heat and for closing said switch to place said electric heater into operation upon further increase in heat demand.

18. In a system for heating a space, in combination, a refrigeration system adapted for transferring heat from a heat source of low temperature level to said space at a higher temperature level for heating the space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, heat exchange means for delivering waste heat from the engine to said space, a waste heat controller for increasing the waste heat output of the engine, automatic starting means for the engine, a speed controller for said engine, thermostatic means for sequentially controlling said automatic starting means and said speed controller in a manner to start said engine upon an initial demand for heat and to increase the engine speed upon an increase in demand for heat, and means for actuating said waste heat controller in a manner to increase the waste heat of the engine when the combined refrigeration system heat and normal waste heat of the engine is insufficient.

19. In a system for conditioning a space and providing a supply of heated medium, in combination, a refrigeration system for conditioning the air in said space, said refrigeration system including a compressor, an internal combustion engine for driving said compressor, automatic starting means for said engine, a speed controller for said engine, thermostatic means responsive to space temperature for controlling said automatic starting means and said speed controller, a heat exchanger for heating said medium, thermostatic means for supplying waste heat from the engine to said space and to said heat exchanger, a controller for increasing the waste heat from the engine, and thermostatic means for actuating said last mentioned controller for increasing the supply of waste heat from the engine when the normal supply is insufficient.

20. In a system for conditioning a space and providing a supply of heated medium, in combination, a refrigeration system for conditioning the air in said space, said refrigeration system including a compressor, an internal combustion engine for driving said compressor, automatic

starting means for said engine, a speed controller for said engine, thermostatic means responsive to space temperature for controlling said automatic starting means and said speed controller, a heat exchanger for heating said medium means including thermostatic means influenced by the demand for heat of said medium for supplying waste heat from the engine to said medium, a controller for increasing the waste heat from the engine, and thermostatic means for actuating said last mentioned controller in a manner to increase the supply of waste heat from the engine when the normal supply is insufficient.

21. In a system for heating a space, in combination, a refrigeration system adapted for transferring heat from a heat source of low temperature level to said space at a higher temperature level for heating the space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, means including a heat exchanger through which exhaust gases of the engine are passed for transferring exhaust heat from the engine to said space, a fuel burner for adding additional gases of combustion to the exhaust gases passing through said heat exchanger, and thermostatic means for placing said burner in operation when the refrigeration system heat and the exhaust heat is insufficient to heat said space.

22. In a system for heating a space, in combination, a refrigeration system adapted for transferring heat from a heat source of low temperature level to said space at a higher temperature level for heating the space, said refrigeration system having a compressor, an internal combustion engine for driving said compressor, heat exchange means for delivering waste heat

from the engine to said space, auxiliary heating means for supplying heat to said space in addition to the heat supplied by said refrigeration system and said waste heat, automatic starting means for said engine, a speed controller for said engine, thermostatic means for controlling said automatic starting means and said speed controller in a manner to start said engine upon an initial call for heat and to increase the speed of the engine as the heat demand increases, and means for placing said auxiliary heating means into operation when the combined waste heat and refrigeration system heat is insufficient to heat said space.

23. In an air conditioning system, in combination, a reversible cycle refrigeration system for heating and cooling a space, said refrigeration system including a condenser for dissipating heat during the cooling cycle and for delivering heat to the space during the heating cycle, a heat exchanger in heat exchange relationship with the space, a normally closed heat transfer circuit between said condenser and said heat exchanger comprising a supply conduit for conveying heat transfer medium from said condenser to said heat exchanger and a return conduit for returning said medium to said condenser, a supply connection for supplying heat transfer medium to said return conduit, a check valve in said return conduit to prevent heat transfer medium admitted from said supply connection from passing through said return conduit to said heat exchanger, and a relief connection in said supply conduit for allowing medium passed into said heat transfer circuit by said supply connection to escape from said heat transfer circuit after passing through said condenser.

ALWIN B. NEWTON.