

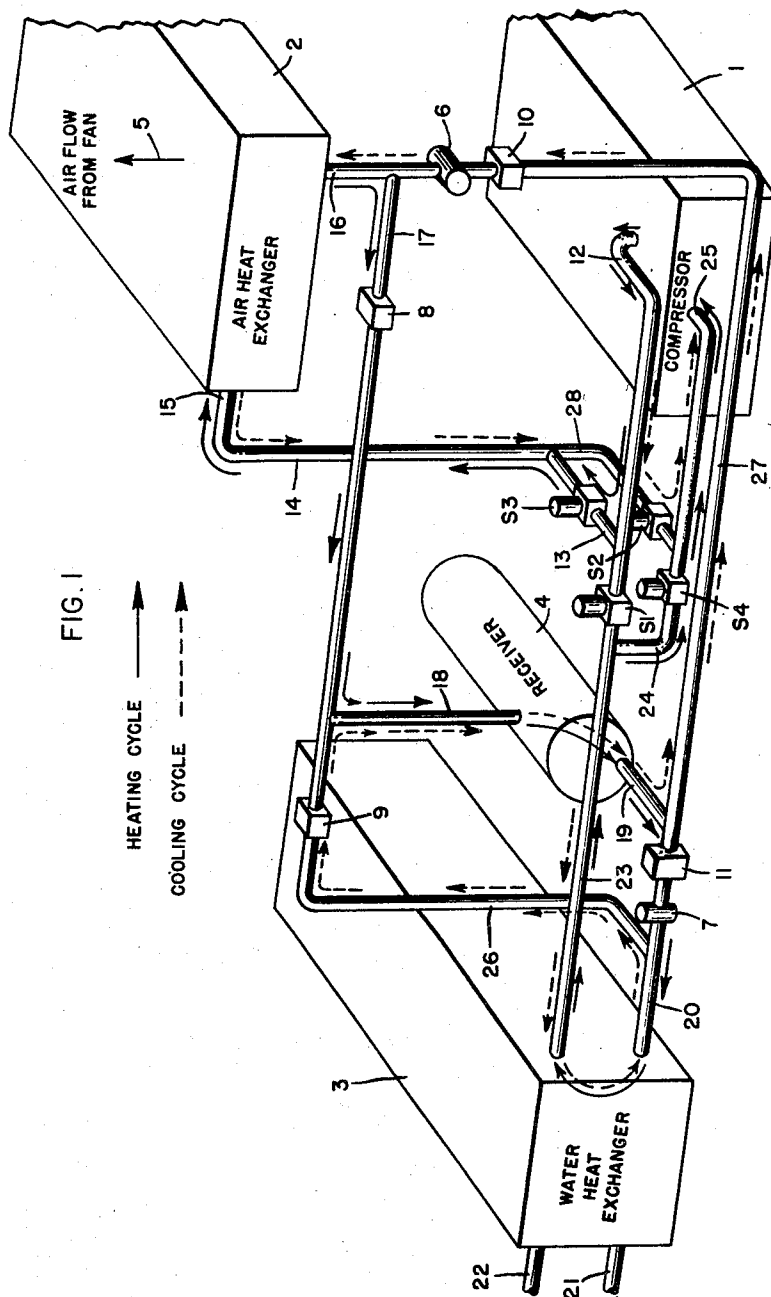
May 18, 1948.

E. N. KEMLER ET AL
HEAT PUMP CONTROL DEVICE

2,441,885

Filed Dec. 26, 1946

5 Sheets-Sheet 1



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FIG. 2

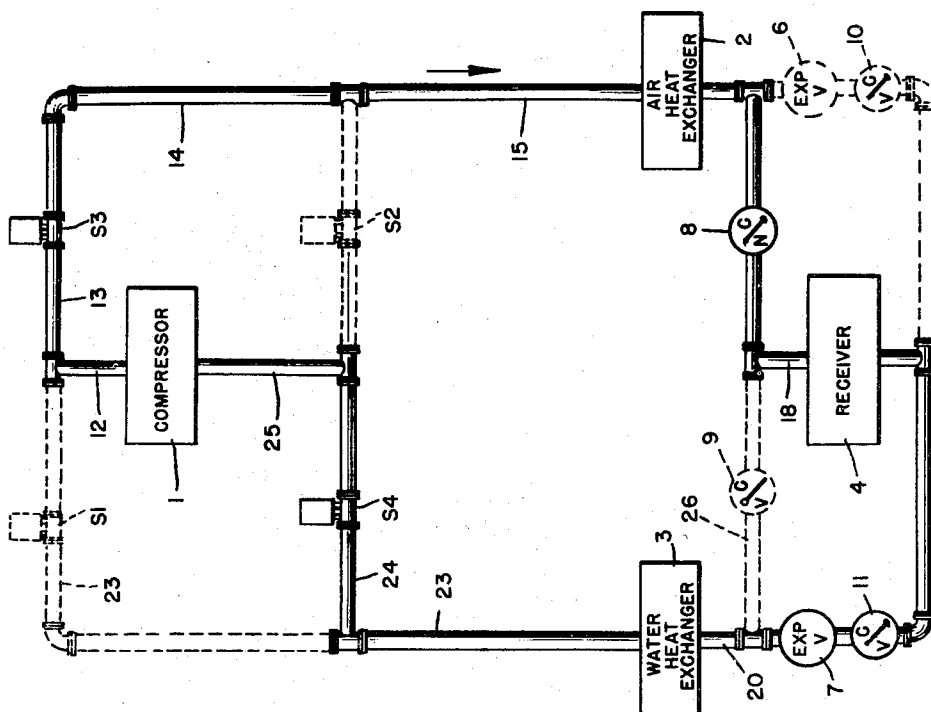
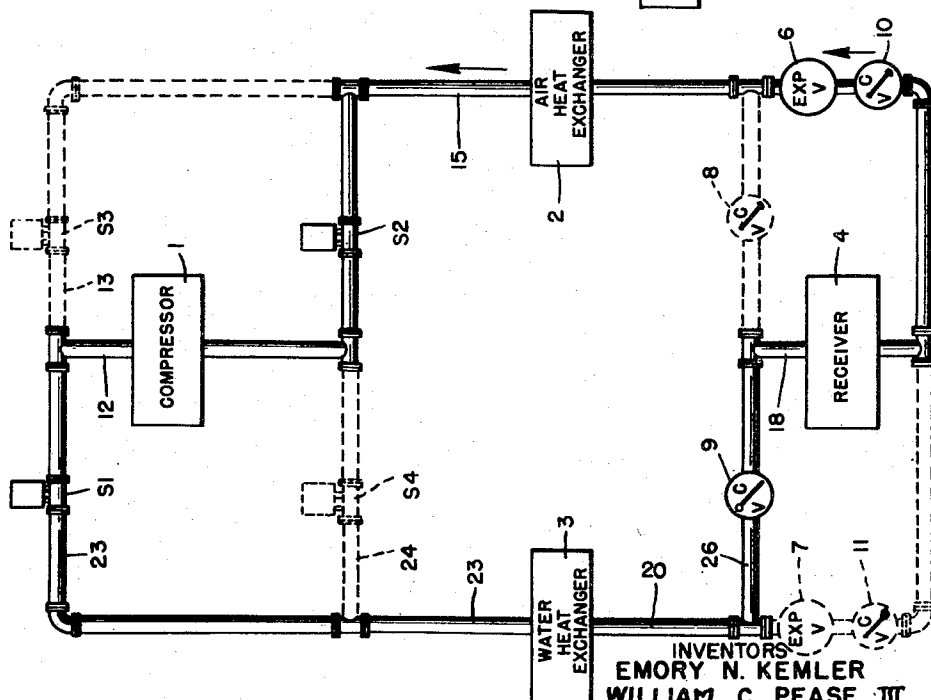


FIG. 3



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FIG. 4

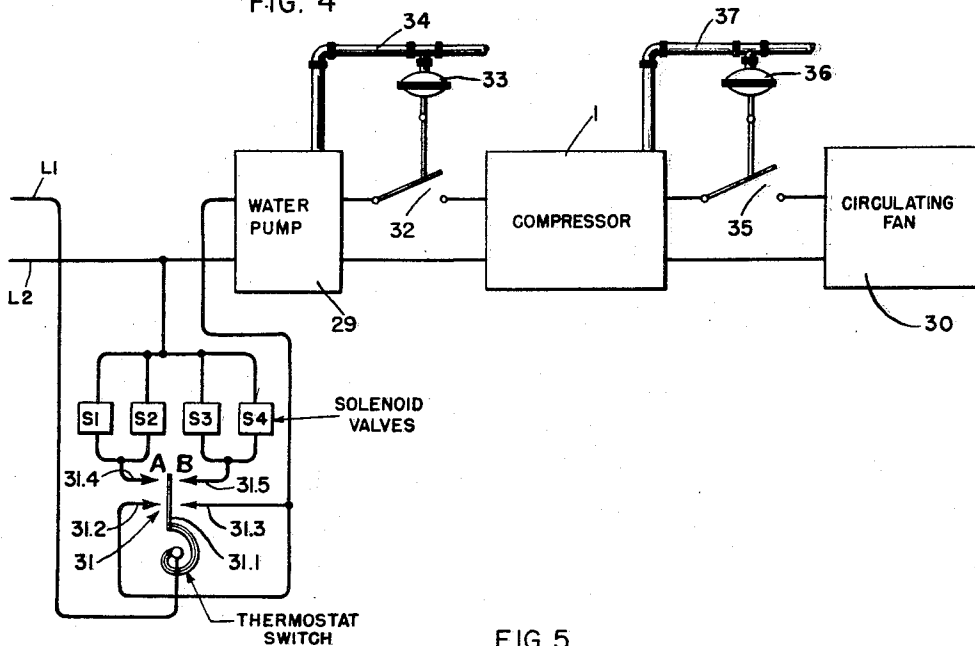
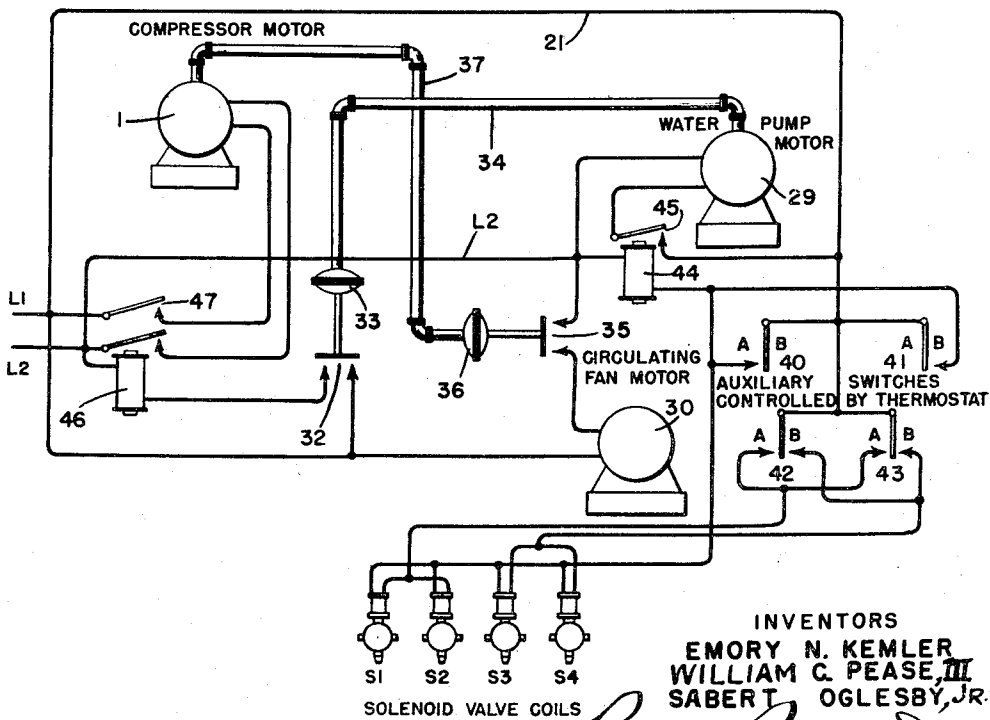


FIG. 5



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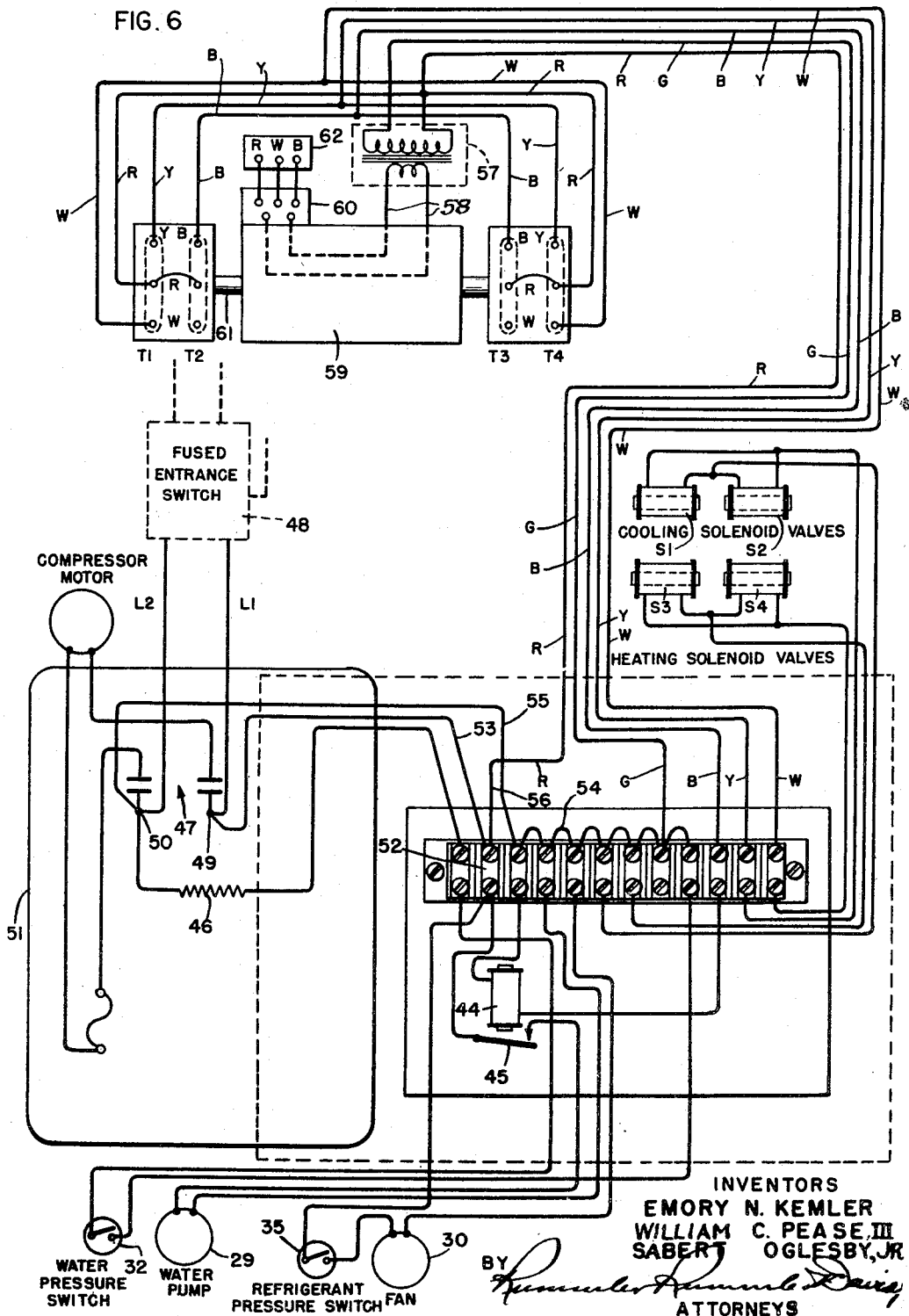
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FIG. 6



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FIG. 7

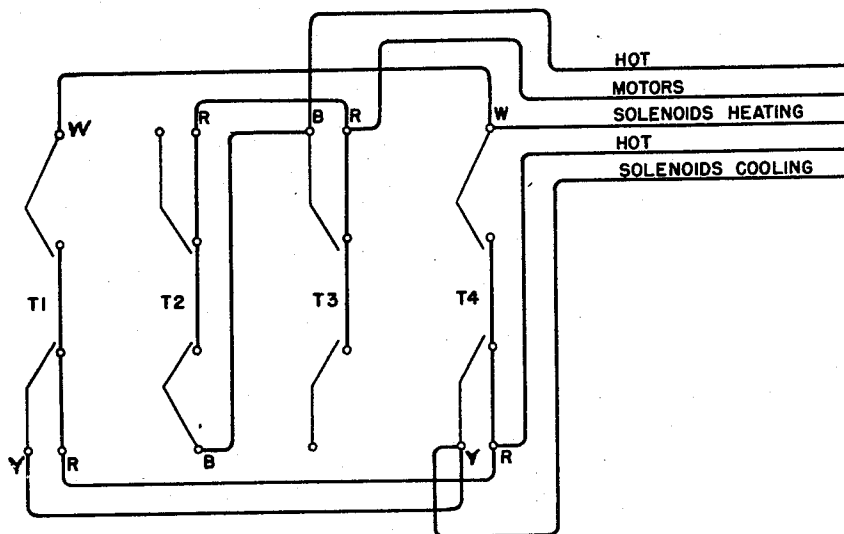


FIG. 8

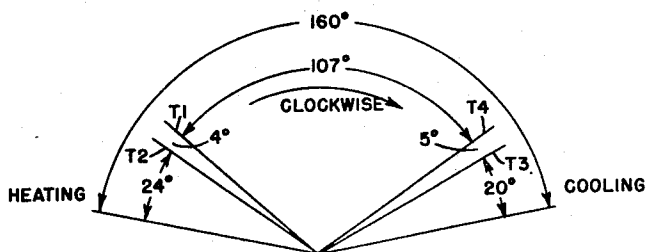
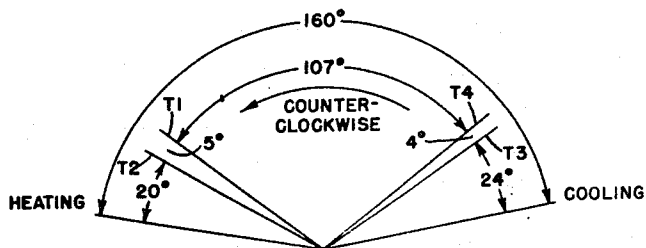


FIG. 9



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2,441,885

HEAT PUMP CONTROL DEVICE

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Application December 26, 1946, Serial No. 718,410

4 Claims. (Cl. 62—6)

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This invention relates to heat pumps and particularly to mechanical and electrical devices for automatically controlling the operation thereof. The general type of heat pump apparatus to which this invention relates is described and claimed in the co-pending application of Marvin M. Smith, filed October 25, 1945, Serial Number 624,351.

The main objects of this invention are to provide improved and simplified means for refrigerant cycle reversal in a heat pump; to provide improved devices for controlling the automatic operation of heat pumps; to provide improved means for stepping the operation of the several motors, or power-consuming elements of a heat pump for decreasing starting resistance; to provide an improved protective system of combined mechanical and electrical power control whereby certain operations can take place only after previous operations are properly functioning; to provide improved control means of this kind which are sufficiently flexible to be readily adaptable to different sizes of heat pump units by changing the pressures controlling the operation of pressure switches; and to provide an improved electrical circuit for automatic thermostatic control of both heating and cooling operations of the heat pump without requiring attention of an operator for year-around maintenance of room temperatures within prescribed limits regardless of outside atmospheric changes.

An illustrative specific embodiment of this invention is shown in the accompanying drawings, in which:

Figure 1 is a diagrammatic three-dimensional view of a reversible refrigerant cycle apparatus of a simple form of heat pump, embodying piping and valve arrangement, whereby one heat exchanger functions to transfer heat between the refrigerant and air in both heating and cooling operations of the heat pump, and another heat exchanger functions to transfer heat between the refrigerant and water during both heating and cooling operations of the heat pump, the direction of flow of the refrigerant being indicated by full line arrows for the heating cycle and with broken line arrows for the cooling cycle.

Fig. 2 is a two-dimensional diagram of the same with conventional emphasis and direction arrows applied so as to indicate the lines of piping that are active during the heating seasonal operation of the heat pump.

Fig. 3 is a similar diagram with conventional emphasis and arrows indicating the course of the refrigerant cycle during the cooling seasonal operation of the heat pump.

Fig. 4 is a simplified block diagram showing the electrically controlled units and broadly illustrative of the timing sequence of their operation.

Fig. 5 is a schematic diagram of an arrangement corresponding generally to that of Fig. 4

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but with greater detail with respect to the electrically controlled devices for producing the stepped operation of the motor-driven units of the heat pump.

Fig. 6 is a diagrammatic view showing schematically an electrical circuit arrangement in the more complete form in which it is used in practice.

Fig. 7 is a diagrammatic detail of the mercury tube wiring corresponding to the circuit arrangement of Fig. 6.

Fig. 8 is a diagrammatic detail showing the angular timing sequence in which the circuits of the respective mercury tubes are closed or opened during clockwise rotation of the modulating motor that tilts the mercury tubes in changing from the heating cycle to the cooling cycle of the heat pump.

Fig. 9 is a view corresponding to Fig. 8 but showing the sequence in which the tube circuits are opened or closed in the counter-clockwise rotation of the modulating motor when changing from the cooling to the heating cycle.

While the basic elements of refrigeration cycles have long been used in heat pumps, the development of a satisfactory heat pump centers around the application of these elements in such a way as to give satisfactory performance and trouble-proof operation.

In the simplified form in which the heat pump structure is illustrated in Fig. 1, the compressor 1, the heat exchangers 2 and 3 and the receiver 4 are connected by appropriate piping for circulating a refrigerant to accomplish either heating or cooling of a flowing body of air and for utilizing water from a deep well or other appropriate source, as a source of heat during the heating season and as a dump for heat during the cooling season.

In the arrangement shown in Fig. 1, the heat exchanger 2 is designed to cooperate with the air current produced by a fan and appropriate duct work represented by arrow 5 and this exchanger functions as the condenser unit of the refrigerant cycle during the heating season and as the evaporator unit of the refrigerant cycle during the cooling season. Correspondingly, the heat exchanger 3 functions as the evaporator of the refrigerant cycle during the heating season and as the condenser of the refrigerant cycle during the cooling season. In heat exchanger 3, the refrigerant is brought into heat exchange relation to water, preferably circulated to and from a deep well as shown in said co-pending Smith application.

An expansion valve 6 is located so as to cooperate with the heat exchanger 2, and an expansion valve 7 is located so as to cooperate with the heat exchanger 3 when such respective heat exchanger is functioning as an evaporator.

Motor controlled valves, shown as solenoid

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valves, and identified by numerals S1, S2, S3 and S4 respectively, are incorporated into the system of piping for controlling the direction of flow of the refrigerant from the compressor to the other units of the refrigerant cycle; and these are supplemented by appropriately located check valves 8, 9, 10 and 11 which cooperate with the solenoid valves to limit the flow of refrigerant to the desired cyclic flow channels.

During the air heating cycle, the refrigerant flows from the compressor through pipes 12 and 13, through valve S3, through pipes 14 and 15 to the air heat exchanger 2 which serves as a condenser and delivers heat to the air, then through pipes 16, 17, check valve 8 and pipe 18 to receiver 4, then through pipe 19, check valve 11, expansion valve 7 and pipe 20 to the water heat exchanger 3, which serves as an evaporator and extracts heat from the coils served by water pipes 21 and 22, then the refrigerant flows through pipes 23 and 24, through solenoid valve 4, and then through pipe 25 back to the compressor 1.

During the air cooling cycle, the refrigerant flows from the compressor 1 through pipe 12, solenoid valve S1, and pipe 23 to the water exchanger 3, which now functions as a condenser, where the refrigerant dumps its heat into the water circulated by pipes 21 and 22. Then the refrigerant flows from heat exchanger 3 through pipes 20 and 26, check valve 9 and pipe 18 to the receiver; thence through pipes 19 and 27, check valve 10, expansion valve 6 to heat exchanger 2, which now functions as an evaporator to cool the air stream 5; then the refrigerant flows through pipes 15, 14 and 28 through solenoid valve S2 and then through pipe 25 back to the compressor.

In Figs. 2 and 3, the respective refrigerant cycles for heating and cooling correspond to those of Fig. 1 and the same reference numerals are applied to the parts of corresponding functions.

It will be noted that solenoid valves S1 and S2 are closed and solenoid valves S3 and S4 are open for the air heating cycle of refrigerant flow (Fig. 2); and that solenoid valves S1 and S2 are open and solenoid valves S3 and S4 are closed during the air cooling cycle of refrigerant flow (Fig. 3). It will be understood that solenoid valves may be normally open with their solenoids functioning to close them, or they may be normally closed with their solenoids functioning to open them, and that the electrical connections may be made accordingly. It is preferred to have these solenoid valves arranged to be normally open in order that the pressures throughout the refrigerant piping system will be equalized when the apparatus is at rest. This assures proper seating of the solenoid valves on closing and also tends to reduce starting load on the compressor.

In Fig. 4, a simplified electrical diagram is shown for the purpose of indicating the sequence of operation of the water pump 29, which serves the water circulation system represented by pipes 21 and 22 in Fig. 1, and the circulating fan 30, which causes the air stream 5 of Fig. 1 to flow through the air heat exchanger, in their relation to the compressor 1. Here the power source is indicated by line conductors L1 and L2 from which power is supplied to the motors of the water pump 29, compressor 1 and fan 30 under control of a thermostatic switch 31 indicated diagrammatically by the bimetallic arm 31.1 which swings between two pairs of contacts A and B respectively functioning for the heating and cooling cycles of operation of the heat pump. Switch contacts 31.2 and 31.3 control the flow of current, during the

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heating and cooling cycles, to the motors of the water pump, compressor and circulating fan. Contact 31.4 controls the flow of current to solenoid valves S1 and S2 and switch contact 31.5 controls the flow of current to solenoid valves S3 and S4.

Pressure switch 32 controls the flow of power to the compressor and is actuated by a suitable motor element represented by the diaphragm 33 actuated by the water pressure in pipe 34 of the water circulating system supplied by water pump 29.

Similarly, refrigerant pressure switch 35 controls the flow of power to the circulating fan 30 and is actuated by a motor element represented by the diaphragm 36 and operated by pressure in pipe 37 which is connected to the high pressure side of the compressor. Thus when the thermostat arm 31.1 swings to the left of Fig. 4 closing contacts 31.2 and 31.4, the water pump will be operated and solenoid valves S1 and S2 will close, while solenoid valves S3 and S4 remain open. This, as explained with respect to Figs. 1, 2 and 3, arranges the piping for the air heating cycle of operation of the heat pump.

Correspondingly, when thermostat arm 31.1 swings to the right and closes contacts 31.3 and 31.5, electric power will again be supplied to the water pump motor and solenoids S3 and S4 will close, while solenoids S1 and S2 remain open to arrange the refrigerant piping for the air cooling cycle of operation.

When the water pump produces a pressure in the water circulating system of an amount for which the motor 33 has been set, say 20 pounds per square inch, then switch 32 will close and electric power will be supplied to the compressor 1. When the compressor operation produces a pressure on the high side of the compressor sufficient to actuate pressure switch motor 36, say 90 pounds per square inch, then pressure switch 35 will close and power will be supplied to the circulating fan 30.

This stepping of the operation of the motors of the water pump, compressor and fan prevents overloading and contributes to successful operation of the heat pump over long periods without requiring any attention on the part of an operator.

In the arrangement shown in Fig. 5, the electrical power source is represented by lines L1 and L2 and the supply of current to the heat pump is controlled by switches 40, 41, 42 and 43, each having a movable element represented diagrammatically as a swinging tongue, movable between the contacts, designated A for the heating cycle and B for the cooling cycle, respectively. The movable elements of these auxiliary switches may in practice be controlled by motor means which in turn may be remotely controlled by a thermostat. A suitable balancing motor and thermostat device will be hereinafter described.

Switches 40 and 41 function to close an obvious circuit through relay 44 which controls switch 45 in the circuit of the water pump motor 29. A pressure switch 32, actuated by pressure motor 33 through pipe connection 34 with the water pump 29, closes the circuit of relay 46 which closes switch 47 controlling the circuit of the compressor motor 1 which builds pressure in pipe 37 to operate pressure motor 36 and close switch 35 to energize the operating circuit of the motor of the circulating fan 30.

Switches 42 and 43 are each connected through obvious circuits with lines L1 and L2 for actuat-

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ing solenoid valves S1, S2, S3 and S4 in pairs as will be understood from Figs. 1, 2 and 3. In the switches 40, 41, 42 and 43 the contacts A are arranged to control the respective electrical circuits during the air-heating operation of the heat pump and the contacts B of these switches control their respective circuits during the air-cooling operation of the heat pump.

In operation of the system shown in Fig. 5, the closing of either of the switches 40 or 41 in either cycle of operation, energizes relay 44, closing switch 45 to energize the water pump motor. Water pressure acting through pipe 34 on the diaphragm of motor 33 closes pressure switch 32, energizing relay 46, which closes switch 47 to energize the motor of the compressor 1. The pressure built up on the high side of the compressor, acting through pipe 37 on diaphragm motor 36, closes the pressure switch 35 and starts the air circulating fan.

More complete electrical circuits, as used in current practice for operation of the system, which is shown in symbolic form in Figs. 4 and 5, are shown schematically in Fig. 6 with panel contacts suitable for field assemblage. Here also is shown the relation of the controlling thermostat to the modulating motor and mercury tube switches T1, T2, T3 and T4 which perform the function of switches 42, 40, 41, and 43 respectively of Fig. 5.

In Fig. 6 current is supplied from the line conductors L1 and L2 which is controlled by a fused main entrance switch 48 and which has leads to contact terminals 49 and 50 of the compressor motor control switch 47 which is housed in an outlet box 51. Terminal 49 of L1 is connected to a wall panel terminal bar 52 by conductor 53 and terminal 50 of L2 is connected to a series of panel bars 54 by conductor 55.

Cable conductors 56 (R) and (G) respectively connect the contact bars 52 and 54 to the primary winding of a transformer 57, of which the secondary winding is connected by conductors 58 through the windings of the balanced or modulating motor 59 to the outlet 60 for cable connection to a thermostat 62 which may be remote from the motor 59. The motor 59, through rotation of its shaft 61, operates a series of mercury tube switches T1, T2, T3 and T4 which are mounted in different angular relations to the shaft 61 and which have terminals connected as shown in Fig. 7 so as to operate to open and close their respective circuits in time sequence as indicated in Figs. 8 and 9.

As is customary in cable connections different wires are identified by different colors, such as black, red, white, green and yellow. In Figs. 6 and 7, the respective cable conductors and their terminals in the mercury tubes are respectively identified by the initial letters of the colors of their respective conductors, B, R, W, G and Y. Details of structure of the modulating motor, the mercury switches and the thermostat are not essential to the present invention and are accordingly omitted from the drawings. A suitable motor for this purpose is one that is sold by Minneapolis-Honeywell Regulator Co. and identified as type M904E.

With the wiring arrangements shown in Figs. 6 and 7, the modulating motor 59 turns the mercury tube switches in a counterclockwise direction when heating is called for and in a clockwise direction when cooling is called for by the thermostat 60. Mercury tube switch T1 controls solenoid valves S1 and S2 (Figs. 2 and 3); mer-

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cury tube switch T4 controls solenoid valves S3 and S4 and mercury tube switch T2 controls the pump motor switch 45.

The mercury tubes are disposed in fixed angular positions with respect to the modulating motor shaft 61 so that, in changing from heating to cooling and vice versa, they operate in predetermined timing sequence, according to the diagram of Fig. 8 during clockwise rotation of the modulating motor and according to Fig. 9 during counterclockwise rotation of the modulating motor. The angular stroke of the balanced motor is 160° and a suitable timing for the performance of the proper sequence of operations of the herein-described control apparatus is accomplished by rotation of the modulating motor at a rate of travel that completes such stroke for complete reversal of cycle in a predetermined period of time, say two minutes.

The diagrams of Figs. 8 and 9 show the full range of movement of the modulating motor shaft in changing from the heating to the cooling seasonal operations and vice versa. Thus during the heating season, the thermostat causes the modulating motor shaft to swing back and forth between the extreme left-hand position shown in Figs. 8 and 9 and some point between the right and left limits of its movement, which is its normal position of rest.

Likewise during the cooling season, the modulating motor shaft swings back and forth at the predetermined timing speed of rotation between the extreme right-hand limit of movement shown in Figs. 8 and 9 and some point intermediate between the right and left-hand limits. When the temperature of the room in which the thermostat is located is at the degree for which the thermostat has been set, all of the motors of the heat pump will be at rest.

Then during the heating season when the temperature falls below this selected normal temperature, the thermostat will call for heat and the modulating motor will tilt the mercury switches in a counterclockwise direction until switch T1 causes the solenoid valves S1 and S2 to close. Then on further counterclockwise movement of the modulating motor through an angle of 5°, mercury switch T2 will close and energize the relay 44 causing switch 45 to close and start the pump 29. The modulating motor will come to rest after it has turned 20° beyond this point and will remain at rest so long as the thermostat continues to call for heat.

When the temperature of the room has risen sufficiently to satisfy the thermostat, the modulating motor will swing back in a clockwise direction, causing switch T2 to open the switch 45 and stop the pump after 24° of movement of the modulating motor and after 4° further movement, mercury switch T1 will release the closed solenoid valves S1 and S2 and allow the pressure in the refrigerant cycle to become equalized. When the thermostat again calls for heat, the modulating motor will again turn in a counterclockwise direction and the cycle will be repeated.

During the cooling season, the sequence of operations will be according to the left hand valves of Figs. 8 and 9 for clockwise and counterclockwise movements of the modulating motor, the difference between the angular positions of the mercury switches in turning on and off being due to the structure of the tubes and the inertia of the mercury globule that controls the electrical contact in these tubes. In the cooling season, as is shown in Fig. 3, solenoid valves S3 and S4

are closed when the refrigerant cycle is in operation and their opening and closing are controlled by switch T4 and switch 45 is controlled by switch T3.

In all cases the closing of switch 45 sets the water pump in operation, a certain rise in pressure in the water system causes pressure switch 32 to close and this, through relay 46, closes the compressor motor switch 47, and then the high side pressure of the compressor causes pressure switch 35 to close to start the fan motor.

When energy is cut off from the water pump motor by opening of switch 45, the pump stops, the water pressure falls allowing pressure switch 32 to open and this causes relay 46 to open switch 47 to stop the compressor motor, whereupon the fall of the compressor pressure releases switch 35 and stops the fan motor.

Thus during the heating season a fall in temperature of the room sets the heat pump in operation until a rise in temperature causes the thermostat to stop the heat pump until the thermostat again calls for heat, and so on.

During the cooling season the operation of the heat pump is just the opposite of that of the heating season, in that when the room temperature rises beyond the degree for which the thermostat is set, the heat pump will be operated in its cooling cycle to lower the temperature of the room and the pump will operate intermittently as the temperature fluctuates.

It will be understood that numerous details of the construction herein shown and described may be altered or omitted without departing from the spirit of the invention as defined by the following claims.

We claim:

1. In a heat pump, a refrigerant cycle system comprising a compressor, a motor therefor, a pair of heat exchangers, and piping connecting said compressor and heat exchangers for alternating the function of said heat exchangers as condenser and evaporator respectively in the refrigerant cycle, motorized valve means controlling said piping for reversing the refrigerant cycle with respect to said heat exchangers, a thermostat, electric circuits for separately energizing said compressor and valve means, and thermostatically controlled motorized switch operating means operable in respectively opposite directions and comprising individual switches to control said electric circuits so as to operate said compressor at opposite limits of movement of said switch means and switches to set said valve means at intermediate positions of said motorized switch operating means for reversing the refrigerant cycle in accord with the direction of movement of said motorized switch operating means.

2. In a heat pump, a refrigerant cycle system comprising a compressor, a motor therefor, a pair of heat exchangers, and piping connecting said compressor and heat exchangers for alternating the function of said heat exchangers as condenser and evaporator respectively in the refrigerant cycle, motorized valve means controlling said piping for reversing the refrigerant cycle with respect to said heat exchangers, a thermostat, electric circuits for separately energizing said compressor and valve means, and thermostatically controlled motorized switch operating means operable in respectively opposite directions and comprising individual switches to control said electric circuits so as to operate said compressor at opposite limits of movement of said switch means and switches to set said valve means at in-

intermediate positions of said motorized switch operating means for reversing the refrigerant cycle in accord with the direction of movement of said motorized switch operating means, said motorized switch operating means being arranged to operate switches in sequence in its travel from one limit of its movement to the other in either direction so as to stop the compressor, then open all said motorized valve means, then to reset said valve means to reverse the refrigerant cycle, and then to start the compressor.

3. In a heat pump, a refrigerant circulating system comprising a compressor having refrigerant inlet and outlet, an exchanger for transfer of heat between the refrigerant and water, an exchanger for transfer of heat between the refrigerant and air, piping connecting both the inlet and the outlet of said compressor with both said heat exchangers, a plurality of valve means in said piping operative in alternative settings to direct the refrigerant flow either from said compressor to said air heat exchanger, then to the water heat exchanger and back to the compressor, or in reversed sequence of said heat exchangers; individual electric motors for operating said compressor and valve means; and circuit control means for said motors comprising a thermostat for starting and stopping said compressor, and motorized switch means actuated by said thermostat to open all said valve means when said compressor is stopped and to close certain of said valve means in timed relation to and in advance of the starting of said compressor.

4. In a heat pump, a refrigerant circulating system comprising a compressor having refrigerant inlet and outlet, an exchanger for transfer of heat between the refrigerant and water, an exchanger for transfer of heat between the refrigerant and air, piping connecting both the inlet and the outlet of said compressor with both said heat exchangers, whereby either heat exchanger may function as the evaporator with other functioning as the condenser of the refrigerant cycle, a plurality of valves in said piping adapted in selected open and closed settings thereof to direct the refrigerant in reversed cycles with respect to said heat exchangers, a motor for said compressor, motor means operative to set said valves according to each of said reversed refrigerant cycles, power circuits for said motor and motor means, a thermostat comprising a member movable between limits in opposite directions by falling and rising temperatures, switches actuated by said member to close said motor circuit when said member is in either of its limiting positions and to open said motor circuit when said member is between its limiting positions, said valve motor means comprising switch means actuated by said member adjacent the falling temperature limit of its movement to set said valves for the air heating refrigerant cycle, and switch means actuated by said member adjacent the rising temperature limit of its movement to set said valves for the air cooling refrigerant cycle.

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